Evidence Report/Technology Assessment
Number 201

Enabling Medication Management Through Health Information Technology

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Evidence Report/Technology Assessment

Number 201

Enabling Medication Management Through Health Information Technology

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Enabling Medication Management Through Health Information Technology

Structured Abstract

Objective. The objective of the report was to review the evidence on the impact of health information technology (IT) on all phases of the medication management process (prescribing and ordering, order communication, dispensing, administration and monitoring as well as education and reconciliation), to identify the gaps in the literature and to make recommendations for future research.

Data sources. We searched peer-reviewed electronic databases, grey literature, and performed hand-searches. Databases searched included MEDLINE,® EMBASE,® CINAHL® (Cumulated Index to Nursing and Allied Health Literature), Cochrane Database of Systematic Reviews, International Pharmaceutical Abstracts,© Compendex,© INSPEC© (which includes IEEE®), Library and Information Science Abstracts,® E-Prints in Library and Information Science,® PsycINFO,® Sociological Abstracts,© and Business Source® Complete. Grey literature searching involved Internet searching, reviewing relevant Web sites, and searching electronic databases of grey literatures. AHRQ also provided all references in their e-Prescribing, bar coding, and CPOE knowledge libraries.

Methods. Paired reviewers looked at citations to identify studies on a range of health IT used to assist in the medication management process (MMIT) during multiple levels of screening (titles and abstracts, full text and final review for assignment of questions and data abstrction). Randomized controlled trials and cohort, case-control, and case series studies were independently assessed for quality. All data were abstracted by one reviewer and examined by one of two different reviewers with content and methods expertise.

Results. 40,582 articles were retrieved. After duplicates were removed, 32,785 articles were screened at the title and abstract phase. 4,578 full text articles were assessed and 789 articles were included in the final report. Of these, 361 met only content criteria and were listed without further abstraction. The final report included data from 428 articles across the seven key questions. Study quality varied according to phase of medication management. Substantially more studies, and studies with stronger comparative methods, evaluated prescribing and monitoring. Clinical decision support systems (CDSS) and computerized provider order entry (CPOE) systems were studied more than any other application of MMIT. Physicians were more often the subject of evaluation than other participants. Other health care professionals, patients, and families are important but not studied as thoroughly as physicians. These nonphysicians groups often value different aspects of MMIT, have diverse needs, and use systems differently. Hospitals and ambulatory clinics were well-represented in the literature with less emphasis placed on long-term care facilities, communities, homes, and nonhospital pharmacies. Most studies evaluated changes in process and outcomes of use, usability, and knowledge, skills, and attitudes. Most showed moderate to substantial improvement with implementation of MMIT. Economics studies and those with clinical outcomes were less frequently studied. Those articles that did address economics and clinical outcomes often showed equivocal findings on the effectiveness and cost-effectiveness of MMIT systems. Qualitative studies provided evidence of

strong perceptions, both positive and negative, of the effects of MMIT and unintended consequences. We found little data on the effects of forms of medications, conformity, standards, and open source status. Much descriptive literature discusses implementation issues but little strong evidence exists. Interest is strong in MMIT and more groups and institutions will implement systems in the next decades, especially with the Federal Government's push toward more health IT to support better and more cost-effective health care.

Conclusions. MMIT is well-studied, although on closer examination of the literature the evidence is not uniform across phases of medication management, groups of people involved, or types of MMIT. MMIT holds the promise of improved processes; clinical and economics studies and the understanding of sustainability issues are lacking.

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Executive Summary

Background

Medication management is a continuum that covers all aspects of prescription medications. Medication management includes prescribing and ordering, order communication (or order transmission) between prescribers and pharmacists, dispensing, administering, and monitoring, as well as reconciliation, adherence, and education.[1] Medication management is complex and costly and enhances the health and well-being of more than half of the population in the developing world. Health information technology (health IT) holds great promise to improve the quality of health care and reduce potential and real errors in medication management while at the same time providing cost-effective care. The Agency for Healthcare Research and Quality (AHRQ) is committed to summarizing and providing the evidence base for health IT. It has produced evidence summaries on health IT related to costs and benefits;[2] barriers and drivers of health IT for the elderly, chronically ill, and underserved;[3] the impact of consumer informatics applications;[4] and telemedicine.[5] AHRQ also has contracted for evidence summaries on the use of health IT in decisionmaking,[6] patient-centered care,[7] and decision support for health care decisionmaking.[8] The contracted reports will be available through www.healthit.AHRQ.gov in mid-2011. Although these reports often mention medication management, the body of published evidence on all aspects of the medication management process and how it is affected by multiple health IT systems has not been consolidated. A single document is needed to summarize the evidence evaluating the effects of health IT on the medication management process across providers, settings, patients, and research methods.

The objectives of this report are to:

1. Review the literature on the effects of health IT on medication management.
2. Synthesize available evidence regarding the effectiveness and effects of health IT in all phases of medication management as well as reconciliation and education.
3. Identify gaps in the literature.
4. Make recommendations for future research.

For the purposes of this review, medication management includes the processes that encompass the five phases of the medication process (i.e., prescribing and ordering, order communication, dispensing, administering, and monitoring) across groups of health professionals, patients, and their informal caregivers, and two aspects of quality with respect to medication management across the five phases of medication management (medication reconciliation and education, both postprofessional education of training and patient education related to medication management). Medication management can also include procurement, storage, and reporting from the first assessment of patients to determine their need for drugs through to optimal care and monitoring after the drugs are prescribed. The organization of the information in this report is based on the Bell framework of the five phases across the continuum of medication management and reconciliation and education.[1]

To address the goals of this report, we further define medication management health IT (MMIT) applications as electronic systems that (1) collect, process, or exchange health information about patients; (2) are integrated with existing health IT systems such as electronic health records or electronic medical record (EMR) systems; and (3) provide advice or suggestions to either the health care provider or the patients and their families on issues or decisions related to medication management. We recognize that functional elements of the MMIT will vary across particular implementation approaches within a given phase of medication management. Many of the MMIT applications we found were designed to encompass more than one phase of medication management. The sophistication of the systems, degree of integration of the health IT into workflow systems, and the broad range of settings in which a particular health IT is implemented and used are also complex and varied. Many health professionals, support staff, patients, and patients' families were involved in medication management in the studies assessed.

The evidence assessing MMIT is large, diffuse, and published across many disciplines. People who can benefit from the knowledge in this report include health professionals, researchers, administrators, and other decisionmakers and those who develop and implement health IT applications. This report is timely because of the Federal emphasis on the use of health IT to improve health care while at the same time making health and wellness care more cost effective and safer. Seven questions structure this evidence report. Within reporting related to the questions, sections are based on phases of medication management. Reporting is done to address the multiple settings where medication management is important, the range of health care providers who deliver and support care using medications, and classes of medications, specific drugs, or a broad spectrum of medications.

Key Questions (KQs)

KQ1. Effectiveness

Within all phases of the medication management continuum, what evidence exists that health IT applications are effective in improving:

a. Health care processes,
b. Other intermediate outcomes (e.g., satisfaction with system, usability, knowledge, skills, and attitude),
c. Costs and economic outcomes,
d. Clinical outcomes for patients,
e. Population level outcomes, and
f. Composite outcomes.
g. To what extent does the impact of health IT on improving health care processes, other outcomes, costs and economics, and clinical outcomes vary depending on the type of medication (controlled or noncontrolled substance) or the form of the medication (e.g., oral, injection, intravenous)?

KQ2. Gaps in Knowledge or Evidence

What knowledge or evidence deficits exist to support estimates of cost, benefit, impact, and net value with regard to health IT applications in all phases of medication management?

KQ3. Value Proposition for Implementers and Users

What critical information regarding the impact of health IT applications implemented to support the phases of medication management is needed to give clinicians, health care facility administrators, patients, and their families a clear understanding of the value proposition particular to them?

KQ4. System Characteristics

What evidence supports or refutes the impact of any of: open source, homegrown, proprietary, local configuration ability, system configuration ability, conformity with standards being Certification Commission for Healthcare Information Technology (CCHIT) certified, system architecture, or feature set on the decision to purchase, implement, or use health IT in medication management systems?

KQ5. Sustainability

What factors influence sustainability of health IT applications that support a phase of the medication management continuum?

a. What evidence exists to demonstrate that health care settings (ambulatory, long-term care, etc.) influence implementation, use, and effectiveness of such health IT applications?
b. What is the impact (challenges, merits, costs, and benefits) of having electronic access to patient data on the quality and safety of care provided by health IT applications that support at least one phase of the continuum of medication management?

KQ6. Two-Way Prescription Electronic Data Interchange (EDI)

In a two-way electronic data interchange (EDI) between the prescribers and pharmacists:

a. What evidence exists demonstrating the barriers and drivers of implementation of complete EDI that can support the prescription, transmittal and receipt, and perfection process of e-Prescriptions?
b. How do barriers, facilitators, and economic incentives vary across pharmacists, physicians, and other relevant stakeholders with respect to adoption and use of complete EDI (e-Prescribing/ordering with e-Transmission)?

KQ7. Randomized Controlled Trials (RCTs) of Clinical Decision Support Systems (CDSS)

What evidence exists regarding the extent of integration of electronic clinical decision support in a health IT system for the prescribing, dispensing, and administering of medications, and to what extent does the use of clinical decision support systems impact the various outcomes (e.g., health care process, intermediate, cost and economics, and clinical) of interest?

Methods

We anticipated finding few RCTs across all phases of medication management and MMIT applications. Studies that employ other research methods can also provide valuable evidence for understanding MMIT applications. We therefore included studies employing a range of research methodologies. We restricted our analysis to hypothesis-driven studies with group comparisons and appropriate statistical analysis in addition to qualitative studies with explicit methods for KQ1: Effectiveness. The only methodological limit was for assessment of the effect of CDSSs on prescribing, for which sufficient RCTs were available to provide evidence for synthesis.

Through consultation with our internal team and AHRQ, we determined that the answers to KQ2: Gaps in Knowledge or Evidence and KQ3: Value Proposition for Implementers and Users would become evident from our review of the evidence in KQ1: Effectiveness. We supplemented these articles with other studies addressing values propositions by stakeholders. KQ4: System

Characteristics addresses the impact of MMIT application features on the likelihood that the systems will be purchased, implemented, and used. The evidence for this question comes from studies of all designs that measure implementation, use, and purchasing decisions. KQ5: Sustainability addresses the factors influencing the sustainability of MMIT applications, specifically the impact of the setting and access to other electronic data within integrated systems on health care quality and safety. To identify articles that addressed this question, the team, in consultation with AHRQ, used the definition of sustainability by Humphreys et al.,[9] which restricted our choice of articles to only a few. Their definition of sustainability was the ability of a health service to provide ongoing access to appropriate quality care in a cost- and health-effective manner. KQ6: Two-Way Prescription EDI relates to the barriers and facilitators to complete EDI between prescribers and pharmacies during the time between prescription writing and dispensing and how these vary across stakeholders. The best evidence available for KQ6 is found in articles studying EDI between prescribers and pharmacies that include original data (qualitative or quantitative). Because insufficient evidence was found on two-way EDI, we included one-way EDI as well. KQ7: RCTs of CDSS addresses the extent to which CDSS systems are integrated into health IT systems for medication management and the impact on outcomes as described in KQ1: Effectiveness. As a team we felt that adequate evidence was available to address this issue so that we could limit our scope to RCTs.

Given the broad range of questions and outcomes addressed, we searched peer-reviewed electronic databases by first using textwords relating to the various types of health IT applied to medication management (Appendix A of the full report). These searches were then combined with a search using subject headings related to the five medication management phases plus reconciliation and education as well as specific health IT application terms (e.g., CDSS). We combined these medication management terms with computer and technology terms. When possible, we excluded letters, editorials, commentaries, and animal studies. Because our interest was in all study designs, we did not limit based on methodology. We also put no limits on language or time to capture the global literature and early studies.

Databases searched included MEDLINE, Embase, CINAHL (Cumulated Index to Nursing and Allied Health Literature), Cochrane Database of Systematic Reviews, International Pharmaceutical Abstracts, Compendex, Inspec (which includes IEEE Xplore), Library and Information Science Abstracts, E-Prints in Library and Information Science, PsycINFO, Sociological Abstracts, and Business Source Complete. We also looked for eligible studies by reviewing grey literature sites, performing hand searches of pertinent reviews, querying our experts, and by reviewing the AHRQ National Resource Center for Health IT Knowledge Library resources (available at: http://healthit.ahrq.gov/portal/server.pt/community/knowledge_library/653).

The search results were downloaded into Reference Manager version 10 (ISI ResearchSoft) and uploaded into a customized systematic review management system (Health Information Research Unit, McMaster University).

Studies were eligible for inclusion if they used health IT in any aspect of the medication management process. We included articles on MMIT only if the system was integrated with at least one existing health IT system and if they processed patient-specific information and provided advice or suggestions. A critical inclusion requirement was the integration of information.

Personal digital assistants (PDAs), which integrated patient-specific information provided by either the clinicians or the patients, were analyzed to assist in medication management decisions (by request of AHRQ). This exception is made because PDAs and hand-held devices are considered an important, and perhaps unique, means of improving health care quality in relation to medications. The use of PDAs to manage medications is especially important for clinicians and patients who are in settings that do not have large, sophisticated, and integrated information systems. Other stand-alone devices with no integration of information with another health IT were excluded. Articles on all five phases of the management process plus medication reconciliation and postprofessional education related to MMIT were included. Once we tagged the articles for content, we assessed whether those that passed our inclusion criteria were pertinent to specific key questions. Many articles were analyzed in several phases of medication management and sections of the report.

Studies were classified as being observational, case-control, cohort, or RCTs. The quality of included studies was assessed using the same criteria employed by Jimison et al. in their AHRQ report.[3] RCT scoring was based on the Delphi consensus work done by Verhagan and colleagues.[10] This scale is referred to in this report as the Verhagen/AHRQ RCT quality scale. Observational studies with before–after, time series, surveys, or qualitative methods were not assessed for quality because few well-validated instruments exist. Bibliographies of systematic and narrative reviews were examined to identify studies, and select reviews were integrated into sections of the report.

Data were abstracted from relevant articles and tagged for applicability to the various key questions. Given the range of questions addressed, data abstraction was performed by a core group of staff and entered into online data abstraction forms. One reviewer did the abstraction, and a second, senior reviewer checked its accuracy. The authors of this report performed a final check on the abstracted data. The reviewers were not blinded to the identity of the article authors, institutions, or journal. Data abstraction was difficult in many instances because of the lack of accepted definitions and absence of important features of the study or MMIT application. For example, we identified problems with the differences between computerized provider order entry (CPOE) for ordering and e-Prescribing systems. Definitions for medication errors and related terms were often inconsistently used. To make data abstraction easier, we established working definitions, which can be found in Appendix F of the full report.

Meta-analysis was not performed on any data because of the heterogeneity of the studies in terms of interventions, populations, technologies used, and outcomes measured, as well as the presence of mostly descriptive and observational studies.

Throughout the project, the core team sought feedback from the internal advisors, our Task Officer from AHRQ, and the Technical Expert Panel.

Results

Our literature search retrieved 40,582 articles. After duplicates were removed, 32,785 articles were screened at title and abstract stage. From a full-text screen of 4,578 articles, we identified 789 articles that were eligible for inclusion in this report. Of these articles, 361 met only our inclusion criteria for content and did not have group comparisons, hypothesis testing, or appropriate analysis. These are listed in the bibliography of the report. Across the seven key questions, we synthesized the information from 428 articles.

KQ1. Effectiveness

All outcomes. KQ1: Effectiveness contains 379 studies assessing changes in process, intermediate outcomes, clinical outcomes, and economic and cost outcomes. The majority of studies were observational, with a fair number of RCTs for prescribing and monitoring phases (Table A). Fifty-three qualitative studies are included in this total. Prescribing and monitoring were the most frequently studied phases of medication management (Table A), with hospital and ambulatory care settings well-represented to the near exclusion of long-term care, home, and community (Table B).

Though dealing with prescriptions and medications, pharmacists were poorly represented in studies, most focused on physicians (Table C). CDSS and CPOE systems were the most often studied MMIT technologies (Table D).

Table A. Research design for studies across the phases of medication management and education and reconciliation

Design	P	OC	D	A	M	E	R
RCT	69	1	2	2	37	1	1
Cohort	13	2	2	1	6	0	1
Observational	144	18	10	26	29	2	4
Qualitative	37	5	3	10	5	0	0
Total	263	26	17	39	77	3	6

Note: some studies cross more than one phase.
Column headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
Abbreviations: RCT = randomized controlled trial

Table B. Settings for the phases of medication management and reconciliation and education

Setting	P	OC	D	A	M	E	R
Ambulatory care (e.g., clinic, doctors office)	94	6	2	1	40	2	0
Community (e.g., school, community center)	0	0	0	0	1	0	0
Home	2	0	0	2	5	0	0
Hospital	164	12	9	34	36	1	6
Long-term care	4	0	2	3	1	0	0
Pharmacy	11	13	10	2	4	0	1

Note: some studies cross more than one phase or setting.
Column headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation

Table C. Clinicians evaluated in outcomes studies of medication management phases, education, and reconciliation

Clinicians	P	OC	D	A	M	E	R
Primary care physicians	25	2	1	0	3	1	0
Specialists	11	0	0	0	1	0	0
Hospitalists	18	0	0	0	2	0	0
Other physicians	7	0	0	0	2	0	0
Physicians undifferentiated	26	1	0	1	3	0	1
Nurses	20	1	0	16	2	0	1
Midlevel practitioners (e.g., PA, NP, MW)	6	0	0	0	2	0	0
Pharmacists	13	6	5	2	1	0	1
Other health professionals	10	0	2	4	1	0	0
Hospital administrators	4	1	0	1	0	0	0

Note: some studies cross more than one phase and clinician type.
Column headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
Abbreviations: MW = midwife, NP = nurse practitioner, PA = physician assistant

Table D. Main health IT studied by medication management phase and education and reconciliation

Health IT	P	OC	D	A	M	E	R
CDSS/reminders	177	8	4	5	63	1	1
CPOE/POE system	90	12	5	9	11	0	0
e-Prescribing	31	10	3	4	2	1	1
Order transmission of the prescription to and from doctor to pharmacy electronically	2	3	0	0	0	0	0
Pharmacy information system	2	3	4	1	0	1	1
Barcoding medication administering	1	0	2	20	0	0	0
Barcoding dispensing	0	0	1	0	0	0	0
eMAR, e-TAR	2	2	2	14	0	0	0
Other	13	2	3	7	14	1	5
Personal digital assistants or hand-helds	7	1	0	4	5	0	1

Note: some studies cross more than one phase and technology.
Column headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
Abbreviations: CDSS = Clinical decision support system, CPOE = Computerized provider order entry, POE = Provider order entry, eMAR = Electronic Medication Administration Record system, eTAR = Electronic Treatment Administration Record system

The results from this section suggest that care processes such as medication errors, time for tasks, workflow and knowledge, skills, and attitudes can be improved with the use of MMIT. The evidence is strongest specifically during the prescribing and monitoring phases. Few studies evaluated clinical outcomes associated with the use of MMIT. Those that did often did not show statistically significant improvements in clinical outcomes. Most of the studies with statistically significant differences in clinical outcomes found small differences. The small number of articles with data on clinical outcomes is probably due, at least in part, to the difficulty in evaluating and establishing a direct association between the use of MMIT and clinical outcomes. This difficulty arises because of the distant nature of the outcome compared with the application of the health IT. Other contributing factors could also be considered.

Much of the relatively new research is addressing the type of research needed to come to a realistic and useful assessment of MMIT: pilot and demonstration projects and quantitative studies. Limited evidence suggests that MMIT can likely be cost effective, although most of the economic data come from cost analyses, which were often incomplete and seldom from head-to-head cost-effectiveness, cost utility or cost-benefit trials.

A substantial body of qualitative literature indicates support for the use of health IT in the various phases of medication management by a number of health care providers and patient groups. Survey studies of satisfaction and use reflect similar findings of acceptance and satisfaction, although most indicated room for improvement. Issues relating to changing care practices and workflow are frequently mentioned. The studies also provide useful summaries of unintended consequences of MMIT applications, which are discussed in detail in the full report.

Process changes. Most of the studies evaluating MMIT applications provided data on changes in process (225 of 378). Distribution in the number of studies across the five phases, plus reconciliation and education, was not equal. Prescribing was studied in 174 studies, order communication in 16 studies, dispensing in 9 studies, administering in 19 studies, and monitoring in 47 studies. Four studies evaluated reconciliation and one studied patient education. Studies often evaluated more than one phase.

Prescribing. The prescribing phase is well studied (174 studies), especially in hospital (61 percent of studies) and ambulatory care settings (39 percent). Long-term care centers (one study) and community and home settings (no studies) are not well studied. Physicians are by far the most studied group of health professionals. More studies are needed that evaluate nonphysician use of MMIT, specifically pharmacists, mental health professionals, nurses, and other nonphysician prescribers, as well as patients and their caregivers. Many of the studies of health care providers who were not physicians were purely descriptive of the people involved with them, and the systems themselves.

Based on the studies of process changes, CDSS and CPOE systems can play an important role in making prescribing and ordering more accurate, improving record keeping, and speeding up and improving communication. Both systems, either alone or, more often, integrated, are well studied (multiple studies with strong methods). Other MMIT applications lack evidence, especially those that involve nurses, pharmacists, and patients and their families.

MMIT in prescribing is associated with improvements in patient safety-related processes of the prescribing process, especially in hospital-based studies (87 percent, 52 of 60 studies), and somewhat less in ambulatory-based studies (68 percent, 28 of 41 studies). Errors related to prescribing and ordering were reduced in hospital-based studies (68 percent, 15 of 22 studies), but prescribing errors were not studied as often in ambulatory settings (two of two studies were positive). Reductions in time were related to the time taken to order or prescribe or the speed of the prescribing-to-administering processes. Most reductions in time were not seen as often in hospital-based studies (four of seven studies positive), but were positive more often in ambulatory settings (four of five studies). Adherence to treatment guidelines, reminders, and recommended practice was improved in hospital studies (83 percent, 19 of 23) and to a lesser but still significant extent in ambulatory studies (64 percent, nine of 14 studies). Workflow was not evaluated in these studies of changes in process, although issues of workflow are addressed in qualitative studies in other sections of this report.

Order communication. Order communication, like dispensing, is one of the two medication management phases with the least number of studies—only 16 were identified. Two-way EDI holds promise to increasing the effectiveness of perfecting the prescription/order interactions between clinician prescribers and pharmacists. Currently, evidence on one-way communication predominates. The changes in process were also varied (two studies of errors, two of prescribing changes, five on time considerations, and three on workflow). Most studies were done using quantitative observational methods and all showed positive results.

Dispensing. Nine studies (three RCTs) assessed process improvements in dispensing. All process changes that were evaluated were found to be positive: four on modifications of the drugs that the pharmacists dispensed, three on errors, two on workflow, and one on adherence to good practice. With these few studies and multiple outcomes, evidence is limited on the role of MMIT in improving dispensing. This supports the findings of a Canadian health technology assessment report on MMIT that evaluated hospital dispensing and administering medications in hospitals.[11]

Administering. Many articles dealing with administering medications were not included in this report because they were descriptive and did not include comparative data. Nineteen studies, 1 RCT, 1 cohort study, and 17 quantitative observational studies, were included. All studies were set in hospitals and included nurses. The MMIT systems were well integrated into multiple hospital IT systems. Error-reduction goals were common in the studies and almost always found to be improved (8 of 13 studies of errors). Errors were mixed, as some related to transcription and some to timing of administration, while some identified more serious errors. Four studies showed no improvement in errors while one study showed increases in errors, mostly related to timing of administration.[12] Four of five studies showed reductions in time from ordering to administering medication. Two studies evaluated the allocation of nursing time: one showed change and one did not in the proportion of time spent on various nursing tasks, including direct patient care, with the introduction of integrated MMIT for medication administering.

Monitoring. In our analysis, 70 percent (33 of 47 studies) of the included studies were associated with a 50 percent improvement in half or more process measures. Of these studies, most targeted physicians exclusively (34 studies), were conducted in academic institutions (33 studies), were developed for use in the ambulatory care setting (28 studies), focused on the adult population (36 studies), and provided CDSS with alerts or reminders to support chronic disease management (12 studies).

Studies that involved laboratory-based medication monitoring were most likely (76 percent of the time) to be associated with a greater than 50 percent improvement in a process outcome(s) than sign- or symptom-based medication monitoring. The most successful types of studies focused on changing prescriber behavior, improving response time to generated alerts, and improving the diagnosis and management of chronic diseases.

*Reconciliation***.** Two systematic reviews and four studies provided evidence for improved reconciliation of medications with health IT. Reconciliation is the matching of medication lists over time, from different health care systems or from different prescribers. The evidence on reconciliation of medication lists is sparse, especially for systems that are fully integrated and capable of providing electronic comparisons of historical and current medications for individual patients at hospital discharge or on transfer to other facilities. All four studies showed improvements in agreement among lists of medications and two extended the evaluation to show improved prescribing[13] and reduced errors.[14]

Unintended consequences. Eighteen studies provided data on adverse effects or unintended consequences. Two qualitative studies identified classes or categories of unintended consequences of health IT, many of which apply to MMIT applications. Some unintended consequences are minor, and some are major. In addition, some are seen to be positive and helpful. Some consequences are serious. For example, a small but statistically significant increase in mortality was seen in a children's hospital that installed a CPOE system that did not match workflow needs.[15] A similar study showed another children's hospital that did not see the same increase in mortality in admitted children after their careful planning and implementation of health IT.[16] Several authors contend that all health IT has unintended consequences. Formal evaluations of health IT installations should seek these unintended consequences and report them in their publications related to the evaluation. The importance of unintended consequences of MMIT also depends on the severity of the event, the degree of invasiveness of the MMIT, and the extent to which the use of the MMIT system disrupts existing workflow and processes. Consideration of formal reporting of serious unintended consequences might benefit all involved in development and implementation of MMIT systems. The qualitative studies in this report supplied a richer understanding of the adverse effects of MMIT, and they can form a strong base for more qualitative and quantitative studies of unintended consequences.

Education. Education related to MMIT centers on three aspects: formal informatics training during professional education or after graduation, training to use the MMIT systems, and improved outcomes based on knowledge and skills because of the use of the MMIT systems for health care providers, patients, and their families. This report does not include preprofessional or professional education related to the use and understanding of MMIT systems or certification in informatics or eHealth, all important aspects of MMIT application development and integration. Although we sought articles assessing postprofessional education related to changes in process associated with MMIT systems, we did not identify any articles that met our criteria. Training in the use of systems was often mentioned in articles but was not evaluated. Only one article was related to the educational component of MMIT systems for patient and family use, and it was associated with improved clinical outcomes. More information on health care professional and patient education is included in the sections of this report dealing with intermediate outcomes.

Intermediate outcomes. Intermediate outcomes deal with use, usability, education, knowledge, skills, and attitudes. Most studies with intermediate main endpoints focused on measuring use, correlates of use, perceptions, and satisfaction in the prescribing phase (26 of 42 studies). As for changes in process, clinicians and prescribing were well-studied. Use, perceptions, and satisfaction were reported to be improved. Factors such as ease of use, perceived usefulness, and improved quality of care predominated. Satisfaction and attitudes varied depending on the role of the health care provider. Variation in needs and roles of health professionals with respect to use of health IT are real and should be considered when choosing or implementing any new IT system. Usability studies with comparison groups are sparse but can provide useful suggestions to improve systems. Usability studies are often difficult to generalize or transfer across settings, in part because MMIT effectiveness is linked strongly to the culture, institutional leadership, and other situation specific factors. Therefore, applicability of findings related to usability is problematic in MMIT applications.

Economic outcomes. Five of 31 articles dealing with costs conducted comprehensive economic evaluations (costs and consequences). Two evaluated a CPOE system and three evaluated CDSS. Most of the studies that included monetary data (22 of 31 studies) were partial economic evaluations in the form of cost analyses (assessing costs of alternatives without analysis of effectiveness or efficacy). Most of these partial economic analyses assessed costs of prescribed medications with the MMIT system compared with not having the MMIT system.

Several studies found that health IT interventions may offer cost advantages despite their increased acquisition costs. These studies showed that over time, a net benefit accrued based on cost reductions resulting from the MMIT (such as lower adverse drug events (ADEs), drug costs, and laboratory test usage). However, given the uncertainty that surrounds the cost and outcomes data, and limited study designs available in the literature, it is difficult to reach any definitive conclusion as to whether the additional costs and benefits represent value for money.

Clinical outcomes. A total of 76 studies sought to measure improvement in clinical outcomes or reduction in ADEs, of which 26 (34 percent) reported significant benefits of health IT. One reported harm—a small but clinically important increase in mortality when an inflexible CPOE was implemented in a children's hospital.[15] Because of the seriousness of the implications of this study, many people reviewed this article and its methods.[17] A later and similar study showed that with careful planning another children's hospital did not see the same increase in mortality in admitted children after the implementation of a health IT.[16]

An additional two studies implemented CDSSs to reduce costs and assessed whether reductions in drug use increased mortality[15] and length of stay.[18] Both studies lacked sufficient power to conduct a valid assessment.

Studies that used laboratory-, sign- and symptom-based monitoring approaches were mostly clinician based. If theMMIT monitoring was used to identify and intervene with patients with actual problems (e.g., excess blood pressure) or needed care (e.g., hemoglobin A1c monitoring), this appears to be more effective than CDSS approaches that identified theoretical problems (potential for ADEs), particularly if patients are also sent reminders and decision support recommendations.

Highly targeted interventions, which focused on specific problems that provide problem-related specific interventions, appear to be more effective than more diffusely focused systems such as CDSS and CPOE. Some of these highly targeted interventions involved CDSS tools for improving the effectiveness of anticoagulants (proportion of days with blood clotting parameters within the therapeutic range), improving the choice, route, and duration of antibiotics, and reducing ADEs related to antibiotic use, and most were successful.

Studies that have been successful in improving patient outcomes target high risk and vulnerable populations who have poor disease control, lack sufficient access to health care providers to manage their condition or subpopulations with sufficient economic resources to respond to the CDSS intervention. The effect of similar CPOE systems on mortality can vary substantially as a function of the extent to which implementation strategies disrupt or delay critical activities in the clinical setting and demand additional time for order entry from clinical staff. Critically ill patients (i.e., those who are most vulnerable) are most likely to be affected by dysfunctional technology and implementation strategies.

Qualitative studies. Qualitative studies seek to understand phenomena and answer questions of why and how as well as to gain insights into real life situations. They often study the more human or "soft" side of health and health care. The preceding sections concentrated on studies with quantitative outcomes. Fifty-three qualitative studies are included in this section. Patient safety was the main health aspect evaluated in qualitative studies. Before MMIT implementation most studies found that clinicians expected that MMIT would improve patient safety and once implemented most clinicians felt that MMIT had improved safety.

The qualitative studies focused on system design including workflow changes, challenges with the system interface, and new communication processes—all of which can generate new kinds of medical errors, which in some cases were detrimental to patient safety.

Early implementers associated MMIT with a lot of self-reported "hard work" by those who were expected to use the new systems. These people, most often health professionals, struggled, often independently, with limited guidance with respect to planning and implementation tactics during preparation for and implementation of the MMIT applications. During planning and early implementation, the users often experienced unanticipated effects. Frequently, the initial stage was disruptive and, consequently, clinicians found provision of care to be more challenging with the MMIT system than without. However, after the initial stage was over, the attitudes of the care providers changed, and the potential benefits of the system become clearer to most. Of special note is that the implementation of MMIT systems generated emotional responses in a broad range of health professionals, both positive and negative. For example, strong feelings were associated with reminders and alerts[19] and CPOE.[20]

MMIT implementation did not just mean that a clinician needed to learn a new IT system, but the implementation also affected most of the other parts of the delivery of care processes, including how the interdisciplinary care team worked together.

KQ2. Knowledge and Evidence Gaps

We identified gaps in the report, some that we expected and some that we did not. We address the question of knowledge deficits across phases and outcomes, settings and participants, grouping similar gaps together.

Phases of medication management. Because of the preponderance of publications on the prescribing and monitoring phases, they are less in need of more study than the other phases of order communication, dispensing and administering, and medication reconciliation. In addition, the educational or training requirements for effective use of MMIT applications by health professionals need to be studied as well as education related to patients as new MMIT applications are developed for their use.

Research methods. MMIT applications are complex interventions and need to be studied in pragmatic (i.e., does it work in real settings?) evaluation projects and using complex interventions methods. The applications also should ideally be studied by teams of researchers with, or teams that seek consultation from, those who have experience in clinical practice, research methods, statistical analysis, and informatics training and experience. Qualitative studies are also vital to understand the complex nature of how systems are used and valued, especially across groups of health professionals who often have different needs and expectations.

Health care providers. Physicians are well studied. Nurses, midlevel practitioners (nurse practitioners, physician assistants, midwives), pharmacists, other prescribers such as dentists and mental health practitioners, and hospital administrators need studies directed at their needs, practice patterns, and health IT tools.

Patients. Many studies included data related to patients, usually in the measurement and reporting of process changes and other outcomes. Few studies, however, concentrated on how the MMIT systems directly affected patients and clinical outcomes important to them. Traditionally, MMIT systems were developed as clinician and administrator tools. Patient and family use of MMIT systems is becoming more important, and this gap in our understanding needs to be addressed.

Settings. Hospitals and ambulatory care settings are well studied. Gaps exist in our knowledge of the effectiveness of MMIT in long-term care facilities, the community, and homes. Long-term care facilities most need strong qualitative and quantitative studies because they rely heavily on medication. Homes, schools, and other community settings will also become more important with shifting care to more self- reliance in relation to wellness care and chronic disease management.

Health IT. Much research has gone into evaluating CDSS and CPOE systems, either alone or integrated. For example, 77 of 88 RCTs evaluated some aspect of CDSSs. Other MMIT applications, especially those that are used by nonphysicians or outside the prescribing and monitoring phases, lack evidence. Examples with little evidence on effectiveness are bar coding for administering and dispensing, pharmacy information systems, electronic medication administration record systems, and fully integrated comprehensive information systems.

Process changes. Patient safety processes such as error reductions and improvement in prescribing have a strong evidence base. Issues related to workflow, communication changes, and unintended consequences are understudied. More study of laboratory-based monitoring of medications, especially in facilities that have highly integrated information systems, is important. More qualitative and controlled studies are needed as well as multicenter studies and those that use methods developed by groups focusing on health technology assessment (HTA). These HTA methods include integrated reports that bring together research syntheses, modeling of processes and full economic reports, and cost studies. Often these HTA reports do not, but can, involve additional collection of evidence.

Intermediate outcomes. More study is needed on the importance of usability testing in all stages of development and use. This must be done with all users and not just segments of those involved in using MMIT. Usability studies have not traditionally been generalizable or transferrable but more limited to a specific setting. AHRQ might consider a research program in how to make these usability studies more applicable to multiple institutions, training in usability methods, collection of usability tools and completed studies, and research into the need for standards of usability testing for new or modified systems. Usability studies must also include all users of systems. For example, systems that have been optimized only for physician users are usually systems that nurses and other health professionals have difficulty using. Workarounds have often been unofficially implemented by users instead of system modifications and improvements.

Clinical outcomes. Findings associated with improvement in clinical outcomes are still equivocal. These studies are difficult to do well, expensive, and time consuming, but they must be done. Multicentered trials planned by strong teams of experienced people from multiple backgrounds are vital.

Cost and economic outcomes. Although many studies exist that list costs and outcomes, few comprehensive and definitive studies of the economic value of MMIT applications exist. Both the potential for improvement and the costs of implementing and maintaining these systems are huge. Again, well-planned studies with broad input from many stakeholders are necessary for understanding the true worth of MMIT applications. HTA or other studies that integrate costs and consequences of MMIT systems would be ideal.

Qualitative. Qualitative studies have provided much valuable information about MMIT. Gaps in qualitative knowledge center on the lack of qualitative studies that address the effects of MMIT on health outcomes. In addition, very few qualitative studies examined the effects of MMIT from the perspective of the patient.

KQ3. Value Proposition for Implementers and Users

Value proposition is determined from a balance of financial, clinical, and organizational benefits. A clear assessment of each of these from the viewpoint of each stakeholder is needed to make a clear value judgment. For each stakeholder—and many are involved with MMIT implementation—the relative importance of these three elements is different. Values will also vary depending on the setting and the type of technology employed. Multiple stakeholders, some of whom may be distant from the MMIT, need to be considered in any value proposition study. Based on the evidence in KQ1: Effectiveness, knowledge about the three elements needed to make value judgments is slowly accumulating. We cite only 31 papers in this section, although some of our assessments come from sections of this report that have included more studies. Gains in productivity and process of care outcomes have been shown, but good evidence of improvement in patient outcomes with MMIT is weak or lacking. The body of economic literature is still sparse and lacks vigorous study. We found little theoretical work or actual studies that were done to determine what each stakeholder takes into account to reach value proposition judgments related to MMIT.

KQ4. System Characteristics

Few studies (n = 21) demonstrated evidence of the impact of the characteristics of MMIT applications on the likelihood to purchase, implement, and use such IT applications. No studies assessed open-source health IT applications, with only one study each on conformity with standards and CCHIT-certified systems. Twenty of the articles related to the prescribing and ordering phase. Almost all of the articles suggest that feature sets of health IT applications have been instrumental in reaching decisions to adopt MMIT applications. Certain features of systems improve the likelihood of purchase, implementation, and use of MMIT. The literature, however, is sparse and observational in nature. Most often authors described barriers and concerns toward implementation and acceptance rather than characteristics of MMIT that could facilitate implementation, purchase, and use of such systems. Authors seldom provided enough details about the technology to form conclusions about the value of feature sets and system characteristics. Head-to-head comparisons of systems differing in their features were not found.

KQ5. Sustainability

Our literature review revealed three important findings: sustainability is frequently mentioned in the core biomedical informatics literature, it is poorly defined, and none of the articles included in this evidence report explicitly studied sustainability. These findings are not entirely surprising. A previous AHRQ-sponsored evidence report that assessed the costs and benefits of health IT in pediatrics found only one article that explicitly discussed sustainability.[21]

Future research would be beneficial for many if a study or group would develop an operational definition of sustainability that could be used to study its determinants. Moreover, it is likely that the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 will lead to improvements and sustainability of health IT applications that specifically support the medication management continuum through meaningful use.

We have summarized a body of literature that uses surveys to detect patterns in the characteristics of people and organizations that are more likely to implement various technologies. These surveys are often the basis for further study into barriers and facilitators to increasing uptake and adoption.

Integration of MMIT with other systems was an inclusion criterion for our report (except for PDAs that analyzed patient-specific data). Some technologies were integrated with a greater number of components than others. Frequently, the descriptions of the systems were inadequate to fully determine how the systems were connected. Access to various other information sources, most notably laboratory reports, enhanced the performance and acceptance of the MMIT applications.

KQ6. Complete Two-Way Electronic Data Interchange

No reports documenting the use of complete two-way EDI systems were found. Evidence from the limited set of one-way, e-Prescribing studies was extrapolated to identify possible key facilitators and barriers to completely electronic, two-way, e-Prescribing systems. Possible facilitators include monetary or other incentives to providers, a permissive regulatory environment, and the existence of an established standard for prescription EDI. Barriers included the low rate of EMR adoption in the United States, regulatory and legal uncertainties, and inadequate consideration of the effects of e-Prescriptions on pharmacists and pharmacies and their processes. While answering this question, we found that the Bell model does not represent the two-way communication between pharmacists and prescribers—it shows only a one-way linear movement of information.

KQ7. Effectiveness of CDSS

Seventy-seven RCTs were designated as primarily studying CDSS related to medication management and integrated with other health IT. These studies involved 4,709 providers and 828,441 patients in total. All studies assisted with at least the prescribing or monitoring phases of medication management. Overall, we found a lack of RCTs addressing electronic decision support integrated with other types of health IT. Statistically significant process changes were often shown in these RCTs. Only a small minority of these focus on clinical outcomes, however. Studies with clinical outcomes are those that are most important to guide decisionmaking of patients' providers and policymakers about the usefulness and need for MMIT interventions. A very small number of studies reported improvement in clinical outcomes.

Discussion

The literature of MMIT presents challenges. It is diffused across multiple disciplines, and much of it is descriptive in nature. We also found that although studies with strong methods exist, they are not uniformly dispersed across phases of medication management, people, settings, or health IT applications.

The literature would be stronger if standardized definitions of issues like medication errors, adverse effects, MMIT applications, and sustainability were implemented. The evidence of effectiveness can be made stronger with directed evaluation funding. With direction the evaluations could be encouragement for studies to be done appropriately and not just on small budgets or by the system developers. Training in research skills as part of informatics training may also enhance the evidence on the effectiveness of MMIT. We noted problems in study methods and often found studies that lacked sufficient numbers for valid statistical analyses and assessment of implications.

Despite the challenges in the evidentiary base for MMIT, it is a vital, vibrant, and a proven component of health and health informatics—at least for improving the processes of care that include patient safety. Qualitative studies have provided data on expectations, hopes, changes in how care is delivered, and the need for deep understanding of the effects of MMIT applications in planning for and implementing them. We are much wiser for bringing this literature together into one resource. Moving forward and with the advent of new systems, greater emphasis on eHealth to improve health care and health care delivery, and the move to more patient-centered care, it is an exciting time for development and integration of MMIT applications.

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Introduction

Scope and Purpose of the Systematic Review

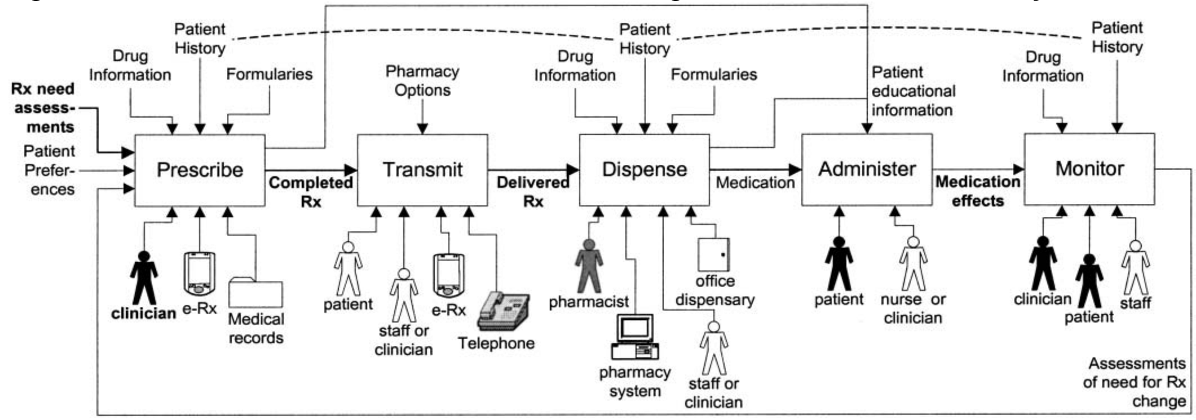
The Agency for Healthcare Research and Quality (AHRQ) has considerable interest in health information technology (health IT). They have contracted several reports that are published or will soon be published. These evidence summaries on health information technology (IT) are related to costs and benefits;[2] barriers and drivers of health IT for the elderly, chronically ill and underserved;[3] the impact of consumer informatics applications;[4] and telemedicine.[5] Currently AHRQ has also contracted for the use of health IT in decisionmaking,[6] in patient centered care[7] and decision support for health care decisionmaking.[8] These latter reports will be available early 2011. AHRQ asked the McMaster University Evidence-based Practice Center to generate an evidence report outlining the impact of health IT on the medication management process. Medication management is a major component of the health care system. Currently, approximately 10 percent of the health care budget in the United States is spent on prescription medications.[22]

To structure this evidence report we use the framework of medication management as presented by Bell and colleagues.[1] They model the medication management continuum into the five phases of this evidence report; Figure 1 is a pictorial representation of the medication management phases.[1]

The first phase of the continuum is ***prescribing*** medications by clinicians who have assessed the patients' conditions and needs. The second phase is to transmit the prescription to the pharmacists who work with the prescriber to clarify and verify the order (referred to as ***'order communication'*** in this report to capture the complexity of the communication that occurs between prescriber and pharmacy). The next step is ***dispensing*** the medication in its required form and dose, followed by ***administering*** the medications to the patient. ***Monitoring*** is the final phase where ongoing oversight occurs to address the changing medication needs and situation of the individual. ***Reconciliation*** of the medications taken by individuals and postprofessional ***education*** or training related to medication management IT (MMIT) are additional aspects (as opposed to phases) of the medication management cycle covered by this report. Reconciliation is a process whereby a patient has their medication lists verified for completeness and accuracy when the patient moves from hospital to home or to a nursing home, or is involved with multiple care providers. Reconciliation can improve care by using health IT to ensure accuracy of medication lists, identification of gaps and conflicts in prescription, and provide timely and efficient transfer of patients and their medication data. Education is also important in MMIT systems for both improving knowledge and skills of patients and care providers and to enable timely implementation and optimal use of MMIT systems. Therefore, AHRQ requested inclusion of both reconciliation and education in this report in addition to the five medication management phases.

This report includes clinicians, patients, informal caregivers, and administrators. All care settings are also covered: home, community, primary care and specialty clinics, all levels of hospitals, long-term care facilities, and pharmacies of all types. This report does not focus on the health insurance or pharmacy industries.

Figure 1. A functional model of the medication management continuum created by Bell et al.[1]



Includes the major activities involved in medication management and forming the basis of our medication management phases. We refer to the transmission of the order/prescription and the bi-directional communication between prescriber and pharmacy staff as "order communication." Used with permission BMJ Publishing Group.

Health IT holds great potential to improve the quality of health care and reduce potential and real errors while at the same time providing cost effective care. The coverage of this report is broad, reflecting the scope and breadth of health IT and the processes of medication management. This report centers on health IT applications that focus on medication management such as e-Prescribing applications, computerized provider order entry (CPOE), bar-coded medication administration (BCMA), pharmacy-based health IT, electronic medication administration record systems (eMAR), and other MMIT tools. Smaller health IT applications such as hand-held devices that provide calculations for dosing, as well as MMIT applications integrated with other health IT systems, such as electronic health or medical records systems (EHRs and EMRs), health information systems, hospital information systems, and personal health records (PHRs), and others as identified, are included. For inclusion, the MMIT had to be integrated into the health care system electronically and process patient-specific information that then provided direction for that patient's care. This integration requirement meant that stand-alone devices such as smart infusion pumps and glucose monitors were not included unless they were integrated with other health IT. This requirement allowed the report to concentrate on MMIT systems and separate out these medical devices with some computing capabilities.

Because health IT is a new discipline that crosses many domains, definitions are not always standard. Therefore we have defined terms related to health IT and other issues in this report in a glossary, labeled as Appendix F.

Key Questions (KQs)

KQ1. Effectiveness. Within and across the phases of the medication management continuum (prescribing, order communication, dispensing, administering, and monitoring, plus reconciliation and education aspects) what evidence exists that health IT applications are effective in improving:

a. Health care process changes (e.g., adherence to guidelines, changes in prescribing behavior, changes in patient monitoring activities, errors, efficiency),
b. Other intermediate outcomes (e.g., use, measures correlated with use, satisfaction with system, usability, knowledge, skills, and attitudes),
c. Costs and economic outcomes,

d. Clinical outcomes for patients (e.g., physiological measures, adverse drug events, length of stay, mortality, quality of life, other patient events),
e. Population level outcomes, and
f. Composite outcomes.
g. To what extent does the impact of health IT on improvement of the health care process, other outcomes, costs and economics, and clinical outcomes vary depending on the type of medication (e.g., controlled or noncontrolled substance) or the form of the medication (e.g., oral, injection, intravenous)?

KQ2. Gaps in Knowledge or Evidence. What knowledge or evidence deficits exist regarding needed information to support estimates of cost, benefit, impact, and net value with regard to enabling health IT applications in terms of prescribing, order transmission, dispensing, administering and monitoring, and adherence? Discuss gaps in research, including specific areas that should be addressed, and suggest possible public and private organizational types to perform the research, analysis, or both.

KQ3. Value Proposition. What critical information regarding the impact of health IT applications implemented to support the phases of medication management is needed to give clinicians (e.g., physicians, nurses, psychologists, dentists, and pharmacists), health care facility administrators, patients, and their families a clear understanding of the value proposition particular to them?

KQ4. System Characteristics. What evidence supports or refutes the impact of any of: open source, home grown, proprietary, local configuration ability, system configuration ability, conformity with U.S. Federal or other interoperability standards, conformity with other standards from other jurisdictions, being Certification Commission for Healthcare Information Technology (CCHIT) certified, system architecture, or feature set on the decision to purchase, implement, or use health IT in medication management systems?

KQ5. Sustainability. What factors influence sustainability (use and periodic updates) of health IT applications that support a phase of medication management continuum: prescribing, order communication, dispensing, administering and monitoring, plus reconciliation and education?

a. To what extent does the evidence demonstrate that health care settings (e.g., inpatient, ambulatory, long-term care) influence implementation, use, and effectiveness of such health IT applications?
b. What is the impact (e.g., challenges, merits, costs, and benefits) of having electronic access to patients' computerized medication records (current and past), EHRs and PHRs, formulary information (inpatient and outpatient issues), billing information, laboratory records, and other electronic patient data in the quality and safety of care provided by health IT applications that support at least one phase of the continuum of medication management (i.e., prescribing and ordering, transmission and verification, dispensing, administering and monitoring and adherence)?

KQ6. Two-way EDI for Order Communication. It has been recognized that implementation and use of a complete, two-way electronic data interchange (EDI) (e-prescribing with e-transmission) between the prescribers' electronic medical records (EMRs), including CPOE and other health IT within EMR, and other similar systems or stand-alone e-prescribing systems, retail, and mail-order pharmacy prescribing systems have been limited. In many instances, health IT systems that facilitate prescribing are used at the point-of-care and are combined with nonelectronic modalities for transmission of prescriptions, such as paper, facsimile, voice, and telephone. On the pharmacy side, prescriptions being received may not automatically populate the pharmacy prescribing system, instead appearing in the fax printer or in a different computer program than the one the pharmacist regularly uses to fill prescriptions, requiring the pharmacist to manually retype the prescription information into the pharmacy's electronic system. This e-Prescribing with e-transmission also includes order clarification with electronic communication between the prescribers and pharmacists.

a. What evidences exists demonstrating the barriers and drivers of implementation of complete EDI that can support the prescription, transmittal, receipt, and order clarification process of e-Prescriptions?
b. How do barriers, facilitators, and economic incentives vary across pharmacists, physicians, and other relevant stakeholders with respect to adoption and use of complete EDI (e-Prescribing/ordering with e-Transmission)?

KQ7. RCTS of CDSS. What evidence exists regarding the extent of integration of electronic clinical decision support systems (CDSS) in a health IT system for the prescribing, dispensing, and administering of medications? To what extent does the use of the CDSS for prescribing/ordering, order communication, and dispensing of medications impact the various outcomes of interest, including health care process, intermediate, costs and economics, and clinical endpoints? CDSSs are broadly defined to include medical and pharmacy systems, reminders, and monitoring.

Background

Medication management is a complex and expensive process with high potential for both benefit and harm. Ninety percent of American seniors and 58 percent of nonelderly adults rely on medications daily. The average cost of prescription drugs per clinic visit in the United States in 1996 was $79. By 2006, this had doubled to $161. Nationally, all prescription drugs costs are projected to be $246.3 billion for 2010. Substantial increases in medication costs are expected until at least 2019 based on the aging population[23] and increased demand for medications (72 percent increase from 1997-2007).[24] The introduction of newer, high cost, nongeneric, and specialty drugs also adds to the projected increases. The amount of new more complex medications also places a substantial cognitive burden on health professionals who prescribe and oversee these medications. Genomics research and its role in medication choices for individualized health care are also going to become more important in the next decades. Health IT can play a strong information support role to help deal with this increased cognitive load and provide efficiencies for provision of prescription medications, control, and recording of use.

In addition to increasing costs, medications can cause substantial health problems. Incorrect choice of medications and over or under use leads to less than optimal care. The U.S. Institute of Medicine (IOM)[25] report on medication errors estimates that errors occur in all levels and locations of care. Estimates for hospitalized patients show 1.5 to 10 errors per 100 opportunities for errors for prescribing and 2.4 to 11 errors per 100 opportunities per dose for dispensing. This translates to approximately one error per patient per hospital day. Error rates in long-term care prescribing are calculated to be from 6 to 20 errors per 100 opportunities per dose. Ambulatory care studies show that up to 21 percent of prescriptions have errors.

Pediatric patients present special challenges in that doses must often be adjusted for body weight and age. As an example, one study showed that errors in acetaminophen use in the emergency department for children were 22 per 100 doses ordered.[26] Elderly patients also have special prescribing and drug monitoring needs based on issues related to aging, multiple conditions, the need for several medications, and often, decreased kidney function.

Pharmacist errors in order communication and dispensing also occur. Cheung and colleagues[27] reviewed the literature of dispensing errors and found that overall errors occurred in the range of 0.2 to 0.8 percent, although the number varied depending on how the errors were detected and reported. The task of medication administering by nurses, other health care providers, as well as patients and families, have also been shown to have associated errors. Many of the errors in medication management described above are preventable. The IOM report shows that preventable errors often constitute 20 to 50 percent of all errors. In addition to mortality, errors and inappropriate use are costly, often cause a huge drain on health care resources, and contribute to substantial morbidity and challenges to well-being.

Historically, the first MMIT application was published in 1979 as a decision support system to help in prescribing appropriate antibiotics.[28] The first RCT was done 5 years later.[29] Health IT has tremendous potential to improve care associated with medication management. For example, the Center for Information Technology Leadership (CITL), in their Value of Computerized Provider Order Entry in Ambulatory Care[30] report that potential savings from implementation of CPOE in ambulatory care prescribing and its ability to detect errors would provide savings in the U.S. of $28 billion annually. Other MMIT applications are projected to have similar cost savings and improved care. However, the promises of health IT have not always been obtained after installation. For example, Mollen and colleagues[31] reviewed CDSSs for prescribing and found 37 reports that successfully showed changed health care provider behavior. Only five of these studies noted improvements in patient outcomes. Similarly, Eslami and colleagues[32] reviewed studies of CPOE applications in outpatient medication ordering. Of 67 studies, only 21 dealt with safety. Most of the evidence they identified used observational study methods. They showed that although CPOE and other information systems are often costly, some evidence supports medication safety benefits. However, they also note that some studies have data that support increased error rates and adverse drug events (ADEs) with CPOE implementation. Kaushal and colleagues[33] show that e-Prescribing with CDSS reduced errors from 52.5 to 6.6 per 100 prescriptions in ambulatory care. Paoletti and colleagues[34] reduced errors from 2.9 percent to 1.6 percent in a U.S. general hospital with the implementation of BCMA and eMAR.

Many groups have studied various components of the medication management process and the effects of multiple health IT systems and programs across settings and populations. However, the body of evidence that evaluates the actual, and not projected, effect of a broad range of MMIT applications and the medication management process is not available in one document or Web site. This evidence report is designed to be that summary.

Methods

The objective of this report is to review and synthesize the available evidence regarding the effectiveness and effects of health IT on all phases of medication management, as well as reconciliation and education. The report considers a broad range of health ITs and medication management processes and concentrates on those people involved in direct clinical care: physicians, pharmacists, dentists, nurses, and other health professionals; patients and their informal caregivers; and health care administrators across all health care settings and levels of care.

Recruitment of Technical Experts and Peer Reviewers

The Medication Management through Health Information Technology (MMIT) team was made up of experts from McMaster University, the University of Pittsburgh, and McGill University. Expertise of the group included medical informatics, primary care, geriatrics, internal medicine, pharmacy, conduct of clinical trials, and systematic literature reviews. Our Technical Expert Panel (TEP) was comprised of 12 external experts from diverse professional backgrounds including medication safety, health information technology in medication management, consumer informatics, and pharmacy. Their clinical expertise included specialization in pharmacy, geriatrics, reproductive health, pediatrics, and primary care. The TEP was involved in the development of the project by helping to refine the questions, focus the scope, solidify and streamline definitions, and approve modified plans and project direction. The members of the TEP and the external reviewers are listed in Appendix E. We also sought advice from other AHRQ Evidence Based Practice Centers who had completed health IT evidence summaries.

Key Questions

The core team worked with the external advisors, the TEP, and representatives of the AHRQ to refine the key questions (KQ) presented in the "Scope and Purpose of the Systematic Review" section of Chapter 1. Before searching for the relevant literature, the content of the questions was clarified, the concepts were defined, and the types of evidence that would be included in the review were ascertained.

KQ1. Effectiveness addresses the evidence that health IT applications improve a broad range of outcomes when health IT is applied to medication management (five phases plus the impact of postprofessional and patient education and reconciliation among those phases). Studies that reported changes in process, cost and economics, intermediate, qualitative, and clinical patient outcomes are included.

Much literature addresses the use of health IT in medication management. To address the MMIT question using the best available research findings, two limitations were placed on the included articles. First, only hypothesis-driven articles were included. For quantitative articles this meant that those with comparison groups and appropriate statistical analysis were analyzed in this report. Qualitative studies were included if they reported use of recognized qualitative methods. Many other articles met our inclusion criteria for content and measured an outcome of interest but they were not hypothesis-driven; the report lists these citations in the KQ1: Effectiveness section of Chapter 3: Results.

KQ2. Gaps in Knowledge or Evidence addresses knowledge and evidence deficits regarding needed information to support estimation of costs, benefits, impact, and net value regarding MMIT applications.

KQ3. Value Proposition requires the identification of information about the MMIT applications needed for each stakeholder to have a clear understanding of the value proposition particular to them. It was determined that the answers to KQ2: Gaps and KQ3: Value Proposition would become evident from the review of the evidence in KQ1: Effectiveness, although studies addressing values propositions by stakeholders are also included.

KQ4. System Characteristics addresses the impact of MMIT application features on the likelihood that the systems will be purchased, implemented, and used. This evidence comes from studies measuring implementation, use, and purchasing decisions. Studies of all designs are included.

KQ5. Sustainability addresses the factors influencing the sustainability of MMIT applications, specifically: (a) the impact of the type of setting, and (b) the impact of access to other electronic data on health care quality and safety. Sustainability is not well-defined. The definition of sustainability provided by Humphreys et al.,[9] "the ability of a health service to provide ongoing access to appropriate quality care in a cost effective and health-effective manner" was incorporated. This definition restricted the number of articles that were included in this review. The topic of sustainability is one that needs further research in defining and further analyses of existing systems.

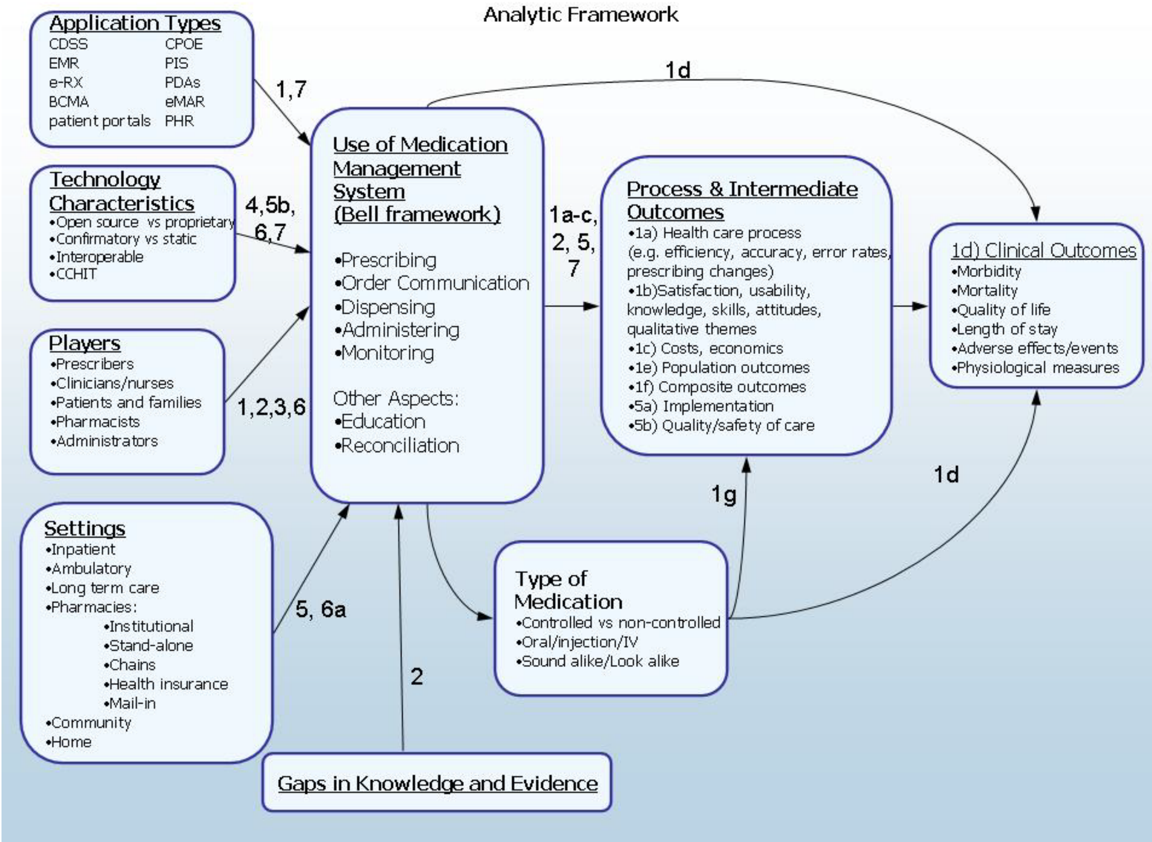
KQ6. Two-way EDI relates to the barriers and facilitators to complete two-way electronic data interchange (EDI) between prescribers and pharmacists and how these factors vary across stakeholder groups. Through discussions with experts and the MMIT writing group we determined that the evidence would be sparse in this category. Any article studying EDI communication (one- and two-way) that includes original data (qualitative or quantitative) is included in the report.

KQ7. RCTs of CDSS addresses the extent to which clinical decision support is integrated into health IT systems for medication management and the impact of CDSS on process and health outcomes. Because of the size of the literature and the improved level of evaluation rigor and generalizability or applicability of RCTs, only RCTs are included. This question included changes in process as well as the broad range of outcomes included in KQ1: Effectiveness (clinical outcomes, behavior change, and costs and economics) across the phases of medication management as well as reconciliation and education.

Analytic Framework

To provide a focus and structure for this review, an analytical model that incorporated the key component for seven key questions was developed. This provided direction for the literature search and guidance for the data abstraction and reporting (Figure 2).

Figure 2. Conceptual model addressing the seven key questions: enabling medication management through health IT



CDSS = computer decision support system, EMR = electronic medical records system, e-RX = e-prescribing, BCMA = bar code medication administration, CPOE = computer provider order entry, PIS = pharmacy information system, PDAs = personal digital assistant devices, eMAR = electronic medication administration records

Literature Search Methods

In the course of searching the literature, reference sources were identified; a search strategy for each source was formulated, executed, and documented (see Appendix A, Exact Search Strings). For the searching of electronic databases, database-appropriate subject headings and text-words were used. Given the broad range of questions and outcomes that the report addresses, searches were performed by first using text-words relating to the various types of health IT applied to medication management. These searches were combined with both medication management terms and computer and technology terms. No limits based on methodological terms were used as all study designs were considered. A number of grey literature resources and AHRQ resources were also searched (see Appendix A, Exact Search Strings).

The search strategies were peer reviewed by a librarian following the Peer Review of Electronic Search Strategies (PRESS) checklist process for systematic review searches.[35] The TEP and internal team provided references from their personal files. The reference lists of review articles were screened for eligibility.

Sources

The following databases were searched: MEDLINE,® EMBASE,® CINAHL® (Cumulated Index to Nursing and Allied Health Literature), Cochrane Database of Systematic Reviews, International Pharmaceutical Abstracts,© Compendex,© INSPEC© (which includes IEEE®), Library and Information Science Abstracts,® E-Prints in Library and Information Science,® PsycINFO,® Sociological Abstracts,© and Business Source® Complete. The search terms used are presented in Appendix A.

Supplemental searches targeting grey literature sources were conducted and included New York Academy of Medicine, SIGLE, U.S. HHS Health Information Technology, Health Technology Assessment reports from the U.K. Centre for Reviews and Dissemination, ProQuest Dissertations, National Library for Health United Kingdom (includes Bandolier), ProceedingsFirst, PapersFirst, National Technical Information Service, and Google. As part of the grey literature search, AHRQ made all references in their e-Prescribing, bar coding, and CPOE knowledge libraries available.

Search Terms and Strategies

Terms related to specific MMIT applications and in combination with both medication management terms and more general computer and technology terms, were prepared. The MEDLINE® search formed the basis for all other databases, but searches were edited as needed depending on the features of the database being used. When possible, letters, editorials or commentaries, and animal studies were excluded electronically. No limits were placed on language or time to capture the global literature and early studies.

Organization and Tracking of the Literature Search

Searching was done in the fall of 2009 and updated in early summer 2010. The results of the searches were downloaded into Reference Manager® version 10 (ISI ResearchSoft) and uploaded into our customized systematic review management system (Health Information Research Unit, McMaster University). The system is Web -based. It allows management of the systematic review process with improved auditing and control capabilities including automatic production of tables and tabulations. The system stores the full text of articles in portable document format (PDF) and tracks duplicates, results of title and abstract review, which articles were included or excluded with reasons, and data abstraction levels.

Title and Abstract Review

The study team reviewed titles and abstracts of all articles retrieved using prepared data abstraction forms (Appendix B, Sample Screening and Data Abstraction Forms). Two blinded, independent reviewers from a team of reviewers conducted title and abstract reviews in parallel. Both reviewers had to indicate that the article was to be excluded for it to be removed. Both reviewers also had to agree on inclusion for the article to be promoted to the next level. In the case of disagreements, a third reviewer determined if the article was to be promoted to the next level of screening.

This first review level was designed to detect all articles that reported on medication management with health IT assisting in the medication management process. Reviewers were instructed to consider applications as health IT if they were integrated with other information systems (rather than stand-alone applications or devices), with the systems being more than passive vehicles for data transfer. We defined health IT as electronic systems that collect, process, or exchange health information about patients and formal caregivers. We included articles only if the MMIT was integrated with at least one health IT system, such as EHR or EMR systems, and that it processed patient-specific information and provided advice or suggestions to either the health care provider or the patients and their families on issues related to health or wellness care. We excluded stand-alone devices (no integration) with the exception of personal digital assistants (PDAs) or handheld devices into which clinicians or patients entered patient-specific information to assist in medication management. PDAs are an important focus for AHRQ. All articles about transmission or order communication between pharmacist and clinical prescriber were also included and tagged as Electronic Data Interchange (EDI).

Review articles were passed through to the second level of screening. Once identified, the bibliographies of the reviews were screened for articles with potential for inclusion and their citations were put through the screening process starting at the title and abstract level if they had not already been captured by the original search. The systematic reviews were also included in the answers to the seven key questions where appropriate.

Defining Medication Management Health IT

To be clear on what kinds of applications were included in MMIT, the following outline for MMIT applications was devised and used by screeners.

MMIT systems or programs were included if:

- The computer or technology processed patient-specific information,
- The information provided by the system was relevant to one of the five phases of medication management or two ancillary aspects (education and reconciliation):
  - Prescribing or ordering medications,
  - Order communication (transmission, clarification, verification),
  - Dispensing,
  - Administering (by health care provider, patient, or caregiver),
  - Monitoring (signs, symptoms, or laboratory data to ascertain patient adherence, adverse events, or the need for medication adjustment),
  - Education (of patients or care providers, but not preprofessional education),
  - Reconciliation of medication lists,
- Someone (e.g., patient, caregiver, family, health care professional) received information in return that was, or could be, linked to patient-specific information used in decisionmaking,
- The technology was part of, or linked to, another electronic information system,
- The article contained outcome data related to one of the areas of interest set out in the key questions.

Articles were to be excluded if they were health IT systems or programs and:

- The IT component was only Web or local browsing of general health information databases or information resources (e.g., online textbooks),
- The system acted as a conduit of information only (except order communication of prescriptions between health care providers and pharmacists),
- Systems where no feedback was provided for patient care (e.g., surveys),

- The system did not help with medication management decisionmaking or provide information about any of the medication management phases (prescribing, order communication, dispensing, administering, and monitoring), or education and reconciliation,
- Systems that made measurements but did not process the information,
- Stand-alone devices that do not integrate with information systems (except PDAs using patient specificinformation),
- The health IT application was used only to extract data (e.g., pill bottles that track opening and closing, smart infusion pumps not tied to other systems, studies using EMRs for data collection if the data were for quality improvement or other related tasks but not direct patient care).

Data Abstraction

Given the range of questions addressed, data abstraction was performed by a core group of staff for KQ1 and KQ7. Abstraction was done by one reviewer, and the accuracy was checked by a second reviewer. The authors of the report performed a final check on the abstracted data. The reviews were not blinded in terms of the article authors, institutions, or journal.

- For all articles, reviewers abstracted information on general study characteristics: study design, the intervention, study population, setting, disease, drugs of interest, and description of the MMIT application (see Appendix B).
- Outcomes data were abstracted from the articles that were applicable to KQ1: Effectiveness and KQ7: RCTs of CDSS regarding the MMIT application impact on a health, health care process, or other intermediate outcomes.
- We abstracted only the main endpoints (major endpoints) that authors indicated as such. If no main endpoint measures were indicated, we abstracted data on outcomes related to medication management and clinical outcomes and relied on the order that those outcomes were presented in the results section, methods description, or abstract.
- We saw great variation in the way outcomes and statistical methods were reported by article authors, even when using similar systems. As a result, for this report it was recorded whether the main endpoint was positively changed by the intervention (noted as + in Appendix C, Evidence Tables). The main endpoint could also be unchanged (noted as = in Appendix C, Evidence Tables). Some studies reported a negative effect where the predefined outcome was found to be in the opposite direction sought (noted as – in Appendix C, Evidence Tables). For example, measuring an increased time to prescribe when the MMIT system was developed to reduce prescriber time. In addition, those studies that identified unintended consequences (adverse effects) of the MMIT systems are summarized in their own section. If more than one main endpoint was reported, the positive and negative referred to the direction of the majority of outcomes.

Articles addressing KQ4: System Characteristics, KQ5: Sustainability and KQ6: two-way prescription EDI were abstracted separately to capture relevant outcome data.

Assessment of Study Quality

The included studies were assessed on the basis of the quality of their reporting of relevant data. Quantitative studies were assessed using the same criteria employed by Jimison et al.,[3] in a previous AHRQ report. RCT scoring was based on Delphi consensus work by Verhagan and colleagues,[10] and is referred to in this report as the 'Verhagen/AHRQ RCT quality scale.' Quality assessments of applicable articles were performed by more experienced reviewers to maintain consistency and accuracy. Studies with before-after, time series, surveys, and qualitative methods were not assessed for quality because few well-validated instruments exist and the study design itself is considered lower on the hierarchy of evidence.

Method assessments used for articles of the relevant design:

Verhagen/AHRQ RCT quality scale (scored out of nine)

1. Was the assignment to the treatment groups really random?
2. Was the treatment allocation concealed?
3. Were the groups similar at baseline in terms of prognostic factors?
4. Were the eligibility criteria specified?
5. Were outcome assessors blinded to the treatment allocation?
6. Was the care provider blinded?
7. Was the patient blinded?
8. Were the point estimates and measure of variability presented for the main endpoint measure?
9. Did the analyses include an intention to treat analysis

Cohort studies (scored out of ten)

1. Was there sufficient description of the groups and the distribution of prognostic factors?
2. Are the groups assembled at a similar point in their disease progression?
3. Is the intervention/treatment reliably ascertained?
4. Were the groups comparable on all important confounding factors?
5. Was there adequate adjustment for the effects of these confounding variables?
6. Was a dose response relationship between intervention and outcome demonstrated?
7. Was outcome assessment blind to exposure status?
8. Was followup long enough for the outcomes to occur?
9. What proportion of the cohort was followed-up?
10. Were drop out rates and reasons for drop out similar across intervention and unexposed groups?

Case-control studies (scored out of nine)

1. Is the case definition explicit?
2. Has the disease state of the cases been reliably assessed and validated?
3. Were the controls randomly selected from the source of population of the cases?
4. How comparable are the cases and controls with respect to potential confounding factors?
5. Were interventions and other exposures assessed in the same way for cases and controls?
6. How was the response rate defined?
7. Were the nonresponse rates and reasons for nonresponse the same in both groups?
8. Is it possible that over-matching has occurred in that cases and controls were matched on factors related to exposure?
9. Was an appropriate statistical analysis used (matched or unmatched)?

Case series (scored out of six)

1. Is the study based on a representative sample selected from a relevant population?
2. Are the criteria for inclusion explicit?
3. Did all individuals enter the survey at a similar point in their disease progression?
4. Was followup long enough for important events to occur?
5. Were outcomes assessed using objective criteria or was blinding used?
6. If comparisons of subseries are being made, was there sufficient description of the series and the distribution of prognostic factors?

Data Synthesis

Evidence tables with article details were created and ordered by key question, subquestion, and medication management phase as applicable (Appendix C). This offered another opportunity to check abstracted elements with the original articles; any errors were brought to the attention of the abstractors of the specific section for correction. Meta-analyses were not performed on any data because of the heterogeneity of the studies, as well as the nature of the observational studies in most sections.

Data Entry and Quality Control

General study data for each article was abstracted by one staff member and entered into the online data abstraction forms (Appendix B). Second reviewers were generally more experienced members of the research team, and one of their main priorities was to check the quality and consistency of the first reviewers' answers and to perform the quality assessment where required.

Grading the Evidence

Because so much of the material was derived from observational studies, we did not provide grades for the evidence beyond quality scoring of the RCTs, cohort, case-control, and case series studies.

Peer Review

Throughout the project, the core team sought feedback from internal advisors and technical experts. These technical experts were members of the TEP and other content and methodology experts as needed. The report was reviewed in several stages, comments considered and incorporated into this final report. Members of the TEP and the peer reviewers are listed in Appendix E. Many of the TEP members also reviewed the initial version of the document. Both the members of the TEP and the review panel provided valuable comments and have made the final document stronger.

Results

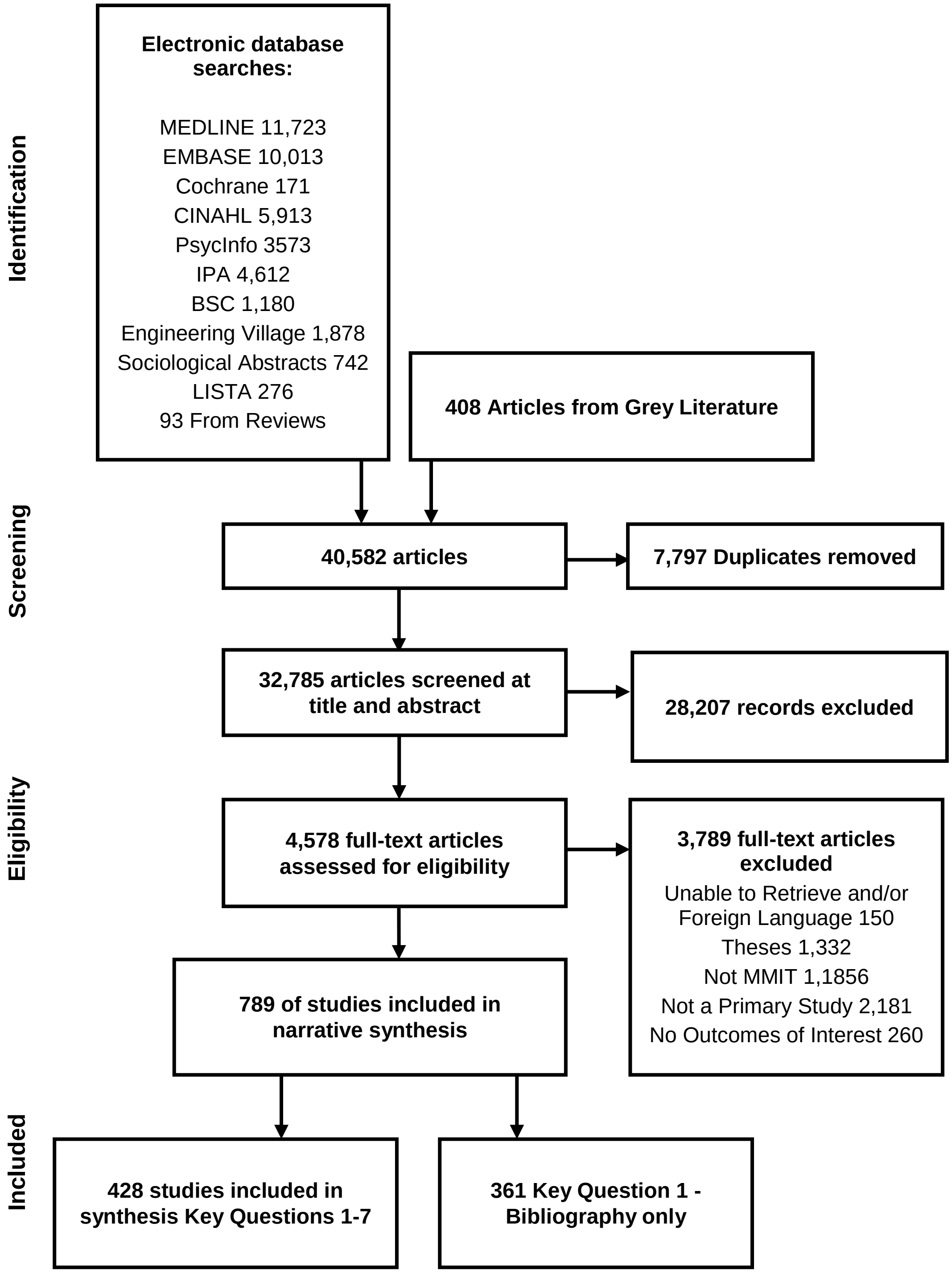
Results of the Literature Search

The literature search retrieved 40,582 articles for screening for inclusion; this includes 93 from hand searches and 408 from the grey literature (Figure 3). We excluded 7,797 duplicates and screened 32,785 titles and abstracts. A total of 4,578 articles were screened at full-text. Reasons for exclusion at this stage included inaccessible copies of full-text, articles in foreign languages that were not translated, unretrievable theses, studies not using integrated technologies or technologies that did not impact on medication management ("not MMIT"), studies that were not a primary study with first hand observations (often review articles), or studies not measuring an outcome of interest to our key questions.

We found 361 articles which met our content criteria for Key Question (KQ) 1: Effectiveness but did not use formal qualitative methods or have comparison groups with hypothesis testing or appropriate statistical analyses (quantitative studies). These articles are not included in the synthesis but they are integrated into the report bibliography with the other articles that were synthesized. This left 428 articles that are synthesized in the evidence report.

A total of 377 articles are quantitatively synthesized in KQ1: Effectiveness. One article was included as evidence for KQ3: Value Proposition although 30 articles were cited directly and many more were used in some of the summaries described in this section; 21 articles were synthesized for KQ4: System Characteristics, 24 for KQ5: Sustainability, 33 for KQ6: Two-way Prescription EDI and 77 for KQ7: RCTs of CDSS. A number of articles were included in more than one key question response as they addressed more than one aspect of medication management.

Figure 3. Literature flow of medication management studies



To address the various outcomes measures or interest in the seven key questions, 428 articles were synthesized. An additional 361 articles met content criteria for integrated technology enabling medication management, but these did not meet methodological criteria of either formal qualitative methods or those with comparison groups and appropriate statistical analysis; these studies are included in the bibliography.

KQ1. Within and across the phases of medication management continuum, what evidence exists that health IT applications are effective?

Effectiveness Studies Overall

KQ1: Effectiveness includes the largest number of articles for any of the seven key questions. Our searching for KQ1 concentrated on content with no limits on methods. The articles were divided into two groups: (1) all qualitative studies were included in the analysis that forms the basis of this report; and (2) all quantitative studies were included in the analysis section if they included a comparison group and data on each group and if they contained statistical methods defined by statistical testing, a statement of hypotheses-based research defined *a priori*, or both.

Articles that met these criteria for qualitative or quantitative studies were analyzed in this report (n = 377). An additional 51 studies that did not meet the above methods criteria were included in KQs 3 to 6; the literature on these topics was sparse. Articles that met content criteria but that did not meet these methodological criteria are included in our bibliography (n = 361) but not in any of the tables nor are they analyzed in the report.[36-396]

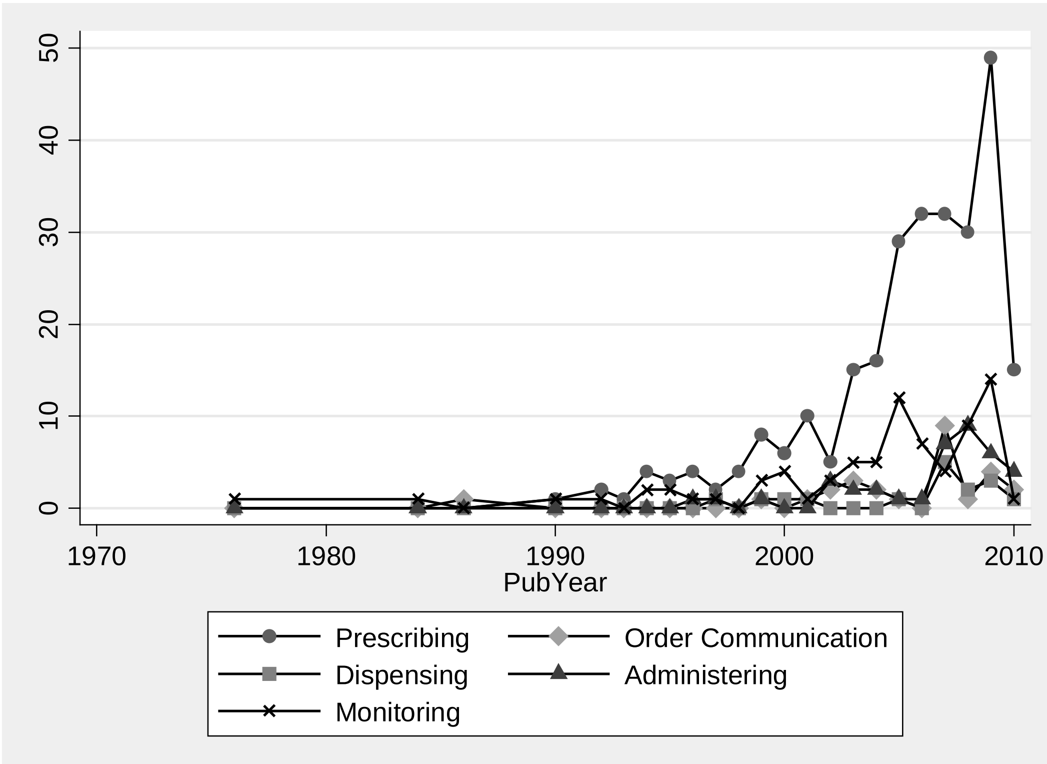
The final analysis for addressing KQ1 included 379 articles. Substantial variation exists in the concentration of evidence and content across issues related to MMIT. Table 1 shows the numbers of studies within each of the five phases plus reconciliation and education by study design. By far, more studies are done in the prescribing phase (n = 263) with a substantial number done in monitoring (n = 77). Dispensing is the phase that is least studied and little evidence exists on education and reconciliation. Figure 4 depicts the trends in publication frequency of articles included for analysis in the report. We saw a dramatic increase in publication of MMIT studies after 2000, most notably in studies dealing with prescribing.

Table 1. Research design for studies across the phases of medication management and education and reconciliation

Design	P	OC	D	A	M	E	R
RCT	69	1	2	2	37	1	1
Cohort	13	2	2	1	6	0	1
Observational	144	18	10	26	29	2	4
Qualitative	37	5	3	10	5	0	0
Total	263	26	17	39	77	3	6

Note some studies cross more than one phase**.** See Appendix C, Evidence Table 16 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
RCT = Randomized controlled trial

Figure 4. Trends in publication of articles relating to the phases of medication management across years until searching was completed in June 2010



Strengths and Limitations of the Evidence

Table 1 illustrates that a variety of research methods were used in the studies, with the majority using observational methods. A substantial numbers of RCTs and qualitative studies were included. The large number of observational studies is reflective of the nature of the domain in that many of the articles retrieved were more often directed at the observational description or evaluation of existing systems rather than based on classical research methods of hypothesis-driven projects.

Settings. Settings where studies were performed also show variation. Table 2 includes the settings for studies across the medication management phases plus education and reconciliation. Studies often reported multiple settings. Most studies were set in hospitals and ambulatory care. Few studies were done in the community (n = 1), home (n = 5), or long-term care (n = 8). The lack of comparative, hypothesis-driven studies set in pharmacies is offset by a larger group of pharmacy studies that were descriptive in nature. Despite the lack of studies set in pharmacies, many studies relied on pharmacies and pharmacists.

Table 2. Settings for the phases of medication management and reconciliation and education

Setting	P	OC	D	A	M	E	R
Ambulatory care (e.g., clinic, doctors office)	94	6	2	1	40	2	0
Community (e.g., school, community centre)	0	0	0	0	1	0	0
Home	2	0	0	2	5	0	0
Hospital	164	12	9	34	36	1	6
Long-term care	4	0	2	3	1	0	0
Pharmacy	11	13	10	2	4	0	1

Note some studies cross more than one phase or setting**.** See Appendix C, Evidence Table 17 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation

Clinicians. Physicians were the most represented clinicians studied (Table 3). Many of the health professionals functioned in primary care and other ambulatory settings. Often studies did not differentiate among specialties or included many specialties in a single study. Nurses were most often studied in the administering phase and pharmacists were involved in order communication. We did not identify any studies that evaluated dentists and found few studies of mental health professionals or midlevel practitioners (e.g., nurse practitioners, midwives, and physician assistants).

Table 3. Clinicians evaluated in outcomes studies of medication management phases, education, and reconciliation

Clinicians	P	OC	D	A	M	E	R
Primary care physicians	25	2	1	0	3	1	0
Specialists	11	0	0	0	1	0	0
Hospitalists	18	0	0	0	2	0	0
Other Physicians	7	0	0	0	2	0	0
Physicians undifferentiated	26	1	0	1	3	0	1
Nurses	20	1	0	16	2	0	1
Mid level practitioners (e.g., PA, NP, MW)	6	0	0	0	2	0	0
Pharmacists	13	6	5	2	1	0	1
Other health professionals	10	0	2	4	1	0	0
Hospital administrators	4	1	0	1	0	0	0

Note some studies cross more than one phase and clinician type. See Appendix C, Evidence Table 18 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
MW=midwife, NP=nurse practitioner, PA=physician assistant

Patient population studied. Patients studied represented those who were most likely to need medication: adults, middle aged people, and those over the age of 65 years. Infants, children, and adolescents were also studied but to a lesser extent (Table 4). Monitoring and reconciliation concentrated on older persons.

Table 4. Patients and caregivers studied by phase of medication management and education and reconciliation

Patients	P	OC	D	A	M	E	R
Infants (0 to 2 years)	6	1	1	1	1	0	0
Children (2 to 12)	11	1	1	1	3	0	0
Adolescents (13 to 18)	15	0	0	0	9	1	1
Adults (19 to 44)	40	0	0	0	23	2	1
Middle age (45 to 64)	56	1	0	1	38	3	1
Geriatric (65 plus)	60	2	2	1	32	2	3
Undifferentiated	9	0	0	0	8	0	0

Note some studies cross more than one phase and patient group**.** See Appendix C, Evidence Table 19 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation

Technology. Tables 5 and 6 list the MMIT applications studied. Table 5 includes those MMIT applications that were the main focus of the study while Table 6 includes the MMIT that were integrated with the MMIT studied. The CDSS and reminder systems were most common in prescribing and monitoring. CPOE and e-Prescribing were also commonly used. Systems associated with pharmacy use were less commonly studied. Considering integration, the health IT in medication management is well-integrated with comprehensive systems such as EMRs and hospital information systems as well as other components of the broader health IT domain, remembering that integration with a health IT system was a requirement for inclusion in our review. Although prescribing again is the major phase studied, the other phases are represented.

Table 5. Main health IT studied by medication management phase and education and reconciliation

Health IT	P	OC	D	A	M	E	R
CDSS/reminders	177	8	4	5	63	1	1
CPOE/POE system	90	12	5	9	11	0	0
e-Prescribing	31	10	3	4	2	1	1
Order transmission of the prescription to and from doctor to pharmacy electronically	2	3	0	0	0	0	0
Pharmacy information system	2	3	4	1	0	1	1
Barcoding medication administering	1	0	2	20	0	0	0
Barcoding dispensing	0	0	1	0	0	0	0
eMAR, e-TAR	2	2	2	14	0	0	0
Other	13	2	3	7	14	1	5
Personal digital assistants or hand-helds	7	1	0	4	5	0	1

Note some studies cross more than one phase and technology. See Appendix C, Evidence Table 20 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
CDSS = Clinical decision support system, CPOE = Computerized provider order entry, POE = Provider order entry, eMAR = Electronic Medication Administration Record system, eTAR = Electronic Treatment Administration Record system

Table 6. Health IT integrated with the health IT being studied

Integrated Health IT	P	OC	D	A	M	E	R
EHR/EMR system	120	11	5	15	39	1	3
Formulary	11	1	1	3	3	0	0
Pharmacy	50	9	8	15	18	0	2
CPOE/POE system	58	0	1	7	12	0	2
Hospital information system	54	4	3	9	13	1	1
Laboratory system	49	3	1	3	27	1	0
Imaging systems	22	2	1	3	7	1	0
CDSS/reminders	24	1	0	1	6	0	0
Billing/administration system	8	0	0	1	4	0	0
Insurance	5	0	0	0	1	0	0
Personal health records systems	1	0	0	0	2	0	0
Patient decision support system	0	0	0	0	1	0	0
Barcoding system	2	0	1	0	0	0	0
Not specified	32	4	4	6	8	0	0
Other	15	3	0	5	6	1	1

Note some studies cross more than one phase and integrated with more than one technology**.** See Appendix C, Evidence Table 21 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
EHR = electronic health records system, EMR = electronic medical records system, CDSS = Clinical decision support system, CPOE = Computerized provider order entry, POE = Provider order entry

Summary. In summary, prescribing is the major medication management phase studied. Studies were often evaluative rather than research centered in nature, as reflected in the number of observational studies. Substantial numbers of RCTs and qualitative studies exist. Most often studies were set in hospitals and in ambulatory care facilities. Few studies were set in pharmacies, although most of the articles showed interactions with pharmacists and pharmacies. Long-term care, community settings, and homes were not often studied. CDSS systems were the most common MMIT application studied. CPOEs were also studied substantially. The MMIT applications studied were very often embedded within a larger EMR, hospital, or pharmacy information system and integrated with other health IT applications. Many different MMIT systems were studied although again few were done outside the prescribing and monitoring phases and variation existed in the number of studies of each kind of health IT. Physicians were the health professionals most often studied. Few patients were evaluated.

Process Changes—Prescribing

Summary of the Findings for Process Changes

Of the 378 articles that have outcomes associated with MMIT, 174 (46 percent) are reports of the evaluation of processes in the prescribing phase of medication management (Appendix C, Evidence Table 1). Because prescribing and ordering are substantially different in the hospitals and ambulatory settings, the remainder of this section will provide analyses with the articles divided into hospital-based studies (n = 107) and ambulatory care-based studies (n = 67). The community- and home-based studies are included with ambulatory care. Only one study in this section was done in a long-term care facility.[397]

General Study Characteristics

Strengths and Limitation of the Evidence. The studies of process changes in MMIT based in hospital settings have a lower proportion of RCTs than ambulatory care studies. The 107 hospital-based studies are comprised of 19 RCTs (18 percent of hospital studies),[398-416] 84 observational studies,[18,417-499] 3 cohort studies,[500-502] and 1 mixed methods study.[503]

The 67 articles set in primary care, communities, and home (ambulatory care) were studied using 40 RCTs (61 percent of nonhospital studies),[504-543] 2 cohort studies,[544,545] 1 case control study,[546] 1 mixed methods study,[547] and 22 observational studies.[431,548-568] The long-term care study was an RCT.[397]

Table 7. Research methods of studies that evaluated process changes associated with the prescribing phase of MMIT

Design	Hospital Based	Ambulatory Care Based	Long Term Care
RCT	19	40	1
Cohort	3	2	0
Case control	0	1	0
Qualitative/Mixed Methods	1	1	0
Observational	84	23	0

RCT = Randomized controlled trial

Patient population. Not all studies included descriptive data on patients. Of those that did, the patient populations reflected the pattern of medication use with more studies including participants who were, on average, over the age of 44 years. All age groups were studied in both hospital and ambulatory settings.

Thirty-seven studies set in hospitals provided descriptive data on participants. Four studies included infants (birth to 2 years),[418,463,467,491] five studies included children (2 to 11 years),[411,418,437,467,569] six studies included adolescents (12 to 18 years),[411,418,437,446,467,490] eight studies evaluated adults (19 to 44 years),[408,411,418,437,446,467,490,492] 22 studies included middle age participants (45 to 64 years),[399,401-403,406,414,425,428,430,431,433,445,448,449,454,467,475,481,485,489,490,493] and 27 studies included geriatric participants (65 years and up).[399,401-403,406,407,413,414,416,425,428,430,431,433,440,445,448,449,453,467,481,483,485,486,489,490,493]

Thirty-six of the 67 studies done in ambulatory settings included descriptive data on the patient population studied. Many studies included participants in a wide range of ages. Of the 36 studies that included patient information, one studied infants (up to 2 years of age),[559] two evaluated medication management in children (2 to 11 years),[539,559] three evaluated adolescents (12 to 18 years),[504,537,539] 15 were of adult population (19 to 44 years),[504,505,508,512,515,522,527,528,530,531,537,541,543,545,565] 24 studied patients in the middle age range (45-64 years),[504,505,508,510,513,515,518-520,522,526-528,530,531,537,538,541-543,545,557,565,568] and 22 studies include geriatric patients (65 years and up).[505,507,510,513,515,519,522,524,528,530,531,533,541-543,545,552,565,566,568] The single long-term care study did not describe its patients.[397]

Clinicians studied. Only 11 of the hospital studies included descriptive information on clinicians. Several of these included multiple groups of health professionals: hospitalists[398,405,407,452,454,486] other physicians,[407,415,487,488,502] other health professionals,[452] and nurses.[439] Many of the other studies evaluated clinicians but did not provide sufficient demographic information for analysis or discussion.

Few of the studies set in ambulatory care provided substantial information on clinicians. Those clinicians who were specifically described were primary care clinicians,[506,510,514,529,532,534,535,552,563,566] other physicians,[514,525,535,544,547,553,554] nurses and midlevel practitioners (physicians assistants, nurse practitioners, advanced practice nurses, and midwives),[535,561] and pharmacists.[518]

Technology. Technology associated with studies set in hospital settings often evaluated several integrated MMIT systems, although some studies included only one MMIT. Individual MMIT applications included CDSS systems,[18,397-399,401-405,407-418,420,422-428,430,431,433,435,448,449,451-454,458,460-462,464,466,468-478,480-483,485,486,489-502] CPOE systems,[400,406,417,419,421,427,429,432,437,438,441-444,446-450,453,455,457,459,463,466-469,479-484,487,488,491,493,503] pharmacy information system,[438] computerized unit dose drug dispensing system,[465] e-prescribing,[434,436,439] medication safety reporting system,[456] an internet electronic diary for patients,[408] and eMAR systems.[439,456]

Studies set in ambulatory care also studied a range of MMIT applications with the majority of the MMIT applications based on CDSS systems. The MMIT applications were CDSS,[504-531,533-543,545,546,548,550-560,563-566,568,570] CPOE,[507,527,532,540,551,558,567] e-Prescribing,[540,544,547,549,561,562] and a pharmacy information system.[507]

These MMIT systems that were the focus of study were also integrated with a range of other MMIT applications, most of which were some form of EHR or EMR systems. The hospital-based studies included integration with bar-coding systems,[493] billing or administration,[400,406,446,474,485] CDSS,[417,429,432,442,448,461,462,479] CPOE,[398,400,402,405,407,410,411,413,415,416,423,426,427,430,433,435,440,445,448,454,458,460-

[462,464,471,472,480,486,490,492,494-497,500,501] EHR and EMR systems,[18,398,405,407,409,411,415,416,418,422,423,430,431,434,436-438,442,444,445,447,448,453,455,460,462,466,473,475,479,480,483,489,492,498,501] hospital information systems,[400,403,406,412,414,415,424,425,428,438,442,443,450,451,453,456,461,465,467-470,474,478,481,482,487,488,491,499] imaging systems,[405,437,442,443,456,463,466-468,470,475,483] laboratory systems,[18,401,405,407,409,415,418,420,437,442,444,446,452,453,456,461,466,470,473,475,477,483,485] formulary systems,[406,442,443] and an integrated pharmacy system.[401,404,415,417,420,434,436,439,441-443,463,473,477,479,485,493,502]

Systems integrated within ambulatory studies were also mostly EMR and EHR systems. The ambulatory studies included billing and administrative systems,[504,511,512,532,564,567] CPOE,[511,512,518,522,529,532,548,550,564,570] EHR and EMR systems,[505-507,510-513,515,517-524,526-528,531,533,535,536,538-540,542,543,545,546,548,550,551,554,556-561,564,566,568] formulary systems,[544,549] hospital information systems,[508,509,541,565] imaging systems,[513,532,538] insurance systems,[542,549] laboratory systems,[504,509,513,516,538,541,548,550,555] and pharmacy systems.[504,508,511,516,518,541,548,552,562]

Outcomes

Prescribing changes. Sixty-one studies evaluated changes in prescribing in hospital settings. Fifty-three (87 percent) showed statistically significant improvements in at least half of its main endpoints. Categorizing these 53 articles into groups based on study methods, 11 were RCTs,[398,399,402-405,408-410,413,416] two were cohort studies,[501,502] and 40 were observational.[417,423,424,426,428,430,431,440,443,446,447,451,452,456,458-460,462,464,466-473,475,478,482,486,489,490,492,496-499,547,571] Eight (13 percent) of the 61 did not show statistically significant changes. Two were RCTs[411,414] and six were observational studies.[418,420,445,449,477,485]

Thirty-two studies set in ambulatory care found improvements in prescribing with the MMIT as defined by at least half of the main endpoints being positive. Twenty-three were RCTs.[504,506-508,511-515,517,522,525,526,528-531,533,535-537,539,541] One was a case-control study.[546] Seven were observational.[549,553,554,562,565,566,568] Eleven studies set in ambulatory care settings sought to determine if prescribing was improved with the introduction of MMIT and they did not demonstrate differences. Of these, five were RCTs,[510,520,523,524,538] two were cohort studies,[544,545] and four were observational.[557,560,564,572]

Errors. Twenty-two articles studied prescribing errors in hospital settings. Fifteen showed statistically significant improvement in at least half of the main endpoints. Two were RCTs[400,405] and 13 were observational.[421,434,438,439,450,453,454,457,465,474,479,491,493] Seven did not show statistically significant improvements: a mixed methods study[503] and six observational reports.[419,432,436,444,455,495] Two studies reported errors related to ambulatory care studies and both were positive, one using CPOE,[558] and one using CDSS,[559] both in observational studies.

Time considerations. Seven studies evaluated time considerations in hospital settings. Two observational studies showed statistically significant improvements in considerations of time.[439,488] One study found a statistically significant increase in time to prescribe.[487] One study evaluated mean time on antimicrobial management but did not do statistical testing.[401] Three observational studies did not show any differences in time.[419,441,481] Five studies assessed time savings in the ambulatory care settings. Four were positive: an RCT of CPOE and CDSS that reduced time to respond to alert situations,[527] a cohort study on time spent on asthma management,[545] and two observational studies, one on e-Prescribing[561] on time spent on computer and paper tasks and one on time spent on ordering laboratory testing for monitoring.[550] One RCT showed that time spent on patient care did not decrease with the introduction of a CPOE system.[532]

Adherence to guidelines, reminders, and recommended practice. Twenty-four studies measured improvements in compliance with guidelines, reminders, and recommended practices in hospital based studies. Nineteen identified statistically significant improvements in compliance: four RCTs,[407,412,521,573] one cohort study,[500] and 14 observational studies.[424,425,427,429,435,437,438,447,461,470,476,483,484,494] Four did not find any differences in compliance: one RCT[415] and three observational studies.[442,448,480] One observational study[422] showed a decrease in adherence after the introduction of a CDSS system into a hospital EHR.

Thirteen studies that took place in nonhospital settings (primary care, community, and homes) considered compliance with guidelines, reminders, or recommended practice. Seven were RCTS of which five showed positive results for at least half of the main endpoints.[505,509,534,542,543] Two RCTs[518,519] did not identify a difference for measured compliance. One cohort study[544] did not show a difference in compliance with the formulary using e-Prescribing and one mixed methods study[547] reported no change in physician compliance with drug alert overrides. Four of four observational studies reported improvements in compliance with guidelines, reminders, or recommended practices.[548,556,563,566]

Workflow. No studies set in hospitals studied workflow as one of their main endpoints that were changes in process. Two studies set in ambulatory care studied workflow. One study using CDSS reminders showed a significant reduction in missed followup appointments that had been scheduled by nurses.[555] An RCT of CDSS and e-Prescribing did not affect the rate of callbacks generated between physicians and pharmacists.[540]

Table 8. Summary of the number of studies reporting statistically significant process changes in studies of prescribing by process for hospital and ambulatory based studies

Process Category	RCTs	Cohort and Case-Control Studies	Observational Studies	Mixed Methods Studies
Change in Prescribing (85 of 104 showed benefit)				
Hospital Studies	11+ 2=	2+ 0	40+ 6=	0 0
Ambulatory	24+ 5=	1+ 2=	7+ 4=	0 0
Errors in Prescribing (17 of 24 showed benefit)				
Hospital Studies	2+ 0	0 0	13+ 6=	0 1=
Ambulatory	0 0	0 0	2+ 0	0 0
Time Considerations (6 of 12 showed benefit)				
Hospital Studies	0 0	0 0	2+ 4= 1-[487]	0 0
Ambulatory	1+ 1=	1+ 0	2+ 0	0 0

Table 8. Summary of the number of studies reporting statistically significant process changes in studies of prescribing by process for hospital and ambulatory based studies (continued)

Process Category	RCTs	Cohort and Case-Control Studies	Observational Studies	Mixed Methods Studies
Compliance with Guidelines, Reminders, and Recommended Practice (28 of 37 showed benefit)				
Hospital Studies	4+ 1=	1+ 0	14+ 3= 1-[422]	0 0
Ambulatory	5+ 2=	1=	4+ 0	0 1=
Workflow in Prescribing (1 of 2 showed benefit)				
Hospital Studies	0 0	0 0	0 0	0 0
Ambulatory	0 1=	0 0	1+ 1=	0 0

+ indicates that half or more of the main endpoints were shown to be statistically significant.
= indicates that at least half of the main endpoints were statistically not significant.
- indicates that the main endpoints were statistically significant in the opposite direction projected at study start.
The citations to the studies listed above are in the text preceding this table.
Ambulatory studies included those that were done outside hospitals including homes and communities.

Summary

Much research has been done to evaluate changes in process related to prescribing in hospital settings and ambulatory care situations. The research is varied in methods although many RCTs exist. A higher proportion of RCTs are done in the ambulatory care studies than in hospitals. Clinicians are the most studied. Pharmacists are often included in studies but are less frequently the major thrust of analyses. Many MMIT applications are studied in the prescribing phase. These prescribing MMIT applications are also frequently supported or integrated with EMR, EHR and hospital information systems. CDSS systems are often studied and frequently integrated with CPOE or e-Prescribing systems. Pharmacy-based MMIT applications generally lack evidence.

With respect to the process changes measured in the prescribing studies, changes in prescribing and compliance with reminders, guidelines, and standard practice are the most common outcomes for hospital- and ambulatory-based studies (Table 8). The RCTs were concentrated on evaluating changes in prescribing with some of them assessing compliance. The RCTs were positive 80 percent of the time while the observational studies were positive 77 percent of the time. Studies done in ambulatory care settings have not evaluated errors as outcome measures. Quantitative workflow studies are generally absent across all settings. MMIT in prescribing is associated strongly with improvements in prescribing and also associated, but to a lesser extent, with reducing errors and improving compliance with guidelines, reminders, and recommended practice. Time reductions or changes are not as often improved and workflow improvement assessments are lacking evidence.

Systems that provide information support, such as CDSS and CPOE systems, are combinations of technical capabilities and a knowledge base. The content of this knowledge base is probably more important than the technical aspects. Research findings and scientific evidence (i.e., evidence-based content) are difficult to compile and even more difficult to keep current. We did not find evaluations of the knowledge base of the systems or comments on updating, although some of the systems depended on clinical practice guidelines for their evidence base. Similarly, outcomes that were associated with correct knowledge such as adherence to best practice guidelines were also not often evaluated to show that they were accurate and current. Future research must address how this need for strong evidence to support the knowledge base of

CDSSs, provide evidence backing for order sets for CPOE systems, and clinical practice guidelines on which to base best practice can be best met.

Order Communication

Summary of the Findings for Process Changes

Order communication is less well-studied than prescribing with only 16 studies: two RCTs,[540,574] and 14 observational studies.[438,552,567,575-585] (Appendix C, Evidence Table 2) Order communication involves clinicians and pharmacists. The oldest study in this group was published in 1999,[574] reflecting the recent advances in communication applications related to MMIT.

Strengths and Limitations of the Evidence

The evidence in this section is predominantly observational with two RCTs. The studies were mainly based on large sample sizes, from 39 clinicians[578] to almost one million prescriptions.[577] The outcomes, most often measures of efficiency and changing work patterns, were usually reported as being positive.

General Study Characteristics

Participants. All studies included physicians, other prescribers, and pharmacists. The main unit of analysis in 12 of the 16 studies was prescriptions, orders, and medications. The main unit of analysis for the other four studies were patients,[552,578] pharmacists,[580] and clinicians.[574] The patients were of geriatric age (65 years or greater) or adults (45 to 64 years),[578] or geriatric alone.[552] Except for these two articles, all others included undifferentiated patients.

Location. All studies included a pharmacy. Most studies were hospital-based but one study was of three mail order pharmacies,[575] two were HMO pharmacies only,[552,574] and three were in community pharmacies.[579,585,586] Nine studies were set in hospitals,[438,574,576,578,580-584] and four in primary care.[540,577,585,587]

Drugs and diseases. Thirteen studies did not concentrate on one disease or disorder. One study each evaluated venous thromboembolism,[578] cancer,[584] and HIV/AIDS.[585]

Technology. The MMIT in the order communication phase is varied: six CDSS,[438,540,552,577,580,582] eight CPOE,[438,567,576,578,580-582,584] two eMAR systems,[581,583] four e-Prescribing,[540,575,579,585] one e-transmission,[575] and two pharmacy information systems.[438,574] Several studies included more than one MMIT as the major focus of the study. The ordering systems (CPOE and e-Prescribing), however, predominate.

The following MMIT applications were integrated in 15 of the 16 studies: one CDSS,[567] nine EMRs,[438,540,574,576-578,580,581,585] three hospital information systems,[438,576,582] two imaging systems,[574,581] three laboratory systems,[574,578,581] six pharmacy systems,[552,577,579,583-585] and one eMAR system.[580] The nine EMRs and three hospital information systems reflect maturing of the MMIT systems with respect to order communication.

Outcomes

No process changes were presented for adherence with guidelines, monitoring, or preventive care. One article described decreases in prescribing of contraindicated drug-drug combinations in ambulatory settings.[577] Another looked at the agreement between pharmacists and family physicians (need for clarification of prescriptions) with and without e-Transmission of prescriptions, again in the ambulatory setting.[575] All other process changes that were the main focus of the order communication articles dealt with errors and efficiencies.

Errors. Two hospital studies addressed errors (Table 9). Mahoney et al.[438] showed a decrease in drug-allergy violations, excessive dose, incomplete or unclear orders, and therapeutic duplication with the introduction of a CPOE and CDSS system into a pediatric standalone and another general hospital. Varkey et al.[567] found an increase in the frequency of intercepted prescription errors after the introduction of another CPOE and CDSS system into the Mayo Clinic ambulatory practices.

Prescribing. Two studies showed improvements in prescribing with increased interaction between pharmacists and physicians (Table 9).[552,577]

Efficiency and workflow. Five hospital-based studies sought to change response times (Table 9). Four showed decreased times for processing and validating orders.[576,578,581,584] One found increased time with the introduction of a CPOE and a CDSS system.[582] Another found an increased time to checking the prescription with an e-Prescribing system compared with a paper based system (11 vs. 6 minutes, $p < 0.01$).[575] Some changes were substantial. For example, a decrease from 115 minutes to 5 minutes for verification of a prescription in a study by Wielthrolter and colleagues.[584] Three hospital studies found changes in work flows and processes with the introduction of a pharmacy information system[574] and a CPOE and CDSS system with eMAR integration.[580] Fewer callbacks occurred with the introduction of a CPOE and CDSS system integrated into a hospital EMR.[540]

Pearce et al.[585] completed an ambulatory care based setting (three HIV clinics and two private pharmacies) and found decreased time to respond to a refill request and changes in communication patterns with MMIT involved in order communication. Mitchell and colleagues[583] found that an eMAR system was associated with more accurate and complete recording of information. Ekeldahl and colleagues showed that the rate of picking up prescriptions did not change with the introduction of an e-Prescribing system.[579]

Summary

The evidence for the effects of MMIT on order communication comes from a limited number of studies, many of which were observational. The studies often include large numbers of participants or prescribing events. Most of the process evaluations show improvements, often in efficiency related to times and changing work patterns (Table 9).

Table 9. Summary of the number of statistically significant process changes in studies of order communication by process for hospital and ambulatory based studies

Process Category	RCTs	Observational Studies
Errors (2 of 2 showed benefit)		
Hospital Studies	0 0	1+ 0
Ambulatory	0 0	1+ 0
Prescribing (2 of 2 showed benefit)		
Hospital Studies	0 0	0 0
Ambulatory	0 0	2+ 0
Efficiencies and Time Considerations (6 of 8 showed benefit)		
Hospital Studies	0 0	4+ 2-[575,582]
Ambulatory	0 0	2+ 1=
Workflow Issues (4 of 4 showed benefit)		
Hospital Studies	2+ 0	2+ 0
Ambulatory	0 0	0 0

+ half or more of the major endpoints showed statistically significant improvements.
= less than half of the major endpoints showed statistically significant improvements.
- the outcomes were found to be in the opposite direction (a true negative study).
RCT = Randomized Controlled Trial

Dispensing

Summary of the Findings for Process Changes

Some overlap and duplication of studies occurs between the dispensing phase of medication management and the phases of order communication and administering. Nine studies were identified as evaluating dispensing (Appendix C, Evidence Table 3).[438,507,552,574,585,586,588-590] Much diversity was seen across these studies. In addition to these articles, a health technology assessment (HTA) report from the Canadian Agency for Drugs and Technologies in Health (CADTH) produced a systematic review on errors in dispensing and administering in hospitals in 2009.[11] It sought to assess the effectiveness and economic impact of MMIT applications designed to improve medication dispensing and administering in hospitals.

Strengths and Limitations of the Evidence

Study methods included three RCTs,[507,574,588] one cohort study,[586] and five observational studies.[438,552,585,589,590] The HTA report found 30 studies on dispensing, administering, or both, most of which were done using observational methods. In addition, many of these studies evaluated technologies that were older, no longer available, or only available in Europe. Overall the authors of the report stated that the evidence on the effectiveness of MMIT for improving medication dispensing is lacking, of poor quality, and has limited applicability.[11] The year of publication of the nine papers in this AHRQ document were more recent: 1997,[589] 1999,[574] 2001,[552] 2007,[438,507,586] 2008,[588] and 2010.[585,590]

General Study Characteristics

Participants. Raebel and colleagues[507] and Halkin and colleagues[552] reported data based on patients as the unit of study. Both studies included patients older than 65 years. Two reports studied pharmacists.[574,588] All others reported data on medications or prescribing events as their unit of analysis.

Location. Four studies were set in community pharmacies[552,585,586,588] and one in an HMO pharmacy.[507] The other study locations were pharmacies and clinics in hospitals.[438,574,589,590]

Drugs and diseases. Aspirin for patients with diabetes was studied,[588] and two others targeted groups of medications with high potential for interactions.[507,552] One study included e-Prescribing in three HIV clinics and two private pharmacies.[585] One article concentrated on drugs that are used heavily by seniors.[507] All others studied the range of prescriptions available in the pharmacies.

Technology. The technology described in these dispensing studies varied considerably. Four studies evaluated pharmacy information systems,[438,507,574,588] three looked at eMAR systems,[585,589,590] and CDSS,[438,507,552] one at an e-Prescribing system,[586] and one evaluated a CPOE application.[438] These systems were integrated with an EHR or EMR system,[438,507,574,585] hospital information system,[438,589] a pharmacy system,[552,585,590] a laboratory system,[574] a formulary,[589] or a CPOE system.[590] The HTA report includes a good description of their evaluation of MMIT that provides additional background information on administering and dispensing MMIT applications.[591]

Outcomes

Each of the main endpoints for the trials was found to be positive. Efficiency, monitoring, and preventive care outcomes were not reported in the nine studies.

Errors. Three of the four hospital based studies assessed errors and all showed improvements with eMAR,[589] CPOE, CDSS and a pharmacy information system,[438] and a pharmacy information system with CPOE.[590] None of the ambulatory care studies assessed errors. The HTA report provided some evidence that BCMA is associated with reduced errors for dispensing (pharmacists) and administering (nursing), with the BCMA either as a stand-alone system or integrated with other health IT applications. Evidence on other outcomes or technologies in dispensing was found to be lacking or inconclusive.[11]

Adherence to guidelines. For pharmacists who were prompted electronically to suggest aspirin to patients with diabetes when they were filling other prescriptions, the use of aspirin increased.[588]

Changes in medications to be administered. Four of the four ambulatory studies demonstrated statistically significant improvements in what drugs were dispensed. Alerts to pharmacists improved dispensing of medications with high potential for interactions in an HMO pharmacy,[552] while the use of contraindicated medications decreased with most of the decrease associated with amitripyline in another study.[507] Refill utilization was improved[585] and aspirin use increased while pharmacists were being prompted to include aspirin use when dispensing medications for patients with diabetes.[588]

Other process changes. Murray and colleagues[574] showed changes in workflow for pharmacists (more time interacting and problem solving) and who they interacted with (more time interacting with peers and physicians). Workflow was also changed in another study using a pharmacy information system.[574] A commercial EMR system reduced the time to process and fill a refill request for HIV medication.[585] Nilsson and colleagues[586] showed that acute prescriptions were picked up more often for an e-Prescribing system compared with a paper-based system (91 percent vs. 85 percent, $p < 0.01$).

Summary

Few reports studied dispensing. Three of these nine studies were RCTs. All studies showed statistically significant improvements in process. External evidence suggests that the existing studies dealing with dispensing are weak and dated, with reports of currently used MMIT applications not being readily available.

Administering

Summary of the Findings for Process Changes

Nineteen studies measured changes in process associated with the administering phase of medication management (Appendix C, Evidence Table 4). All deal with nurses and either pharmacists or physicians. The technology is complex, integrated and often part of a complete package of a hospital information system or an EMR or EHR system. All studies but two[12,592] were done using observational methods.

As noted in the dispensing section, CADTH produced a systematic review in 2009 on errors in dispensing and administering in hospitals.[11] This HTA report assessed the effectiveness and economic impact of MMIT applications designed to improve medication dispensing and administering. They found that the evidence on medication administering with MMIT was based on observational studies and that many of the studies were done on systems that have been updated or are no longer available. Many studies and descriptive papers that reported on medication administering and health IT, including Bar Code Medication Administration (BCMA) were reviewed for this report and were rejected. Most of the rejection decisions were because the medication administration system was stand-alone and not integrated with other MMIT applications. This nonintegration was especially true for older studies—most of the more recent studies show medication administering systems that are integrated. One good example of this integration is by Helmons and colleagues.[593] Nonintegrated systems are not included in this report, as integration with other MMIT applications was an inclusion criterion.

Strengths and Limitations of the Evidence

One document was an RCT[592] and one was a cohort study.[12] All of the others were observational studies.[34,438,439,581,583,589,593-602] Two were published in the late 1990s and 12 of the 19 were published since 2004.

General Study Characteristics

Participants. All but one study included nurses. Three studies included pharmacists,[439,589,598] and four discussed physicians.[465,592,593,596] The main focus of the study was medications or prescriptions,[34,438,439,465,581,589,592-595,598,599,601,602] nurses[597,600] and patients: infants[12] and those whose ages were unspecified.[596] Medications were not limited to a specific drug or class of drugs except for one study of the need for antibiotics[596] and one study of aspirin use.[592]

Location. All of the studies but one were set in hospitals: acute care or tertiary,[439,465,581,596,598,600-602] critical care units,[12,593-595] pediatric standalone hospitals,[438,465] general hospitals,[34,438] other specialty hospitals,[465,581] and the emergency department.[597] Pediatric hospitals or wards were often studied: neonatal ward and adult ICU,[595] general pediatrics,[438] and pediatric nephrology.[465] One of the studies was done in an ambulatory setting,[592] and none were done in long-term care, community, or home settings.

Technology. The MMIT applications that were the focus of the administering phase of medication management were varied: automated drug dispensing system,[599] BCMA systems,[12,34,593,594,598,600,601] eMAR systems,[12,34,439,583,589,601,602] CDSS,[438,592,596] computerized unit dose drug dispensing system,[465] CPOE,[438,581,595,597] e-Prescribing,[439,602] and a pharmacy information system.[438]

The MMIT systems that are integrated with these systems above are most likely to be hospital wide or pharmacy systems: a CPOE system,[593] EHR and EMR systems,[438,581,592,593,596,601] hospital information system,[34,438,465,589,598] imaging systems,[581,597] laboratory systems,[581,597] eMAR,[594] a formulary,[589] and pharmacy information systems.[12,34,439,583,595,597,599,601]

Outcomes

Errors. Thirteen studies evaluated administering errors. The issue of errors in administering drugs using MMIT is complex as many errors identified in MMIT systems are related to transcription and timing. These easily measured errors may be masking other more substantial errors. Eight studies had major endpoints that were found to be positive in reporting decreased errors.[438,439,465,581,589,594,601,602] Another measured variances (differences between the order and administered medications) and found significant reductions after the introduction of a CPOE system integrated with the pharmacy and eMAR systems in a hospital.[595] The relative risk reduction in many of the studies was high and often approximately 40 to 50 percent. Four studies had endpoints that were not found to show statistically significant improvements.[34,583,593,598] Another hospital-based study showed increased errors, mostly related to a BCMA system,[12] because the BCMA system recorded issues such as timing of medication administering more accurately. The HTA report from CADTH also provided evidence that BCMA reduced errors in administering medications in hospitals.[11]

Efficiency. Efficiency is also important in medication administering. Four of five studies that measured efficiencies showed improvements. One study showed that time from ordering to administering in a hospital setting decreased from 90 minutes before implementation of comprehensive MMIT systems to 11 minutes.[438] Another article that measured time efficiencies had similar reductions (79 percent vs. 89 percent of medications were administered within 1 hour of ordering).[439] An eMAR system reduced time from ordering to administering from 325 to 88 minutes.[581] Shirley and colleagues[599] did not find a change in time to administering after implementation of an eMAR. No changes in time allocation were seen for direct patient care and medication administration after a BCMA system integration for hospital nurses.[600] In contrast, Banet and colleagues described a system that integrated CPOE and eMAR and showed that nurses spent less time on paper documentation and searching for charts and more time on working with computers and charting in patient rooms with no changes in documentation time overall or time spent on direct patient care.[597]

Adherence to guidelines. One study with an anesthesia medication system had improvements in adherence to administering antibiotics during surgery.[596] Shirley and colleagues[599] found improved adherence to scheduled dosing. Persell and colleagues[592] identified no difference in self-reported aspirin use.

Other changes in process. Helmons and colleagues[593] found no changes in error rates (they had few errors at baseline) but measured improved charting and labeling.

Summary. Although few studies evaluated administering with the use of MMIT, most of the 19 showed improvements, mostly in the realm of errors and efficiencies. Results were mixed with respect to whether the MMIT systems for drug administering altered the time nurses spent on various tasks.

Monitoring

Summary of the Findings for Process Changes

Medication monitoring can been defined as the process of assessing a patient's response to a medication and documenting its outcomes.[603] Suboptimal medication monitoring describes a common pathway of systems failures that underlie monitoring errors and can be categorized as over, under, or inappropriate monitoring. Medication monitoring errors generally refer to one of three situations: inadequate **laboratory** evaluation of drug therapies, or a delayed or failed response by the clinician to **symptoms** (patient reported aspects of their disease or disorder), or to clinician observed or measured **signs** of the condition or of drug toxicity, or laboratory evidence of toxicity.[604] Therefore, for the purposes of this report, we divided the health IT interventions designed to improve medication monitoring into studies that enhance ***laboratory-, sign-,*** or ***symptom-based*** medication monitoring. In the clinician and patient encounter the patient reports **symptoms** they are experiencing (e.g., fatigue, sudden weight gain, or dizziness) and the clinician observes or measures **signs** of the disease or disorder (e.g., blood pressure, heart rate, fever). Clinicians integrate information gained from assessments of symptoms, signs, and results of laboratory tests to determine disease status, often putting varying weights on the three aspects.

Previous systematic reviews provided information on the impact of health IT on medication monitoring.[605-607] However, these systematic reviews are limited to a specific type of medication monitoring system (e.g., clinical event monitors), a single practice setting (e.g., ambulatory or acute care), or are more than 5 years old. This evidence report yielded a total of 47 articles describing health IT intervention designed to improve one or more change in process related to the medication monitoring phase in the acute, ambulatory, or long-term care settings (Appendix

C, Evidence Table 5).[397,401,402,407,412,437,442,446,461,472,473,477,481,505,511,515,516,518-520,526-528,534,537,541,543,553-555,608-624]

For consistency, author-reported changes in process were selected. By definition, a study which showed statistically significant changes in at least half of its main endpoints was considered a positive study. Overall, 70 percent (33 of 47 studies) of the articles were rated as positive studies.[397,401,402,407,412,437,461,472,473,477,505,515,516,527,528,537,541,554,555,608,610,612-623]

Study methods included 30 RCTs[397,401,402,407,412,505,511,515,516,518-520,526-528,534,537,541,543,609-613,616-620,624] and 17 observational studies.[437,442,446,461,472,473,477,481,553-555,608,614,615,621-623] Monitoring, along with CDSS, are the two areas that include the highest proportion of RCTs.

General Study Characteristics

Intervention targets. Nearly three-quarters (72 percent; 34 of 47) of the health IT medication monitoring interventions targeted physicians exclusively.[397,401,402,407,412,437,442,446,461,472,481,505,511,515,520,527,528,534,543,553,554,609-611,613,615-620,622-624] Eight of these studies targeted physicians along with other health care professionals,[518,519,526,537,541,555,612,621] four targeted pharmacists,[473,477,516,614] and one targeted nurses.[608]

Location. The overwhelming majority of health IT medication monitoring interventions studies (70 percent; 33 of 47) were conducted in an academic setting.[397,401,402,407,412,437,442,446,461,472,473,477,481,505,515,518-520,527,534,554,608-611,614-619,621,622] Of those that were conducted in an academic setting, 19 of these studies[402,407,437,446,477,505,515,518,519,527,554,609-611,614-616,618,619] came from the following benchmark institutions: (1) Brigham and Women's Hospital/Partners Health Care, (2) LDS Hospital/Intermountain Health Care, (3) the Department of Veterans Affairs, and (4) the Regenstrief Institute.

The preponderance of studies (59 percent; 28 of 47) took place in the ambulatory care setting.[472,505,511,515,516,518-520,526-528,534,537,541,543,553-555,609-613,616,617,619,620,624] Eighteen of the studies took place in the acute care,[401,402,407,412,437,442,446,461,473,477,481,608,614,615,618,621-623] and one in the nursing home setting.[397]

Patient populations studied. The vast majority (n = 36) of the health IT interventions targeted the adult population.[397,401,402,407,412,461,472,481,505,511,515,516,518-520,526-528,534,537,541,543,554,609-612,614-617,619-622,624] Only four of the 44 articles were conducted in the pediatric population,[437,442,446,553] and two targeted both adult and pediatric patients.[477,613] Five studies did not explicitly mention the study patient population studied.473,555,608,618,623

Type of medication monitoring. The majority (n = 29) of the health IT interventions focused on ***laboratory-based*** *medication monitoring*.[397,401,402,407,412,442,461,472,473,477,481,511,515,516,527,528,534,537,541,543,555,609,611,612,614,615,619,620,623] Five studies[505,518,526,613,624] targeted ***sign-based*** (clinician observed or measured aspects of the disease process) *medication monitoring*. While three interventions focused on ***symptom-based*** *monitoring* (patient reported symptoms),[520,608,621] ten studies[437,446,519,553,554,610,616-618,622] provided a combination of ***laboratory-***, ***sign-***, or ***symptom-based*** *medication monitoring*.

A significant degree of overlap (n = 36) of health IT interventions that involved ***laboratory-***, ***sign-***, or ***symptom-based*** *monitoring* along with the prescribing phase of the medication use process existed.[397,402,412,437,446,461,472,473,477,481,505,515,518,519,526-528,534,537,541,543,553-555,610,613-620,622-624]

Prescribing was most commonly associated with ***laboratory-based*** *medication monitoring* (n = 30),[397,402,412,446,461,472,473,477,481,515,519,527,528,534,537,541,543,553-555,610,614-620,622,623] followed by ***sign-based*** *medication monitoring* (n = 15),[437,446,505,518,519,526,553,554,610,613,616-618,622,624] and ***symptom-based*** *medication monitoring.*[437,553] This overlap was most often a result of the evaluation of clinical practice guidelines, order sets, or both that contain prescribing and monitoring elements.

Drugs and diseases. Twenty-four of the health IT medication monitoring interventions studies dealt with chronic disease management such as asthma,[446,553] asthma and chronic obstructive pulmonary disease,[518,613] congestive heart failure and coronary artery disease,[519] deep venous thromboembolism,[402] depression,[520] diabetes,[537,610,619] diabetes and coronary artery disease,[554,616] HIV,[527] hyperlipidemia,[515,528,534,541,543] hypertension,[505,526,624] and multiple common chronic conditions.[617,620,623] Sixteen studies addressed potentially nephrotoxic,[397,615] hepatotoxic,[241] or cardiotoxic[473] medications with a narrow therapeutic index,[442,461,555,618] and certain laboratory and medication combinations.[407,412,481,511,516,609,611,612] Four provided guidance about potentially inappropriate antibiotic management,[401,477,614,622] and three provided information about pain management.[437,608,621]

Technology. Almost all of the included studies regarding MMIT interventions (91 percent; 43 of 47)[397,401,402,407,412,442,461,472,473,477,481,505,511,515,516,518-520,526-528,534,537,541,543,553,555,608,609,611-624] used a CDSS with alerts or reminders. Three studies used a CPOE system without alerts[437,442,446] and one study involved the use of a personal health record (PHR).[610] Twelve of the studies used interruptive alerts to display and prompt the clinician for an immediate response while providing patient care.[397,407,412,472,481,505,543,608,609,611,613,624]

Outcomes

As noted above, more than two-thirds (33 of 47) of the interventions were associated with a positive process outcome. A number of themes emerged from the variety of interventions that were conducted in various health care settings, using varying degrees of technological sophistication, and providing information to a number of health care professionals, as well as directly to patients.

By type of medication monitoring. The majority of the health IT interventions focused on ***laboratory-based*** *medication monitoring*.[397,401,402,407,412,442,461,472,473,477,481,511,515,516,527,528,534,537,541,543,555,609,611,612,614,615,619,620,623] Of these 29 studies, 22[397,401,402,407,412,461,472,473,477,515,516,527,528,537,541,555,612,614,615,619,620,623] or 76 percent of these interventions showed statistically significant changes in at least half of these main endpoints**.** Two[505,613] of the five[505,518,526,613,624] studies (40 percent) that targeted ***sign-based*** *medication monitoring* showed that greater than 50 percent of the process endpoints improved. Of the three interventions that focused on ***symptom-based*** *monitoring*,[520,608,621] two[608,621] resulted in statistically significant changes in at least half of their main process endpoints**.** Ten studies[437,446,519,553,554,610,616-618,622] provided a combination of ***laboratory-***, ***sign-***, or ***symptom-based*** *monitoring*, and seven[437,554,610,616-618,622] or 70 percent showed statistically significant changes in at least half of their main process endpoints**.**

By type of intervention. One of the most frequently reported types of intervention (n = 12) provided decision support to improve chronic disease management (i.e., prescribing, monitoring, and clinical endpoints).[505,520,526,528,537,541,543,554,555,610,616,624] The type of chronic diseases varied based on patient population, but included the management of asthma, chronic obstructive pulmonary disease, depression, diabetes, hyperlipidemia, and hypertension. Overall, 67 percent of these interventions resulted in a statistically significant change in at least half of its major endpoints. Another common intervention (n = 10) assessed the *adherence to guideline recommendations* for a variety of acute and chronic medical conditions including asthma, atrial fibrillation, coronary artery disease, cardiovascular disease, congestive heart failure, chronic obstructive pulmonary disease, depression, diabetes, glucose regulation in the ICU, pain management, and peripheral vascular disease.[402,412,446,518,519,553,617,620,621,623] Overall, 60 percent of these interventions resulted in statistically significant change in at least half of its main endpoints.

Other common interventions (n = 8) included providing alerts and reminders to obtain laboratory testing for newly prescribed or chronically used medications.[407,442,472,511,516,609,611,612] Overall, 50 percent of these interventions showed a statistically significant change in at least half of their main endpoints.

Seven studies targeted *changing prescribing behavior* by providing ***laboratory-***, ***sign-***, or ***symptom-based*** *monitoring* information for potentially nephrotoxic medications, medications for asthma and COPD, and hyperlipidemia.[473,505,515,534,613,614,622] Overall, 86 percent of these interventions resulted in improvements in at least half of the major process changes reported as endpoints. Another metric commonly assessed was the *response time* to a variety of alerts (n = 7) including the management of narrow therapeutic index and potentially nephrotoxic medications, initiation of primary and secondary prevention, and time to pain assessment and management.[461,477,481,527,615,618,619] Overall, 71 percent of these interventions showed statistically significant improvements in at least half of its main endpoints.

Finally, two interventions assessed *pain management* including error reassessment rate and patient controlled analgesia order set use.[437,608] Overall, both of these interventions showed statistically significant changes in at least half of its main endpoints.

In our analysis, 70 percent (33 of 47 studies) of the included studies showed statistically significant changes in at least half of their main endpoints. Of these studies, the majority targeted physicians exclusively (n = 34), were conducted in academic institutions (n = 33), were developed for use in the ambulatory care setting (n = 28), focused on the adult population (n = 36), and provided CDSS with alerts or reminders to support chronic disease management (n = 12). When compared with ***sign-*** or ***symptom-based*** *medication monitoring*, ***laboratory-based*** *medication monitoring* studies were most likely (76 percent of the time) to be associated with a statistically significant change in at least half of its main endpoints. Moreover, these ***laboratory-based*** *medication monitoring* studies were conducted in a variety of health care settings including ambulatory, acute, and long-term care. The most successful types of studies focused on changing prescriber behavior, improving response time to generated alerts, and improving the diagnosis and management of chronic diseases.

Reconciliation, Discharge Summaries, and Education

Summary of the Findings for Process Changes

Reconciliation. Reconciliation of medications using MMIT is a complex process. Some of this stems from the complexity of medication management itself. Another issue is the challenge of interoperability of health IT across health care systems. The problem of medication reconciliation is especially acute for patients who receive care across settings: from hospitals, specialists, and primary care—most often the elderly and those with multiple health challenges. Two review articles provide documentation of the difficulties of effective medication reconciliation using health IT and the lack of published evidence to support its value.[625,626]

Four studies on medication reconciliation are included (Appendix C, Evidence Table 6).[13,14,627,628] One was a cohort study[628] and the others are quantitative observational. All were set in hospitals with the reconciliation done at discharge or transfer to another facility. One hospital was a Statepsychiatric hospital[13] and the others were general hospitals.

One study was PDA-based,[13] one was based on an e-MAR system,[14] and the others were based on integrated systems: CDSS and COPE within an EMR,[627] and an e-Prescribing system integrated with a pharmacy information system.[628]

All studies showed substantial improvement in agreement among records of medications provided by various clinicians involved in the care of the patients (Appendix C, Evidence Table 6). For example, one Dutch study showed improvements in agreement on prescriptions between the pharmacists and general practitioners with e-Prescribing compared with paper systems at discharge (31 percent vs. 49 percent) and at 10 days after discharge (33 percent vs. 53 percent).[628] Grasso and colleagues[13] showed a decrease in errors in the psychiatric hospital with the use of PDAs for reconciliation compared with paper summaries (rate of errors before PDAs was 22 percent compared with 8 percent after). Poole and colleagues[14] also showed improvements in prescribing (more therapeutic drug duplications were identified and resolved with an automated discharge medication worksheet for physicians).

In summary, although few studies exist on MMIT for medication reconciliation, the four included showed substantial improvements in the ability to electronically reconcile medication lists and make the necessary adjustments resulting in reduced errors and better prescribing.

Education. Only one article targeted the education associated with MMIT systems and measured change in processes as their main endpoint (see Appendix C, Evidence Table 6).[537] This RCT showed that combining patient education with submission of blood glucose levels to ambulatory care clinicians showed improvements in prescribing as well as improved hemoglobin A_{1c} levels. Most of the articles targeting educational aspects of medication management that measured changes in knowledge are covered in the section with intermediate outcomes.

Combined Phases of Medication Management

Summary of the Findings for Process Changes

Although some studies in this report assessed systems that covered the whole medication management process (five phases plus reconciliation and education), only one provided cross-phase study with changes in process. This observational study by Mahoney and colleagues[438] took place in a U.S. pediatric hospital and an affiliated acute care hospital. The study started in 2002 and was completed in 2006 with publication in 2007. The hospitals included a full EMR system that incorporated CPOE, CDSS, and the pharmacy information system into one clinical information technology (hospital information system). All aspects of the medication management system were addressed electronically. An analysis of 1.4 million orders after implementation as compared with a similar number before implementation showed reductions in drug allergy violations, excessive doses, incomplete or unclear orders, and therapeutic duplication.

PDAs

Summary of the Findings for PDAs

We included 13 studies using PDAs.[13,514,534,553,563,593,629-635] The studies often covered multiple medication management phases, such as prescribing (n = 7), order communication (n = 1), administering (n = 3), and monitoring phases (n = 6), as well as reconciliation (n = 1). Outcome measures focused on process and other intermediate measures, only two measured patient outcomes (blood glucose levels in both cases).[630,631] Eight of the studies included a CDSS component.[514,534,553,563,593,630,631,634] Two applications were tied to handheld BCMA units,[593,635] and two were used for e-Prescribing.[639,632] Most interventions targeted specific diseases such as diabetes,[630,631] asthma,[553,634] cancer,[633] high blood pressure,[534] psychiatric patients,[13] or the use of certain classes of medications such as nonsteroidal anti-inflammatory drugs[514] and antibiotics.[563] Two studies were qualitative,[629,632] two mixed methods,[633,635] five observational,[13,553,563,593,631] and four were RCTs.[514,630,633,634] Of the quantitative studies, five reported significant improvements as a result of the intervention[13,563,630,631,634] and four reported no significant effects.[514,534,553,593] An RCT of adherence to nonsteroidal anti-inflammatory drug prescribing guidelines in an ambulatory clinic showed stable levels of safe prescribing in the intervention group and a deterioration in the control group given PDAs without the guidelines.[514] Similarly, a PDA which provided physicians with Framingham scores and recommendations for patients at risk of high blood pressure, found no difference in levels of screening of patients and no effect on lipid management.[534] A PDA-based CDSS for international asthma guidelines improved quality-of-life scores for patients and cost reductions.[634] A crossover RCT of diabetic patient use of an insulin regimen dosage optimizer showed improvement in blood glucose levels during the phase when the advice was switched on.[630]

Intermediate Outcomes

Summary of the Findings

Articles measuring intermediate outcomes as their main endpoint were selected. We focused on the intermediate outcomes of: use; measures which were correlated with use (such as ease of use of the system, perceptions of users of the system, computer experience, etc.); knowledge, skills, and attitudes of the users; satisfaction; and usability (Table 10). Few hypothesis-driven studies with comparison groups assessed such intermediate outcomes as their main measure; 42 studies published in 44 articles were retrieved (Appendix C, Evidence Table 7). Only six studies were RCTs with quality scores from two to seven out of nine. The study results tended to show positive levels of satisfaction and use and measured a number of correlates of both to determine driving factors barriers, or both. Some negative impacts of systems on work processes were found.

Table 10. Intermediate outcomes across the phases for medication management

Outcomes	P	OC	D	A	M	E	R
Use	5	0	1	1	2	0	0
Measures correlated with levels of use	6	0	1	0	0	0	0
Knowledge, Skills, and Attitudes of users (usually measured as perceptions)	5	3	0	3	1	1	1
Satisfaction	9	1	1	2	0	0	1
Usability	3	0	0	0	0	0	0

Note some studies cross more than one phase**.**
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation

Strengths and Limitations of the Evidence

Of the 43 included studies, 25 were observational, nine mixed methods or qualitative, six RCTs, and three cohort (Table 11). The RCTs rated two,[636,637] four,[638] six,[639] and seven[540,640] out of eight on the methods quality scale. The cohort studies scored three,[641] five,[642] and six[643] out of nine. Studies of complex interventions often covered more than one phase of medication management.[540,644-647]

Table 11. Study designs used in studies measuring intermediate outcomes across the phases for medication management

Design	P	OC	D	A	M	E	R
RCT	5	1	0	0	1	0	0
Cohort	1	0	0	0	2	0	0
Observational	17	2	2	5	1	1	1
Qualitative or mixed methods	4	1	0	3	1	0	0

Note some studies cross more than one phase**.** See Appendix C, Evidence Table 22 for references.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
RCT = Randomized controlled trial

General Study Characteristics

Study participants tended to be practicing clinicians (Table 12). Most of the studies were conducted in hospitals (n = 27) or primary care (n = 17), one in long-term care, and four in pharmacies, and assessed intermediate outcomes for health care staff. Twenty-two of the studies were performed in academic settings. Prescribing was the most commonly studied phase of medication management, but each other phase was represented. Three systems used hand-held devices. CDSS, e-Prescribing, and CPOE systems were most commonly studied. Most studies did not report on the proprietary nature of their systems, 17 studied commercial systems and seven were home grown. Many studies looked to correlate use of medication management systems with other factors. Only nine studies assessed intermediate outcomes for patients (Table 13).[633,637,639,641,642,648-651]

Table 12. Clinician study participants in studies assessing intermediate outcomes across the phases of medication management

Clinicians	P	OC	D	A	M	E	R
Primary care physicians	6	1	0	0	0	0	0
Specialists	6	0	0	0	0	0	0
Hospitalists	4	0	0	0	0	0	0
Other Physicians	2	0	0	0	0	0	0
Physicians undifferentiated	9	0	0	0	1	0	1
Nurses	7	0	0	6	0	0	1
Mid-level practitioners	1	0	0	0	0	0	0
Pharmacists	2	3	1	1	0	0	1
Other health professionals	4	0	0	1	0	0	0
Hospital administrators	0	0	0	0	0	0	0

Note some studies cross more than one phase.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation

Table 13. Patient study participants in studies assessing intermediate outcomes across the phases of medication management

Patients	P	OC	D	A	M	E	R
Infants (0 to 2 years)	0	0	0	0	0	0	0
Children (2 to 12)	1	0	0	0	0	0	0
Adolescents (13 to 18)	2	0	0	0	0	0	1
Adults (19 to 44)	2	0	0	0	2	1	1
Middle age (45 to 64)	1	0	0	0	4	1	1
Geriatric (65 plus)	2	0	0	0	2	1	1
Undifferentiated	0	0	0	0	0	0	0

Note some studies cross more than one phase.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation

Prescribing and ordering. Twenty-six studies looked at intermediate outcomes for interventions aimed at the prescribing phase (see Appendix C, Evidence Table 22). CDSS (n = 12), CPOE (n = 11), and e-Prescribing systems (n = 6) formed the bulk of the primary systems studied. Three studies assessed usability issues related to CPOE or CDSS.[638,647,652] One study focused on the use of standards for medical history, formulary, and benefits.[653] Satisfaction and correlates of satisfaction were measured in ten studies;[636,637,644,645,654-659] use and measures correlated with use were studied in 11 studies.[534,643,649,650,653,660-665] Pirnejad and colleagues[666] used mixed methods to determine the impact of CPOE on the collaboration of nurses and physicians in hospitals. Glassman and colleagues[667] looked at the impact of drug-drug interaction alerts on physician knowledge over time. Two studies assessed perceptions of technology on work.[656,658] Participants were generally health care providers, located in either hospitals (16 studies), primary care (ten studies), or both, and one pharmacy.[540] The majority were performed in the United States.

Order communication. Four studies looked at the order communication phase;[540,645,668,669] three focussed on e-transfer of prescriptions,[540,645,668] and all studied the perceptions of pharmacy staff as well as other stakeholders. Rupp and Warholak[645] administered a survey and followed up with interviews of American chain community pharmacy staff to assess their attitudes towards e-Prescribing and recruited a sample of 1094 pharmacists, technicians, and interns from 276 pharmacies. Porteous and colleagues[668] surveyed 494 patients, 145 general practitioners, and 148 pharmacists, and held interviews and focus groups to assess peoples' views regarding the upcoming implementation of e-Transfer of prescription information in the United Kingdom. On the other hand, Kirking and Thomas[669] performed a survey looking at pharmacists' attitudes towards computer technology used to detect and prevent adverse drug interactions, and correlated their findings with pharmacist computer use. Their sample included 218 pharmacists in Michigan using one of two pharmacy computer systems and a group of nonusers. Johnson and colleagues[540] assessed the perceived usefulness of alerts and override comments appended to e-Prescriptions.

Dispensing. Two studies looked at dispensing. Chan[646] looked at factors associated with the use of drug dispensing and eMAR systems in nursing homes by analyzing surveys of long-term care facilities. Rupp and Warholak[645] assessed pharmacist personnel staff views of e-Prescribing.

Administering. Eight studies assessed technologies used at the administering phase. O'Morrow,[670] Hurley,[671] Holden,[672,673] Topps,[674] and their colleagues assessed American nurses' attitudes and satisfaction toward bedside point-of-care BCMA technologies to verify drug administering. The usage patterns of BCMA verification in five medical departments of a Dutch hospital were tracked.[675] The perceptions of the effects of a newly implemented CPOE in two groups of 211 Dutch nurses previously using different paper prescription systems were assessed by Niazkhani et al.[644] Chan[646] assessed factors associated with medication administration records use in nursing homes.

Monitoring. Four of the five monitoring studies focused on patient self-monitoring. Weingart and colleagues[641] measured the use of PatientSite, a patient internet portal, by 416 patients in three primary care practices to facilitate communication between physicians and patients regarding medication adherence and adverse effect rates. In an RCT involving 117 patients, Ross and colleagues[639] provided patient online records for heart failure patients and assessed self-efficacy. McCann and colleagues[633] performed an RCT on 112 cancer patients with a mobile phone application to monitor their chemotherapy toxicity symptoms compared with standard care and measured perceived benefits. Schmidt and colleagues[642] tested patient adherence using a telemonitoring intervention which included a beeping medication box integrated with the patient's EHR data. The final study assessed the usability of a CDSS Antibiotic Wizard in an ICU using an ergonomic survey tool to detect deficiencies in the system as viewed by 40 physicians.[647]

Reconciliation. One study evaluated patient and physician satisfaction and perceptions of a discharge reconciliation application.[651]

Education. The study by Liu and colleagues[648] is the only study focusing on the education aspect of medication management.Their study provides hospitalized patients in a Taiwanese hospital with a system that integrates their pharmacy, EMR, and CPOE information into an education tool to increase their knowledge of their medication regimens. Knowledge was assessed in pre-post surveys of 154 patients and they reported perceived knowledge gains.

Outcomes

Prescribing. Many studies measured use descriptively (e.g., presenting the percentage of time e-Prescribing was used for writing prescriptions), but did not meet our criteria for having comparison groups and being hypothesis-driven. From our included studies, use and measures that were correlated with use were frequently measured. Rogers and colleagues[660] found that usage rates increased following iterative changes made to a CDSS system based on feedback from users. Shannon and colleagues[643] reported a significantly higher rate of e-Prescribing after emergency department physicians were allocated hand-held PDAs with e-Prescribing software. Access to medication history was more frequently used for patients with low socioeconomic status and a greater number of medications.[650]

Some studies found that ease of use and perceived usefulness relating to improved care and care processes of the MMIT applications were positively correlated with level of use.[653,661-664] Kralewski and colleagues[665] found that use of e-Prescribing systems was correlated with such cultural factors in primary care practices as trust, adaptability, and business orientation. Wang and colleagues[653] found that a positive performance measure based on ease, efficiency, and care was correlated with nonuse of an e-Prescribing system incorporating standards for medication history, benefits, and formulary. Use of a CDSS in an Australian hospital was positively correlated with computer sophistication and access to laboratory data and negatively with years of experience.[661] Musser and Tcheng[640] measured preference and use of a graphic interface compared with a text-based interface for an anesthetic CPOE; clinicians used the graphic interface more often, but both interfaces had their proponents. A study assessing the frequency of use of three common pediatric order sets found differential use rates, with asthma order sets used significantly more often than both appendectomy and community-acquired pneumonia order sets.[649]

Usability. Three studies looked at usability and also included data on comparison groups.[638,647,652] Rosenbloom and colleagues[638] found that highly visible hyperlinks significantly increased the use of educational material and patient information. Rohrig[647] and Li and colleagues[652] used usability testing to identify issues in a CDSS and CPOE system respectively. Their results were used to inform new iterations of their existing systems.

Satisfaction. Ten studies measured satisfaction as a main outcome. Satisfaction with various systems used by various health care providers tended to be positive.[644,645,656-658] Satisfaction was lower in an intervention group of residents provided with CDSS within an e-Prescribing system in a small RCT, but they only used the system for 2.8 percent of their prescriptions.[636] No difference in satisfaction levels were detected for patients or physicians using a discharge CPOE application compared with usual care.[637,659]

Differences in satisfaction and perceptions of the systems were found between nurses and physicians;[656,657] medical and surgical staff;[654,657] and residents compared with physicians.[654] Perceptions of the system impact on work were also found to be different among health care providers.[656,658] Other factors correlated with satisfaction included computer sophistication, experience, training, system characteristics, and perceived improvements in care.[654-657]

Knowledge. Glassman and colleagues[667] found no change in physician knowledge of selected drug-drug interactions over 2 years of using a CDSS with alerts in 97 American primary care physicians, although most preferred having the system.

Attitudes. Pirnejad and colleagues[666,676] studied nurses' and physicians' attitudes to the impact of CPOE on the nurse-physician collaboration in the medication process. They found that the original paper-based system and the new CPOE system supported their work and collaboration differently. The new system led to problems in the synchronization and feedback aspects of the joint medication care, leading to the recognition that new systems do not always directly replace the work entailed in old systems and that care processes can be negatively impacted.[666]

Attitudes toward MMIT often varied by groups of users. Junior students were more positive about CPOE than interns and residents.[677] Similarly, using a diffusion of innovations model, Rahimi and colleagues[678] found that a CPOE was perceived to work better for nurses than physicians (57 percent vs. 13 percent); further, more physicians felt that the system was not adapted to their practice and more would have liked a return to the old system, compared with the nurses.

Johnson and colleagues[540] measured perceptions of pharmacists to appended alerts and override comments on e-prescriptions; they found some information (e.g., allergy alerts) more useful than others (e.g., insurance status).

Order communication. Of the four studies assessing the communication phase, outcomes assessed included only satisfaction[645] and attitudes.[540,668,669]

Rupp and Warholak[645] found that chain community pharmacy personnel who dispensed e-Prescriptions were generally satisfied with e-Prescribing and rated e-Prescriptions more favorably than paper prescriptions on seven criteria related to safety, efficiency, effectiveness, communication, and relationships with patient and prescriber. They further produced 11 best practice recommendations to improve e-Prescribing in a community pharmacy setting. In the United Kingdom, before e-Transfer of prescription information being implemented, Porteous and colleagues[668] found that various stakeholders viewed e-Transfer as a good idea (68 percent of patients [95 percent confidence interval (CI), 64 percent to 72 percent], 83 percent of general practitioners [95 percent CI, 77 percent to 89 percent], and 87 percent of community pharmacists [95 percent CI, 82 percent to 92 percent]). Concerns were expressed about security and sharing of confidential information. Benefits revolved around improved repeat prescription processes, convenience, and a greater role for pharmacists in medication management.

The potential for pharmacy systems to assist pharmacists in detecting adverse drug interactions by having greater access to patient information in the form of patient medication profiles was assessed by Kirking[669] in a survey study asking pharmacists using two systems and a third group using no system how often they detected potential drug interactions and how often they contacted prescribers. Computer users reported an average of twice as many detected interactions per week (16.1 vs. 8.7, ns) and had significantly more contacts with prescribers per week (21.5 vs. 16, $p < 0.05$). The majority of the differences were the result of users of one of the unnamed computer systems, while the other groups had use rates similar to the noncomputer group.

Dispensing. One study suggests that drug dispensing and eMAR technologies were used more in nursing homes with higher occupancy rates; fewer metropolitan than rural homes using systems.[646] Rupp and Warholak[645] presented best practice recommendations for community pharmacies using e-Prescribing based on surveys showing satisfaction with e-Prescribing in community chain pharmacies.

Administering. Administering phase articles focused on nurses using BCMA systems[670-675] or eMAR systems.[646] O'Morrow[670] found no differences in the attitudes of 17 nurses regarding patient care, charting, computer benefits, computer capability, computer characteristics, legal issues, or management tools before and after implementation of a BCMA system. Hurley and colleagues,[671] on the other hand, found significant improvements on a satisfaction scale of 1,087 nurses after implementation of a similar system for efficacy, safety, care, and access factors. Holden et al.[672,673] assessed nurses' perceptions and acceptance of BCMA; perceived ease of use and perceived usefulness; predicted satisfaction with the process before and after BCMA.[673] In their second study, nurses' perceptions of the medication administering process changed with the implementation of BCMA compared with a control group; while perceived safety, accuracy and consistency in checking patient identification improved, ease of use, usefulness, and efficiency were perceived to decrease.[672] Topps and colleagues[674] looked at nurse, pharmacist, and respiratory technicians' perceptions of BCMA before and after implementation; surveys after implementation showed that the staff felt that fewer medication errors occurred with a smoother administering of medication; they did, however, perceive that more time was spent administering medications, which took time away for other patient care. Overall, satisfaction and perceived benefits were improved in the study, by Niazkhani and colleagues,[644] of nurses who went from two paper-based prescribing systems to a CPOE system. Perception of effects did depend on which previous paper system they were used to, and workflow support was perceived as worse by both groups.

Van Onzenoort and colleagues[675] measured usage of bar code point-of-care systems by nurses and found that only 55 percent of 23,492 drug administrations were verified using the system; use depended on department, drug route, nurses available, nurse age, and timing of administering.

Monitoring. Most monitoring phase interventions were geared toward patients and showed positive effects on the intermediate outcomes of use, knowledge (self-efficacy), and satisfaction. PatientSite patient internet portal had a 48 percent response rate to index messages and a higher rate of ADE reporting via site (13 percent vs. 3 percent nonresponders, $p = 0.01$).[641] Ross and colleagues[639] found that online records for heart failure patients improved self-efficacy (91 percent vs. 85 percent $p = 0.08$) and satisfaction. Chemotherapy patients using a mobile phone symptom system reported a number of benefits: better communication, better symptom management, and reassurance of physician access.[633] Finally, patients who telemonitored their congestive heart failure issues consistently used a beeping medication box integrated with their EHR to increase adherence to their regimen.[642]

One study assessed usability; the Rohrig[647] usability study of Antibiotic Wizard showed good usability. Physicians did report some weaknesses in the design of health IT which were to be used to inform future versions.

Reconciliation. A study of satisfaction with a reconciliation system found that patients reported satisfaction for self-reported perceptions of clear instructions on what medications to take, how much and how often the medications were to be taken, other instructions on taking the medication, potential side effects, and general understanding of the medications. Health care provider perceptions of satisfaction with reconciliation and instructions did not differ for five factors except for three factors reported by physician assistants and nurse practitioners. Physician assistants and nurse practitioners reported that patients had clearer instructions on discharge ($p = 0.01$); how much, how often, and when to take their medications at home ($p = 0.05$); and the medication discharge process was viewed as being sufficient for them as caregivers ($p = 0.0003$).[651]

Education. Use of an integrated pharmaceutical system to provide information to patients to understand the pharmacological properties of their medications resulted in significantly improved patient knowledge after use of the system.[648]

Economic Outcomes

The introduction of health IT in the medication management process holds the promise of increasing efficiencies, improving quality of care, and reducing costs. However, even if these technologies are effective, they are expensive to implement and maintain and thus a review of the economic literature to determine cost-effectiveness and value for money for such interventions is warranted.

All studies passing the inclusion criteria that were considered to be cost or economics studies were reviewed and categorized into two groups based on the type of economic evaluation used in the analysis: (1) full economic evaluations; and (2) partial economic evaluations. A full economic evaluation is the comparative analysis of alternative courses of action in terms of **both** costs and consequences. Therefore, the economic evaluations which identify, measure, value, and compare the costs and consequences of the alternative being considered were further classified into one of the three categories: (1) cost-effectiveness analysis; (2) cost-utility analysis; and 3) cost-benefit analysis.[679] The label, partial economic evaluation, indicates that the studies do not entirely fulfill both of the necessary conditions for a full economic evaluation (i.e., costs and consequences). However, cost analyses can provide useful information on 'upfront' costs compared with 'downstream' cost avoidance.[679] For this reason, both full economic evaluations and cost analyses were included in this review. In each of these classifications, articles were further categorized by setting (i.e., hospital or community).

Descriptive information on the populations, interventions evaluated, the study year, perspective, and country of study were abstracted for each study. Data specific to the costs and effectiveness of each comparison were also abstracted and summarized in Appendix C, Evidence Tables 8a and 8b.

Full Economic Evaluations

Only five of the 31 (16 percent) economic articles reviewed conducted economic evaluations that provided information on the incremental costs and the incremental effects of an MMIT application. The following section reports the findings of five economic evaluations dealing with the use of CPOE (n = 2) and CDSS systems (n = 3) for improving prescribing practices for various conditions (Appendix C, Evidence Tables 8a).

Hospital. The potential economic consequences of implementing an eMAR system were estimated in a study using data from various literature sources.[680] In a tertiary care hospital setting, the projected incremental effectiveness of the eMAR was 261 ADEs averted over the 10-year time horizon compared with the standard paper ordering approach. Given that the incremental cost of the new electronic medication ordering system was USD$3.3 million during that same period, the incremental cost-effectiveness ratio was USD$12,700 per ADE averted.

A 1-year RCT in a hospital family medicine center evaluated the effect of three reminder systems on compliance with tetanus vaccination.[530] A computer-generated physician reminder system was found to cost $0.43 per additional vaccination recorded compared with usual care.

The telephone reminders to the patients cost $5.43 per additional vaccination, while the mailed letter reminder to the patients to recommend tetanus vaccination was $6.05 versus standard care.

Community. A group of Norwegian researchers[510] conducted a cost-effectiveness analysis alongside an RCT involving 146 general practices from two separate geographical areas. The objective of the evaluation was to compare the costs and effects of a multifaceted intervention, including computerized reminders to physicians, aimed at improving prescribing of antihypertensive and cholesterol-lowering drugs compared with the passive dissemination of guidelines. The cost per additional patient started on a thiazide rather than another antihypertensive agent in the intervention group was compared with usual care. Over the 1-year study period, the authors calculated that the incremental cost-effectiveness ratio of the intervention was USD$454 per additional patient started on thiazides. It was found that reduced drug expenditures based on increased use of thiazides did not outweigh the costs of the intervention. The authors commented that if the effect was sustained for a second year, the intervention would have been expected to lead to savings.

A Spanish study published in 2005[634] evaluated the cost-effectiveness of a CDSS designed to promote guidelines for the treatment of asthma. Over the 1-year study period, the authors found that from a societal perspective, the intervention dominated standard care (i.e., less costly and more effective). From the health care payer perspective, the incremental cost-effectiveness ratio was €61 per percentage point reduction in the St. Georges Respiratory Questionnaire.

Setting not stated. Using information obtained from a systematic review of the literature, Karnon et al.[681] developed a decision tree model to estimate the net benefits of three interventions aimed at reducing medication errors (i.e., CPOE, ward pharmacists, and bar coding), either through prevention or detection. Based on estimated quality of life utility decrements associated with experiencing a preventable ADE, it was concluded that the CPOE had a mean net benefit of GBP £31.5 million, ward pharmacists of GBP £27.25 million, and bar-coding of GBP £13.1 million over a 5-year time horizon with the intervention and maintenance costs included in their model. It was noted that the monetary value of lost health needed to be included for the interventions to have a high probability of producing positive net benefits.

Partial Economic Evaluations

Most of the economic literature reported the results of partial evaluations (26 of 31 studies, 84 percent). All of these evaluations took the form of cost analyses. In other words, the costs of the alternatives were examined separately and the effectiveness, efficacy, or both measures were not used in the analyses, which results in an inability to answer efficiency questions about an intervention.

Hospital. A computerized ADE surveillance system was used to help identify and prevent specific types of ADEs in patients in hospitals.[682] The authors compared the length of stay in hospital of patients incurring an ADE with a historical control group of inpatients who did not have ADEs, and showed that the average length of stay for patients with severe ADEs was 20 days, 13 days for patients with moderate ADEs, and five days for those with no ADEs. This translated into a cost of USD$38,007 for patients with severe ADEs compared with USD$22,474 for patients with moderate and USD$6,320 for patients with no ADEs. Given this significant difference in the length and cost of hospitalization between patients with severe and moderate

ADEs, the authors concluded that this *suggests* that the prevention and reduction of ADEs could reduce the length and cost of hospitalization for certain patients. However, it is important to acknowledge that the cases were not matched for disease severity and that no direct cost analysis was made of the ADEs prevented by the system compared with before the implementation of the system.

The same author measured the effect of a CDSS aimed at improving the use of and reducing the cost of antibiotics in four separate studies. The first was conducted in an academic, tertiary, private hospital and the average cost for 24 hours of antibiotic therapy recommended by the CDSS was USD$10.85 less per patient than what was actually prescribed by physicians.[409] The same CDSS was evaluated in two studies that took place in a 12-bed shock/trauma/respiratory ICU. The 7-month pilot study revealed a mean reduction in the cost of antibiotics of USD$87.03 per patient compared with the preintervention period.[683] The other ICU study was 12 months in duration and the mean cost of antibiotics for the computer regimen followed, regimen overridden, and no CDSS, respectively was USD$102 compared with USD$340 and $427, while the cost of hospitalization was USD$26,315 compared with USD$35,283 and USD$44,865.[475] Finally, an antibiotic-dose monitor was incorporated into the CDSS to check the renal function of patients to identify those who were potentially receiving excessive dosages of antibiotics.[614] The patients in the intervention group received fewer mean doses of study antibiotics at a lower average cost (USD$80.62) than patients during the preintervention period (USD$92.96) of this 12-month study. If this reduction of USD$12.34 per patient is summed for all 4,483 patients in the intervention period, this would result in a total decrease in cost of more than USD$55,000 a year.

Another CDSS by Barrenfanger and colleagues,[684] designed to improve antibiotic prescribing by electronically notifying the pharmacist of potential problems with a patient's antimicrobial therapy, was introduced in a 450-bed community teaching hospital and evaluated over a 5-month time period. The study compared patients whose microbiologic data were processed in the normal manual manner in the pharmacy to patients whose microbiological data were processed using the computer software. The study patients were matched by diagnosis related groups to patients in the control group. Additionally, the control group patients were adjusted for severity to make the groups more comparable. The study group had an average total standard cost of USD$13,294 per patient; the severity adjusted control group had an average total standard cost of USD$16,106 per patient, a decrease of USD$2,812 per patient in the study group. By using these severity adjusted data, the estimated variable cost savings annually from the improvement of interventions is USD$2,932,000 (2,000 inpatients for whom susceptibility testing is done multiplied by $1,466). If the list price of the CDSS (USD$44,500) was subtracted from the expected annual cost savings from the use of the program to improve interventions (USD$2,932,000), the resulting savings (USD$2,887,500) was still substantial in the first year.

A 3-month RCT was designed to evaluate the effect of a CDSS for the management of antimicrobial utilization in a 648-bed tertiary care academic hospital.[401] Antimicrobial utilization was managed by an existing antimicrobial management team using the system in the intervention arm and without the system in the control arm. The Web -based system was developed to alert the AMT of potentially inadequate antimicrobial therapy (a "back-end"` or postprescription review). Expenditures for antimicrobial drugs were USD$285,812 for the intervention group and USD$370,006 in the control arm, for a savings of USD$84,194 (23 percent) overall or $37.64 per patient.

An antiinfective decision support tool, designed specifically for a pediatric population, was introduced in a 26-bed ICU in an academic hospital.[469] During the 6-month period before CDSS installation, all patient care orders from the physicians were handwritten. The study found no difference in hospital costs in the period before CDSS installation (USD$28,257.67) compared with the time after CDSS installation (USD$25,032.11) or in antiinfective costs per patient (USD$274.79 in the control group compared with USD$289.60 in the intervention group).

An evaluation of a CDSS on appropriate antibiotic treatment used a cohort study followed by a multicentre, cluster RCT.[399] The cohort study compared the advice of the CDSS with physician performance with respect to appropriate empirical antibiotic treatment and costs. The RCT compared hospital wards using the CDSS compared with antibiotic monitoring without the CDSS. In the cohort study, all cost components, except those related to expected adverse events, were significantly lower for the treatments suggested by the CDSS compared with those used by physicians. Total antibiotic costs were €289 lower per patient for CDSS, a relative decrease of 48 percent. In the RCT, the use of the CDSS resulted in significantly lower antibiotic costs in intervention versus control wards, the difference originating from lower ecological costs in intervention wards in Israel and Italy. Direct antibiotic costs, as well as costs incurred by observed adverse events, were similar.

A Canadian study in an orthopedic institution assessed the safety and potential cost savings of a computerized, laboratory-based program (i.e., CPOE and CDSS) to manage inpatient warfarin therapy after major joint arthroplasty.[685] The authors estimated that the potential savings per patient of CAD$5.50 per day was due to a reduction in nursing time, for a total annual figure of CAD$55,836. It is important to note that the cost estimates and potential cost savings are speculative and are meant to be illustrative and not conclusive in nature.

A computerized order set within an CPOE was designed to manage pediatric inpatients with asthma.[446] A before-after study of the system found no significant difference in the total inpatient costs among the groups before and after intervention. The hospital charges were USD$3,567 and USD$3,759, while the pharmacy charges were USD$373 and USD$429 in the groups before and after intervention, respectively.

The costs associated with the implementation of a CPOE and CDSS system over 10 years (1993 to 2002) were measured in a 720-adult bed, tertiary care academic hospital.[686] Using data on the reductions in items such as ADEs, drug costs, and laboratory test usage, it was estimated that the system saved the hospital USD$28.5 million over the 10-year period, even after including the capital and operational costs of USD$11.8 million. The authors stated that it took over 5 years to realize a net benefit and over 7 years to realize an operating budget benefit.

Chertow et al.[468] studied the effect of adding a CDSS to an existing CPOE for prescribing drugs to patients with renal insufficiency in a hospital setting. The authors measured the difference between the intervention and control groups in hospital and pharmacy costs and found no differences between the groups (USD$4,881 compared with USD$4,968 in total costs for the intervention and the control groups, respectively).

An evaluation of the introduction of a CPOE and eMAR system on the delivery of health care in an academic health system was done using a before-after design.[581] Based on total costs per admission, no significant difference was seen in any of the U.S. hospitals in the system.

A cost analysis of the implementation of an expensive CPOE (i.e., total capital cost of implementation was USD$2.9 million and operating costs were USD$2.3 million) in the management of surgical patients in an academic, multispecialty hospital was done by Stone et al.[419] Based on the data from 6 months before and 6 months after the intervention, a redistribution of workload was found. The personnel changes resulted in a savings of USD$445,500. The authors also noted that because of considerable gains in efficiencies (e.g., time necessary to have orders accessible to nursing, radiology, and laboratory), this implementation would likely result in long-term cost savings and improved quality of care.

An RCT done in 1993 assessed the effects of a network of microcomputer workstations for writing all inpatient orders (i.e., CPOE) on health care resource utilization.[687] The overall aim of the CPOE was to encourage cost-effective ordering and to reduce costs. Using the costs associated with inpatient charges (i.e., bed, tests, and drugs), it was determined that total charges per admission were significantly less (USD$887) for the intervention teams than for the control teams, with similar differences in all types of charges. The authors claim that if these effects were extrapolated to all medicine service admissions at that hospital, the projected savings in charges per year would be $3 million in 1993 U.S. dollars. It was noted that the workstation network hardware costs were approximately USD$20,000 per ward, with additional costs for installation and maintenance.

In two separate RCTs, Tierney et al. evaluated the effect of a CDSS that provided guidelines for the treatment of patients with ischemic heart disease or chronic heart failure[519] and patients with asthma or chronic obstructive pulmonary disease.[518] In both studies, care recommendations were displayed electronically to either physicians, pharmacists, or both physicians and pharmacists, compared with no care recommendations. In the heart disease study, the patients in the group receiving only the physician intervention had significantly elevated total health care charges (physician only: USD$6,302, compared with pharmacist only: USD$7,387, compared with physician and pharmacist: USD$7,639, compared with control: USD$7,025). In the asthma and chronic obstructive lung disease study, the authors found no difference in total costs (i.e., total inpatient and outpatient charges) across groups (physician only: USD$8,006, compared with pharmacist only: USD$5,333, compared with physician and pharmacist: USD$5,652, compared with control: USD$5,800).

A recent publication by Pointek and colleagues[688] measured the impact of an ADE alert system on cost and quality outcomes in seven community hospitals within a health network. The ADE alerts were triggered in real time, which enabled immediate pharmacy intervention. The results showed a statistically significant decrease in average pharmacy department costs per patient (USD$867 versus USD$826, $p < 0.001$) from before to after implementation. In contrast, the external control group had a significant increase in pharmacy department costs (USD$734 versus USD$797, $p = 0.029$). Drug costs decreased significantly from baseline (USD$360 versus USD$337, $p < 0.001$) in the study group. Conversely, there were significant increases in drug costs in the external control group (USD$401 versus USD$429, $p = 0.029$). The authors applied the observed percentage of cost decrease from baseline exhibited by the study group to both the internal and external control groups' results and found that this yielded a combined pharmacy department cost savings estimate in excess of USD$11 million. It was noted that these savings coincided with only modest quality improvements in projected mortality rates and length of stay. An important limitation in this study is that it did not compare ADE rates before and after implementation of the system.

Community. McMullin and colleagues[689,690] published two papers that evaluated the impact of a CDSS on prescription costs on a range of medications used in primary care. The first study was a retrospective cohort study using pharmacy claims data, which found that the average cost per new and refilled prescriptions was USD$4.99 lower in the intervention group, with the 6-month savings being USD$3,450 per clinician. A 6-month extension of this study showed a 12-month savings on new prescriptions of USD$109,897.

A cluster, unblinded, pragmatic (i.e., real world) RCT was conducted in a routine clinical setting, to assess the cost and effectiveness of a CDSS based on recommendations of the European Society of Cardiology and other societies for hypercholesterolemia management in comparison with usual care for patients with hypercholesterolaemia.[528] The total direct costs of hypercholesterolaemia management (i.e., physician visits, laboratory analyses, and the lipid-lowering drugs prescribed) for the intervention and control groups were calculated. The impact on total costs was markedly different in the two groups: €264,658 in the usual care group and €170,061 in the intervention group.

Ornstein et al.[691] set out to measure the impact of displaying prescription cost information in a computer-based patient record system at the time of prescribing on reducing drug costs by family physicians. When compared with a 6-month period where cost information was not displayed, it was concluded that no impact was found on overall drug costs to patients that could be related to the intervention. The mean cost per prescription in the control period was USD$21.83, and in the intervention period was USD$22.03.

Weingart et al.[692] designed an empirical study to understand the potential benefits of medication safety alerts generated by an e-Prescribing system in ambulatory care. Using a modified Delphi technique and data on 1.8 million prescriptions, the authors estimated that e-Prescribing alerts possibly averted 133 to 846 ADEs. These alerts could have avoided health care resource utilization in a number of areas (e.g., hospitalizations, emergency room visits), for a total savings to the system of USD$141,012 to USD$1,012,386. An expert panel reviewed a sample of common drug interaction alerts, estimating the likelihood and severity of ADEs associated with each alert, the likely injury to the patient and the health care resource utilization required to address each ADE. The analysis estimated that the cost savings due to the e-Prescribing by using third-party-payer and publically available information was USD$402,619 (inter quartile range [IQR] $141,012-$1,012,386) with an average cost savings per clinician of USD$173 (IQR $61-$436).

Community and hospital. One group of researchers developed a CDSS that used the clinical information contained in administration claims data from physicians, hospitals, pharmacies, and laboratories to identify common errors in care and departures from widely accepted clinical guidelines.[620] This differs from the other CDSSs discussed in this section, in that the CDSS was not deployed within a hospital setting or within an integrated delivery system in which EHR systems provided the backbone of clinical information. The authors conducted a 12-month RCT to test the hypothesis that the claims-driven CDSS could increase compliance with evidence-based practices and effect improvements in patient outcomes as measured by decreased hospitalization and attendant cost. The sentinel system was designed as a rule-based artificial intelligence engine combined with an automatic message generator that conveys clinical recommendations and supporting literature to treating physicians. Nine hundred and eight clinical recommendations were issued to the intervention group. Among those in both groups who triggered recommendations, there were 19 percent fewer hospital admissions in the intervention group compared with the control group ($p < 0.001$). Charges among those whose recommendations were communicated were USD$77.91 per member per month lower and paid claims were USD$68.08 per member per month lower than among controls compared with the baseline values ($p = 0.003$ for both). According to the paper, the intervention cost USD$1.00 per member per month to deploy and was associated with lower paid claims of USD$8.07 per member per month in the intervention group compared with controls, suggesting an eightfold return on investment from the payer perspective. However, it is important to note that this study was not intended as a formal cost-effectiveness analysis or cost savings analysis in that they did not directly measure costs at the patient or caregiver level, nor did they consider noneconomic costs or benefits.

An extension of this analysis was published 3 years later.[504] This study used data from two additional years to analyze the effect of the intervention on resource utilization. This evaluation showed that the intervention reduced the average total charges (i.e., billing, pharmacy, and laboratory data) in the study group by USD$24.77 per member per month compared with the group without the CDSS.

Economics Summary

Most of the studies (84 percent) reviewed that evaluated the economics of MMIT would not be considered full economic evaluations. Full economic evaluation studies measure the cost per successful patient outcome over time, whereas cost analyses measure only the costs of the alternatives examined. Cost analyses can provide useful information on 'upfront' costs compared with 'downstream' cost avoidance but an ideal economic evaluation would explicitly measure all direct health care costs (e.g., capital costs, health professional's time) and direct nonhealth care costs (e.g., home care services, transportation), as well as indirect costs (e.g., productivity gains or losses related to illness or death by the patients and caregivers) that could be affected by the intervention of interest. It is important to be aware that the greatest costs of these health ITs are associated with the purchase of new software (capital outlay) to add to preexisting EMR systems, as well as implementation costs (e.g., management, clinical team involvement, training costs, maintenance costs), which were not included in the cost side of the economic evaluation in most studies. Additionally, the full enumeration of the total costs needs to be synthesized with the consequences or outcomes of the intervention (i.e., cost-effectiveness analysis, cost-utility analysis, and cost-benefit analysis). The effectiveness of any given system is dependent on the system's design, implementation, the users of the system, and the setting into which the system is being introduced. Adoption of newer technologies needs to be based on formal evaluation of whether the additional health benefit (effectiveness) is worth the additional cost. Given the tension between the clinical benefits of integrated CPOE and CDSS systems and the high upfront costs, decisionmakers deciding whether to implement them need to better understand how and when financial benefits of such systems accrue (e.g., short-term compared with long-term benefits). These types of analyses are important for well-informed decisionmaking.

In summary, a few of the studies reviewed found that health IT interventions may offer cost advantages despite their increased acquisition costs compared with care provided without the health IT. However, given the uncertainty that surrounds the cost and outcomes data, and limited study designs available in the literature, it is difficult to reach any definitive conclusion as to whether the additional costs and benefits represent value for money. It is necessary that sophisticated concurrent prospective economic evaluations be conducted in the real world to address whether health IT interventions in the medication management process are actually cost-effective.

Clinical Outcomes

Summary of the Findings

Among the clinical outcomes assessed in 76 articles (Table 14), 54 percent reported significant benefits (Table 15). Studies that used monitoring approaches to identify and intervene with patients with actual problems (e.g., excessive blood pressure, increase in creatinine after being placed on a nephrotoxic drug) or needed care (e.g., hemoglobin A_{1c} monitoring) appear to be more effective than CDSS approaches that identify theoretical problems (potential for adverse drug events). The effectiveness of monitoring interventions in ambulatory care is enhanced (or only effective) if patients are also sent reminders and decision support recommendations.

Highly targeted interventions, focused on specific problems that provide problem-related specific interventions appear to be more effective than a more diffusely focused CDSS integrated with a CPOE system (e.g., nonpatient-specific guidelines for cardiovascular risk reduction).

Many studies have evaluated CDSS tools for improving the effectiveness of anticoagulants (proportion of days in therapeutic anticoagulant range) and improving the choice, route, duration of antibiotics, and reducing ADEs related to antibiotic use and most are successful.

Studies that have been successful in improving patient outcomes target high risk and vulnerable populations who have poor disease control,[515,610,624,693] lack sufficient access to health care providers to manage their condition,[408] or subpopulations with sufficient economic resources to respond to the CDSS intervention.[694]

While high risk groups have the potential to show the greatest benefits of IT, one study, which implemented a CPOE (prescribing, dispensing, and order communication system) in a children's hospital, reported substantial harm—a 270 percent relative increase in mortality after CPOE was implemented (2.8 percent vs. 6.6 percent unadjusted, adjusted OR 3.81, 95 percent CI 1.94 to 5.55).[15] This before-after study and its methods have been debated[17] and its conclusions contested. However, the increase in mortality they found provides important lessons about CPOE implementation, particularly in settings which include high-risk patients. Critically ill patients are most likely to benefit from IT but also most likely to be affected by dysfunctional technology and implementation strategies because delays in definitive treatment can increase the risk of mortality. As other groups have shown that CPOE systems either have no effect or a nonsignificant reduction in mortality in children's hospitals,[16] the disparity in findings likely relates to the extent to which both the technologies and implementation strategies have disrupted or delayed critical activities in the clinical setting, and demanded additional time for order-entry from clinical staff.

Two studies that implemented computerized decision support CDSS drug use increased mortality,[15] and length of stay.[18] Both studies lacked sufficient power to conduct a valid assessment.

Table 14. Research design for studies across the phases of medication management and education and reconciliation that address clinical outcomes as their main outcomes

Design	P	OC	D	A	M	E	R
RCT	21	0	0	1	21	1	1
Cohort and case control	7	0	0	0	6	0	0
Observational	27	2	1	2	13	0	0
Qualitative	0	0	0	0	0	0	0
Total	55	2	1	3	40	1	1

Note some studies cross more than one phase**.** See Appendix C, Evidence Table 16 for references to the included articles in each cell.
Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
RCT = Randomized Controlled Trial

Table 15. Summary of the number of studies reporting statistically significant differences in clinical primary endpoints between study groups for hospital and ambulatory based studies

Clinical Endpoints	RCTs	Cohort and Case-Control Studies	Observational Studies
Mortality (0 of 7 showed benefit)			
Hospital Studies	1 =	1=	4= 1-[15]
Ambulatory	0	0	0
Quality of Life (1 of 5 showed benefit)			
Hospital Studies	0	0	0
Ambulatory	1+ 3=	1=	
Length of stay (7 of 14 showed benefit)			
Hospital Studies	1=	1+ 1=	6+ 4= 1-[18]
Ambulatory	0	0	0
Adverse Drug Events (8 of 10 showed benefit)			
Hospital Studies	1+ 1=	0	6+ 1=
Ambulatory	0	1+	0
Physiological (18 of 32 showed benefit)			
Hospital Studies	0	4+	5+ 2=
Ambulatory	6+ 11=	1+ 1=	2+
Other adverse events (e.g., readmissions, hospitalizations, etc.) (six of 16 showed benefit)			
Hospital Studies	1+ 3=	1+ 3=	2+ 2=
Ambulatory	2+ 1=	0	1=

+ indicates that half or more of the main endpoints were shown to be positively statistically significant.
= indicates that at least half of the main endpoints were statistically not significant.
- indicates that half or more of the main endpoints were shown to be negatively statistically significant.
RCT Randomized controlled trial

Strengths and Limitations of the Evidence

Overall, 28 of 76 (37 percent) studies assessing clinical endpoints were RCTs, and the mean quality rating was 4.4 out of 9 (range two to seven).[401-403,407,408,515,518-520,524,526-528,537,541,543,610,620,624,630,634,637,695-700] Low ratings are because most RCTs of health IT cannot be blinded, and the majority are cluster RCTs, where equivalence in the distribution of measured and unmeasured confounders (clinician and patient characteristics) cannot be assured. Statistical adjustment for differences in the intervention and control groups has not been conventionally advocated even though it is likely required for unbiased comparisons.

The remaining studies were cohort, case control or observational; the majority were before-after studies or variants of this approach. Typically, in the before-after variant design, three time periods were assessed. Preintervention outcomes were compared with outcomes evaluated at two time periods of after implementation intervention. These comparisons sought to assess changes in care and the care processes associated with the interventions that were subsequently introduced. Only one study was a true time-series.[482] In most of the before-after studies, no adjustment was done for differences in patient mix or cointerventions in the time periods with and without the intervention. Unless a systematic trend for changes in the patient population mix was shown, this problem may have minimal effect on the reported results. The only exception is with length of stay, where well-documented trends in reductions in length of stay due to many factors unrelated to IT interventions are shown. For these outcomes, the positive benefits in reductions of length of stay shown in nine of 15 studies that measured this outcome are likely overestimated.

While the absence of a contemporaneous comparable control group is a problem with all before-after studies, the creation of control groups by comparing intervention patients to those that do not participate, or do not have a problem, to those that do is fundamentally far more likely to introduce major bias in the comparison (e.g., comparing patients with alerts to no alerts,[18] pharmacists volunteering to provide the intervention compared with those that do not volunteer,[694] and other similar problems[642,701]). The direction of the bias will depend on the study. Volunteers in any study tend to have better outcomes than nonvolunteers, and selecting patients with problems compared with those that do not will ensure that at least both will regress to the mean—people with problems get better and those with no problems get worse, resulting in an overestimation of the effect of most interventions.

Many of the observational studies suffered from selecting an outcome that was distantly or only marginally related to the intervention. Almost all of the studies that measured quality-of-life, length of stay, and all cause ADEs were examples of this problem. Gurwitz and colleagues[697] were able to show that only one-third of ADEs could have been prevented by the CDSS alerts that were provided. Moreover, in a substantial proportion of negative studies, minimal adoption was evident. The clinicians failed to adjust therapy or treatment to match the recommendations, and thus it was not surprising to find that the interventions had no effect on outcomes. Finally, the rate of some outcomes such as readmission, mortality, and nosocomial infections were too low to detect clinically meaningful differences if they had existed.

General Study Characteristics

A total of 76 studies assessed improvements in clinical endpoints or reduction in adverse events (Appendix C, Evidence Table 9).[15,16,18,401-403,407,408,423,425,430,437,446,452,453,455,459,467,468,475,482,489,501,515,518-520,524,526-528,537,541,543,545,550,555,581,610,614,615,620,624,630,631,634,637,641,642,682-685,688,693-714] Prescribing and monitoring are the phases that were well-studied with respect to clinical outcomes (95 percent of all studies). Forty included the monitoring phase, only two evaluated clinical outcomes associated with order communication,[15,581] three studied drug administering[581,630,693] and one each looked at dispensing,[15] reconciliation,[695] and a cell phone-based diabetes management program for educational purposes.[537] A total of 85 different endpoints were assessed for different aspects of MMIT (Table 14).

Outcomes

Prescribing. Clinical outcomes have always been the most important and the most difficult to measure and study in health IT applications. The studies must be done in clinical settings which are complex and nonstandard. The health IT must be held constant to fit the traditional model of clinical trials and this does not reflect the reality of clinical practice and technology use. It is also difficult to ascertain if a technology can affect clinical outcomes—drugs, surgeries, and other similar interventions are easier to tie to outcomes. The health IT is a "long distance" from actual clinical care with many steps and factors involved and the latency between exposure to the health IT and outcome.

Many studies have been done on the effect of health IT on prescribing. Consequently, many systematic reviews have addressed the effects of these applications on clinical outcomes. Two Cochrane reviews have been done. One addresses onscreen point-of-care computer reminders on outcomes of clinical importance. The review by Shojania and colleagues[715] found some clinical improvements across studies with blood pressure (being reduced by a mean of 1.0 mmHg). Durieux and colleagues[716] showed small improvements in time to therapeutic stabilization, risk of toxic drug levels and length of hospital stay (mean decrease of 0.4 days). Another eight reviews show similar findings for clinical outcomes: more changes in process and some limited and rather small improvements in clinical outcomes: alerts and prompts to improve prescribing behaviors (five studies, three showed statistically significant improvements),[717] CDSSs to improve prescribing in older adults (two studies, mixed outcomes),[718] CDSSs on medication safety (five CPOE and seven CDSS of which three did not show improvements),[719] e-Prescribing in hospitals (23 of 25 studies showed medication error reduction and four of seven with reduced ADEs of 35 percent to 98 percent),[720] CPOE in pediatric and ICUs (12 studies of proven error reduction but no effect on clinical outcomes),[721] CPOE in neonatal ICUs (reductions in errors but little if any effect on clinical outcomes),[722] outpatient CPOE (five studies of medication safety of which one showed reductions),[723] and CPOE with CDSS to reduce ADEs in hospitals and ambulatory settings (10 studies: five showed improvements, four showed trends and one was not significant).[724]

Prescribing—Strengths and Limitations of the Evidence

The evidence in this section is weak although many RCTs exist (Table 14). Numbers of participants in the trials are often small, studies are short term, and are often done by those who have developed and implemented systems. To support the potential for bias in assessment of a health IT by its developers, Garg and colleagues[725] completed a large and well-done systematic review of CDSSs. Their review evaluated RCTs of CDSSs for improving practitioner performance and patient outcomes. Using the data on practitioner performance, they found that if the trialists evaluated their own CDSS the trials were successful in 51 of 69 studies (74 percent). If the trialists were independent of the system being evaluated (i.e., not the developers), only five of 18 trials were positive (28 percent). The odds ratio (OR) adjusted for trial quality for a successful trial designed to improve practitioner performances if the evaluator was the developer was 6.6 (95 percent CI 1.7 to 26.7). The only other predictor of success besides the evaluator being the developer, in improving provider performance was if the users of the CDSSs were prompted to use the system automatically (adjusted OR 2.8, CI 1.2 to 7.1). It is difficult, however, to separate out developer bias from system effectiveness as they are confounded.

Commercial systems often do not have the resources to show changes in clinical outcomes and therefore this proof of clinical effectiveness is not completed.

Twenty-one RCTs studied the prescribing phase.[401-403,407,408,515,518-520,524,526-528,537,541,543,630,637,697-699] In addition, seven cohort or case-control studies,[501,545,701,702,709,710,712] and 27 observational studies[16,18,423,425,430,437,446,452,453,455,459,467,468,475,482,489,550,555,631,683,688,693,703,704,706,708,714] also looked at the prescribing phase and reported clinical outcomes. Only the RCTs will be discussed below because of their strength of evidence. Four studies were done in the late 1990s.[407,527,630,699] All of the rest were done after 2000.

Prescribing—General Study Characteristics

Participants. Because these studies evaluated clinical outcomes, all assessed patients and their caregivers. All RCTs used cluster randomization (clinicians or care units) to avoid problems of contamination (where the same caregiver is asked to use decision-support for a random half of patients but not the remainder).

Location. One study was done in a long-term care center,[697] one was set in homes,[630] and five were set in hospitals.[401-403,407,637] All of the others were done in ambulatory care settings.

Drugs and diseases. Most studies evaluated specific diseases or conditions: asthma,[519] high cholesterol levels,[515,528,699] hospitalized patients at risk of deep venous thrombosis or pulmonary embolism,[519] depression,[520] infections in hospitalized patients,[403] high blood pressure,[526,699] and HIV.[527]

Technology. All studies involved CDSS. Six also included CPOE.[402,407,519,527,697,699] A PDA was also featured in the home-based article.[630]

Prescribing—Clinical Outcomes

Please also see the section on CDSS (KQ7: RCTs of CDSS) for additional description of clinical outcomes. As seen in the systematic reviews, fewer articles address clinical outcomes than address process or other outcomes such as satisfaction and attitudes. Many of the studies that did evaluate clinical outcomes also did not find the expected improvements.

Adverse drug events. Gurwitz and colleagues[697] found that the rate of ADEs and preventable ADEs were not decreased with implementation of a CDSS and CPOE system in a long-term care setting.

Disease related outcomes. A number of studies looked at disease outcomes. Kucher and colleagues[402] found that fewer patients at risk for venous thromboembolism were diagnosed with either deep venous thrombosis and pulmonary embolism at 90 days with the introduction of CDSS and CPOE in an academic hospital. Zanetti and colleagues[403] studied prophylactic antibiotics in prolonged cardiac surgery. This RCT found similar rates of infection in both study groups. Of note, both control and intervention groups reduced their rates of infection. Rollman and colleagues[520] addressed identification of depression in adult ambulatory care and found that the CDSS did not affect the rates of depression in the control or intervention groups in an RCT. Both groups improved their depression scores over time to the same extent.

Hospital stay. Three RCTs on prescribing looked at hospital length of stays. One RCT did not find differences in quality-of-life scores, hospitalizations, emergency department visits, or heart failure exacerbations.[519] Safran and colleagues,[527] in another RCT of CPOE and CDSS for clinic patients in an academic setting, did find a lower hospitalization rate for intervention (reminders) group (44 percent vs. 35 percent, RRR 26 percent, p = 0.04). Hospital length of stay was not different in the RCT by Overhage and colleagues[407] of CDSS and CPOE (eight days for both groups), nor in the study by McGregor and colleagues.[401]

Physiological measures. Eleven RCT studies of the prescribing phase addressed physiological outcomes: hypertension in two articles and both showed no difference,[526,699] high cholesterol with some positive findings in one[541] but not the other four[515,524,528,543] and two with reductions in blood glucose levels.[537,630] A study on depression found no change in patient depression rating scores.[520] One study with asthma patients found improved lung function and airway hyperresponsiveness.[408]

Order communication. Order communication issues seemed to be at the heart of this before-after study of a children's hospital by Han and colleagues[15] which showed increases in mortality after introduction of CPOE and CDSS integrated within a hospital information system. This is an important study and has garnered much discussion in the literature of its methods and findings with respect to the increase in mortality (2.8 percent vs. 6.6 percent unadjusted, adjusted OR 3.81, 95 percent CI 1.94 to 5.55). Length of stay showed improvement in one hospital, but not another in a study of CPOE implementation by Mekjjan and colleagues.[581]

Dispensing and administering. The study by Han and colleagues[15] evaluated dispensing; while three studies addressed administering.[581,630,693] One study was an integrated system in the Ohio State University Health System (James Cancer Center and three other tertiary care hospitals). The hospital information system included laboratory, imaging, dietary, eMAR, and CPOE as well as all EMR capabilities. They found a reduced length of stay for patients with heart disease (14 percent) and transplant patients (15 percent) but not for those with cardiothoracic surgery or those in the cancer center.[581] Holdsworth et al.[693] found significant reductions in ADEs following the implementation of a CPOE system in a pediatric population. The third administration study was a cross-over RCT of diabetic patients using a hand-held insulin regimen optimizer, which showed improvements in blood glucose levels when patients received advice through the device.[630]

Monitoring. Most of the prescribing interventions were integrated with hospital clinical information systems or EMR systems. This provided the opportunity to use existing structured electronic information to assist clinicians in identifying patients who needed a change in their treatment plan. The system made recommendations that suited the particular patient profile. Starting with monitoring of treatment choices for antimicrobial therapy in relation to antibiotic choice, a wide range of clinically useful monitoring and prescription and treatment recommendation options have been studied including those aimed at improving chronic disease management (e.g., Asthma-Critic), providing early detection of adverse events (e.g., creatinine monitoring for nephrotoxic effects), and glycemic and coagulation monitoring to predict and recommend optimal dose changes. Of the 21 RCTs that included the monitoring phases, 15 were set in the prescribing phase. The issues related to RCTs and observational studies have been addressed in the general overview of studies in this area.

Reconciliation. One RCT at two academic hospitals studied a computerized reconciliation program that was integrated into a CPOE system and that required a process redesign.[695] They found a reduction in unintentional discrepancies between preadmission medication and admission or discharge medication that had potential for harm (1.44 vs. 1.05 potential ADEs per patient, absolute risk reduction 0.72, 95 percent CI 0.52 to 0.99).

Education. In another RCT, Grant and colleagues[610] studied a PHR system for patients with diabetes that was integrated into a fully functioning EMR (laboratory, imaging, CDSS, and pharmacy). Patient education was a major, but not the only, component of the PHR. No change was noted for hemoglobin A_{1c} levels, although it is important to note that the patients were fairly well-controlled at baseline (7.1 percent vs. 7.2 percent, $p = 0.45$).

Qualitative Studies

Summary of Findings

Fifty-three articles that were complete or partially qualitative studies were identified that dealt broadly with MMIT (Appendix C, Evidence Table 10).[20,439,503,540,547,597,629,632,633,635,652,666,671,674,726-764] No qualitative studies were identified that directly addressed the effect of an MMIT system on intermediate health care outcomes for any phase of the medication management continuum (prescribing, order communication, dispensing, administering and monitoring, as well as reconciliation, education, and adherence).

Strengths and Limitations of Evidence

The primary limitation of synthesizing qualitative studies to gain a deeper insight into the effect of MMIT applications in improving other intermediate health care outcomes within and across the medication management continuum is that no qualitative studies are available that directly address this question. Most of the qualitative studies identified examine the expectations or experiences of implementing an MMIT system on the process (but not the outcomes) of medication prescribing. These studies identify a large number of benefits to the health care delivery processes as well as a large number of barriers to uptake and use of the various systems studied. The strengths of the amalgam of evidence are that similar themes were identified across studies, health care settings were assessed by more than one study, studies were carried out in settings across the care continuum, study participants included physicians, pharmacists, nurses, other health care providers as well as some administrative management personnel, and multiple different types of qualitative data collection approaches including interviews, focus groups, observations, and document reviews were used across the set of studies evaluated. A small number of qualitative studies were available that examined MMIT systems on the processes of care for other phases of the medication management continuum.

MMIT is tremendously complicated and at the same time undeniably valuable. Strong and varied evaluations are vital and we have many evaluations of MMIT already. These evaluations show important changes to process. Clinical outcomes are more often mixed or nonexistent. We also see, in our evaluation studies, unintended consequences of MMIT and surprising results such as the increased mortality in a children's hospital after a poor implementation of a set of MMIT applications.[15] Because of these challenges in our results of quantitative studies, we include a fuller discussion of some of the qualitative studies in MMIT. These qualitative studies hold the promise of understanding more richly how MMIT is and should be used. The following paragraphs provide descriptions of some of the more important qualitative studies and their findings.

Prescribing and ordering. No qualitative studies were identified that directly addressed the effect of an MMIT system on intermediate health care outcomes. However, many qualitative studies provided evidence and examined positive and negative expectations and experiences of how an MMIT system designed to improve prescribing of medications could affect medication errors and medication safety,[20,439,503,547,629,632,652,666,676,726,727,729-731,733-736,738-740,742,745,746,748,749,751-753,755,759,761-767] which could be considered as precursors to intermediate health care outcomes.

Before system implementation. Positive and negative expectations of an MMIT system designed to improve prescribing and ordering of medications were identified by physicians and other health care providers or staff in hospital or ambulatory clinic staff prior to system implementation. Some positive expectations were that an MMIT would reduce medication errors,[727,733] increase pharmacological knowledge available,[740] provide educational benefits,[726,727] improve patient confidentiality,[727] be flexible (e.g., prescribing from any location),[666,729] allow for customization or tailoring to the individual prescriber or the patient (e.g., patient reminders), allow switching the system on and off,[729,733] be concise,[729,733] provide access to other areas of a medical chart,[740] save time,[740] and incorporate valuable allergy, dosing, and interaction alerts.[745,746] Pharmacists felt that MMIT would facilitate new collaborations among physicians, pharmacists, and nurses.[746]

One group of physician study participants had a positive attitude towards implementation of a CDSS, provided that they had some control over the system.[729] Many groups studied could be described as hopeful but cautious[727,729,733,740,748] while others, mainly physicians (although they were who was studied most often), were skeptical.[726,735,761,765] Hospital pharmacists felt that MMIT would allow them to spend more time with patients and improve collaborative working relationships with physicians and nurses.[746]

Only one study was identified that used qualitative methods to solicit patient views before implementation of an MMIT system focused on improving prescribing.[748] Patients on a general surgery ward were interviewed before implementation of an e-Prescribing and an eMAR system. Their attitudes about the current paper-based system were generally positive and many had a mistrust of computer systems in general. However, they anticipated advantages of the e-Prescribing and eMAR system in terms of time, improving accuracy and efficiency, and decreasing mistakes. Patients identified that an electronic system may be an advantage for staff when the first language is not English.

Despite the willingness of many of the participants to use a new MMIT system designed to improve prescribing of medications including CPOE, some negative expectations were that the MMIT system would impair existing interactions and relationships among health care providers and between physicians and patients (e.g., diminishing patient contact because they need to leave the consulting room to enter the prescriptions),[726,727,729,740,762] the ability to cope with the new system,[726] implementation would be onerous,[726] the costs of the system,[727] especially to the health profession including the time efficiency and workload redistribution,[735] the technical challenges such as data entry time, software compatibility and updating,[727,729] problems with availability or level of technical support,[727,735] social and cultural barriers,[727] deskilling of staff (people becoming dependent on the system for routine decisionmaking without understanding the background, reasons, or consequences of the decision made by the MMIT),[726] need for more security,[726] errors in prescribing such as decisionmaking errors,[727] transcription errors,[727] or overconfidence errors,[727] that the system would not remove medication errors but could even create new errors,[735] obscured responsibilities,[729] loss of own reasoning and clinical autonomy,[729] ensuring that the patient and not the computer would have the leading role in the encounter,[729] difficulty with knowledge management (e.g., too much information or erroneous information—'garbage in–garbage out'),[729,740] including prescribing alerts that were redundant or repetitive, of low priority, or difficult to interpret,[739] resistance towards change,[729] computer shortages,[740] and altering workflow routines.[740]

Some underlying key needs for an MMIT system designed to improve prescribing of medications would be that the system would not diminish the patient provider relationship,[726,727,729,740] be easy to use,[733] flexible, concise, and customizable,[729,733] clinically and technically trustworthy, reliable, and fast,[729,733] integrated into other relevant systems,[740] workflow needs to be maximized including development of new workflows[726,727,739,735,740] and there be enough time and resources available to support implementation.[726,727,735,740]

A Delphi survey was done in the United Kingdom to identify and reach consensus on the key clinical issues involving patient safety for which general practitioners in primary care might benefit from MMIT support, particularly in relation to medicines management. The key themes that emerged were importance of computerized alerts, need to minimize spurious alerts making it difficult to override critically important alerts, having audit trails of such overrides, support for safe repeat prescribing, effective computer–user interface, importance of call and recall, and need for safety reports. User interface, repeat prescribing, need to be able to run safety reports, and other safety issues were also agreed upon.[738]

After system implementation. The reporting of how MMIT systems designed to improve prescribing of medications improved intermediate health outcomes were also sparse among the qualitative studies. Drug alerts, including drug interaction alerts, were stated to be beneficial to improve patient safety.[547,632,666,767] E-Prescribing triggered a variety of clinician behaviors (other than terminating or changing a prescription) that may improve patient safety.[632] One study identified 22 previously unexplored medication error sources users reported to be facilitated by CPOE which would likely have a detrimental effect on health outcomes.[752] These were grouped as (1) information errors generated by fragmentation of data and failure to integrate the hospital's several computer and information systems, and (2) human-machine interface flaws reflecting machine rules that do not correspond to work organization or usual behaviors such as selecting the wrong patient because a list is alphabetical versus by team or floor, or unclear log on and log off procedures or processes so that the next person does work using the previous person's permissions.

During or after system implementation, physicians, nurses, and other health care providers or staff in hospital or ambulatory clinic found that health IT improved safety alerts,[666] provided useful drug alerts including drug interaction alerts, which appeared even if a different prescriber had ordered some of the drugs,[547] allowed physicians to prescribe electronically from everywhere in the hospital, improved on features of a previous paper-based system,[666] were user friendly and allowed benefits when the system was integrated,[751] and was designed to take into account diverse cultures.[751]

Physicians in one study felt that an electronic CPOE system improved the quality of care for patients because they got faster access to information and more up-to-date information, they received automatic reminders, and they could speed up care because knowing what had already been done would allow them to reduce the number of duplicate procedures carried out.[761] The multiple checks within the system also could lead to improved patient safety.[761] Better communication among physicians and structured reports for patients (e.g., discharge summaries) were also felt to improve quality of care.[761]

In another study, physicians, physician assistants, and nurse practitioners felt that a computerized patient record system-based pain CDSS played a very positive role in assisting them with patient care. They reported that this was because data were more legible, could be accessed remotely, and reminders provided helpful decision support. However, they also reported that at the same time as being helpful, the reminder system was considered time consuming, redundant, and the speed of the system slow.[763] Medical trainees also reported that an MMIT system provided valuable educational content such as geriatrics pharmacology review and nonpharmacologic treatment options.[731]

MMIT systems designed to improve prescribing of medications also generated some challenges that could be categorized as challenges: (1) with the computer system and software, (2) of the interaction between the MMIT system and the health care provider working with the system, (3) of the effects of the system on the collaborative working relationships of the health care team, and (4) of the MMIT working within the local context and environment. Computer system and software challenges include difficulties with user rights, inflexibilities, and displacements with the use of CPOE,[734,764] CPOE design failures, especially a faulty computer interface, lack of connection with other parallel systems, inadequacy of decision-support, and human errors occurring in interactions with the computer,[503,727,759,761,767] difficulties with the text presentation (e.g., too much information presented, data density), too many decisions that needed to be made at one time, unappealing color scheme and lack of notation, caution or problems with a prescription,[652,761,767] interface problems,[750,755] content problems,[755] and increased data entry time.[727]

Challenges generated from the interaction of the MMIT system and the health care provider working within the system included the need to take up new tasks and increased demands on the clinicians with the CPOE system),[734,764] maintaining complete lists of patients and their medications,[632,736] poor recording of data within the record such as allergy information,[632] propagation of errors if information was cut and pasted compared with creating new information and other mistakes,[755,761] transcription errors,[727] getting patient-specific formulary data,[736] encouragement to ignore interactions alerts as many were viewed as too trivial or unnecessary, which indicated that sensitivity and specificity required improvements,[547,632,753] initial difficulties with the technical components of the system,[439,767] awkward prescription writing leading to workarounds,[632] unfamiliarity with the disease codes in the system,[751] difficulties with finding information in the chart because of multiple places where the information was stored,[761] reducing clinical situation awareness,[759] overconfidence,[727] and increased workload.[750]

Challenges generated by the MMIT system that affected collaborative working relationships of the health care team included damaging the workflow, synchronization and feedback mechanisms between nurses and physicians,[666,676,750] altering the pace, sequencing, and dynamics of clinical activities,[750,759] and providing only partial support for the work activities of all types of clinical personnel.[759]

Challenges related to the MMIT working within the local context and environment included external implementation challenges (e.g., communication with pharmacists and vendor support),[736] lack of computer resources,[751] the need to keep their EHR systems up to date,[751] poorly reflecting organizational policy and procedure,[759,766] doctors' concerns that their views and opinions about the design and implementation of the new system had not been adequately addressed,[764] high cost,[727] social and cultural barriers,[727] and problems with technical support.[727]

A number of studies related that participants felt it took longer to prepare a prescription using the MMIT system compared with conventional pen and paper.[761,764,767] One study identified that physicians and nurses in an acute care setting found that CPOE did not meet naive and early expectations.[734] Some adverse effects of the CPOE system were noted.

Attitudes towards MMIT systems in the early stages were mixed.[768] Over time, and with experience of making the system work for them, attitudes changed to become more balanced and the potential benefits of the system become clearer to most.[439,676,761] Some physician participants felt the MMIT was more efficient during consultation and led to better quality, while others were felt it took longer and took away from patient focus.[751] Physician users tended to provide comments related to the culture of professional quality (feeling that the computer facilitated quality). Alternately, those physicians that chose not to use the system tended to provide comments that focused on human relations. For example, they reported on their relationships with their patients that they felt were detrimentally affected by computer use.[751] Some physicians felt that MMIT helped physicians become more cost conscious by suggesting therapies that were less costly. This cost savings however, only directly benefited insurers and not the clinicians, patients, or health care facility.[751] Some physicians felt the MMIT systems improved their personal performance by allowing them to log on to the system from anywhere including home, while others felt this was an intrusion into their home life.[761,767] Basic formatting and organization of information such as information that was legible, could improve order accuracy, or all in one place was seen as a benefit to MMIT.[761] MMIT applications were also felt to improve interdisciplinary work by improving communication with colleagues,[761] and having everyone reading from the same page.[767]

Alerts and reminders are important components of MMIT for prescribing. Important themes of these alerts or reminders in EMR systems included themes of efficiency, usefulness, information content, user interface, workflow, and training.[742,745] Effectiveness focused on the positive effect of alerts on allergy awareness and patient education.[745] Efficiency related to ensuring that the alerts and reminders were efficient, useful, and did not waste time.[742,745] Usefulness concerned whether the alerts were helpful and appropriate.[742] Information content was concerned with accurate, comprehensive, timely, rich, and accessible information.[742,745] The user interface was felt to be important for smooth and efficient work and provision of valuable information that was accurate and provided quickly.[742,745]

The value of e-Prescribing alerts was diminished by the quantity of irrelevant and inappropriate alerts.[632] Workflow issues related to the information being available when and only when needed.[742] The need for training to improve the use of alert was noted.[745] Attitudes to evidence-based guidelines were also seen as an important factor as to how alerts would be taken up, with physicians preferring that alerts be severity-rated, that only substantial ones should appear, and that user interface design be enhanced.[745] The biggest surprise from a set of focus groups (reported in 2002) with a group of clinicians (physicians, physician assistants, and nurse practitioners) was the considerable negative emotion associated with alerts and reminders (feelings of being criticized, embarrassment, guilt, frustration, annoyance, and anger).[742] One study of a set of three successful and three unsuccessful CPOE implementations across six hospitals identified 14 facilitating factors and 14 barriers comparing successful and unsuccessful implementation.[20] More people from the successful hospitals group reported supportive administering and heads of medical sections, direct involvement of physicians, mandatory implementation, adequate training, and sufficient hardware facilitated success. In terms of barriers, only inadequate hardware and lack of ability to easily complete patient transfer and advance admission orders (medical records package) differentiated the successful compared with unsuccessful groups. Changes involved in instituting a physician CPOE system are system wide and involve individual as well as organizational factors.[20] One study was identified that determined how clinicians use information management strategies during adaptation to an established CPOE system.[749] User created strategies identified that information overload must be carefully managed and communication is vital and is often negatively affected by new systems.

Only one study using qualitative methods to solicit patient views after implementation of an MMIT system that focused on improving prescribing was identified.[748] Patients on a general survey ward were interviewed after implementation of an e-Prescribing and administering system. Concerns were identified including loss of personal touch, not understanding the system, and perceived extra time needed if nursing staff had to check the drugs prescribed on the computer.[748] Despite the concerns raised, on balance the feedback provided by patients was that generally they did not have a strong opinion (assessment) either positively or negatively as to whether MMIT would impact the quality of medication prescribing compared with paper-based process.[748]

MMIT also impacted the professionalization of pharmacy. The effects of a health IT system that generated an e-Prescription on the professionalization of community pharmacists were improving the analytical capacity of the pharmacists and physicians, greater dissemination of therapeutics and professional knowledge, better integration of process tasks, increased process automation, elimination of intermediaries, facilitation of the interpretation of prescriptions, increased tracking capability, and greater informational capability improves relevance and meaningfulness of interaction and improves quality of information transmitted.[730] E-Prescribing has tremendous capacity to change and improve pharmacists' professional work and interactions.[730] One study showed that overly ambitious expectations sometimes lead to failed implementation.[629]

Order communication. Seven qualitative studies specifically addressed the implementation of an MMIT system to affect the order communication and verification of prescriptions.[540,597,671,732,736,746,752] None of these studies focused specifically on how MMIT affected intermediate health care outcomes. All of the studies addressed implementation issues. Nursing perspectives based on implementation of a BCMA system within the hospital setting found that an MMIT system was more time consuming but the nurses acknowledged that it produced a positive benefit because the extra time available was wisely spent to assure verification, generating an increased sense of safety for the patients,[671] or made improvements in the clarify of orders, organization of time their tasks, improved efficiency and standardization of documentation provided by templates, general improvement in emergency department processes, and decreased number of verbal orders and time searching for charts.[597] One study identified 22 previously unexplored medication error sources that users reported to be facilitated by CPOE including errors related to order communication and verification such as information errors generated by fragmentation of data and failure to integrate the hospital's several computer and information systems.[752]

These findings were consistent with another study carried out in a long-term care setting where numerous workarounds associated with the implementation of an eMAR and medication safety practices in nursing homes, were identified related to the technology itself creating unintentional blocks including slow wireless speed and the need to print each order on a separate page.[732] Organizational processes such as the limited resource of fax machines were also identified.[732] In the ambulatory setting limited electronic connectivity of e-Prescribing systems to pharmacies or pharmaceutical benefits managers (who administrate pharmacy prescriptions) meant that despite one-way electronic (non-fax) communication of prescription information from the practice there was still conventional communication (e.g., fax) back from pharmacies for clarifications and renewals.[736] Pharmacist perspectives about a commercial e-Prescribing system revealed barriers to that systems' ability to maintain complete lists of patients and their medications, use of CDSS, and getting patient-specific formulary data.[736] Factors associated with these issues related to product limitations, external implementation challenges (e.g., communication with pharmacists and vendor support), and physician preferences on specific product features.[736] A system that appended alerts and comments to the bottom of e-Prescriptions and was designed to reduce pharmacy callbacks did not reduce the number of callbacks but did change the nature of the callbacks.[540] Hospital pharmacy leaders with and without CPOE entry system experience all believed CPOE would improve patient safety through the allergy, dosing, and interaction alerts which they saw as valuable to medication management processes.[746] Some expressed concern that poor design or implementation could lead to increased errors.[746] Most believed the system would lead to improved efficiencies facilitating more time spent with patients.[746] Most felt CPOE would improve working relationships with physicians and nurses by facilitating new collaborations.[746]

Medication dispensing and administering. Ten qualitative studies focused on evaluating health IT applications to improve medication dispensing and administering including studies of BCMA,[635,671,674,728,743,754,756] PDA,[769] eMAR,[732,754] CPOE,[597] and automated medication dispensing.[744] All of these studies focused on evaluation of the process of care delivery before or after implementation of the systems.

Before implementation of a bar-code point-of-care eMAR system a group of pediatric nurses working in an American pediatric hospital provided qualitative responses to questions as part of a survey.[674] Themes derived from the survey done before implementation indicated that the nurses felt that medications would be given in a timely manner with less error, but may result in an increase in time with this increase in safety, along with more reported errors, but fewer errors in administering actual meds (near misses). The surveys collected after implementation indicated that the staff felt there were fewer medication errors with a smoother administering of medication.[674] Implementation of MMIT applications for medication dispensing and administering generated substantial number of nonIT workarounds.[728,732] In one study done in a hospital setting, these workarounds were categorized into omission of process steps (seven workarounds), steps performed out of sequence (one workaround), and unauthorized process steps (seven workarounds).[728] Probable causes for these workarounds included technology, task, organizational, patient, and environmental related causes.[728] A further study examined how nurses integrated BCMA and an eMAR system into everyday clinical practice and found that the implementation of new IT in the clinical setting can be disruptive to existing patterns of articulation work, or work that coordinates the activities of people across time and space.[754]

Another study of a system put in place in a long term care institution identified workarounds related to the technology itself and organizational processes.[732] The workarounds occurred at new medication order entry, communication with the pharmacy, and administering.[732] The technology introduced intentional blocks (safety features such as excessive dose blocking, dual documentation, and ADE monitoring) that led to workarounds related to the technology itself and organizational processes.[732] Organization process blocks leading to workarounds included the double checking of preparation and administration documents.[732] Integrating BCMA systems within real-world clinical workflows requires critical attention to ensure that technology safety features are used as intended and that nonIT systems are designed to support this use.[728,732]

Nursing perspectives about a BCMA, eMAR system integrated with pharmacy, CPOE, and electronic charting in a hospital after implementation found that in terms of access, the nurses appreciated greater access to medications and information (e.g., policies, guidelines, drug resources, patient files), but identified some delays in getting medications from the pharmacy.[671] Another study carried out in a hospital and long-term care setting found that nurses were surprised that BCMA generated unanticipated side effects such as confusion created by automated removal of medications by BCMA, degraded coordination between nurses and physicians, and dropping activities such as not scanning wristbands or medications to reduce workload during busy periods.[743] One study conducted interviews with nurses before and after the implementation of a BCMA. Before implementation most nurses expected the system to improve patient safety and after BCMA implementation most of the nurses reported that they felt BCMA improved safety although a number of concerns remained about the cumbersome and technical aspects of the system itself.[756]

After an automated medication dispensing system was installed interviews with all workers and managers who were affected (nurses, pharmacy managers, pharmacists, pharmacy technicians, hospital administrators, and patient care managers) resulted in themes of distrust, resistance, miscommunication, unrealistic expectations (skepticism that it reduced medication errors), speed and scale of implementation, concurrent changes, inadequate support, and social factors.[744] Nursing perspectives were mostly positive on the use of a mobile PDA with a bar-code reader used to obtain medication profiles of patients and then uses as a decision support to identify drug therapy problems (e.g., drug interactions) for elderly home care patients, despite some system usability issues with the machine.[635] Furthermore, some patients showed an interest when they saw the results from the electronic assessment.[635]

One ethnographic case study identified that the physician–nurse communications, mechanisms to ensure cooperation, and the procedures for preparing and administering the medications are the key process areas to address before implementing a system to augment the nursing administering of medications.[762]

Monitoring. Four qualitative studies assessed the clinician[737,747] and patient[633,760] perspective on the use of MMIT for medication monitoring. None addressed the effect of the systems on intermediate health care outcomes. The use of MMIT systems both facilitated and generated barriers to the process of patient monitoring by clinicians.[737,747] One mobile phone-based system study showed that the MMIT system was well-accepted by patients as a mechanism to monitor symptoms for chemotherapy related toxicity.[633]

Adherence. No qualitative studies examined the effect of MMIT systems on medication adherence. MMIT systems facilitated patient monitoring[737] by clinicians, however, barriers were reported to using health IT systems for patient monitoring.[747] EMR with e-Prescribing facilitated monitoring and communication between physicians and patients with respect to the process of care that included checking active and inactive prescriptions and new and refill prescriptions, names of medication, and other medication themes (ordering and refilling prescriptions, mail-order issues, adherence, self regulation, alternate over the counter medication use issues).[737] Clinicians caring for patients with HIV/AIDS using a CPOE and CDSS system integrated with the hospital, pharmacy, and laboratory systems identified six barriers to using reminders, including workload, time to document, reminders not applying, inapplicability to the situation, training shortcomings, quality of provider-patient interaction, and use of paper forms.[747]

Patients' perceptions and experiences were studied based on their use of a mobile phone-based advanced symptom management system (ASyMS©) for chemotherapy-related toxicity monitoring and management.[633] Patients with lung, breast, or colorectal cancer who used the system generally felt that, with training, the handset was straightforward and easy to use, entering data twice a day for 14 days was acceptable, the system did not impact on patients' daily routines, and the set of six symptoms that were recorded on the handset were adequate (although some patients did indicate that they would have liked the opportunity to report other symptoms). They were very happy with the alerting facility of the system often reporting that they felt 'secure' in the knowledge that someone was being alerted about their symptoms, the real time, quick response rate of the data collection and alerting facility was viewed positively.[633] However, one patient viewed the alerting system negatively, as she felt this part of the system was not sufficiently individually tailored.[633]

Another study focused on the patient perceptions of MMIT by studying a home telemonitoring device for ulcerative colitis that included their list of medications and questions designed to gather medication side effects.[760] Patients felt that the system improved safety, feeling that the program 'would catch something I might not recognize' or help them 'respond quickly to a threat' to their health.[760]

Other studies with qualitative findings were also found.[757,758,770]

Population Level Outcomes

Only one study met our inclusion criteria that assessed population level outcomes as a primary endpoint (Appendix C, Evidence Table 11). Yu and colleagues[712] in 2009 conducted a case-control study using actual reportable ADEs from a relatively large number of pediatric hospitals, comparing the rates of ADEs between cases and controls in hospitals with various degrees of CPOE implementation. The study found that patients from hospitals without CPOE were 42 percent more likely to experience a reportable ADE after adjusting for comorbidities; thus a significant benefit is associated with CPOE implementation.

Composite Outcomes

Only one included study assessed a composite outcome as their primary endpoint (Appendix C, Evidence Table 11). Holbrook and colleagues[771] performed an RCT of 511 adult patients with type 2 diabetes receiving either usual care or an intervention involving shared access by patient and primary care provider to a Web -based diabetes tracker. The tracker interfaced with the providers' EMR and a phone reminder system, which sent monthly reminders for medications, laboratory reports, or physician visits. The main endpoint of process composite score for checks of glycated hemoglobin, blood pressure, low density lipoprotein cholesterol, albuminuria, body mass index, foot surveillance, exercise, and smoking improved significantly more in the intervention group than in the control group (1.33 vs. 0.06 composite score scale; difference 1.27, 95 percent CI 0.79 to 1.75, $p < 0.001$).

Variation in Impact Depending on Medication Type or Form

Summary of the Findings

Although most studies looked at medication management in general, regardless of drug families, types or forms, 135 articles dealt with one or a few drugs or drug classes.[18,399,401,403-405,409-411,414,416,418,420-428,430,431,433,437,440-442,444-449,451,452,454,458-464,466,469-473,475-478,481,482,486,489,491,492,494,496-499,501,502,505-512,514-517,520-525,530,534,535,538,542,545,546,548,553,555,557,559,562-566,568,570,577,578,582,588,592,596,608,611-615,618,621,622,624,630,631,633,647,661,683-685,698,701,702,705,713,731,772]

Prescribing and monitoring phases were again most often studied, with few studies looking at order communication, dispensing, or administering, and none on education (Table 16). No included studies addressed the issue of sound-alike or look-alike drugs, and four dealt with altering prescribing of generic drugs over name brand.[414,458,510,535]

Specifically, 30 articles focused on antibiotics,[18,399,401,403,405,409,418,423,426,428,451,452,458,460,464,469,475,477,482,506,523,525,562,563,596,614,647,661,683684] seven on vaccinations,[404,410,411,424,478,530,566] two on respiratory medications,[446,613] three on psychotropics,[476,502,520] two on nonnarcotic pain relievers,[514,773] three on lipid-lowering agents,[515,517,706] two on corticosteroids,[462,553] 12 on cardiovascular drugs,[414,448,449,505,509,510,521,522,534,588,592,624] and four on insulin.[466,630,631,703] Narrow therapeutic index drugs were considered in 20 studies,[421,425,427,447,461,463,470-472,481,507,512,555,577,612,618,633,685,701,702] and controlled substances in seven.[437,445,486,501,535,564,731]

The form of medications was rarely mentioned, and was detected in only 18 studies.[405,433,456,460,464,470,496,530,538,545,548,559,578,630,675,701,713,772] Prescribing changes from one drug form to another was the focus of two of these.[460,464]

We focused here on narrow therapeutic index, controlled drugs, and the forms of drugs. The 20 studies reporting on narrow therapeutic index drugs overwhelmingly measured process (n = 15) and clinical outcomes (n = 5), only two measured costs,[612,685] and one study was a qualitative assessment of patients on chemotherapy.[633] The effect of the MMIT systems was generally positive on the main outcomes of process change measures of prescribing or laboratory monitoring changes. Clinical outcomes frequently were better with the use of the MMIT, but in some instances no change was observed.[425,702] Systems used to assist monitoring or prescribing of narrow therapeutic index drugs were all either CDSS or CPOE systems.

Six of the seven studies on controlled substances measured changes in process, four of which showed a positive impact.[437,486,501,535] Only two measured clinical outcomes with mixed results.[437,501] The controlled substance interventions were some form of reminders, alerts, or CDSS in all cases but one, which dealt with order sets for opioids in CPOE.[437]

The evidence in this small selection of articles indicates that health IT interventions designed to influence the management of patients taking narrow therapeutic index or controlled drugs have positive impacts in terms of changes in process; results are less clear for clinical outcomes with a number of studies showing no change.

Only two studies targeted changing the form of a drug,[460,464] both of which employed a CDSS and had positive results. Due to a lack of reporting of the form of medication being studied, we can make no conclusions about the variation in effectiveness of MMIT by drug form.

Strengths and Limitations of the Evidence

Narrow therapeutic index drugs. Of the 20 narrow therapeutic index drug studies, three are RCTs[507,612,618] with quality scores eight, seven, and seven out of nine respectively. Three cohort studies are included[685,701,702] with low quality scores of three, two, and three out of 10 respectively. The remaining studies were observational[421,425,427,447,461,463,470-472,481,512,555,577] or mixed methods.[633]

Controlled substances. The evidence for managing controlled substances rests on seven studies. The quality scores for the one RCT,[535] one nonrandomized controlled trial,[445] and one cohort study[501] were generally low. The other four studies included a qualitative study,[731] and three observational studies.[437,486,564]

General Study Characteristics

Narrow therapeutic index drugs. The narrow therapeutic index drug studies took place in hospitals (n = 14), ambulatory care (n = 6), and one at home. The drugs included digoxin,[461,618] chemotherapy,[421,447,633] anticoagulants,[425,427,470,471,481,512,555,685,701,702] and others[463,472,612] (Table 16). Three studies included CPOE interventions to assist with inpatient dosing,[421,447,701] one on side effect monitoring by patients,[633] and the remainder were CDSS alerts or reminder systems. Studies on anticoagulents measured adherence to prescribing and monitoring guidelines facilitated by some form of computer decision support.[425,463,470,471,481,685] Two studies were of alerts sent to pharmacists for prescriptions written in primary care; one for prescriptions of drugs determined to be inappropriate for elderly patients[507] and one for drug-drug interactions.[577] One study implemented order sets within a CPOE for dosing of gentamicin and caffeine in the neonatal ICU, and assessed errors and drug turn-around times.[463] Niiranen[555] studied a computer-based warfarin followup system used by nurses to ease the burden on clinic physicians. Otherwise, prescribing physicians were most often the target of the alerts, reminders, or dosing support.

Table 16. Number of studies across the medication management phases using MMIT to assist in the management of specific drugs or drug classes

Drug category	# of Studies	P	OC	D	A	M
Controlled	7	0	0	0	0	0
Benzodiazepines	5	5	0	0	0	1
Opioids	4	4	0	0	1	2
Narrow therapeutic index	20	0	0	0	0	0
Anticoagulants	10	6	0	0	0	5
Antineoplastic	3	2	0	0	0	1
Cardiovascular	2	1	0	0	0	2
Multiple narrow therapeutic index drugs	1	0	1	0	0	0
Psychotropic/hypnotics	1	1	0	1	0	0
Insulin	4	4	0	0	1	2
Antibiotics	30	26	0	0	1	6
Anti-infective (HIV)	1	1	0	0	0	0
Vaccines	7	7	0	0	0	2
Other	37	32	0	0	1	16
Antidote	1	0	0	0	0	1
Antiemetics	1	1	0	0	0	0
Anti-hyperglycemic drugs	1	0	0	0	0	0
Cardiovascular	12	11	0	1	0	0
Corticosteroids	2	2	0	0	0	1
Lipid lowering	4	3	0	0	0	2
Non-narcotic pain relievers	2	2	0	0	0	0
Psychotropic	3	3	0	0	0	1
Respiratory drugs	2	2	0	0	0	2

Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring
Some studies encompassed more than one phase. No studies looked at education for a specific drug or drug class.

Controlled substances. Two studies of controlled substances occurred in primary care settings. In an RCT, Fortuna and colleagues[535] assessed the effect of computerized prescribing alerts on the prescription rates of heavily marketed hypnotics and benzodiazepines compared with their generic counterparts in 257 physicians. Smith and colleagues[564] implemented a CDSS module to reduce prescribing on nonpreferred drugs in elderly patients in 15 primary care clinics. The other five studies were performed in hospital settings and used CDSS interventions[445,486,501,731] and order sets in a CPOE[437] geared towards prescribing physicians.

Outcomes

Narrow therapeutic index drugs. The interventions aimed at pharmacists both resulted in significant reductions in inappropriate prescribing. Raebel and colleagues[507] reported a relative risk reduction of 16 percent inappropriate prescribing for elderly patients, and Humphries et al.[577] reported a 31 percent relative risk reduction in drug-drug interaction prescribing. The studies of CDSS dealing with narrow therapeutic or narrow therapeutic index drugs frequently resulted in better laboratory monitoring of patients,[461,472,612,618] prescribing adherence,[427,470-472] dosing,[447,555,618] or avoidance of errors.[421,463,512] Cordero and colleagues[463] found reduced errors and quicker medication turnaround times with the use of CPOE ordering and dosing in the neonatal ICU. Negative results were found by Riggio[481] with longer times to stop heparin treatment in patients experiencing heparin induced thrombocytopenia following implementation of an alert for 100 patients. Time from alert to laboratory test and start of direct thrombin inhibitor treatment did not vary before and after the implementation.

Clinical outcomes were measured in six studies. We considered positive studies to have at least 50 percent of the outcomes as being significantly impacted by the technology. Under this measure, four of the studies did not show significant impact of the technologies on patient outcomes[425,555,685,702] though they tended towards being positive. Balcezak and colleagues[701] found better prescribing of heparin when a computerized nomogram was used by prescribers, but the nomogram was only used for 10 percent of prescriptions written. The highest quality evidence comes from Raebel,[507] White,[618] and Feldstein[612] and their colleagues who all showed positive, significant impacts of the technologies on narrow therapeutic index drug management.

Controlled drugs. The primary care RCT by Fortuna and colleagues[535] found a significant decrease in the prescribing rates of heavily marketed drugs with the implementation of an alert plus education intervention, with a relative risk reduction of 74 percent. The observational study by Smith and colleagues[564] in 15 primary care clinics to reduce prescribing on nonpreferred drugs in elderly patients showed a significant decrease in exposure of elderly patients to nonpreferred drugs, but no change in nonelderly patients, and a nonsignificant positive trend of preferred drugs in elderly patients.

The hospital-based quantitative studies showed generally positive process measures,[437,486,501] with improved adherence to dosing in two,[486,501] and better monitoring of patient pain levels.[437] Morrison and colleagues[445] found no change in prescription rates for laxatives to patients on opioids. Clinical outcomes were only measured by Peterson[501] and Wrona[437] and their colleagues. Peterson and colleagues found no change in length of stay or rate of altered status, but a significant reduction in falls ($p = 0.001$). Wrona and colleagues found improved respiratory rate in patients on morphine and hydromorphone with order sets outlining monitoring and documentation requirements.

Unintended Consequences of MMIT Applications

Summary of the Findings

The unintended consequences of health IT are important and often not well-studied. (Note that this section is not about drug-related ADEs.) These unintended consequences associated with an MMIT are often identified after a system is implemented, despite careful planning and installation. Unintended consequences can be minor or major and they can be viewed as being helpful to the installation or detrimental. Eighteen studies were identified that reported unintended consequences of MMIT installations (Appendix C, Evidence Table12).[15,16,450,457,480,503,508,732,734,743,752,759,774-779] Because we report only those outcomes that the authors reported as the primary or main findings of the study, this listing of articles on unintended consequences is likely not comprehensive.

Strengths and Limitations of the Evidence

One study is a large observational study of medication errors reported to MEDMARX facilities that covers all the phases of medication management.[774] As in previous sections of this report most of the studies evaluated prescribing. All of the remaining 17 studies (one RCT,[508] eight quantitative observational studies,[15,16,450,457,480,732,775,777] six qualitative studies,[734,759,776,778-780] and two mixed methods studies[503,752]) evaluated prescribing. Several of these studies also evaluated other phases. The order communication phase was evaluated in two studies, one observational[15] and one qualitative study.[732] Dispensing was studied in one observational study.[15] Administering has one observational study[15] and two qualitative studies.[732,743] No studies of unintended consequences evaluated the monitoring phase or education and reconciliation.

General Study Characteristics

Participants. Most of the studies were done at an institution level rather than a patient or provider level. Raebel and colleagues[508] studied medications with potential for harm to pregnant women and Han and colleagues[15] studied admissions to a children's hospital after implementation of a CPOE system. Nurses were evaluated in two studies,[732,743] and the rest of the studies included a range of clinicians.

Location. All studies were done in single hospitals or groups of hospitals. One study was done in a long-term care center.[732]

Drugs and diseases. Raebel and colleagues[508] studied drugs with potential for harm to the fetus in pregnant women (category D and X medications). All other studies included all medications.

Technology. All of studies but two involved CDSS and CPOE systems integrated with EMR systems, dispensing systems or pharmacy information systems. The two studies that did not include CDSS and CPOE systems involved BCMA[743] and eMAR systems.[732] They were both integrated within a hospital-based information system.

Outcomes

Ash and colleagues list a number of unintended consequences of MMIT and other health IT systems.[778] These unintended consequences were categorized into direct compared with indirect, desirable compared with undesirable, and anticipated compared with unanticipated occurrences. Ash and colleagues contend that most unintended consequences center on errors, security concerns, and issues related to alerts, workflow, ergonomics, interpersonal relations, and reimplementation (e.g., updates). They also assert that all health IT systems will have unintended consequences.

Mortality. The University of Pittsburgh study of increased mortality with the introduction of an inflexible CPOE system is an example of a very serious unintended consequence.[15] Because of the seriousness of the implications of this study, many people reviewed this article. Much attention has been given to this article and its methods.[17] Another similar study shows that with careful planning, another children's hospital did not see the same increase in mortality in admitted children after careful implementation of health IT.[16]

Errors. New and different types of errors were identified as unintended consequences in three studies.[450,457,503] Although most MMIT systems are associated with decreased errors, not all of the systems sought to determine **new or different** types of errors—they most often studied existing types and classes of medication errors. One study felt that problems with communication would probably lead to errors in medication management,[775] and another study postulated the same increase in errors based on challenges to existing and changing roles.[734] The study of use of inappropriate medications during pregnancy was stopped early because the system was not accurate enough, causing the system to "miss" notification of drugs that should have been alerted and to give alerts that were not needed.[508]

Prescribing. Prescribing was not addressed specifically, although alert fatigue was a common theme in the studies of unintended consequences of MMIT.[480,752]

Efficiency. Ash and colleagues[776] list 47 types of unintended consequences and Kopppel and colleagues[752] list 22. Ash and colleagues go on to verify that the types of unintended consequences they found were common in institutions outside those that she and her colleagues studied.[777] Unintended consequences were related to roles,[734,743,752,776,781] communication,[775,779] workflow alterations or automation of poor existing workflows,[752,759,779] inflexibility of the new system,[743,752,759] poor content or poor display of content,[752,759,776] alert fatigue,[480,776,779] and overdependence on the system.[779] Rather than fix the system, most often workarounds were instituted by clinical staff.[732,743]

Summary. Seventeen of the 18 studies listed above report serious unintended consequences of MMIT in multiple categories. From these studies we see that unintended consequences exist for many health IT projects regardless of the quality of the implementation or the amount of planning that went into the project. Although consequences were viewed as being positive or negative, both provided useful information for those interested in MMIT implementation.

KQ2. What knowledge or evidence deficits exist regarding needed information to support estimates of cost, benefit, impact, and net value with regard to enabling health IT applications in terms of prescribing, order transmission, dispensing, administering, and monitoring, as well as reconciliation, education, and adherence? Discuss gaps in research, including specific areas that should be addressed and suggest possible public and private organizational types to perform the research and/or analysis.

Introduction

We identified gaps in the report—some that we expected and some not. We address gaps by the key questions (Table 17). In this section, some overlap exists with Chapter 5 (Future Research). Most of the gaps cross multiple phases of medication management. Where an issue is more strongly associated with a phase we mention the phase or other aspect (e.g., reconciliation).

Table 17. Summary of gaps and needs across key questions

Gaps and Needs in Evidence and Knowledge	Strengths and Substantial Evidence
KQ1. Effectiveness: Medication Management Phases and other Processes	
Order Communication, especially two-way e-communication Dispensing Administering Reconciliation Education and training for professionals and patients System wide MMIT applications	Prescribing* Monitoring
KQ1. Effectiveness: Research Methods	
Controlled trials with comparative groups Trials with strong methods regardless of research method used Trials of whole systems and also components of MMIT Studies with outcomes important to patients Studies with population based outcomes Studies that address issues related to evaluation of complex interventions Pragmatic trials Multicenter trials Studies done by others besides developers Qualitative studies, especially of patients and families Evaluations of the evidence content of MMIT applications Knowledge translation (translational research) studies Understanding applicability of MMIT applications in relation to the complexities of MMIT systems Research teams or consultations that include clinicians, researchers, and informaticians as well as all major stakeholders	Observational studies Descriptive studies Studies that measure changes in process Studies done in one institution or location
KQ1. Effectiveness: Participants and Settings	
Nurses Pharmacists and other pharmacy personnel Other health professionals Patients and families especially in home situations Children Pharmacies, especially those outside of hospitals Long term care facilities Community Homes Specialty clinics Population based studies	Physicians* Hospital based settings Primary care/ambulatory care settings
KQ1. Effectiveness: Health IT Systems	
Fully integrated MMIT systems MMIT used by nonphysicians MMIT used by patients and families (patient-based systems) MMIT in relation to health information exchange systems	CDSS* CPOE
KQ1. Effectiveness: Reporting	
Reports of harms and other unintended consequences of MMIT systems and system integration Lack of consensus on terminology related to IT and MMIT Lack of standardization in reports of studies of MMIT despite having published standards	

Table 17. Summary of gaps and needs across key questions (continued)

Gaps and Needs in Evidence and Knowledge	Strengths and Substantial Evidence
KQ1: Effectiveness: Outcomes and other study endpoints	
Usability studies, especially those that can be generalized or transferred Workflow effects on both functional and dysfunctional groups before implementation Unintended consequences, with emphasis on major ones	Changes in process
KQ1: Effectiveness: Costs and Economics Studies	
Strong and full economics studies that include both costs and consequences Cost and economics studies of non-CDSS and CPOE systems	CDSS CPOE
KQ3: Value Proposition for Implementers and Users	
Full economic analyses Personal values of multiple stakeholders and what makes them decide to buy or use a system Patients and their families and their values Effectiveness research and pragmatic trials with an emphasis on outcomes important to patients The effect of MMIT on risk mitigation	
KQ4: System Characteristics	
Reporting and standardization of reporting of system characteristics, feature sets Head to head comparisons of systems taking into account their features and characteristics Health information exchanges and MMIT	
KQ5: Sustainability	
Operational definition of sustainability accepted by multiple stakeholders Studies that measure and report sustainability that are comparative across many groups and issues	
KQ6: Two-way EDI	
Studies of **complete** two-way EDI Studies of the effects of e-Prescribing on pharmacists, pharmacy personnel and patients and their families	The effects of e-Prescribing on hospital and primary care physicians
KQ7: RCTs of CDSS	
Strong trials on clinical outcomes	Trials of CDSS

*substantial strength

General Gaps

Medication management phases. The literature places a great emphasis on studying the **prescribing** phase of medication management, with 263 of our included studies falling in that phase (Table 18). We feel that more study should be done on the phases of **order communication, dispensing,** and **administering**. In addition, the **educational requirements** for effective use of MMIT applications by health professionals needs to be studied. The evidence on the need to train patients and their families on how best to use MMIT systems as well as incorporating disease-specific information and management education into patient-based MMIT applications is needed.

Reconciliation of medications is vital, especially at the time of transfer to another health care setting, including transfer to and from home and community. Little evidence is available that MMIT systems are capable of and effective at doing this medication reconciliation and making adjustments to regimens. Challenges with system interoperability and standardized representation of medication data make effective reconciliation using MMIT applications difficult.

Order communication is ripe for more research and development, especially in two-way communication to improve and speed up “perfection” of orders and prescriptions.

Table 18. Frequency of medication management phases studies plus reconciliation and education

Phase	Frequency
Prescribing	263
Order communication	26
Dispensing	17
Administering	39
Monitoring	77
Education	3
Reconciliation/Other	6

Research methods. This same pattern of disparity for the number of studies in the medication management phases exists for the distribution of study methods. Most included studies are quantitative observational studies (Table 19). Although these studies provide good evidence for understanding and evaluating MMIT applications, more studies with control groups are needed to provide stronger methods where appropriate. MMIT applications are “complex” interventions and can be considered to be programmatic and pragmatic in their evaluation. Future research using methods appropriate for these complex interventions are needed. Studies of full MMIT systems and components of MMIT systems are needed.

Many studies were not powered to find the differences sought. We also identified other issues in study methods including inappropriate analyses, labeling of methods, and adjusting data sets in some of the observational studies. For example, studies seeking to identify such factors as barriers or facilitators of use of health IT systems did not report adjustment for multiple comparisons (e.g., Bonferroni corrections, bootstrapping, or Monte Carlo simulations). Some studies addressing feature preferences tested for 40 or more associations without adjustment. The authors of sections of this report also have commented on incorrect choice of statistical analysis techniques in some studies that could have led to positive findings that are not justified. Studies need strong statistical and methodological advice. We also agree with Bernstam and other informatics researchers and educators who suggest that research into MMIT systems needs to include those with informatics and research training and experience.[782]

Another gap in the research realm is the absence of formal study of MMIT in relation to knowledge translation (translational research). Much evidence exists on many aspects of MMIT.

Table 19. Frequency of research designs for included studies

Design	Frequency
RCT	88
Cohort or case-control studies	21
Observational studies	207
Qualitative studies	39
Total	355

RCT Randomized controlled trial

Participants

Health care providers. Physicians are well-studied. Nurses, pharmacists, midlevel practitioners (e.g., nurse practitioners, physician assistants, advance practice nurses, and midwives), and hospital administrators are not (Table 20). Studies that include mental health professionals are also lacking. Studies that include nonphysician clinicians are not focused on the unique needs of the participants. The important issue of nursing workarounds that have developed to deal with systems that match physician but not nursing needs is also inadequately studied. Use and usability studies need to include all health professionals who use MMIT systems and studies need to be done that will allow knowledge gained in usability studies to be transferred to other settings.

Table 20. Number of studies that evaluated the effects of MMIT on clinicians (the clinicians were the major focus of the outcomes of the articles)

Provider	Frequency
Physicians, undifferentiated	28
Primary care physicians	29
Specialists	11
Hospitalists	18
Other Physicians	8
Midlevel practitioners (physician assistants, nurse practitioners, advance practice nurses, midwives)	7
Nurses	36
Pharmacists	23
Hospital administrators	5
Other health professionals	17

Patients. The age range of patients impacted by the MMIT were generally well-represented across age groups with notable concentration among those who require more prescription medications (e.g., middle age and geriatrics) (Table 21). However, the special needs of medication management for children such as age- and weight-based dosing were not adequately pursued. More study of pediatric patients would be beneficial. Many of these patient-specific studies used data from patients to evaluate MMIT systems and their functioning in hospitals and primary care settings. However the needs of the patients and their families to manage medications outside of hospitals and clinics were not studied. This lack of evaluation of MMIT systems that patients and families will use at home and the effects of these systems on patient care and outcomes is an important gap that will only grow because of the advent of new systems, improvements in existing ones, and the move of patient centered care, chronic disease management with the aid of health IT, and continued time and money pressures on health care providers. Qualitative studies that address pharmacists as well as patient needs and opportunities and important outcomes were also lacking.

Table 21. Frequency with which patients or caregivers across age groups were studied as the main focus of an article (how MMIT affects patients)

Patient	Frequency
Infants (0 to 2 years)	9
Children (2 to 12 years)	13
Adolescents (13 to 18 years)	20
Adults (19 to 44 years)	52
Middle age (45 to 64 years)	80
Geriatric (65 years plus)	85
Patients with Undifferentiated Ages	14

Settings. Hospitals and ambulatory care, but not necessarily specialty clinics, are also well-represented in the studies of this report (Table 22). The gaps are in other settings. Very few pharmacies or long-term care facilities were studied. Many existing articles on pharmacies and pharmacists were excluded because of lack of comparative data or integration of MMIT. Long-term care facilities, community locations, and homes also need formal evaluation to determine the effectiveness and use of MMIT applications for their constituents. One study evaluated outcomes at the population level.[712] MMIT applications tend to target individuals and few of them measure population level effects. Research into the effect of MMIT on populations is challenging and research will have to be carefully planned.

Table 22. Study settings in which the MMIT application was studied (studies could take place in more than one setting)

Setting	Frequency
Hospital	224
Ambulatory care (primary care offices and clinics and specialty hospital-based clinics)	119
Community	1
Home	6
Long term care facilities	8
Pharmacies	28

Health IT systems. CDSS and CPOE systems are well-studied, most often in the prescribing and monitoring phases (Table 23). All other MMIT applications lack evidence of their effectiveness, especially in terms of workflow, communication, and clinical outcomes. Many studies did not report important details of the MMIT application itself, making the studies in this report more difficult to synthesize. From the descriptions in the articles we felt that descriptions of the system, including components and implementation issues such as training could have been added but they were not.

Another substantial gap that we noted is that the content of the MMIT systems was not studied. Systems like CDSS and CPOE and functions like drug-drug interactions and the knowledge base that reminders, alerting systems, and order sets are based on need a strong, evidence-based foundation of knowledge that is based on health research and reliably updated and disseminated. Assessment of the need for and value of this clinical evidence base was absent.

Table 23. Technologies that were the main focus of the studies of MMIT

Technology	Frequency
CPOE/POE system	102
CDSS/CDS/CCDS/reminders	213
E-Prescribing	41
Order communication of the prescription to/from doctor to pharmacy	3
Pharmacy information system	7
Other	35
Barcoding-medication administering	20
Barcoding-dispensing	1
eMedication administration system (eMAR, eTAR)	15

CPOE = Computerized provider order entry, POE = Provider order entry, CDSS = Computerized decision support systems, CDS = Computerized decision support, CCDS = Computerized clinician decision support

Health information exchange. Health information exchange is defined as the movement of health information across organizations using nationally accepted standards was not studied in any of the documents retrieved. Medication management is complex and challenged by interoperability of systems, and like reconciliation, it has not been evaluated in MMIT studies that we identified in this document.

Reporting. Through the process of data abstraction, we found problems with standardization and expanded inclusion of data elements in terms of reporting health IT studies. We feel that authors should be encouraged to strive for publication in the peer-reviewed literature rather than trade publications and news magazines. We also feel that authors should include more data in their publications of MMIT interventions. Lacks appear in descriptions of what was in place for medication management before implementation of MMIT systems (baseline data), full explanations of the MMIT system and its implementation process, settings, including culture, and participants (both health professionals and patients and their families). A guideline for writing evaluation reports in health IT, the STARE-HI, was published in 2009.[783] We recommend that this document be used for planning and reporting research studies of MMIT. A list of the STARE-HI elements follows:

1. Title
2. Abstract
3. Keywords
4. Introduction
    a. Scientific background
    b. Rationale for the study
    c. Objectives of study
5. Study context
    a. Organizational setting
    b. System details and system in use
6. Methods
    a. Study design
    b. Theoretical background
    c. Participants
    d. Study flow
    e. Outcome measures or evaluation criteria
    f. Methods for data acquisition and measurement
    g. Methods for data analysis
7. Results
    a. Demographic and other study coverage data
    b. Unexpected events during the study
    c. Study findings and outcome data
    d. Unexpected observations
8. Discussion
    a. Answers to study questions
    b. Strengths and weaknesses of the study
    c. Results in relation to other studies
    d. Meaning and generalizability/applicability of the study

e. Unanswered and new questions
9. Conclusion
10. Authors' contribution
11. Competing interests
12. Acknowledgements
13. References
14. Appendices

Another of the challenges in this report to do with retrieval of studies from the bibliographic databases and also for abstraction and combining data, were inconsistencies in the use of terminology. We observed differences in how authors categorized medication errors, ADEs, and therapeutic failures. Several authors are seeking consensus on terminology in health IT. These definitional aspects are also addressed in the STARE-HI reporting guidelines listed above.[783] Most of the studies in this evidence report do not follow these guidelines.

Benefit and impact. Benefit and impact are similar but not identical. In the pharmaceutical world benefit can be thought of as being "can it work" often under ideal situations (i.e., efficiency research). Much of the evidence answering KQ1: Effectiveness is of this kind of research: evaluation of a project, often near its implementation and for a short period of time. Many of these studies attest to the fact that for process and other soft outcomes, many of the MMIT systems do work.

Impact, or pragmatic studies, refer to measuring the effect of an intervention in the real world. Very few studies in this report are in this category. Trials of this nature are complex, long-term, have large numbers of people/situations being studied, and are done on mature and well-functioning systems. These trials are costly to complete and require maturity in the systems. Their location is likely best at those centers in the United States that have established and mature health care systems that have solid support for technology, strong research teams, experience with qualitative and quantitative methods and expertise in collaborative projects that include clinicians, experienced informaticians, and patients and their families.

The gaps for completing benefit studies include the medication management phases of order communication, dispensing, and administering; people besides physicians (pharmacists, nurses, other health care professionals, patients and families, vulnerable populations); nonhospital settings (long-term care facilities, community, pharmacies, and home settings); generics, forms of medication, and controlled substances; MMIT applications beyond CDSSs; and dispensing, administering, adherence tools, and patient involved health IT.

Cost and economics. Cost and economics are complex issues and important to many people, groups, organizations, and governments. To complete a comprehensive economic evaluation (e.g., cost-effectiveness, cost-utility, or cost-benefit analysis) one needs to quantify all costs and benefits within a given perspective (e.g., societal). Strong economic evaluations can piggyback on an RCT, or an economic model may be developed with data from a number of sources. Well-designed studies with an economic evaluation component included, is the best way to move forward in this area.

Many studies have provided cost data, but useful economic data involves far more input. An example of a cost study with data that is limited in its use is by Chisolm and colleagues,[446] who did a before-after study of children with asthma in a children's hospital. Their pharmacy charges were $373 before CPOE with standardized order sets were put in place, and $429 after implementation.

Therefore, the gaps for estimates of costs in this report of MMIT are almost identical to those listed above. In addition, we identified gaps in research quality centering on research design and analysis. We need highly trained and experienced researchers and economists to complete useful and usable cost and economics studies in the complex and changing domain of MMIT.

Summary

This report identified broad based strengths and gaps in the MMIT literature. Many of the major endpoints sought were found to show positive and statistically significant improvements, especially those that dealt with process and issues related to use, usability, knowledge, skills, and attitudes. Clinical endpoints and full economic evaluations were lacking. We also identified gaps in the study of the phases of medication, people involved, locations of studies, and research methods. We also identified areas where these gaps are becoming more important such as patient and family needs and opportunities related to MMIT, complete MMIT systems, and interoperability. Much research has been done in MMIT, and moving forward needs directed and careful planning and vision to fill gaps in our evidence base, harness the best established and new research methods, and build on what we already know to embrace new and advancing abilities of MMIT.

KQ3. What critical information regarding the impact of health IT applications implemented to support the phases of medication management is needed to give clinicians (physicians, nurses, psychologists, dentists), pharmacists, health care administrators, patients, and their families a clear understanding of the value proposition particular to them?

The value propositions of health IT applications have been difficult to quantify with more of a focus in recent years on framing how best to consider and measure it.[784] Menachemi and Brooks[785] review the benefits and costs of EHRs and associated patient safety technologies. They have found that studies assessing the benefits of the technologies in process and clinical outcomes are far more frequent than those assessing the return on investment. This trend is supported by the considerable evidence presented in the current report; while we include numerous studies assessing process changes and clinical outcomes, the body of evidence on cost-effectiveness is sparse. A number of barriers to measuring return on investment in health technologies exist. Technologies do not result in a direct income stream and the benefits often accrue to organizations other than the ones making the investment as, for example, clinical benefit to patients and financial benefits to payers rather than the hospitals making the investments.[785] Investments in health IT produce a fundamentally different kind of asset to health care providers, and the technologies and changes they bring are so complex that it is difficult to measure their benefits.[784] Certainly the body of literature looking at return on investment for the various technologies covered in this report, across the various settings, is very limited.

We use the Center for Information Technology Leadership's (CITL) value framework (Table 24), which defines value as the sum of a technology's financial, clinical, and organizational benefits.[786] This fits well with the definition used by AHRQ whereby "value" is defined as "clinical, organizational, financial, or other benefits derived from the adoption, utilization, and diffusion of health IT less the costs of achieving these benefits" (http://grants.nih.gov/grants/guide/rfa-files/RFA-HS-04-012.html). The same considerations for stakeholder value propositions are elements outlined by Ash and colleagues[787] as important themes to consider when implementing a system, specifically CPOE. We recognize that this framework does not include patients as an element, but we believe that the framework could be applied to the patient perspective and incorporate value propositions for patients where applicable.

The required information to make an assessment of benefits is different depending on the stakeholder. The costs incurred by primary care physicians in practice will be different and balanced against different organizational benefits than those incurred in hospitals, and influenced by factors such as practice size, the sophistication of the technology, and others.[786] Similarly, what constitutes benefits to a patient will be different from that of other users. Subramanian and colleagues[788] have looked at costs and benefits to a number of stakeholders using CPOE with CDSS in long-term care facilities. Their process sheds light on the facets that we need to understand and study before we can make sweeping generalizations about value of health IT application. They identified the various stakeholders, the potential costs and benefits of the health IT, and factors which could affect costs and benefits. Ideally, such an assessment would be available for each stakeholder using each technology in each setting. This is not often the case so realistically we will broadly look at factors taken into account in making a value assessment and determine what we know and where the gaps lie.

Table 24. Summary of the evidence in relation to the CITL value framework[786]

CITL Value Framework[786]		Current knowledge
Financial	Cost reductions	• The limited cost analyses evidence available indicates that MMIT may offer some cost advantages despite acquisition costs. • Cost of system purchase, implementation and maintenance are rarely reported in the primary literature • Investors in the technology do not always reap the rewards • It is difficult to reach any definitive conclusion as to whether the additional costs and benefits represent value for money due to a lack of high quality, full economic evaluations.
	Revenue enhancements	• MMIT rarely results in increased revenue • Not within the purview of this report
	Productivity gains	• Some improvements seen in length of stay • Some evidence of increased efficiency • Qualitative evidence of workflow and health care provider relationship disruptions • Seldom measured as main endpoints
Clinical	Care process advances	• A significant body of literature indicating positive, if modest, improvements • Still a lack of quality studies with strong methods • Clear indications that unintended consequences can impact the value of the systems to stakeholders
	Improved patient outcomes	• Shortage of quality studies with strong methods • Some technologies show a positive effect on patient outcomes • Often measured as secondary outcomes and lack power
Organizational	Stakeholder satisfaction improvements	• Qualitative and quantitative support for improved satisfaction and perceptions for a range of stakeholders, including patients, using a number of different technologies in various settings • Even when positive satisfaction is reported, improvements to the systems are often suggested
	Risk mitigation	• Not within the purview of this report

Summary of the Findings

Given that the value framework is the sum of financial, clinical, and organizational benefits, the current body of literature summarized in our systematic review in KQ1: Effectiveness would indicate that too many unanswered questions exist to make a true value assessment for the different stakeholders and technologies in the applicable settings.

Financial Benefits

Cost reductions. The data on cost savings from the use of health IT in medication management are sparse. The few studies included in our review suggested that some cost savings may exist, which could be substantial over time. The economic information looks more favorable after the technology has been in place for an extended period of time so that the large upfront investment gets spread over time and then do we start to see a return on investment. However, a full economic evaluation requires the comparative analysis of alternative courses of action in terms of both costs and consequences, which provides the best information for making a decision to adopt an intervention or not, and very few of these have been rigorously completed in this field. We don't have good evidence of a positive return on investment. Also, the initial expenditure and ongoing costs were rarely reported and the included cost analyses were based on projections of savings given reported changes in care processes rather than improved clinical outcomes for patients.

Revenue enhancements. No studies that quantified revenue enhancements were captured for this review. Because of the nature of health IT assets, they do not per se bring about additional revenues to the investors.

Productivity gains. Evidence captured in KQ1: Effectiveness suggests that some productivity gains are achieved, often measured as improvements in efficiency in care processes.[429,457,463] Gains achieved by reductions in outcomes such as lengths of stay or rehospitalizations have been less successful, though Durieux and colleagues[716] do report a significant decline in hospital length of stay in a review of drug dosing decision support technologies. A number of studies reported positive improvements in efficiency outcomes such as drug turnaround times,[584,586,628] and time to administering drugs.[439,600] One study reported that nurses spent about the same time on computer documentation as paper documentation.[561] In our review, efficiencies were rarely the main endpoints of any of the studies; they were frequently reported as secondary outcomes or additional measures analyzed, but without any assessment of the power of the analysis. Because of the quality of the studies, it is difficult to attribute true productivity gains except in the cases of some well-established systems as suggested by Chaudhry and colleagues.[607] The qualitative evidence indicates that stakeholders believe that gains in productivity have occurred.[439,547,632]

Clinical Benefits

Care processes. Certainly this aspect of values is the most studied across the phases of medication management, with 379 studies included in our review in KQ1: Effectiveness. These studies included a number of settings and stakeholders, and most reported improvements in processes of prescribing changes, adherence to guidelines or quality measures, error reductions, preventive care procedures done, and monitoring initiated. However, the studies were often observational and often had small sample sizes. In more than 80 percent of the cases in which an improvement in process was sought, it was found to be positive. The findings of improvement were consistent across settings, levels of care, providers, and medication management phase. We report a positive effect in the use of MMIT in the prescribing and monitoring of controlled and toxic drugs as well. To balance this positive nature of the results, a growing body of evidence delineates unintended consequences of some technologies that will also contribute to the value proposition of stakeholders.[632,734,752]

Patient clinical outcomes. We reported on 78 studies that assessed clinical outcomes as their primary endpoints, the majority of which focused on prescribing and monitoring phases. About half of these studies reported positive effects of the MMIT on patient outcomes. However, when clinical measures were the primary endpoint, often no differences between the intervention and control groups in the higher quality studies were seen (see Table 15). The strongest evidentiary weight for clinical outcomes is found in the use of CDSSs for the prescribing and monitoring phases, and the overall benefit is somewhat positive but most often mixed.[725] The measurement of clinical outcomes is often so far removed from the MMIT intervention that it becomes difficult to make general conclusions about their efficacy, and adoption rates are still quite low. We found that efficacy was greater in interventions targeting specific populations or applications. Thus, a value assessment on patient outcomes would warrant a look at specific technologies, populations, and settings beyond the scope of this report.

Organizational Benefits

Stakeholder satisfaction. For implementation, adoption, and ongoing use of any technology to be successful, the people using the system need to find it useful, usable, and nondisruptive. Many studies have looked at workflow issues, satisfaction, and perceptions of users with regard to health IT. Our review includes only those providing qualitative data or comparison groups. The literature on satisfaction indicates that generally the stakeholders studied were satisfied with the technologies of interest, namely CPOE, CDSS, and e-Prescribing.[651,654-656,656-658] Some studies, however, found no differences in satisfaction.[651,659] Levels of satisfaction and positive perceptions were shown to be positively correlated with measures such as ease of use, productivity, quality of care, and reliability.[654-657,661,673] Our review of the qualitative research in the area shows that the implementation of MMIT generates emotion, both positive and negative. MMIT implementation did not just mean that a clinician needed to learn a new IT system but it also affected most of the other parts of the delivery of care processes including how the interdisciplinary care team worked together. When determining the proposition values, the type of technology and how well it meets expectations and workflow are important considerations for users, greatly impacting their perceptions and openness to adoption/use.

Some literature has focused on comparing perceptions and attitudes of different health care providers, such as nurses compared with physicians and trainees;[656,678] and residents compared with physicians using the same technologies.[654,657,677] The findings from these studies indicate that perceptions of the benefits of MMIT can depend on the role of the user. The type of system and how it affects health care providers' work will impact how satisfied these stakeholders are with the technologies.

For any one technology or setting, insufficient data exist to determine levels of satisfaction among all stakeholders. From the literature we see that satisfaction and perceptions of the MMIT can vary according to provider role, setting, and technology, and no overall answer to the question of stakeholder satisfaction exists. We have a deficiency of comprehensive studies of patients as stakeholders.

Risk mitigation. No literature was captured on risk mitigation in relation to the use of MMIT. A focus of the greater body of research, especially commentaries and narrative reviews, is on the use of technologies to reduce medication errors. Such benefits could have repercussions on risk mitigation, but also needs to be balanced with the fact that some technologies have been shown to result in new kinds of errors.

Conclusions

Only one study attempted to look at the value propositions across stakeholders in the use of MMIT and they concluded that to facilitate adoption of CDSSs in the long term care setting, financial incentives to both the institutions and physicians should be considered.[788] Certainly, from the literature, we see no clear understanding of what information is needed from the standpoint of each stakeholder. We can surmise from studies that physicians consider cost, usability, patient improvements, and easy integration into workflow as important factors to consider before they purchase MMIT technologies. Hospital administrators place emphasis on other aspects such as costs, return on investment, and organizational change. The relative importance of these factors will vary among physicians practicing in different settings, with cost being more important to physicians in private practice than in hospitals, and other related issues. Capitation rates will also be a factor for physicians and will vary across U.S. states.[786] Similarly, the importance of these factors will vary among pharmacists depending on their practice setting and the type of technology. For patients, convenience, usability, portability, and patient-centered functionality have been reported as important factors in their value assessment of consumer health IT.[4] For MMIT, patients will likely be concerned with reduced medication costs, avoidance of ADEs, and improved disease management, although no studies evaluated their value-based concerns. Work needs to be done to identify the needed critical information before we can truly assess what is missing.

From the information garnered in this report, a growing body of evidence supports the use of some technologies (e.g., CDSSs) in prescribing and monitoring, which show positive changes in process, while large gaps in knowledge of the impact of the use of MMIT for other applications still exist (see KQ2: Gaps in Knowledge).

KQ4. What evidence exists regarding the impact of the characteristics of medication management health IT applications, such as open source, proprietary, conformity with Federal and other interoperability standards, and being Certification Commission for Healthcare Information Technology (CCHIT) certified, impact, likelihood for purchase, implementation, and use of such IT applications.

Summary of the Findings

Few studies (n = 21)[45,48,632,653,661,663,667,789-802] demonstrated evidence of the impact of the characteristics of MMIT applications on likelihood to purchase, implement, and use such IT applications (Table 25). Little substantial evidence was found from studies that assessed open source health IT applications that met our inclusion criteria. Only two articles discussed conformity with standards[653,801] and one the Certification Commission for Healthcare Information Technology (CCHIT) certified system.[800] Such system characteristics as the use of proprietary IT systems was suggested by seven articles[45,632,653,663,798-800] and homegrown IT application by one article.[667] Two reported on a stand-alone e-Prescribing system.[653,798] Most of the articles suggest that the decision to adopt health IT applications has been influenced by the feature sets of health IT applications. Each of the 21 articles included in this section established evidence on likelihood to use, one on purchase,[800] and five on implementation.[653,789,791,793,798] A sizeable number (n = 20) of articles were on the prescribing and ordering phases, with only one on the administering phase of medication management.[45]

The findings of the articles included in our study suggest that certain features of systems improve the likelihood of purchase, implementation, and use of MMIT. However, the literature is sparse and evidence from studies with stronger methods that can address this question is lacking. Most often authors spoke about barriers and concerns towards implementation and acceptance rather than characteristics of MMIT that could facilitate implementation, purchase, and use of such systems. Insufficient details were given about the technology they were studying. Head-to-head comparisons of systems differing in these features were not found.

A systematic review on CDSS revealed that widespread dissemination of appropriate CDSS might improve clinical practice, but providing information in electronic format alone does not ensure uptake.[803] Fundamental issues related to system characteristics included the availability and accessibility of hardware, technical support and training, system integration into clinical workflow, timeliness of clinical messages, and acceptance of the system by various stakeholders.[803] Another review involving descriptions of 112 information systems identified that for successful implementation, core components were order entry, guideline adherence, and decision support.[804] Involving end users in the development process was also shown to be a key to success.[804] However, these systematic reviews did not explore whether health IT system characteristics like proprietary or homegrown, system configuration, system characteristics, CCHIT certified, conformity with interoperability standard and standalone or integrated had any impact on purchase, implementation, or use.[803,804]

Table 25. Number of articles addressing system type in relation to likelihood to purchase, implement, or use an MMIT system

Systems	Likelihood To Purchase	Likelihood To Implement	Likelihood To Use
CPOE alone	0	0	Hospital[663]
CPOE with CDSS	0	Hospital[793]	Hospital[45,667,793]
CDSS	0	0	Hospital[661]
e-Prescribing	0	Ambulatory Care[653,798]	Expert Panel[801] Mixed set up[48,802] Ambulatory Care[632,653,798]
Pharmacy information system	0	0	Hospital[45]
EMR/EHR/ clinical information systems	Ambulatory Care[800]	Hospital[789]	Primary Care[794,797] Ambulatory Care[799,800] Hospital[789,790] Mixed set up[792]
Health IT (Type of system not specified)	0	Hospital[791]	Hospital[791] Primary Care[795] Mixed set up[796]

Strengths and Limitations of the Evidence

Most of the studies were surveys (n = 18), although two used qualitative research methods[632,801] and one collected data from scientific literature, organizations, government, and professional reports.[797] Therefore, the strength of the evidence is relatively weak. Nineteen articles were published in the original literature and one was from the grey literature.[800]

General Study Characteristics

Participants. More than half of the studies (n = 13)[48,653,661,663,667,790,792,794-797,799,802] evaluated physicians as the user of the technology. One article each included pharmacists,[661] nurses,[667] directors and the leader of IT application users,[45] chief information officer,[791] pharmacy directors,[45,793] and two administrative and other medical staff.[661,667] Two reported combinations of different types of health care providers.[632,798] One study convened a panel of technical experts representing organizations having direct experience in implementing e-Prescribing standards.[801] The size of the studies ranged from 14 to 18,600 participants.

Study setting. In most of the studies, the participants were primarily from hospitals,[661,663,789-791,793] and some were set in pharmacies,[45] ambulatory care,[632,653,667,798-800] and primary care.[794,795,797] Four evaluated a combination of various settings.[48,792,796,802]

Technology. Primarily five groups of health IT systems, namely, CPOE, CPOE with CDSS, CDSS, e-Prescribing, EHRs, and five other systems were studied.

Research methods. Research methods were weak: eighteen articles were surveys, two used qualitative research,[801,805] while one used data from scientific literature, organizations, government, and professional reports.[797]

Outcomes

Identification of feature sets. Bell and colleagues conducted an expert panel consensus that resulted in 60 specific functional recommendations for e-Prescribing to improve patients' health outcomes and reduce costs.[806] This list of features is useful for those considering an assessment in this area. We identified that one or more of these recommended features were the driving forces toward possible purchase, implementation, and use of health IT applications. Major features addressed in most of the articles were medication lists,[208,632,653,663,789,792,794,798,801] dosing calculations,[661,789,792,793,799] CDSSs (alerts and messages for allergies, drug-drug interaction, drug approval),[45,632,653,661,667,789-794,796,798-801] e-Prescribing,[48,208,632,653,667,790,792,794-798,802] and order communication of the prescription to pharmacies.[45,632,792,794,798] Other factors were access to laboratory test results,[45,789,790,792,794,797,799,800,802] implementation of guidelines,[661,789,792,795,796,799] transcription services,[791] formularies,[653,793,795,801] tallman letters and change of color to differentiate between look-alike drug name pairs,[45] integration with another system like BCMA, pharmacy information systems, etc.,[45,791,793] and medication reconciliation (Table 26).[792,793] (Tallman letters are the use of capitals to help guarantee recognition of differences between drugs with similar names, as for example, Novo**LOG** and Novo**LIN**, and Huma**LOG** and Humu**LIN**, helps differentiate these products.)

Table 26. List of articles addressing various features that were instrumental in the decision to purchase, implement, and use

Features	Number of Studies Addressing the Features
Medication list	9[632,653,663,789,792,794,798,799,801]
eDosing calculations	5[661,789,792,793,799]
Clinical decision support (alerts and messages for allergies, drug-drug interaction, drug approval)	16[45,632,653,661,667,789-794,796,798-801]
e-Prescribing	13[48,632,653,667,790,792,794-799,802]
Order communication of prescription to pharmacies	5[45,632,792,794,798]
Access to laboratory test results	9[45,789,790,792,794,797,799,800,802]
Implementation of guidelines	6[661,789,792,795,796,799]
Transcription services	1[791]
Formulary information	4[653,793,795,801]
Tallman letters and change of color to differentiate between look-alike drug name pairs,	1[45]
Integration with another system (e.g., BCMA, pharmacy information systems etc.)	3[45,791,793]
Medication reconciliation	2[792,807]

BCMA = Bar coded medication administration

Standards and conformity. Wang and colleagues[653] suggest that mandating the use of standards is necessary but not sufficient for achieving the desired effects of e-Prescribing. Bell and colleagues evaluated two standards (Medication History Standard and Formularies and Benefits Standards) from the U.S. National Council for Prescription Drug Programs (NCPDP) that were considered as initial standards for e-Prescribing under Medicare.[801] Another study considered CCHIT certified IT applications to be the deciding factor for likelihood to purchase, implement, and use.[800] The 2008 Healthcare Information and Management Systems Society Analytic Ambulatory health IT survey reported commercial, proprietary EMR systems were being used without any one vendor being the dominant leader.[800] Apart from these two articles,[653,800] four other articles[45,632,663,799] reported the use of commercial proprietary systems with medication management health feature sets.

Use. All the studies addressing the decision to use were based primarily on one or more of the feature sets discussed above (Table 26). Three studies were on CPOE systems with CDSS capabilities[45,667,793] and one on a CPOE system alone.[663] The features that were more important were allergy checking, drug interactions, medication formulation, interface with the pharmacy information system and direct order communication, and integration with the BCMA and laboratory systems. Two studies were on CDSS,[661,667] with one being integrated with CPOE.[667] Their important features were e-Prescribing, drug-drug interactions, calculation of dosing, and access to additional information.

Seven studies were based on EHR, EMR, or clinical information systems[789,790,792,794,797,799,800] with one study[789] mentioning that a sizeable number of hospitals reported having implemented several key functionalities of CPOE and CDSS. The important features were CPOE with CDSS, electronically available laboratory test results, medication lists, e-Prescribing with electronic transmittal of prescriptions to pharmacies, access to reference materials, and dosing calculations.

Three studies were on general health IT systems.[791,795,796] Grossman et al.,[796] found the percentage of physicians reporting access to clinical activities such as obtaining guidelines, generating reminders, and writing e-Prescriptions increased from 2000-2001 to 2004-2005 ($p < 0.05$). Six studies[45,48,632,653,798,801,802] were on e-Prescribing with one being integrated with another system and hand-held access.[632] Some of the more important features addressed by these studies were e-Prescribing, medication lists, drug interaction and allergy alerts, receiving laboratory results electronically, changing doses, formularies, and order communication of prescription to pharmacies. According to the study by Bell and colleagues,[801] implementation of medication history standard and formulary and benefit standards in e-Prescribing would likely enhance usability of such systems if standard implementation was improved.

The qualitative study by Weingart and colleagues[632] found that the most valuable aspects of e-Prescribing in ambulatory care were the ease of changing doses, renewing prescriptions, ensuring legibility, and transmitting prescriptions to in- and out-of-state pharmacies. Participants were dissatisfied with the unreliability of transmitting prescriptions successfully to the pharmacy, creating medication lists, recording of allergy information, and quantity of irrelevant and inappropriate alerts. Despite their complaints about alerts, participants preferred to continue receiving alerts as a safeguard against missing a major interaction.

The studies of such health IT systems as pharmacy information systems found that important features were CDSS alerts, interface with the laboratory system, and tallman letters and change of color to differentiate between look-alike drug name pairs.[45]

Purchase. One article reported on likelihood to purchase in a group of which half of the respondents of that survey were planning to purchase a CCHIT certified EMR system.[800] The important features were electronic connectivity for laboratory test results and orders, nursing and physician orders for medications, and prescription refills.

Implementation. Five articles reported on the likelihood to implement an MMIT system.[653,789,791,793,798] Larger hospitals, those located in urban areas, and teaching hospitals are more likely to implement EHR systems.[789] Collectively, the important features were allergy checking, drug interactions, medication history, dosing calculation, medication formulation, and availability of laboratory test results.

Wang and colleagues[653] conducted a descriptive field study of ten commercially available ambulatory e-Prescribing systems, to compare the functional capabilities offered by commercial ambulatory electronic system with 60 expert panel recommendations suggested by Bell and colleagues.[798,806] Data were collected from vendors by telephone interview and at sites where the systems were functioning, through direct observation of the systems and through personal interviews with prescribers and technical staff. Five of the systems were full EHR systems and five were nonEHR systems. Among the 60 e-Prescribing recommendations by Bell and colleagues,[80]6 nine recommendations were not implemented by any of the ten systems.[798] These included recommendations that would require e-Prescribing systems to handle prescription fulfillment data (their recommendations 10, 47, and 48), to use more complex drug benefit data (recommendation 22), and to use more advanced drug knowledge bases (recommendations 26 and 49).[798,806] Prescribing systems that were part of EHR systems implemented more recommendations than did stand-alone nonEHR systems. Considering all 60 recommendations, the median EHR-based system fully implemented 60 percent, whereas the median nonEHR system fully implemented 35 percent ($p = 0.09$). Including partial and full support together, median implementation levels were 72 percent for EHR systems and 46 percent for nonEHR systems ($p = 0.06$). On average, the systems fully implemented 50 percent of the recommended capabilities, with individual systems ranging from 26 percent to 64 percent implementation. Only 15 percent of the recommended capabilities were not implemented by any system.

Level of care. Six studies evaluated systems for ambulatory care.[632,653,667,798-800] Features of the six ambulatory care studies centered around clinician experience using commercial proprietary systems, with CDSS capabilities being the most common feature used.

KQ5. What factors influence sustainability (use and periodic updates) of health IT applications that support a phase of medication management continuum (prescribing, dispensing, administering, and patients' taking of medications)?

Sustainability of Health IT and Medication Management Systems

AHRQ seeks to support activities that can demonstrate the effect of health IT on important outcomes relating to quality, safety, efficiency, and effectiveness. Moreover, AHRQ places priority on initiatives to identify and overcome barriers to health IT implementation and adoption and to foster long-term sustainability.[808] Intuitively, a system's sustainability refers to its capacity to continue providing value. Sustaining the benefit of health IT applications may require ongoing resources for maintenance and updating, training and support for those who use the systems, as well as institutional support that encompasses planning, implementation and maturing of the systems, and replacement as needed. Thus the concept of sustainability raises questions about the long-term viability of many health IT interventions, as well as important concerns about the potential health impact of migrating existing processes to less sustainable or costly forms.

We conducted an additional comprehensive review of the literature to find a suitable operational definition and set of metrics of sustainable health IT. We found this necessary because we did not have, and could not readily find a prespecified definition that was widely accepted or supported in the literature of health IT.

In search of a definition of sustainability relevant to health IT, we did additional searching in the core informatics journals using the key term "sustainability" to identify articles that have discussed the concept (Table 27). Some articles defined sustainability quite narrowly (e.g., the decline of prescribing improvements once experimental alerts were removed from a system that had integrated CPOE and CDSS systems). We believe that the most relevant available definition comes from Humphreys and colleagues,[9] who defined sustainability as the ability of a health service to provide ongoing access to appropriate quality care in a cost effective and health-effective manner.

Our literature reviews revealed three important findings: although sustainability is mentioned frequently in the core informatics literature, it is poorly and infrequently defined, and none of the articles identified in the primary literature searching done to produce this evidence report explicitly studied sustainability. These findings were not entirely surprising. A previous AHRQ-sponsored Evidence Report that assessed the costs and benefits of health IT in pediatrics found only one article that explicitly discussed sustainability.[21]

Table 27. Frequency of core informatics journal articles that mention sustainability to the end of 2009

Informatics Journal	Frequency of mention of sustainability to the end of 2009
Journal of the American Medical Informatics Association	28
Journal of Medical Internet Research	90
Medical Decision Making	3
Journal of Biomedical Informatics	9
International Journal of Medical Informatics	22
Methods of Information in Medicine	30
BMC Medical Informatics and Decision Making	9

Future Sustainability of Health IT and Medication Management Systems

In 2009, the United States passed the Health Information Technology for Economic and Clinical Health (HITECH) act to authorize incentive payments through Medicaid and Medicare to clinicians and hospitals when they use electronic health records (EHRs) for patient care. The legislation ties payments specifically to the achievement of advances in health care processes and outcomes. Starting in 2011, the HITECH act will make available incentive payments totaling up to $27 billion over 10 years. This legislation will require substantial collaboration between health IT workforce professionals including those from IT, health information management, and biomedical informatics to accomplish its goals.

According to Dr. David Blumenthal, the U.S. National Coordinator for Health Information Technology at the Department of Health and Human Services, "[this legislation] will lead us toward improvements and sustainability of our health care system that can only be attained with the help of a reliable and secure nationwide electronic health information system."[809] HITECH's goal is not just based on the adoption, but also on the "meaningful use" of EHRs. Meaningful use is defined by a set of core health IT objectives that constitute an essential starting point, as well as an additional menu of activities which providers and hospitals will choose to implement during 2011 to 2012 (see Figure 5).[809] Overall, these features should help clinicians make better medical decisions and potentially avoid preventable errors.

This legislation may lead to improvements and sustainability of health IT applications that specifically support the medication management continuum. For example, to receive incentive payments, eligible professionals (e.g., physicians, optometrists, podiatrists, and chiropractors), and hospitals (e.g., acute care hospitals and critical care access hospitals) must implement and use the following ***core set*** of objectives that relate to medication management: CPOE, e-Prescribing, implementation of at least one decision support rule, and maintenance of active medication and allergy lists. Eligible professionals and hospitals may implement and use the additional ***menu set*** of objectives that relate to medication management: incorporation of clinical laboratory test results in the EHRs, performance of medication reconciliation across care settings, and sending reminders to patients for followup care.

Conclusions

We conducted an additional literature review of the core informatics journals to identify articles that have discussed sustainability related to MMIT systems and found that while sustainability is not infrequently mentioned in this informatics literature, it is often poorly defined, and none of the articles included in this evidence report explicitly discussed sustainability. Future research should develop an operational definition of sustainability that can be used to study its determinants. Moreover, it is likely that the HITECH Act of 2009 will lead to improvements and sustainability of health IT applications that specifically support the medication management continuum through meaningful use.

Figure 5. Summary overview of meaningful use objectives

Summary Overview of Meaningful Use Objectives.*	
Objective	**Measure**
Core set†	
Record patient demographics (sex, race, ethnicity, date of birth, preferred language, and in the case of hospitals, date and preliminary cause of death in the event of mortality)	More than 50% of patients' demographic data recorded as structured data
Record vital signs and chart changes (height, weight, blood pressure, body-mass index, growth charts for children)	More than 50% of patients 2 years of age or older have height, weight, and blood pressure recorded as structured data
Maintain up-to-date problem list of current and active diagnoses	More than 80% of patients have at least one entry recorded as structured data
Maintain active medication list	More than 80% of patients have at least one entry recorded as structured data
Maintain active medication allergy list	More than 80% of patients have at least one entry recorded as structured data
Record smoking status for patients 13 years of age or older	More than 50% of patients 13 years of age or older have smoking status recorded as structured data
For individual professionals, provide patients with clinical summaries for each office visit; for hospitals, provide an electronic copy of hospital discharge instructions on request	Clinical summaries provided to patients for more than 50% of all office visits within 3 business days; more than 50% of all patients who are discharged from the inpatient department or emergency department of an eligible hospital or critical access hospital and who request an electronic copy of their discharge instructions are provided with it
On request, provide patients with an electronic copy of their health information (including diagnostic test results, problem list, medication lists, medication allergies, and for hospitals, discharge summary and procedures)	More than 50% of requesting patients receive electronic copy within 3 business days
Generate and transmit permissible prescriptions electronically (does not apply to hospitals)	More than 40% are transmitted electronically using certified EHR technology
Computer provider order entry (CPOE) for medication orders	More than 30% of patients with at least one medication in their medication list have at least one medication ordered through CPOE
Implement drug–drug and drug–allergy interaction checks	Functionality is enabled for these checks for the entire reporting period
Implement capability to electronically exchange key clinical information among providers and patient-authorized entities	Perform at least one test of EHR's capacity to electronically exchange information
Implement one clinical decision support rule and ability to track compliance with the rule	One clinical decision support rule implemented
Implement systems to protect privacy and security of patient data in the EHR	Conduct or review a security risk analysis, implement security updates as necessary, and correct identified security deficiencies
Report clinical quality measures to CMS or states	For 2011, provide aggregate numerator and denominator through attestation; for 2012, electronically submit measures
Menu set‡	
Implement drug formulary checks	Drug formulary check system is implemented and has access to at least one internal or external drug formulary for the entire reporting period
Incorporate clinical laboratory test results into EHRs as structured data	More than 40% of clinical laboratory test results whose results are in positive/negative or numerical format are incorporated into EHRs as structured data
Generate lists of patients by specific conditions to use for quality improvement, reduction of disparities, research, or outreach	Generate at least one listing of patients with a specific condition
Use EHR technology to identify patient-specific education resources and provide those to the patient as appropriate	More than 10% of patients are provided patient-specific education resources
Perform medication reconciliation between care settings	Medication reconciliation is performed for more than 50% of transitions of care
Provide summary of care record for patients referred or transitioned to another provider or setting	Summary of care record is provided for more than 50% of patient transitions or referrals
Submit electronic immunization data to immunization registries or immunization information systems	Perform at least one test of data submission and follow-up submission (where registries can accept electronic submissions)
Submit electronic syndromic surveillance data to public health agencies	Perform at least one test of data submission and follow-up submission (where public health agencies can accept electronic data)
Additional choices for hospitals and critical access hospitals	
Record advance directives for patients 65 years of age or older	More than 50% of patients 65 years of age or older have an indication of an advance directive status recorded
Submit of electronic data on reportable laboratory results to public health agencies	Perform at least one test of data submission and follow-up submission (where public health agencies can accept electronic data)
Additional choices for eligible professionals	
Send reminders to patients (per patient preference) for preventive and follow-up care	More than 20% or patients 65 years of age or older or 5 years of age or younger are sent appropriate reminders
Provide patients with timely electronic access to their health information (including laboratory results, problem list, medication lists, medication allergies)	More than 10% of patients are provided electronic access to information within 4 days of its being updated in the EHR

* This overview is meant to provide a reference tool indicating the key elements of meaningful use of health information technology. It does not provide sufficient information for providers to document and demonstrate meaningful use in order to obtain financial incentives from the Centers for Medicare and Medicaid Services. The regulations and filing requirements that must be fulfilled to qualify for the Health IT financial incentive program are detailed at www.cms.gov.

† These objectives are to be achieved by all eligible professionals, hospitals, and critical access hospitals in order to qualify for incentive payments.

‡ Eligible professionals, hospitals, and critical access hospitals may select any five choices from the menu set.

Source: New England Journal of Medicine, 2010.[809] Used with permission.

5a. To what extent does the evidence demonstrate that health care settings (inpatient, ambulatory, long-term care, etc.) influence implementation, use, and effectiveness of such health IT applications?

Implementation

Reports of implementation tend to be opinion pieces or descriptive studies. A number of articles looked at some or all of implementation, adoption rates, and factors related to adoption. These focused mostly on CPOE in hospitals,[789,810-814] e-Prescribing, or ambulatory CPOE in primary care.[48,172,794,796,815-819] These articles did not meet our criteria for inclusion in KQ1: Effectiveness because of methods limitations. The general findings for hospitals show that implementation and adoption are generally greater in larger, academic, urban, public hospitals. Adoption in primary care practices tends to increase with younger, recent medical grads, larger practice size, and also with more specialized physicians. Yet, overall, actual usage of the systems is low with varying rates across MMIT systems, facilities, and groups of people.

Poon and colleagues[820,821] discussed a number of barriers to CPOE implementation in U.S. hospitals, and provided recommendations to overcome the barriers based on experiences in successful hospitals. They categorized barriers into physician and organizational resistance, cost and lack of capital, and vendor or product immaturity. They further provided recommendations to overcome these barriers.

Ash et al.[787] provided a consensus statement with a list of categories and considerations for a successful implementation of CPOE (see http://cpoe.org/ for more details). Their predominant themes to consider are: motivation for implementation; CPOE vision, leadership, and personnel; costs; integration; value to users; project management and implementation staging; the technology; ongoing staff training, support, and evaluation. These themes reflect the considerations for the values propositions of the various stakeholders as addressed in KQ3: Value Proposition.

The implementation of a new health IT can have unintended consequences, often as a result of the interaction between the technology and the sociotechnical system within which it is implemented. This would include the workflows, culture, social interactions, and technologies in place. Harrison et al.[822] have modeled this interactive sociotechnical system to help users and implementers understand how and where unintended consequences could arise within a particular setting. Some examples of unintended consequences have been reported in this document, and our sections on intermediate and qualitative research in KQ1: Effectiveness describe some information on workflows, social interactions, communication, and interdisciplinary work challenges with MMIT implementation. Assessing the potential impact of a new MMIT system using the framework of Harrison et al.[822] could easily help to avoid some of the unintended consequences reported to date.

Beyond CPOE and e-Prescribing systems, the useable literature on implementation and adoption of other technologies is negligible. Some surveys did look at the adoption of various health IT applications for patient safety. Menachemi and colleagues[823] measured rates of adoption of CPOE, BCMA applications, pharmacy IT systems, pharmacy dispensing, EHRs, PDAs and CDSSs in Floridian acute care hospitals. Pharmacy systems were widely adopted (85 percent for IT systems and 64 percent for dispensing), and the rest ranged from 12 to 40 percent. They also studied health IT adoption in U.S. pediatric hospitals and found a fairly high level of adoption (almost 50 percent for EHRs, 40 percent CPOE, and 36 percent CDSS). Furukawa and colleagues[824] used national survey data to measure adoption of technologies across the United

States. They found a range of levels of adoption across technologies, from 62 percent for automated drug dispensing to five percent for BCMA. Their analysis supports the findings that hospital size, teaching status, hospital or clinical ownership, and system membership are associated with adoption. Robinson et al.[790] found that adoption of 19 health IT capabilities, including MMIT, was higher when practices were evaluated for pay-for-performance and public reporting purposes, and in practices participating in quality improvement initiatives. From our review of the qualitative literature, we find that unintended negative consequences, the need to develop workarounds including changes to workflow, and the resultant negative emotions generated with MMIT implementation are important to recognize and deal with in order to improve the success of implementation.

The American Society of Health-System Pharmacists (ASHP) have published the results of an ongoing series of surveys assessing the adoption and use of pharmacy informatics applications in U.S. hospitals and trends in pharmacy practice.[825] Again the studies are descriptive surveys and not included in our KQ1: Effectiveness. They do, however, show how hospitals are progressing rapidly in their adoption of health IT used in their pharmacies.[826,827]

Effectiveness

Due to the observational nature of many of the studies assessing health IT across settings, this question is difficult to answer. Hospitals and primary care are well-studied, especially for the two phases of prescribing and ordering, and monitoring. Gaps are seen in the other phases of medication management, and education and reconciliation. Further, some MMIT applications are well-studied while others, such as those that pharmacists and nurses use, are less well-evaluated. A limited number of studies are carried out in long-term care settings, pharmacies, or with patients at home, or other community settings. Many of the hospital- and clinic-based studies tended to show improvements in process with some, but limited, evidence of clinical improvements. These research gaps in settings, MMIT applications, and health professionals, together with proof of effectiveness are similar to the deficiencies seen with cost-effectiveness or other types of economics studies, especially full economic analyses which are required to address and satisfy the definition of sustainability used here.

Use

From KQ1: Effectiveness we see that the study of use of systems is rarely done in a completely rigorous way. Articles that measure use tend to frame it in the context of adoption and implementation, looking merely to ascertain if systems are used, not how they are used and if they are being used appropriately. Few measure levels of use. Again, the definition of sustainability is not met without the inclusion of economics studies.

5b. What is the impact (challenges, merits, costs, and benefits) of having electronic access to patients' computerized medication records, formulary information, billing information, laboratory records in the quality and safety of care provided by health IT applications that support at least one phase of the continuum of medication management (prescribing, dispensing, administering, and patients taking of medications)?

Almost all of the MMIT applications we report were integrated with at least one other system. The systematic review in KQ1: Effectiveness addresses the effect of these integrated technologies on a range of outcomes, many related to patient safety and health care quality. Evidence is available to address prescribing and also monitoring. The other phases are not well-evaluated. The study of patient access to their medication records and integration of these data into clinic and hospital information systems (EMRs and EHRs) is exciting. Some evidence exists that the use of MMIT integrated into clinician-based systems holds much promise and will be an exciting area of research in the next decade. This is especially important with the efforts by the U.S. government to improve health care delivery and to implement health IT systems to enhance this expanded delivery.

KQ6. Two-Way Prescriber and Pharmacy Electronic Data Interchange (e-Prescribing)
(a) What evidences exists demonstrating the barriers and drivers of implementation of complete EDI that can support the prescription, transmittal and receipt, and perfection process of e-Prescriptions?
(b) How do barriers, facilitators, and economic incentives vary across pharmacists, physicians and other relevant stakeholders with respect to adoption and use of complete EDI (e-Prescribing/ordering with e-transmission)?

All studies eligible for inclusion in this evidence report were reviewed to determine if they evaluated two-way, complete EDI between prescribers and pharmacies, commonly referred to as e-Prescribing. To be considered a true one-way e-Prescribing system the article had to describe a computer system used by a prescriber to generate a prescription (authorization to supply drug) that is transmitted electronically to a pharmacy information system. Further, for the system to be considered a two-way e-Prescribing system it had to be capable of transmitting a message from dispenser to prescriber by electronic means. This criterion is broadly consistent with the definition of e-Prescribing promulgated under the U.S. Medicare Modernization Act of 2003.[828] We did not consider systems used for inpatients of a hospital to be an e-Prescribing system; these technologies are reviewed elsewhere in the report, often under the rubric of CPOE systems.

Summary of the Findings

Thirty-three reports[434,549,561,575,579,584-586,645,668,724,730,736,797,800,801,806,829-844] were checked for eligibility and only one[585] met the above criteria for inclusion for bidirectional e-Prescribing systems. Nearly all systems self-described by investigators as “e-Prescribing” allowed physicians or other prescribers to generate a prescription through a software application that were later reproduced in paper form prior to being dispensed by a pharmacist (incomplete one-way e-Prescribing). One report[585] described an interrupted time-series study of a two-way e-Prescribing system intended to reduce the time required for prescribers to respond to pharmacist queries and refill requests. The authors did not describe any barriers or facilitators to uptake of the system used in the small pilot study.

We have extrapolated key themes from the data available on one-way or incomplete one-way e-Prescribing to describe potential barriers and drivers to implementation of complete two-way EDI. These data may be useful indicators of issues that would need to be addressed before widespread implementation of two-way EDI would be expected to yield benefits for stakeholders. The following facilitators and barriers are listed in order of high to low frequency of mention in the reviewed literature.

Facilitators

1. ***External monetary or other incentives to prescribers.*** Nearly all reports of e-Prescribing implementations in the United States described some financial incentive that was offered to prescribers to adopt an e-Prescribing system.[839] In most of those cases where no financial incentive was offered, the system was adopted by a health system that required its prescribers to adopt the system.
2. ***Supportive regulatory environment.*** Formal endorsement by regulators such as the State Boards of Pharmacy or Medicine seemed necessary enablers for prescribers to adopt e-Prescribing systems.[736,839]
3. ***Existence of some standard for prescription electronic data interchange.*** A set of messaging standards to enable the electronic flow of prescription information between diverse software platforms have been developed for use in the prescribing and order communication processes.[834,836,845] While not all standards have been judged suitable for implementation,[839] the core set of standards currently available should facilitate further development and testing of e-Prescribing solutions.

Barriers

1. ***Incomplete consideration of the effects of e-Prescribing on pharmacists and pharmacies.*** Most evaluations of one-way e-Prescribing systems conducted in the United States focused almost entirely on the e-Prescribing system from the perspective of the prescriber, the prescriber's staff, or both.[736,833-836,838,839] Several of these reports described a lack of awareness of the e-Prescribing process on the part of pharmacies and pharmacists and a subsequent need to educate pharmacists on the specific e-Prescribing process adopted by the prescriber.[736,835] Pharmacists and pharmacy staff generally reported that e-Prescribing systems negatively impacted their workflow.[645,833,834] The authors of an AHRQ commissioned report[839] on e-Prescribing pilot projects conclude that the prescribing workflow advantages observed for prescribers using e-Prescribing may actually reflect a burden shift to pharmacists. While reduced pharmacy to prescriber callback rates are touted as a potential advantage to e-Prescribing, the highest quality evidence available did not support a reduced callback rate.[575] A sample of e-Prescribing prescriptions sent to selected pharmacies in Denmark was prospectively compared with a sample of handwritten prescriptions sent to the same set of pharmacies. The investigators' adjusted analysis indicated a significantly higher likelihood (relative risk, 1.7; 95 percent CI, 1.3 to 2.2) of pharmacy callbacks to prescribers for electronic compared with paper prescriptions.[575] This finding is especially significant as nearly two-thirds of prescriptions are transmitted electronically in Denmark.[575,797] All pharmacies in Denmark are government owned and therefore likely share the same IT infrastructure.
2. Pharmacists are an essential part of the medication use process and better integration of e-Prescribing and pharmacy information systems through, at a minimum, one-way complete electronic data interchange should be a focus of further research.
3. ***Regulatory and legal uncertainties.*** Some participants in U.S. studies were unsure whether complete one-way e-Prescribing was permitted under relevant State laws.[736,839] e-Prescriptions for controlled substances were not evaluated as a component of the reviewed studies because of the perceived prohibition on the use of e-Prescribing for these drugs under relevant State and/or Federal laws. Prescribers were also concerned

that notification by pharmacies of prescription fill status (filled or not filled) could increase their exposure to malpractice claims.[839]

4. ***Low preexisting adoption rate of EMRs and EHRs.*** Nearly all of the systems evaluated in the United States described the use of prescription writing software limited to generating e-Prescriptions, but without any other clinical record keeping functionality.[736,839] These systems generated prescriptions and retrieved pharmacy dispensing histories while requiring providers to concurrently maintain paper-based medical records. Prescribers report deferring adoption of e-Prescribing (prescription writing) systems in favor of complete EMR systems that include e-Prescribing functionality.[839] Thus the low rate of EMR adoption in the U.S. likely decreases the rate of e-Prescribing adoption. Addressing barriers to EMR adoption[800] may increase the rate of e-Prescribing amongst physicians and other providers.

Summary of Evidence

No reports documenting the use of complete two-way EDI (prescribing) systems were located in the literature search for this report. Evidence from the limited set of one-way e-Prescribing studies was extrapolated to identify possible key facilitators and barriers to completely electronic, two-way e-Prescribing systems. Possible facilitators include monetary or other incentives to providers, a permissive regulatory environment, and the existence of enabling technical standards necessary for e-Prescribing. Barriers identified included the low rate of EMR adoption in the United States, regulatory and legal uncertainties, and inadequate consideration of the effects of e-Prescriptions on pharmacists and pharmacies.

KQ7. What evidence exists regarding the extent of integration of electronic clinical decision support (CDS) in a health IT system for prescribing and dispensing of medications? To what extent does the use of CDSS in a health IT system for prescribing and dispensing of medications impact the various outcomes of interest including health care process, intermediate and clinical?

Summary of the Findings: All Phases of Medication Management

Seventy-seven RCTs in total were designated as primarily studying CDSSs related to medication management and with integration with other health ITs.[397-399,401-405,407,409-416,504-531,533-543,592,609,611-613,616-620,624,630,634,636-638,697-700,771] Full details of the studies are contained in Appendix C, Evidence Tables 13-15. These studies involved 4,709 providers and approximately 828,441 patients in total (numbers were not specified in all articles). Patients included were primarily adults, with only two studies addressing issues specific to children. Seven studies addressed seniors exclusively. Currently, AHRQ has contracted with Duke University to prepare an evidence report focused on CDSS due for release in 2011.[8]

All studies assisted with at least the prescribing (71 percent) or monitoring (29 percent) phases of medication management. Notably, none concentrated solely on the order communication, dispensing, or administering phases of medication management. Reconciliation and education were also not addressed.

The studies were much more likely to focus on process changes than clinical (patient-important) outcomes. Furthermore, many studies did not report directly which outcome was their main endpoint—a fundamental flaw. A total of 36 articles measured changes in process as their main endpoints, 24 of which were deemed to have positive results—meaning that at least 50 percent of the changes in process measured showed that the MMIT improved medication management. Only five of 34 studies measuring clinical outcomes, whether a main endpoint or not, had a statistically significant impact on a clinical outcome. These five RCTs were all published recently (since January 2005), addressed primarily the prescribing and monitoring phases of MMIT, and a variety of disease and drug target groups, usually in an outpatient setting.[402,537,541,620,634] Where clinical outcomes were thought to be designated main endpoints, 12 of 16 studies showed no differences in clinical outcomes between intervention and control groups.[403,518-520,526,528,624,630,637,697,699,700] No study was able to demonstrate a positive impact on mortality.

Regarding integration of the CDSS, authors used various descriptions of other components of the integration. EMRs, EHRs, and hospital information systems were specified in 41 of the studies, and CPOE was integrated with CDSS in 10 studies, seven of which specified CPOE in addition to the EMR.

Strengths and Limitations

As per our inclusion criteria, all trials used randomization for allocation. However, by applying the Verhagen/AHRQ RCT quality scale,[10] the overall quality of methods of the studies was generally only fair at best with a mean quality score of 4.4 out of total possible nine points. One of the most important features to avoid bias, allocation concealment was only described to a minimally acceptable degree by 25 studies. Twenty articles scored six or more and none of the studies scored the maximum nine points. Mean followup of the studies was 9.9 months. Twenty-four studies (31 percent) used a cluster design. This design is prone to bias. Cluster numbers are often small, and therefore, if clusters initially randomized to control group drop out, or participants within the clusters (who are known to be in the intervention or control group) are selected in a biased manner, trial results may not be valid.

Overall, high quality is lacking from RCTs that address CDSS integrated with other types of health IT. Only a small minority of these focus on clinical outcomes—those outcomes that are most important to guide decisions of patients' providers and policymakers about these interventions. Furthermore, a very small number report improvement in these clinical outcomes.

General Study Characteristics

Of the 77 trials, 46 (60 percent) were rated as impacting primarily the prescribing phase of medication management, 12 (16 percent) aimed primarily at medication monitoring, 15 (19 percent) tried to impact both phases and one addressed administering. Three trials (4 percent) attempted to influence a mix of prescribing, monitoring, order communication, and administering phases of medication management.

The setting for the studies was judged to be ambulatory care in 53 (69 percent), or hospital-based in 19 (25 percent), with a small minority based in long term care (two (3 percent)), or other settings (three (4 percent)) such as community or home. Approximately half (36 or 47 percent) of these studies were identified as associated with academic institutions.

Health care providers were a target of the CDSS in 64 studies and included physicians in most cases where targets were specified. However, many studies did not address the specific type of provider targeted by the intervention. Three studies identified pharmacists as one of the intervention targets and one study targeted nurses specifically. Patients were named as targets of the intervention in 22 studies, 13 of which exclusively targeted patients.

A wide variety of diseases and drugs were studied as the topic of the CDSS. Of the 42 studies where disease targets were mentioned, 19 dealt with vascular disease including risk factors, eight with diabetes, six with asthma, and four with infections, including HIV. Drug topics were evaluated in 42 studies—19 were vascular medications, 13 antibiotics or vaccines, and five addressed multiple medications. The CDSS system was known to be 'home grown' in 26 studies, a commercially available product in 14, a hybrid of both in four, and unknown in 33.

Thirty-five CDSS were thought to be integrated with an EMR or EHR system. Fourteen were integrated with CPOE or prescription writing systems, another 17 with a laboratory or imaging system and ten other multiple systems.

Characteristics of each of the CDSS were beyond the scope of this review, so it is unclear whether any signals from these RCTs indicated how a system should be designed, installed, maintained and training supplied, to optimize the chance of success. Similarly, we were not able to critique the suitability of control groups in this systematic review, which were typically described as usual care.

Outcomes

Of the 77 studies, 54 indicated in some way that they had a primary or main outcome and only 16 appeared to have designated a clinical outcome as a main endpoint. Clinical outcomes were defined liberally as any clinical morbidity, mortality, quality of life, adverse event, or clinical surrogate such as improved LDL cholesterol levels. Only eight studies addressed mortality in any way; none had a significant effect.

Overall, only five studies noted a positive change in clinical outcomes.[402,537,541,620,634] All were published since early 2005. Four of the five took place in an outpatient setting.[537,541,620,634] The studies addressed venous thromboembolism prophylaxis,[402] asthma control,[634] cholesterol management,[541] diabetes care,[537] and recommended drugs.[620] The mean quality score of these five studies was only 4.8 out of nine. Two studies with the highest methodologic quality (six out of nine) are further described. One evaluated a CDSS which calculated venous thromboembolism risk and recommended venous thromboembolism prophylaxis when the risk was high thus improving their main endpoint of venous thromboembolism rates in a group of inpatients primarily with cancer. The other used a university affiliated managed care plan data to identify gaps in recommended drug therapy and monitoring to recommend drugs to stop or add, or for monitoring to take place. However, this analysis was based on a post-hoc outcome applied to a subgroup of the original participants and the changes in hospitalization are very high given the small change in recommendation use. In summary, we found no consistent impact of CDSS on clinical outcomes, and the quality of the studies is generally inadequate.

In 38 studies, a process endpoint was determined to be a main endpoint. In 26 cases, the process was judged to be positively affected; with improvement in at least 50 percent of the process measures reported. The changes in process measured in these studies generally dealt with reminders about recommended medications or vaccines,[403,404,407,410,509,525,530,535,536] dose adjustments,[398,412] recommended laboratory monitoring for medications prescribed or chronic disease management,[412,504,513,516,612,619,771] 'inappropriate' medications avoided,[397,413,416,507,508,512,533] and other similar outcomes. Some of the alerts or reminders were based on established guidelines, while others were assessing more locally derived quality measures and standards of care.

Only one of the studies we reviewed scored at least eight out of nine for the AHRQ methods quality assessment. Terrell et al.[416] randomized 63 emergency physicians to receive or not receive alerts to disrupt intended prescriptions of nonrecommended medications for seniors to be discharged from the emergency department. The CDSS resulted in a small decrease in the number of visits with a nonrecommended prescription from 3.9 percent to 2.6 percent (95 percent CI 0.34 to 0.89, p = 0.02). No clinical outcomes were measured in this study.

One article measured a composite score in which a shared CDSS to support the primary care of diabetes improved the process of care and some clinical markers of the quality of diabetes care.[771] One other study evaluated whether actively or passively displaying context-sensitive links to infrequently accessed educational materials and patient information using an inpatient CPOE would affect access rates to the materials, and found that the active alerts were more effective.[638]

Notably, the negative effects of the CDSS intervention were virtually never reported. Specifically, only two studies referred to any harm incurred by the study intervention.[508,630] This implicates a major publication bias, a result of not requiring studies to measure and report on harm.

In terms of costs, 11 studies reported that they had intended to measure costs or cost-effectiveness. However, no full cost-effectiveness analysis was found as part of the RCT. Separate publications on resource utilization are covered in the KQ1: Effectiveness section on economics outcomes.

Summary

In summary, despite it being 34 years since the first RCT[619] in 1976, in this important area of health IT research, little high quality evidence shows a consistently positive effect of CDSS on clinical outcomes. Implementers, developers, and funders of MMIT applications need to continue to produce and rely on the best possible research evaluating outcomes important to people and institutions. The informatics world can strengthen their abilities to determine value for money in MMIT projects by obtaining input during planning for research projects from health technology appraisal methods and those who have expertise in clinical care, research methods, informatics, statistics, and stakeholders who will be affected by the MMIT system.[846]

Discussion

Summary of Key Findings

We have presented the results of a systematic review of the literature regarding the use of health IT to enable all phases of medication management as well as reconciliation and education. We have focused on MMIT systems that were integrated with other health IT systems. Our review identified a total of 789 studies dealing with health IT and medication management. Three hundred and sixty-one of these articles were only listed in the bibliography of this report and were not synthesized because they did not include comparative data, statistical methods, or qualitative methods. The remaining 428 articles were synthesized after being identified from an initial retrieval of 40,582 articles. We used these 428 articles to address the seven key questions (KQs). Overall, we found that the literature on MMIT applications was heterogeneous. The majority were based on observational methods, often with identifiable opportunity for bias (e.g., descriptive before and after studies without statistical adjustment for time trends or group differences). Research methods were not uniform across MMIT applications, with 77 of 88 RCTs studying CDSS.

KQ1. Effectiveness

Process and other outcomes related to use and satisfaction with MMIT were often improved, especially for prescribing and ordering and the monitoring phases. Improvements in the appropriateness of prescribing and decreased errors (e.g., correct doses and timing, better choices of antibiotics, fewer drug-drug interaction potentials, and corrected doses related to body weight or liver function) seem to be consistently shown. Changes in workflow, improvements in communication, and improved efficiencies such as time reductions are also positive, although fewer studies addressed these types of outcomes. Clinical endpoints were sometimes found to be improved with the use of MMIT, more often in the observational studies than in controlled clinical trials. CDSS applications and, to a lesser extent, CPOE systems have been shown to be useful, especially when studying prescribing and monitoring in hospitals and clinics. Notable was the identification of strong emotions expressed by users of CPOE (clinicians), both positive and negative, which were reported in the qualitative studies. A number of unintended consequences of the technologies were found, some of which were unfortunate and some of which were beneficial. Few cost studies and full economic evaluations were identified. Those articles that were included found that health IT interventions may offer cost advantages despite their increased acquisition costs. Proof of clinical improvements and economic effectiveness through the use of MMIT is lacking. However, given the uncertainty that surrounds the cost and outcomes data, and limited study designs available in the literature, it is difficult to reach any definitive conclusion as to whether the additional costs and benefits represent value for money.

KQ2. Gaps in Evidence and Knowledge

The major gap in the research is true full economic evaluations, weighing all costs and benefits of the various MMIT technologies across all settings and participants. For the effectiveness research, we found gaps were related to setting (few studies were carried out in pharmacies, long-term care facilities, homes, or communities), people (few studies assessing outcomes for pharmacists, nurses, nurse practitioners, physician assistants, other health professionals including dentists and psychologists, or patients and families), and MMIT technologies (rigorous studies of all but CDSS and CPOE, and especially those related to dispensing and administering, were sparse). Prescribing and monitoring were relatively well-studied while order communication, dispensing, administering, reconciliation, and education were understudied.

Gaps were also found in the sophistication and complexity of the quantitative research methods. Many of the studies initially identified were descriptive in nature. These are listed in the bibliography of this report. Qualitative studies and the quantitative studies that were hypothesis-based and comparative were analyzed. A good number of the studies, including those that were more strongly controlled (e.g., RCTs and cohort studies), often had methodology or reporting flaws or both including inconsistent use of standard methods for identifying and describing their methods, poorly justified or incorrect choices, or poor application of statistical tests and failure to adjust for group differences or cluster randomization. We also often found underpowered studies and situation-specific studies that were difficult to generalize or transfer to other settings or situations.

In addition, we found substantial deficiencies in reporting data important to the understanding of published studies. Although we identified data deficiencies in many aspects of studies, most serious were in descriptions of baseline data related to what was in place with respect to medication management in the health care setting before implementation of the MMIT system and descriptions of the MMIT implementation itself. Context is important for understanding studies and assessing their potential for application; detailed information on the setting and participants was also not often provided in studies.

KQ3. Value Proposition for Implementers and Users

Value propositions are determined by the balance of financial, clinical and organizational benefits. Limited data were available to address these issues comprehensively. Of note, we found that the various stakeholders had very different needs, perceptions, and access to MMIT systems and this must be addressed in valuing systems.

KQ4. System Characteristics

Different features of MMIT are important to various groups and settings. Very few studies (n = 21) reported on the specific feature sets of the systems being used and their links to purchase, implementation, and use. Few head-to-head comparisons using comparative effectiveness analysis methods, for example, were found. The evidence identified uses both qualitative and quantitative methods to gain an understanding of which features are important to users and stakeholders. Of note, we found that desired feature sets differed between the planning phase (perceived to be of value) and after implementation (based on actual use).

KQ5. Sustainability

Sustainability is vital to health IT. Before it can be fully understood and studied, it must be defined. For this document we chose to use a definition of sustainability that suggests sustainable systems are cost effective and clinically-effective. Because the evidence on economics data are lacking, we can add only a small amount of information on the sustainability of MMIT applications. Some data exist on effectiveness and use. We have included some data on patterns and characteristics that are important to use, including data on barriers and facilitators of successful implementations and ongoing system use. Use is higher in physicians, larger and better funded organizations, hospital settings, some larger primary care groups, and in academic medical centers.

KQ6. Two-Way EDI

Very little evidence exists on bidirectional communication between pharmacists and physicians to enhance the order communication process. Extrapolation of data on one-way communication, factors that work to increase electronic communication on medications between prescribers and pharmacists are external incentives, a supportive regulatory environment, and existence of standards for prescribing EDI. Three factors work against effective EDI: incomplete consideration of the workflow and financial effects of e-Prescribing on pharmacists and pharmacies, regulatory and legal uncertainties, and low adoption rates of EDI capable EMR systems. Further development and evaluation of two-way EDI technologies for outpatient order communication regarding drugs is required to facilitate adoption. Pharmacies and pharmacists should take a more active role in the EDI development and evaluation process.

KQ7. RCTs in CDSS

CDSS applications are well-studied although problems with methods and reporting exist. CDSS is probably the best studied type of MMIT in terms of studies with strong methods and a sufficient number of studies to provide reliable answers to research questions of any of the MMIT applications. The first RCT was published in 1976, over 35 years ago. Of the 88 RCTs in this document, 77 are on CDSSs. The quality and sophistication of study methods, analysis, and reporting of the RCTs has improved over time, and there tends to be more measurement of clinical outcomes. However, evaluations of health care delivery, such as comparisons of effectiveness of treatment or prevention methods (e.g., drugs, services, and medical devices) are held to a higher standard than the types of reported research projects included in this evidence report. The studies in this report, while they met their own research objectives, collectively do not contain the research designs and associated clarity of findings to be able to definitively inform patients, clinicians, and policymakers regarding the effectiveness and overall impact of CDSS applications. Furthermore, the more rigorous and transferable research conducted tends to show no or limited effect on patient-important clinical outcomes.

This report was not designed to evaluate specific MMIT applications. In addition, MMIT interventions were not catalogued and characterized in great detail. Therefore we found no obvious themes that would suggest that a certain type of MMIT intervention with a certain type of implementation for a certain type of user in a particular setting would be successful. However, the following areas of commonality emerged in our analysis.

General

1. Research to date has concentrated on measurement of process changes and descriptive and pilot studies. In addition, some studies based on stronger methods have failed on issues such as adequate concealment of allocation and blinding, poor understanding of some methods, lack of adjustment of groups, and statistical challenges. Processes in health care are poor surrogates for clinical- or patient-important clinical outcomes, therefore it is important that new studies address clinical outcomes and use the most appropriate methods, and use them correctly, to adequately study MMIT applications. Researchers should also be encouraged to consider the generalizability or transferability of their results for all of their projects. Researchers in health IT could strengthen their

studies by using interdisciplinary teams with representation of multiple stakeholders, learning from other domains such as health technology assessment and economics, and with better reporting of their studies and results.

2. Standard and accepted definitions are lacking for MMIT applications, as well as standards for presenting the results of studies of health IT applications. Definitions are inconsistent for MMIT applications (e.g., e-Prescribing, CPOE, EMR, or EHR hospital information systems), study designs (e.g., observational or before-after), and outcomes (e.g., adverse drug events, adverse drug effects, prescribing errors, or errors per patient, 100 orders, day, hospital day, or physician). This has made identification of studies, data abstraction, synthesis of evidence, and presentation of findings challenging. Many study reports did not include important information that would have made this report stronger. Noticeable deficiencies centered on the MMIT application, its setting within the institution, training and implementation details, and maintenance and updating information. Professional associations interested in MMIT are pushing for standardization of definitions. AHRQ can join this movement for more standardization of terminology and definitions.

Effectiveness

1. Interventions most frequently targeted prescribing and monitoring stages of the medication use process.
2. Physicians who provided care in the hospital and ambulatory care settings were most likely to be the target of the intervention.
3. CDSS and CPOE applications were the most frequently studied type of health IT application studied. Seventy-seven of the 88 RCTs in this report study CDSSs.
4. Improvements in prescribing accuracy and decreased errors such as appropriate scheduling and choice of medications, prescribing taking into account weight-based dosing and dosing based on liver function, avoidance of drug-drug interactions and potential allergies and in being in accordance with guideline recommendations were consistently identified as improvements with the use of MMIT. Workflow, communication, interaction with peers and time considerations were found to be improved less often.
5. Studies that used health IT to identify and intervene on patients with actual problems (e.g., elevated blood pressure) or needed care (e.g., hemoglobin A_{1c} monitoring) appear to be more effective than CDSS approaches that identify potential problems (e.g., potential adverse drug events). This was particularly true when patient-centered principles were employed, such as providing patients with reminders and decision support recommendations about their current health status. However, this may be alternatively explained by the greater difficulty in measuring outcomes, such as potential for ADEs.
6. Studies that have been successful in improving a patient's clinical outcomes target high risk and vulnerable populations who have poor disease control,[515,610,624,693] lack sufficient access to health care providers to manage their condition,[408] or subpopulations with sufficient economic resources to respond to the CDSS intervention.[694]
7. The effect of similar CPOE systems on mortality can vary substantially as a function of the extent to which implementation strategies disrupt or delay critical activities in the clinical setting, or demand additional time for order-entry from clinical staff.

8. Highly targeted interventions, focused on specific medical problems appear to be demonstrated as more effective than more diffusely focused CDSS and CPOE. Again this may be due to the greater difficulty in measuring the outcomes of diffusely focused CDSS and CPOE in the generally smaller sample size (and inadequate power) studies that were identified.

Qualitative

1. No qualitative studies were identified that directly addressed the effect of an MMIT system on intermediate health care outcomes for any phase of the medication management continuum (prescribing, order communication, dispensing, administering and monitoring). Patient safety was the main health outcome mentioned in qualitative studies. Before MMIT implementation, most studies found that clinicians expected that the MMIT system would improve patient safety. Once implemented, most clinicians felt that MMIT did improve patient safety.
2. Differences in study outcomes for similar qualitative studies across settings were not apparent, suggesting that findings from qualitative studies could be transferrable across settings.
3. Despite the willingness of many of the participants to use a new MMIT system designed to improve prescribing and ordering of medications including CPOE, reservations were expressed by some implementers that the MMIT system and the resulting change in workflow would impair existing interactions and relationships among health care providers and between physicians and patients.
4. MMIT systems often substantially facilitated clinicians' monitoring of patients' adherence with their prescribed medication regimen.[737] However, barriers were reported to using health IT systems for medication monitoring in some situations.[747] For example, clinicians caring for patients with HIV/AIDS using a CPOE and CDSS system integrated with the hospital, pharmacy, and laboratory systems identified six barriers to using reminders, including workload, time to document, reminders that did not apply, inapplicability of reminders to the situation, lack of training to teach the users how best to use the new or modified system, quality of provider-patient interaction, and use of paper forms.[747]
5. From qualitative studies, system design including workflow changes, challenges with the system interface and new communication processes demonstrated that without adequate attention to system changes, the new kinds of medical errors with potential detrimental impact to patient safety could occur. Unintended negative consequences including the need to develop workarounds (one-off or nonstandardized changes) to workflow and the frustration generated in some studies with MMIT implementation are important to recognize and deal with to improve the success of implementation.
6. MMIT implementation did not just mean that a clinician needed to learn a new IT system but it also affected most of the other parts of the delivery of care processes, including how the interdisciplinary care team worked together.

Economics and Costs

1. Cost analyses can provide useful information on 'upfront' costs compared with 'downstream' cost avoidance if they explicitly measure all direct health care costs (e.g., capital costs, health professionals' time), direct nonhealth care costs (e.g., home care

services, transportation) as well as indirect costs (e.g., productivity gains or losses) that could be affected by the intervention of interest.

2. It is important to be aware that the greatest reported costs associated with these health IT are associated with the purchase of new software to add to preexisting EMR systems, as well as implementation costs (e.g., management, clinical team involvement, training costs) and maintenance costs. This assumes a large investment has already been made to purchase, implement, and maintain an MMIT system.
3. The full enumeration of the total costs needs to be synthesized with the consequences or outcomes of the intervention (i.e., cost-effectiveness analysis, cost-utility analysis, and cost-benefit analysis). Full economic evaluations linked to clinical outcomes need to be done.
4. Adoption of newer technologies needs to be based on formal evaluation of whether the additional health benefit (effectiveness) is worth the additional cost. Given the tension between the clinical benefits of CPOE and CDSS and the high up-front costs, decisionmakers deciding whether to implement CPOE and CDSS need to better understand how and when financial benefits of such systems accrue (e.g., short-term compared with long-term benefits). These types of analyses are important for well-informed decisionmaking.

Unintended Consequences

1. Unintended consequences, both positive and negative, were found across many of the studies as main endpoints, or were alluded to in others. Some were minor and some much more serious. A tracking system of major and clinically important unintended consequences would be useful for many audiences and should be considered by system developers and funding agencies.

CDSS

1. Many studies have evaluated CDSS tools for improving the effectiveness of anticoagulants (proportion of days in therapeutic range for anticoagulants) and improving the choice, route, duration of antibiotics, and reducing ADEs related to antibiotic use, and most are successful.
2. Sophisticated CDSS and other advanced clinical support should be built to insure added clinical value without being burdensome to those who use them. These sophisticated systems are difficult to develop, implement, and maintain.

Values

1. Values related to MMIT systems and implementations need to be determined from all stakeholders. Clinicians, administrators, and likely patients and their families have different values and place varying importance on each.

System Characteristics

1. Most often authors spoke about barriers and concerns towards implementation and acceptance, rather than characteristics of MMIT that could facilitate implementation, purchase, and use of such systems.

Two-Way EDI

1. Two-way EDI between prescribers and pharmacists is not common. Both facilitators and barriers exist that impact movement to implementation of e-Prescribing and two-way communication designed to enhance and streamline prescription optimization.

Limitations

Our review has a number of limitations. With the exception of PDA applications using patient-specific input, we focused on applications that enable medication management and that are integrated with other health IT systems. A number of technologies, such as smart intravenous pumps, bar-code scanners, and reporting systems for diabetes or asthma monitoring were not integrated with other health IT systems and were thus excluded. Indexing of individual articles in electronic databases is poor. Although we tried to be thorough in our search methods, we feel that we did not capture all potential articles—a very difficult task in new and multidisciplinary areas of study.

Further, we concentrated only on the main or major endpoints reported in studies with comparison groups and hypothesis testing. Given the heterogeneity in the literature, it was often difficult to discern main endpoints; where possible we determined main endpoints as those declared as such, or those that were the basis of power calculations (infrequently), or were stated to be main outcome measures in the abstract or objectives. We identified instances where the main endpoint was not clear. In these cases we gave priority to outcomes related to medication management and clinically important patient outcomes. We did not test the replicability of our abstraction of these outcomes.

Because of the lack of clear definitions on some of the technologies and issues associated with health IT, we were unable to address some key questions as thoroughly as we would have liked. This is especially noted in KQ5 relating to sustainability and KQ3 on value propositions. We feel that these are important issues for all health IT, that need to be addressed to effectively answer questions about ongoing use and effectiveness of these technologies.

It has proven difficult to synthesize the evidence on such a range of technologies, implemented in a number of settings and used by various stakeholders. Each intervention is so complex that it is often difficult to tell which studies are assessing the same processes. Also, outcome measures used by authors were variable. For example, similar outcomes such as prescribing changes were measured as changes in daily doses; prescribing rates per hospital, per physician, per 1,000 patient days, etc. The number of orders and compliance rates were difficult to extract and synthesize.

Our ability to draw conclusions is also reliant on the quality of the evidence we have found. In most cases, the research relies on observational studies, with RCTs and other methodologies with stronger controls only available on a select group of health ITs and phases of medication management. Even in the case of CDSSs, a lack of RCTs addressing electronic decision support integrated with other types of health IT still exists. Only a small minority of these studies focus on clinical outcomes—the endpoints that are most important to guide decisions by patients, providers and policymakers, about adopting these interventions. Furthermore, a very small number report improvement in these clinical outcomes.

We found great variation in the level of description of the health IT employed, with studies frequently lacking details on standards, hardware, integration, implementation dates and processes, and other similar factors. A large number of studies neglected to report the study dates (see Evidence Tables in Appendix C). We repeat Chaudhry's call for a set of standards for reporting on health IT research.[607]

Although the absence of a contemporaneous comparable control group is a problem with all observational studies, the creation of control groups by comparing intervention patients to those that do not participate, or do not have a problem to those that do is fundamentally far more likely to introduce major bias in the comparison (e.g., comparing patients with alerts to no alerts,[18] pharmacists volunteering to provide the intervention compared with those that do not volunteer,[694] and other similar problems[701]). The direction of the bias will depend on the study.

Many observational studies suffered from selecting an outcome that was distantly or only marginally related to the intervention. Length of stay, all-cause ADEs were examples of this problem. Gurwitz and colleagues[697] were able to show that only one-third of ADEs could have been prevented by the CDSS alerts provided. Moreover, in a substantial proportion of negative studies, minimal adoption was seen. The clinicians failed to adjust therapy or treatment based on recommendations, and thus it is not very surprising to find that the interventions had no effect on outcomes. Finally, the rate of some outcomes such as readmission, mortality, and nosocomial infections was too low to detect clinically meaningful differences if they had existed with the numbers involved in the study.

Implications

The strength of this document lies in the breadth of health IT applications used across the phases of medication management, and in the organization of those findings, both through synthesizing the body of evidence by key questions and a tabular presentation of those findings. A review of this scope for MMIT has not been completed previously. We searched for literature across many domains and reviewed a substantial number of studies. The implications of the report fall within the purview of future research, policy, and evaluation. We have detailed gaps in evidence in KQ2 and future research needs in Chapter 5.

Important implications of this evidence report exist for health care decisionmakers, especially AHRQ and the U.S. National Coordinator of Information Technology. A large amount of health care spending in the United States is currently being funneled into development and implementation of various health ITs. Certainly the burden of evidence is towards positive effects on process changes and measures of satisfaction and perceived benefits among users. These early indications are logical precursors to changes in demonstrated effects in benefits such as quality of care and clinical outcomes, economic benefits, or both as the technologies advance and mature. A lack of proven effectiveness in improving patient outcomes and a lack of studies on value and cost-effectiveness still exist. Currently, most systems are in their infancy and need to be continued to be scrutinized for effectiveness and safety.

Because MMIT systems specifically, and health IT in general, are expensive to develop, support, and update, it is essential that these burgeoning health ITs be rigorously assessed for cost-effectiveness and clinical-effectiveness. This effectiveness information is essential for policymakers who are allocating scarce health care resources which have multiple competing priorities. Computerization of health care will continue with the adoption of more and newly developed MMIT and other health IT applications. Clinicians, researchers, policy advisors, and health administrators should be prepared for a major investment of time and resources for implementation and use. They need to consider direct and indirect effects on health care processes such as altered work flows, adverse patient outcomes, and indirect costs. Because of the paucity of successful clinical outcome studies, and the heterogeneity of the systems, the specific interventions, and measures of effectiveness, this systematic review has been unable to clarify which factors of topic, design, or implementation may assist in the success of the MMIT.

Administrators will be able to plan for implementation better using the quantitative and qualitative findings and results. They will also be able to use this report to balance their expectations of MMIT installations and interact better with vendors and consultants.

Researchers and research funders will have a roadmap of the evidence that supports the effectiveness of MMIT applications, an outline of gaps, and lists of remaining challenges. Researchers should be aware of quality and reporting issues related to research methods as described in this review, as well as the need for research teams to include expertise or consultation from all clinician groups affected by the technology, informaticians, and those with research skills in a wide range of methodologies (research synthesis, complex interventions, pragmatic trials, usability studies, statistical planning and analysis, health technology assessment methods, and knowledge translation skills). Researchers and evaluators also need to adhere to established publication guidelines such as the STARE-HI guidelines[783] for presenting results of their studies, to ensure that readers will have the information they need to plan for implementation of MMIT systems.

The meaningful use objectives should also be deployed in all projects and implementations. Research funders can direct their programs and reinforce use of standard definitions, reporting standards, and meaningful use objectives. They can also encourage multicenter trials and those that have potential for broad applicability. Adherence of the MMIT systems to local, regional, and national standards is also important to encourage and foster. At the same time, incremental studies which show the transferability and reproducibility of findings from one study to other health care settings, systems (vendors), and health care issues (type of disease or patient and setting) should also be encouraged.

Although the strength and breadth of the body of evidence supporting the usefulness of MMIT for improving health care is not uniform across people, places, and technology, it still is substantial. We can learn much from reviewing the original studies and systematic reviews on MMIT. We also feel that the content of this report can help us leverage our existing knowledge of MMIT to a broader audience and that this can improve the health and health IT effectiveness for many people in various health care settings.

Future Research

We reviewed a large body of literature from many domains. From a content point of view, medication management information technology (MMIT) is well-covered, although coverage in the literature is not uniform for all aspects of MMIT. Effective medication management is important for many people and costly for individuals and society. Medications themselves are changing and becoming more complex with the emergence of new drugs and the integration of health information and genomics research to set the stage for individualized health care. As the population ages, we start to rely more on medications, and polypharmacy becomes standard. At the same time that the management of drugs and medications is becoming more complex and costly, the move to health IT is occurring at an increasing rate and with increasing sophistication. Newer health IT applications hold tremendous potential for patients through their health care providers and also with the move to self-management of chronic diseases, patient-centered care, personal health record systems tethered to electronic medical record systems (EMRs), and automatic monitoring devices built into smart homes to increase and prolong independence.

We provide some future directions for consideration (Table 28). We saw much that was exciting and challenging in the evidential base of MMIT in this report. Future research should be conducted in those areas we have identified that can build on the existing evidence, address the gaps that have become evident, and to support trends that can improve the quality, efficiency, and cost of health care. The section on KQ2: Knowledge and Evidence Gaps has additional and supporting information.

Table 28. Issues of consideration and/or further exploration in future research

Research Methods: • Research studies with control groups, statistically appropriate comparisons, and sufficient power and funding to produce unequivocal answers. These studies should recognize that MMIT applications need to be treated as complex interventions and evaluated as pragmatic studies (i.e., can they work in real life situations and settings). • We need large overarching trials of complete systems, and we also need smaller scale research and evaluation of the components of MMIT systems. Studies of components, such as two-way communication between pharmacists and prescribers or email between caregivers and patients are important to aid in our understanding of the contribution that each makes towards building a complete MMIT system (complex interventions). • Multicenter studies. Most studies seem to focus within a single organization using the same system and often done by those who built or developed the application. Multicenter studies can be supported, including involvement of centers that use different systems. A single study can yield valuable information about the system deployed as well as the organizational culture around the acceptance and use of the system, but understanding and enabling of generalizabilty or applicability and interoperability are more likely to occur with multicenter studies. • Studies and guidance of how best to conduct usability studies and how to make their results applicable and available to others with the same or similar applications, target populations, and clinical settings. Tool kits, training sessions, and encouragement to publish usability studies are important steps towards improved usability testing and transfer of knowledge rated to the findings of these usability studies. • Adherence to standardized reporting and communication guidelines such as STARE-HI for published articles and technical reports. Consistency in reporting details of systems include substantial details and descriptions of the features and characteristics of the MMIT system, and how it fits into existing systems, priorities, and cultures of the institution; settings and user groups; exact details of the interaction of the system with clinicians and patients; and concise reporting of the outcomes assessed. • Research into studying how best to collect and analyze existing health data from patient care records (e.g., EMRs and EHRs) to produce new knowledge related to treatment outcomes, prognostic information and other related health issues. Newer methods to collect (harvest and analyze) research data from clinical health IT systems deserve further study taking into account ethics, privacy, and security issues.”

Table 28. Issues of consideration and/or further exploration in future research (continued)

Research Needs: • Studies for order communication, dispensing and administering phases, and related aspects of medication management such as post-professional and professional education, electronic medication reconciliation, and health information exchange methods and standards. • Studies in pharmacy settings to better understand how MMIT can be used to improve interprofessional communication, communication between pharmacists and patients, and prescribing outcomes. • Studies that focus on patient-centered MMIT applications, such as medication adherence and automated and self-reported measures of monitoring medications tied to integrated systems. • Studies of issues related to standards and interoperability and how these affect generalizabilty or transferability, and the spread of MMIT across institutions and geographic regions. • Studies targeting nonphysicians including pharmacists, advanced practitioners (e.g., nurse practitioners and physician assistants), nurses, mental health professionals, and patients, as well as formal and informal caregivers who might use MMIT applications as part of providing care. • RCTs and other studies with appropriate methods that concentrate, if possible, on clinical outcomes related to the use of medications and detailed costs. Special consideration needs to be given to adherence to accepted research methods and newer research methods such as cluster randomization. • Studies of MMIT that leverage existing sources of electronic data such as clinical chemistry, hematology, and therapeutic drug monitoring across various health care settings to improve laboratory-based medication monitoring. • Recognition that genomic data will likely have a major effect on choices of medications once the research has evolved to the extent where drug treatment decisions can be made for individuals based on their genetic profiles. This genomic information will become an essential part of the data in the next generation of CDSSs and will likely need to be evaluated as such. • Qualitative and mixed methods studies on the effects of MMIT from the perspective of the patients and their existing needs and values and the implications of developing MMIT applications. • Qualitative and mixed methods studies to provide a greater understanding of the role, function, and effects of MMIT on clinician workflow, inter- and intra-personal communication and satisfaction. • Studies in older adults who reside in long-term care settings (e.g., nursing homes, assisted living, home-based primary care) and studies that centre on the geriatric population and those with complex care needs related to medications. • Studies with pediatric populations in inpatient and outpatient settings. • Improved methods of dissemination of MMIT research methodologies, strategies, and results. Those interested in MMIT can learn much from those who have expertise in clinical and translational research and knowledge translation (i.e., application of research findings) using improvement science principles. • Comparative effectiveness research to compare the effect of more than one type of MMIT on process or outcomes. • Data on unintended positive and negative consequences of MMIT applications should be collected and disseminated with priority given to those consequences that have substantial potential for harm or benefit or occur frequently. • Sophisticated concurrent prospective economic evaluations conducted in the real world to address whether MMIT interventions are cost effective are vital for policymakers and decisionmakers. • Studies of the ability to apply standard health technology appraisal methods to improve the ability to determine value for money of MMIT interventions to show if these methods should be adopted. • Study the value of feature sets of the various technologies and how they impact purchasing and use for multiple MMIT intervention stakeholders and insure that results are applicable to multiple stakeholders. Studies must include multiple stakeholders: clinicians, other health care providers, patients, caregivers, administrators, vendors, computer programmers, etc. • Study of how best to keep systems that rely on a strong knowledge base (e.g., CDSS, CPOE, order sets, drug-drug interaction programs) current with new scientific knowledge (i.e., guaranteeing the fidelity of evidence-based knowledge resources) • Develop a more relevant operational definition of sustainability related to MMIT applications, and require future studies to state explicitly how they intend on studying and reporting on these results. • Consensus meeting of experts on the types of preferred research methods to ascertain effectiveness and ensure production and reporting of quality evidence. • Series of related studies, building sequentially, testing interventions across facilities, vendors, and settings to improve applicability and transferability of research findings.

Need for High Quality Evidence

High quality evidence is lacking in many MMIT phases, care settings, and populations (Table 29). Despite the fact that many RCTs exist in the MMIT literature, they are concentrated in certain areas: 77 of 88 RCTs evaluated CDSSs. The prescribing and monitoring phases have a strong base of studies and systematic reviews. Almost completely lacking were studies in the other phases. For this report we provide the numbers of studies and research methods used (Table 29). In addition, we used the bibliographies and summaries from more than 100 systematic and narrative review articles for this report.

Table 29. Study design of included studies across the medication management phases (plus education and reconciliation)

Design	P	OC	D	A	M	E	R
RCT	70	2	3	2	37	1	1
Cohort	13	1	1	1	6	0	1
Observational	146	19	10	26	29	2	4
Qualitative	37	5	3	10	5	0	0
Total	266	27	17	39	77	3	6

Column Headings: P = Prescribing, OC = Order Communication, D = Dispensing, A = Administering, M = Monitoring, E = Education, R = Reconciliation
RCT Randomized controlled trial

Almost half of the articles that met the content criteria for MMIT did not include a comparison group, hypotheses testing or qualitative methods. These articles were not formally evaluated but are listed in the bibliography. We need well-designed research studies with control groups and appropriate analysis. Research needs center on issues related to:

- Appropriate methods for MMIT and the needs of the stakeholders. Important issues are multicentered studies, research teams with a broad experience or consultation in research methods, statistical analyses, clinical care, and informatics, and that represent the interests of all groups involved in the use of the MMIT system.
- Recognition that MMIT applications are complex interventions and their evaluation must reflect their use in real life settings and situations (i.e., complex interventions methods and pragmatic trials).
- Qualitative and mixed methods studies to understand issues related to workflow, communications, interdisciplinary collaboration and care processes, and patient use and values.

We also found that certain technologies (CDSSs, either stand-alone or integrated with CPOE systems) are well-studied. Although much data exist, as these CDSS and CPOE systems evolve and have greater penetration among health care settings, we should continue to evaluate their effectiveness. The tools that are outside the prescribing phase of medication management and the health IT tools that pharmacists, nurses, other health care professionals, and patients use are less well-studied—fewer studies and weaker methods.

Need for Well-Designed Research

Despite having 88 RCTs in the MMIT literature base, many of the studies have weaknesses. This is shown by the low quality scores, most of which were in the range of four to five out of nine points. In addition, we saw errors and poor methods in published studies. For example, most of the RCTs with clinical outcomes (n = 28) used cluster randomization methods to allocate clinical units or clinicians to study groups, but analyzed and reported results based on patients or medication events. Many authors did not test or adjust for clustering so that complex analyses could be accomplished appropriately. We also identified problems with poor application of methods in most other research studies.

Training informaticians in research methodology and statistical methods is crucial. Many programs sponsored by the U.S. National Library of Medicine and other institutions are graduating health informaticians. Training programs are content-rich because of the breadth of the field. Formal training and experience in the research methods and statistical analyses components of the training initiatives might be useful to determine what is being taught and if it is sufficient to produce researchers who are competent in evaluating MMIT and other health IT systems.

By settings and levels of care. Adult hospitals were relatively well-studied and we have sufficient evidence to show that MMIT systems for ordering medications improve processes and reduce medication errors. Adult ambulatory care clinics were also well-represented in the literature, although studies of errors and error prevention have not been done. Additional studies are especially needed in the nursing home setting, where some 1.6 million people receive care annually, and concern continues about the quality of pharmaceutical care, the frequency of polypharmacy, and an insufficient health care workforce with a poorly developed safety culture. Other long-term care settings such as assisted living and home-based primary care also need more research. The number of older adults continues to increase rapidly and they frequently have multiple comorbidities resulting in complex medication regimens, polypharmacy, and ADEs. Studies conducted in pediatric hospitals are warranted because these patients are particularly vulnerable to medication errors and those medication errors that do occur have three times the potential to cause harm.[847] Community pharmacies and the newer mail-order and online pharmacy services were not studied. Evaluating these settings may be problematic because of their commercial nature. Homes and other residential or community settings will become more important to study with the spread of patient-centered medicine and associated technologies such as PHRs and remote MMITs.

Monitoring. Our data suggest that interventions that focused on *laboratory-based* medication monitoring (22 of 29 studies) were associated with the most number of interventions, and showed statistically significant changes in at least half of its main endpoints. We recommend additional research in this area especially because laboratory data are readily available in most clinical settings, and studies in the acute, ambulatory, and nursing home settings suggest that failure to act on available laboratory information accounts for a substantial number of ADEs.[848-850] With the integration of more health IT systems and the move to more patient directed care, systematic monitoring will become even more important.

Practitioners and patients. Nurses and pharmacists are not studied as thoroughly as physicians. Mental health professionals and other health care workers who prescribe, including dentists, are studied even less than nurses and pharmacists. Each group of health professionals reports different needs for their MMIT and health IT tools (e.g., specialist physicians compared with primary care, nurses compared with physicians in hospital wards need compatible but different MMIT tools for ordering, dispensing, and administering). These differences need to be studied and applied in building, evaluating, and implementing MMIT applications. Nurse practitioners, advance practice nurses and physician assistants, and allied and other health professionals should also be the target of MMIT interventions, especially because they play an increasing role in providing primary and subspecialty care, especially in the United States. The move to patient-centered care and chronic disease management also make the study of patients and their informal caregivers an important area for research and development.

Unique needs of evaluation of health IT. MMIT applications are neither simple nor isolatable components that can be easily studied as such. Research methods to evaluate MMIT applications should be based on principles of complex interventions. For example, the U.K. Medical Research Council provides a framework for individuals to consider when planning complex intervention projects (http://www.mrc.ac.uk/Utilities/Documentrecord/index.htm?d=MRC003372).

In addition, MMIT applications are often being changed and modified to address problems or to implement fixes or upgrades. This ever changing aspect of health IT poses challenges for health researchers. Classical evaluation and research methods dictate that what is being evaluated needs to be stable over the time period of the study. "Fast" analysis methods may need to be developed.

MMIT systems, as for any IT system, are easiest to study in laboratory settings. Because health care is so complex, the study of MMIT systems must be done in real settings. Pragmatic trials methods (trials done in real life situations) may also need to be applied in many research projects related to MMIT systems.

Commercial interests also complicate the evaluation of MMIT and health IT. This makes research harder to do and provides barriers to the most common government-based funding sources. AHRQ has provided funding for many unique and valuable health IT applications that have included much evaluation of MMIT. They should be encouraged to continue to provide leadership in this domain.

Another challenge to research methods is that often the existing evaluations have been done by system developers or implementers. This ownership can cloud an evaluator's vision (i.e., bias) or at least stand in the way of publication of negative findings. Some evidence exists that evaluation of one's own system contributes to biases towards the system being found to be positive.[725]

Knowledge translation/translational research. Because many of the studies in MMIT are small descriptive studies and often done by developers, generalizabity or transferability are often not ideal. Researchers in this domain of "getting research into practice" (i.e., knowledge translation or translational research) can provide tools and insights in two areas. The first is how to harness existing knowledge tool development such as building the knowledge base behind health IT systems such as CDSS, CPOE systems, and other knowledge summaries such as clinical practice guidelines and order sets. Second, those involved in knowledge translation can assist in the dissemination of studies of MMIT applications, or provide leadership in how we can disseminate studies of health IT.[725]

MMIT applications do not stand alone. MMIT implementation has had substantial impact on communication, interpersonal, and inter-professional relationships, and development of unintended consequences. In some cases, issues such as rage against the machine, guilt, embarrassment associated with reminders and alerts, and frustration have been reported. The qualitative and mixed methods studies summarized in the KQ1: Effectiveness section are examples of studies that have shown how MMIT and health IT can and do affect individuals on a personal level. More of these studies of the effects of these technologies on people, clinicians, and individuals need to be done in various settings and with all technologies. Workflow and communication are ideally studied using qualitative and mixed methods.

Sustainability. Sustainability is tremendously important to MMIT and other health IT applications. See also KQ5: Sustainability. We could not find an agreed upon definition and used one from Australia: “the ability of a health service to provide ongoing access to appropriate quality care in a cost effective and health-effective manner.” The informatics domain needs to have an agreed upon definition of sustainability. Once this is established, research needs to be done to identify our current “sustained” systems and determine the factors that are associated with them. Qualitative and quantitative studies are essential and they need to be done by people with strong content and methods background and sufficient financial backing. Partnerships among Federal groups (e.g., AHRQ, Office of the National Coordinator for Health Information Technology, Health Resources and Services Administration, and Centers for Medicare and Medicaid Services), vendors, professional organizations (e.g., Healthcare Information and Management Systems Society, American Medical Informatics Association, and the major pharmacy associations such as the American Pharmacists Association, American Society of Health System Pharmacists, Academy of Managed Care Pharmacy, American College of Clinical Pharmacy, American Society of Consultant Pharmacists, National Community Pharmacists Association, and National Association of Chain Drug Stores), researchers, and others could work together to address the sustainability challenge. We also need studies of successful MMIT applications as well as systematic study of failures. Perhaps the HITECH Act of 2009 will lead to improvements and sustainability of health IT applications that specifically support the medication management continuum through meaningful use.

Standards and certification. We were asked to provide the evidence on the influence of standards and certification and how they affect MMIT systems. This evidence is sorely lacking. Standards are necessary for interoperability and smooth functioning of existing systems and large scale integration of data at State and national levels. Leadership, probably more than research efforts, continues to be needed in this domain.

Measurement and definitional issues. Other gaps in the evidence that need addressing are definitional or measurement issues. Because health IT is an interdisciplinary field, standard definitions are crucial. Producers and users of research and evaluations function best when everyone is using the same terms with the same parameters. One simple example we found is a formal working definition of the difference between an e-Prescribing system and a medication-based CPOE system. Some European literature described a system as e-Prescribing, while the same system in the United States would be classified as COPE. Another idea that seemed to cause confusion among authors and readers is the use of EMR or EHR systems, and hospital information systems. Consistency in reporting and communicating MMIT information is also important.

Clinical practice guidelines, CPOE, and CDSS. One final issue that seems unresolved centers on the evidentiary nature and strength of the knowledge base that forms the foundation of CDSS applications, order sets, and most other MMIT systems. Some systems linked to established clinical practice guidelines, but we did not find studies that addressed the strength of the evidence base of MMIT systems. We feel that a strong, reliable, consistent, fully disseminated, and continually updated evidence base for MMIT and other health IT systems is vital. More emphasis has been placed on the mechanics of these systems than content. Establishment of standards and content for the knowledge base is something that is potentially more important than the mechanics of these decision-support systems. The U.S. National Library of Medicine could provide leadership here. They have already built strong knowledge management tools such as their Unified Medical Language System that knits together multiple vocabularies in a machine processable form. They have also developed other information handling and processing tools, and techniques such as natural language processing capabilities of medical text, RxNorm (a standardized electronic nomenclature for clinical drugs and drug delivery devices), and codified drug allergy information provision and transfer. Their work in genomics and proteomics is also important once an individual’s genetic information is ready for useful integration into our health IT and MMIT systems to provide individualized medicine.

Conclusions

Our evidence review on the use of health information technology (health IT) in enabling medication management derives from a summary of 428 studies assessing the use of integrated health IT that assisted with at least one phase of the medication management process, and associated aspects of education and reconciliation. We define the medication management process as having five phases; prescribing, order communication, dispensing, administering, and monitoring. For this report we also included medication reconciliation, education, and adherence.

Key Question (KQ) 1: Effectiveness assessed the effectiveness of health IT on changes in process and intermediate, cost, and clinical outcomes. We limited our studies to those that used qualitative methods or included comparison groups, hypothesis testing, and appropriate statistical analysis. We did this in an effort to limit inclusion to studies that used research methods and had data that we could use to draw conclusions. The majority (378 of 428 studies) of the evaluated studies were included in KQ1: Effectiveness. Even so, our findings indicate that RCTs and other methodologies with controlled populations are lacking in adequate details and robust methods, which result in an only incremental addition to the evidence base for the use of MMIT. Most of the studies in this evidence report are quantitative observational assessments, often using historical controls.

The evidence from these studies indicate positive effects on improving process, often measured as improvements in medication orders during the prescribing and monitoring phases. The bulk of this evidence of improvement is shown in studies set in hospitals. We also found improvements associated with MMIT systems related to use, usability, knowledge, skills, and attitudes. These cumulated changes can, but may not always, lead to efficiency and cost gains. On the other hand, little work is being done on the other phases of medication management with integrated health IT. Some IT applications used in dispensing and administering are stand-alone technologies and, by definition, not included in this report.

We found little evidence of significant effects on clinical outcomes; possibly because of the small number of events, the outcomes being far removed from the application of the technology; or that they were often not the main endpoints of the studies included in the review. We do not know if MMIT applications are clinical- and cost effective because of a lack of sound economic data.

The qualitative literature highlighted positive and negative perceptions and satisfaction with the integrated health IT applications, supporting much of the literature on the importance of the effects of the technologies on workflow and the working relationships of the users.

We have identified a number of gaps in the evidence of the effects of MMIT applications: most notably the order communication, dispensing, and administering, as well as reconciliation and education. Inpatient care is well-studied, followed by ambulatory care. A low number of studies assessed long-term care and effects on pharmacies, especially those outside the hospital setting. Gaps in research also exist for studies that evaluate MMIT that are not computerized decision support systems (CDSSs) or computerized provider order entry (CPOE) systems. The domain of patient and informal caregiver access to MMIT applications, especially those applications that are integrated with such existing clinical applications as electronic medical record systems (EMRs), will be an exciting and promising new domain of study. One major gap is the assessment of MMIT tools that are used by nonphysicians.

The value of the MMIT systems needs to be summed up across financial, clinical, and organizational components. The values proposition for each stakeholder will be different based on their own value set, and what is important to each has not been well-studied. Though some evidence suggests positive financial and organizational gains, these gains are not universal and will depend on the technology, the setting, and the impact on the stakeholders using them. Clinical benefit is proving difficult to assess. Rigorous studies are needed to truly assess economic and other values.

This broad scoped review sought to include a large number of health ITs across an array of settings and users. As such, the literature was heterogeneous and difficult to synthesize. Based on our findings, we feel that it is important to note that the burden of proof of the value of MMIT is somewhat limited, but promising. We feel also that decisionmakers must be aware of the potential for negative impacts of the technologies and carefully consider these possibilities during implementation and provide for continued monitoring across all stakeholder groups. . The evidence base of MMIT applications is strong and varied, and it can be further strengthened by using multicentered studies, building an integrated body of evidence which will demonstrate the transferability and applicability of the systems, and multidisciplinary teams of researchers, or at least consultation input from clinicians; methodologists, including biostatisticians; informaticians; particular health IT users and representatives of various stakeholders. We can also learn much from those who work with complex interventions, pragmatic trials, research syntheses, knowledge translation or translation research challenges, and health technology assessment studies to enhance the construction, conduct, and communication of health IT implementation and use research findings.

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Acronyms and Abbreviations

Abbreviation	Words/Phrases
ADE	Adverse Drug Event
AHRQ	Agency for Healthcare Research and Quality
AMIA	American Medical Informatics Association
ASHP	American Society of Health-System Pharmacists
BCM	Bar Code Medication
BCMA	Bar Code Medication Administration
CA	Cost Analysis
CBA	Cost Benefit Analysis
CCA	Cost Consequence Analysis
CCHIT	Commission for Healthcare Information Technology
CDSS	Clinical Decision Support System
CEA	Cost Effectiveness Analysis
CI	Confidence Interval
CINAHL	Cumulated Index to Nursing and Allied Health Literature
CITL	Center for Information Technology Leadership
CPOE	Computerized Provider Order Entry
CUA	Cost Utility Analysis
EDI	Electronic Data Interchange
EHR	Electronic Health Record
E-LIS	Eprints in Library and Information Science
e-MAR	Electronic Medication Administration Record
EMBASE	Excerpta Medica Database
EMR	Electronic Medical Records
e-TAR	Electronic Treatment Authorization Request
Health IT	Health Information Technology
HIV	Human Immunodeficiency Virus
HMO	Health Maintenance Organization
HTA	Health Technology Assessment
ICU	Intensive Care Unit
IEEE	Institute of Electrical and Electronics Engineers
IOM	Institute of Medicine
IPA	International Pharmaceutical Abstracts
IT	Information Technology
JAMIA	Journal of the American Medical Informatics Association
MEDLINE	Medical Literature Analysis and Retrieval System
MMIT	Medication Management Information Technology
MMS	Medication Management System
NICU	Neonatal Intensive Care Unit
PDA	Personal Digital Assistants
PHR	Personal Health Record
RCT	Randomized Controlled Trial

Appendix A. Exact Search Strings

MEDLINE® Ovid MEDLINE(R) <1950 to September Week 2 2009>
Date searched: Sept 21-09
Number of retrievals: 10767
1 electronic prescribing/ (61) 2 drug therapy, computer assisted/ (1151) 3 (electronic adj3 prescri*).mp. (351) 4 electronic medication*.mp. (116) 5 automated prescri*.mp. (25) 6 (automated adj3 medication*).mp. (72) 7 (online adj3 prescri*).mp. (39) 8 (online adj3 medication*).mp. (17) 9 e-prescri*.mp. (163) 10 eprescri*.mp. (12) 11 e-medication*.mp. (4) 12 emar*.mp. (169) 13 (bcma and (medication* or prescri* or drug)).mp. (24) 14 e-rx.mp. (11) 15 ((bar cod* or barcod*) and (prescri* or medication* or drug*)).mp. (280) 16 (computer* adj2 prescri*).mp. (310) 17 prescri* monitor*.mp. (89) 18 clinical pharmacy information systems/ (986) 19 prescri* order entry.mp. (56) 20 pharma* order entry.mp. (5) 21 computer* order entry.mp. (115) 22 automated dispens*.mp. (82) 23 or/1-22 (3403) 24 exp pharmaceutical services/ (38883) 25 exp medical errors/ (64473) 26 exp drug therapy/ (864020) 27 exp drug interactions/ (122756) 28 exp drug monitoring/ (9813) 29 exp medication systems/ (3386) 30 exp drug administration schedule/ (71159) 31 exp drug costs/ (9397) 32 exp dose-response relationship, drug/ (288539) 33 drug therapy, computer assisted/ (1151) 34 (prescri* or medication*).mp. (218668) 35 pharmacotherap*.mp. (14545) 36 pharmaceutical*.mp. (115354) 37 dispens*.mp. (18455) 38 exp therapeutic uses/ (3544181) 39 (safety or safe).mp. (310321) 40 error*.mp. (173803) 41 (adverse adj3 event*).mp. (46457) 42 (adverse adj3 effect*).mp. (79271) 43 mistake*.mp. (11308) 44 complication*.mp. (744423) 45 (risk adj5 manag*).mp. (21572) 46 (risk adj5 assess*).mp. (138608) 47 harm*.mp. (57502) 48 exp medical errors/ (64473) 49 safety management/ (11037) 50 patient safety/ (0) 51 medical error/ (8433) 52 medication error/ (7690) 53 risk management/ (11711) 54 risk assessment/ (109320)

55 adverse drug reaction reporting systems/ (4027)
56 or/24-55 (5187543)
57 cdss.tw. (355)
58 ccdss.tw. (2)
59 (comput* adj3 decision support*).mp. (603)
60 reminder system*.tw. (380)
61 decision support systems, clinical/ (3072)
62 reminder systems/ (1486)
63 therapy, computer assisted/ (3599)
64 decision making, computer assisted/ (2051)
65 (comput* adj3 order entry).tw. (714)
66 provider order entry.tw. (196)
67 cpoe.tw. (492)
68 clinician order entry.tw. (4)
69 physician order entry.tw. (443)
70 nurs* order entry.tw. (2)
71 pharma* order entry.tw. (5)
72 medical order entry systems/ (799)
73 patient portal*.mp. (67)
74 personal medical record*.mp. (42)
75 personal health record*.mp. (215)
76 (patient adj2 access* adj2 record*).mp. (728)
77 (patient adj2 carried adj2 record*).mp. (3)
78 (patient adj2 held adj2 record*).mp. (52)
79 (patient adj2 shared adj2 record*).mp. (14)
80 patient internet portal*.mp. (9)
81 phr.mp. (484)
82 ephr.mp. (11)
83 exp medical records/ and patient access to record*.mp. (478)
84 kiosk*.tw. (105)
85 point-of-care systems/ (4135)
86 computers, handheld/ (1396)
87 Medical Records Systems, Computerized/ (15799)
88 or/57-87 (31551)
89 56 and 88 (7973)
90 guideline adherence/ (12072)
91 exp patient compliance/ (38269)
92 (patient compliance or patient adherence).tw. (5892)
93 (comput* or online or internet or electron*).mp. (1263766)
94 or/90-92 (53419)
95 94 and 93 (3358)
96 56 and 95 (1775)
97 23 or 89 or 96 (11560)
98 97 not letter.pt. (11306)
99 98 not editorial.pt. (11144)
100 99 not news.pt. (11001)
101 animal/ not (human/ and animal/) (3351990)
102 100 not 101 (10767)

EMBASE Ovid EMBASE <1980 to 2009 Week 38>

Date searched: Sept 23-09

Number of retrievals: 8693

1 electronic prescribing/ (8)
2 computer assisted drug therapy/ (168)
3 electronic prescri*.mp. (256)
4 electronic medication*.mp. (101)
5 automated prescri*.mp. (22)
6 automated medication*.mp. (25)
7 online prescri*.mp. (12)
8 online medication*.mp. (6)

9 e-prescri*.mp. (105)
10 eprescri*.mp. (5)
11 e-medication*.mp. (2)
12 emar.mp. (11)
13 (bcma and (medication* or prescri* or drug*)).mp. (90)
14 e-rx.mp. (6)
15 ((bar cod* or barcod*) and (prescri* or medication*)).mp. (141)
16 computer* prescri*.mp. (182)
17 prescription monitor*.mp. (64)
18 electronic medication administration record.sh. (2)
19 computer assisted drug therapy/ (168)
20 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 (1096)
21 exp medical errors/ (31362)
22 exp drug therapy/ (905532)
23 exp drug interactions/ (141655)
24 exp drug monitoring/ (28295)
25 exp medication systems/ (4626)
26 exp drug administration schedule/ (791038)
27 exp drug costs/ (36734)
28 exp dose-response relationship, drug/ (230877)
29 drug therapy, computer assisted/ (168)
30 (prescri* or medication*).mp. (209602)
31 pharmacotherap*.mp. (15893)
32 pharmaceutical*.mp. (86405)
33 dispens*.mp. (13409)
34 pharmacy/ (23073)
35 (safety or safe).mp. (358398)
36 error*.mp. (213771)
37 (adverse adj3 event*).mp. (46207)
38 (adverse adj3 effect*).mp. (74072)
39 mistake*.mp. (8656)
40 complication*.mp. (439160)
41 (risk adj5 manag*).mp. (19630)
42 (risk adj5 assess*).mp. (204644)
43 harm*.mp. (48109)
44 exp medication error/ (3076)
45 drug safety/ (140603)
46 patient safety/ (14509)
47 risk assessment/ (186991)
48 drug surveillance program/ (7404)
49 drug monitoring/ (28295)
50 or/21-49 (2850800)
51 cdss.tw. (285)
52 ccdss.tw. (0)
53 (comput: adj3 decision support*).mp. (972)
54 reminder system*.tw. (239)
55 decision support system/ (1700)
56 reminder systems/ (166)
57 computer assisted drug therapy/ (168)
58 cpoe.tw. (228)
59 (comput* adj3 order entry).tw. (443)
60 provider order entry.tw. (88)
61 clinician order entry.tw. (1)
62 physician order entry.tw. (265)
63 nurs* order entry.tw. (1)
64 pharma* order entry.tw. (6)
65 hospital information system/ (1335)
66 medical information system/ (7562)
67 patient portal*.mp. (30)
68 personal medical record*.mp. (27)
69 personal health record*.mp. (109)
70 (patient adj2 access* adj2 record*).mp. (51)

71 (patient adj2 carried adj2 record*).mp. (2)
72 (patient adj2 held adj2 record*).mp. (48)
73 (patient adj2 shared adj2 record*).mp. (14)
74 patient internet portal*.mp. (4)
75 electronic medical record/ and patient access.tw. (12)
76 kiosk*.tw. (69)
77 microcomputer/ (5437)
78 electronic medical record/ (4542)
79 or/51-78 (20325)
80 50 and 79 (6242)
81 (guideline adherence or adherence to guideline*).tw. (639)
82 patient compliance/ (49247)
83 (patient compliance or patient adherence).tw. (5413)
84 or/81-83 (51850)
85 (comput* or online or internet or electron*).mp. (939381)
86 84 and 85 (2902)
87 20 or 80 or 86 (9504)
88 87 not letter.pt. (9125)
89 88 not editorial.pt. (8694)
90 89 not news.pt. (8694)
91 animal/ not (human/ and animal/) (14494)
92 90 not 91 (8693)

CINAHL via EBSCOhost

Date searched: Sept 25-09

Number of retrievals: 4692

S97 (S96 not PT(editorial))
S96 (S24 or S88 or S94) not PT(letter)
S95 (S24 or S88 or S94)
S94 (S92 and S93)
S93 (S89 or S90 or S91)
S92 (comput* or online or internet or electron*)
S91 (patient compliance or patient adherence)
S90 MH(patient compliance+)
S89 MH(guideline adherence)
S88 (S59 and S87)
S87 (S60 or S61 or S62 or S63 or S64 or S65 or S66 or S67 or S68 or S69 or S70 or S71 or S72 or S73 or S74 or S75 or S76 or S77 or S78 or S79 or S80 or S81 or S82 or S83 or S84 or S85 or S86)
S86 MH (risk assessment)
S85 MH (risk management)
S84 MH (patient safety+)
S83 (safety manage*)
S82 (harm*)
S81 (risk N5 assess*)
S80 (risk N5 manage*)
S79 (complication*)
S78 (mistake*)
S77 (adverse N3 effect*)
S76 (adverse N3 event*)
S75 (error*)
S74 (safety or safe)
S73 (MH “Therapeutics”)
S72 (dispense*)
S71 (pharmaceutical*)
S70 (pharmacotherap*)
S69 (prescri* or medication*)
S68 (drug cost*)
S67 MH “drug therapy, computer assisted”
S66 MH “dose-response relationship, drug”
S65 MH “drug administration schedule”

S64 MH “medication systems”
S63 MH “drug monitoring”
S62 MH “drug interactions+”
S61 MH “drug therapy+”
S60 MH “treatment errors”
S59 (S25 or S26 or S27 or S28 or S29 or S30 or S31 or S32 or S33 or S34 or S35 or S36 or S37 or S38 or S39 or S40 or S41 or S42 or S43 or S44 or S45 or S46 or S47 or S48 or S49 or S50 or S51 or S52 or S53 or S54 or S55 or S56 or S57 or S58)
S58 (MH “patient record systems”)
S57 (MH “Computers, Hand-Held”)
S56 (point-of-care) or (point of care)
S55 (kiosk)
S54 MH(medical records+) and (patient access*)
S53 MH(computerized patient record)
S52 MH(medical records, personal)
S51 “(ephr)”
S50 “(phr)”
S49 “(Patient internet portal)”
S48 (MH “Patient Access to Records”)
S47 (patient N2 shared N2 record*)
S46 (patient N2 held N2 record*)
S45 (patient N2 carried N2 record*)
S44 (patient N2 access* N2 record*)
S43 (personal health record*)
S42 (personal medical record*)
S41 (patient portal*)
S40 MH(electronic order entry)
S39 (pharma* order entry)
S38 (nurs* order entry)
S37 (physician order entry)
S36 (clinician order entry)
S35 (cpoe)
S34 (provider order entry)
S33 (comput* N3 order entry)
S32 MH(decision making, computer assisted)
S31 MH(therapy, computer assisted)
S30 MH(reminder systems)
S29 MH(decision support systems, clinical)
S28 (reminder system*)
S27 (comput* N3 decision support*)
S26 (ccdss)
S25 (cdss)
S24 (S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8 or S9 or S10 or S11 or S12 or S13 or S14 or S15 or S16 or S17 or S18 or S19 or S20 or S21 or S22 or S23)
S23 (automated dispens*)
S22 (MH “Electronic Order Entry”)
S21 (computer* order entry)
S20 (pharma* order entry)
S19 (prescri* order entry)
S18 (prescri* monitor*)
S17 (computer* N2 prescri*)
S16 ((bar cod* or barcod*) and (prescri* or medication* or drug*))
S15 (e-rx)
S14 (bcma)
S13 (emar*)
S12 (emedication*)
S11 (emedication*)
S10 (eprescri*)
S9 (e-prescri*)
S8 (online N3 medication*)
S7 (online N3 prescri*)
S6 (automated N3 medication*)

S5 automated prescri*
S4 (electronic medication*)
S3 (electronic N3 prescri*)
S2 MH (“drug therapy, computer assisted”)
S1 MH (“clinical pharmacy information systems”)

Cochrane Library

Date searched: Sept 29-09

Number of retrievals: 148

#1 MeSH descriptor Drug Therapy, Computer-Assisted, this term only
#2 MeSH descriptor Electronic Prescribing, this term only
#3 electronic prescri* OR “electronic medication*” OR “automated prescri*” OR “automated medication*” OR “online prescri*” OR “online medication*” OR “e-prescri*” OR “eprescri*” OR “e-medication*” OR “emar” OR (bcma and (medication* or prescri* or drug*)) OR “e-rx” OR ((bar cod* or barcod*) and (prescri* or medication)) OR “computer* prescri*” OR “prescription monitor*” :ti,ab,kw
#4 (#1 OR #2 OR #3)

IPA Abstracts

Date searched: Sept 21-09

Number of retrievals: 4387

((((patient and compliance) or (patient and adherence) or (guideline and adherence) or (guideline and compliance)) and (comput* or online or internet or electron*)) or (computer assisted drug therapy or (electronic adj3 prescri*) or (electronic adj3 medication*) or (automated adj3 prescri*) or (automated adj3 medication*) or (online adj3 prescri*) or (online adj3 medication*) or e-prescri* or eprescri* or e-medication* or emar or bcma or e-rx or (bar cod* or barcod*) or (computer* adj2 prescrib*) or prescri* monitor* or information systems* or automated dispens* or cdss or (comput* adj3 decision support*)) or (reminder system* or (clinic* adj3 decision support*) or (therapy and computer assist*) or (decision making and computer) or (comput* adj3 order entry) or (provider adj3 order entry) or cpoe or (clinician adj3 order entry) or (physician adj3 order entry) or (nurs* adj3 order entry) or (pharma* adj3 order entry) or (prescri* adj3 order entry) or order entry systems or patient portal* or (personal adj2 record*) or (patient adj2 access* adj2 record*) or (patient adj2 carried adj2 record*) or (patient adj2 held adj2 record*) or (patient adj2 shared adj2 record*) or patient internet portal*) or (phr or ephr or kiosk* or point of care or point-of-care or handheld)).af. (4387)

Compendex AND Inspec via Engineering Village

Date searched: Sept 28-09

Number of retrievals: 1503

(((((medication*)WN ALL)) NOT (({461.2} OR {804.1} OR {a8770e} OR {921} OR {a8730c} OR {716} OR {804} OR {922.2} OR {b7510d} OR {801} OR {802.3} OR {741.1} OR {461.5} OR {921.6} OR {801.2} OR {a8745h} OR {804.2} OR {701.1} OR {803} OR {931.2} OR {717}) WN CL)) NOT ((({462} OR {723.4} OR {731.1} OR {c3385} OR {462.1} OR {b7510} OR {a8770} OR {c1140z} OR {a8730} OR {a8745d} OR {a8725} OR {622.3}) WN CL))

LISTA (1974-2009) via EBSCOhost

Date searched: Sept 25-09

Number of retrievals: 276

S3 (S2 and S3)
S2 (comput* or online or internet or electron*)
S1 medication* or prescri*

PsycINFO <1967 to September Week 3 2009>

Date searched: Sept 23-09

Number of retrievals: 3074

1 computer assisted therapy/ (177)
2 (electronic adj3 prescri*).mp. (16)

3 electronic medication*.mp. (16)
4 automated prescri*.mp. (1)
5 (automated adj3 medication*).mp. (2)
6 (online adj3 prescri*).mp. (10)
7 (online adj3 medication*).mp. (3)
8 e-prescri*.mp. (3)
9 eprescri*.mp. (0)
10 e-medication*.mp. (4)
11 emar*.mp. (16)
12 (bcma and (medication* or prescri* or drug)).mp. (1)
13 e-rx.mp. (1)
14 ((bar cod* or barcod*) and (prescri* or medication* or drug*)).mp. (6)
15 (computer* adj2 prescri*).mp. (12)
16 prescri* monitor*.mp. (24)
17 prescri* order entry.mp. (1)
18 pharma* order entry.mp. (0)
19 computer* order entry.mp. (3)
20 automated dispens*.mp. (3)
21 or/1-20 (292)
22 pharmaceutical services.mp. (15)
23 medical error*.mp. (231)
24 exp drug therapy/ (82011)
25 exp drug interactions/ (5922)
26 drug monitor*.mp. (250)
27 self monitoring/ (1987)
28 medication system*.mp. (3)
29 exp drug administration methods/ (6226)
30 drug administration schedule.mp. (8)
31 drug cost*.mp. (177)
32 exp “Costs and Cost Analysis”/ (12017)
33 (dose-response or dose response).mp. (3282)
34 computer assisted therapy/ (177)
35 exp “Prescribing (Drugs)”/ (2025)
36 prescription drugs/ (1311)
37 (prescri* or medication*).mp. (57547)
38 pharmacotherap*.mp. (7804)
39 pharmaceutical*.mp. (3033)
40 dispens*.mp. (1442)
41 therapeutic uses.mp. (259)
42 (safety or safe).mp. (33813)
43 error*.mp. (50722)
44 (adverse adj3 event*).mp. (4502)
45 (adverse adj3 effect*).mp. (8104)
46 mistake*.mp. (5096)
47 complication*.mp. (10447)
48 (risk adj5 manag*).mp. (4103)
49 (risk adj5 assess*).mp. (11152)
50 harm*.mp. (22923)
51 exp “quality of care”/ (5241)
52 drug interactions/ (5922)
53 “side effects (drug)”/ (16075)
54 medication error*.mp. (153)
55 risk management/ (2007)
56 risk assessment/ (4872)
57 (adverse adj3 drug adj3 reaction).mp. (110)
58 client treatment matching/ (763)
59 treatment planning/ (2623)
60 or/22-59 (272739)
61 cdss.tw. (75)
62 ccdss.tw. (3)
63 (comput* adj3 decision support*).mp. (126)
64 reminder system*.tw. (49)

65 (comput* adj3 order entry).tw. (23) 66 provider order entry.tw. (7) 67 cpoe.tw. (8) 68 clinician order entry.tw. (0) 69 physician order entry.tw. (15) 70 nurs* order entry.tw. (0) 71 pharma* order entry.tw. (0) 72 patient portal*.mp. (6) 73 personal medical record*.mp. (3) 74 personal health record*.mp. (20) 75 (patient adj2 access* adj2 record*).mp. (18) 76 (patient adj2 carried adj2 record*).mp. (0) 77 (patient adj2 held adj2 record*).mp. (16) 78 (patient adj2 shared adj2 record*).mp. (2) 79 patient internet portal*.mp. (1) 80 phr.mp. (36) 81 ephr.mp. (0) 82 exp medical records/ and patient access to record*.mp. (4) 83 kiosk*.tw. (55) 84 exp expert systems/ (3289) 85 prompting/ (229) 86 computer assisted therapy/ (177) 87 intelligent agents/ (185) 88 information technology/ (1944) 89 computer applications/ (9604) 90 automated information processing/ (952) 91 exp information systems/ (14268) 92 microcomputers/ (1111) 93 computer peripheral devices/ (329) 94 or/61-93 (29083) 95 60 and 94 (2751) 96 (patient compliance or patient adherence).tw. (889) 97 treatment compliance/ (7750) 98 treatment guidelines/ and (complian* or adheren*).mp. [mp=title, abstract, heading word, table of contents, key concepts] (219) 99 (comput* or online or internet or electron*).mp. (109841) 100 or/96-98 (8282) 101 99 and 100 (323) 102 21 or 95 or 101 (3123) 103 102 not letter.dt. (3112) 104 103 not editorial.dt. (3074)

Sociological Abstracts via Scholar's portal
Date searched: Sept 28-09
Number of retrievals: 489
(KW=(comput* or electron* or online*) or KW=(internet or (information within 3 system*) or automat*) or KW=technolog*) And ((((KW=medic*) or(KW=prescri*) or(KW=pharma*) or(KW=drug*)) and((KW=monitor*) or(KW=administr*) or(KW=adhere*) or(KW=comply*) or(KW=complian*) or(KW=dispens*))) or((KW=(drug within 1 therap*)) or(KW=(drug within 1 safe*)) or(KW=(medical within 2 error*)) or(KW=(medication within 2 error*)) or(KW=(patient within 2 safe*)) or(KW=(order entry)) or(KW=(decision within 2 support)) or(KW=(adverse within 2 event*)) or(KW=(adverse within 2 effect*)))

Business Source Complete via EBSCOhost
Date searched: Sept 29-09
Number of retrievals: 1055
S9 (S8 or S7)

S8 (S1 and S6) Limiters - Publication Type: Academic Journal, Book, Primary Source Document Narrow by Subject0: - MEDICAL technology S7 (S1 and S6) Limiters - Publication Type: Academic Journal, Book, Primary Source Document; Narrow by Subject0: - MEDICAL care S6 (S4 or S5) S5 (drug N1 therap*) or (drug N1 safe*) or (medical N2 error*) or (medication N2 error*) or (patient N2 safe*) or (order entry) or (decision N2 support) or (adverse N2 event*) or (adverse N2 effect*) S4 (S2 and S3) S3 (medicin* or medic* or drug* or pharma*) S2 (monitor* or administ* or adhere* or comply* or complian* or dispens* or prescri*) S1 (comput* or electron* or online* or internet or (information N2 system*) or automat* or technolog*

Grey Literature Source Date searched	Search Terms	Retrieved	Reviewed
New York Academy of Medicine 2-Nov-09	“medication management “ returned 1716 results.-first 40 reviewed	1716	40
	“medication management information “ returned 156 results.-first 40 reviewed	156	40
	“kw,wrdl: technology and kw,wrdl: drug medication “ returned 36 results.-all reviewed	36	36
	and kw,wrdl: medication drug “ returned 3 results.	3	3
	su,wrdl: medical informatics returned 156 results -first 40 reviewed	156	40
	“computer and drug “ returned 29 results.	29	29
	“computer and medication “ returned 451 results-reviewed first 40	451	40
SIGLE 25-Nov-09	(((medication)) or ((“medication management”))) AND (((computer)) or ((informatics)))	317	all
US HHS Health Information Technology 27-Nov-09	none- searched ‘reports’ page and selected reports possibly on topic		all
Health Technology Assessment reports CRD 24-Nov-09	((medicat* or “medication management”)) AND ((comput* or informatic*))	393	all
ProQuest Dissertations 25-Nov-09	((medicat* or “medication management”)) AND ((comput* or informatic*))	264	all
National Library for Health UK, includes Bandolier 25-Nov-09	(medicat* or “medication management”) AND (comput* or informatic*).	74	all
ProceedingsFirst Nov-25-09	(kw: medicat* and kw: medication w management) and (kw: comput* or kw: informatic*).	16	all
PapersFirst 25-Nov-09	(kw: medicat* or kw: medication w management) and (kw: comput* or kw: informatic*).	143	all
National Technical Information Service 4-Nov-09	ALL: medicine computer drug	46	46
Google 27-Nov-09	medication management health information technology	about 651,000	First 50 websites searched for relevant documents
AHRQ 30-Nov-09	eRx, Bar Coding and CPOE knowledge libraries	254	254

Appendix B. Sample Screening and Abstraction Forms

Defining Medication Management IT

To be clear on what kinds of applications we're including in MMIT, we've devised the following outline for MMIT applications:

Include:

Medication Management Health information technology systems/ programs where:

The computer/technology processes patient specific information in some way

AND

The information provided by the system is relevant to one of the following processes in medication management:

- Prescribing/ordering medications
- order communication
- dispensing
- administering (by health care provider or care giver)
- monitoring (patient adherence/compliance, adverse event surveillance)
- education (of patients, not pre-professional education)
- reconciliation

AND

Someone (patient, care giver, family, health care professionals) receives information in return that is/can be linked to patient-specific information and which is used in decision making

AND

The technology is part of or links to an information system

OR

The article is about transmission/order communication eg. Electronic Data Interchange (EDI)

AND

The article contains outcome data

Examples: CPOE, CDSS for prescribing, automated pharmacy systems coupled with CPOE

Exclude:

Health information technology systems/programs with:

The IT component is only web browsing of general health information databases

OR

The system acts as a conduit of information only (except transmission of prescriptions between Health Care Provider and Pharmacy)

OR

Systems where no feedback is provided (eg surveys)

OR

The system does not help with medication management decision-making or provide information about any of the 6 medication use/process steps (prescribe/transmit/ dispense/administer/monitor/educate)

OR

Systems that make measurements but do not process the information

OR

Stand-alone devices that do not integrate with information systems

OR

HIT application is used only to extract data

Examples: pill bottles that track opening/closing, smart pumps not tied to other systems, studies using EHR for data collection only (eg. quality improvement tracking), ,

Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Original or Review articles	Letters, editorials, news items
Relates to at least 1 step in the medication management process	Not related to the medication management process
Medication management assisted by Health IT	Health IT not involved in medication management
Computerized order entry, e-prescribing, computer decision support for medication management, barcode medication administration, medication reminders for patients and clinicians	HIT that is only used to extract data
Deals with a Medication Management System or an application that feeds into/out of a system	Devices that are stand-alone. They may administer drugs etc but are not tied to a medication management/information system. E.g. MEMS
Article Contains data	Article Does not contain data
Foreign language with data	Foreign language with no access to full-text articles
Articles on Electronic Data Interchange/electronic transmission between Health Care Providers and Pharmacies	Technologies that are passive, don't process information. eg. only take measurements, transmit data (except EDI) or administer drugs
Prescribed drugs or medications only	Over-the-counter drugs or prescribed devices
Medical, Dentistry, Nursing articles	Veterinary articles
PDAs or stand-alone devices that take personal patient data and provide decision support	

Title and Abstract Screen Guide

This screening will establish if the articles are to continue to full-text screening (medication management and IT)

1) Is this article an original[a] or review article[b]?
    a) If Yes, select and continue to Q2.
    b) If No, select and submit
    c) If Uncertain, select and continue to Q2.

2) Does the article relate to at least one step in the medication management process (prescribing/ordering, transmitting, order communication, administering, monitoring-patient or population, reconciliation or education)?
   a) If Yes, select and continue to Q3.
   b) If No, select and submit
   c) If Uncertain, select and continue to Q3.
3) If you answered yes above, which step(s) in the medication management process are involved (select all that are relevant)?
   a) Prescribing/ordering
   b) Transmitting
   c) Order communication (verification, transformation, and communication (perfecting))
   d) Administering
   e) Monitoring (patient or population)
   f) Medication reconciliation
   g) Patient education
4) Is a medication management process assisted by Health IT?
   a) If Yes, select and continue to Q4.
   b) If No, select and submit
   c) If Uncertain, select and continue to Q4.
5) Is this article relevant for background information (can be included or excluded articles)?
   a) Yes
   b) No
   c) Uncertain

Submit to move to the next article. If you have left a question unanswered and have not selected no or uncertain, the system will display an error and you will need to check for any unanswered questions.

[a]An original study is any full text article in which investigators report first-hand observations- quantitative or qualitative, except for case reports

[b]A review article is any full text article that indicates the intent is to review, summarize, highlight (or similar terms) the literature on a particular topic. This intent may be explicitly stated in the text of the article or it may be bannered as a review, overview or meta-analysis in the title or in a section heading. This may not be clear from the abstract.

(case reports, general and miscellaneous articles (no stated purpose, no methods, not bannered review anywhere), secondary publications and abstracts only are not considered original or review)

Full-Text Screening Guide

1) Does this article contain data (quantitative or qualitative; simulated or real patient)? Look for tables and graphs OR THE WORD QUALITATIVE. (qualitative research 'results' are text-based so there will be no numbers, BUT they will describe their methods as qualitative...they actually talk to people.
   a) Yes, continue
   b) No, exclude and go to next article
   c) Uncertain

2) Is the MM information technology integrated into an IT system? (If it is a stand-alone device or software that is not hooked into a MM system, then exclude). Integrated systems include EHRs, CPOE, CDSS, etc.
   a) Yes, continue
   b) No, exclude and go to next article
   c) Uncertain, continue

3) Which medication management phases are reported on? (Mandatory to answer this question, and can choose more than one).

If it's about patients taking drugs or someone deciding what/how much or =when to take a drug, then include it. If it is about using a system to make decisions about drugs then include it. Remember that MM includes the decision support in making prescribing decisions all the way through to medication reconciliation, post-marketing surveillance and patient monitoring/education.

   a) Medication management in general
   b) Prescribing/ordering
   c) Transmission, order communication
   d) Dispensing
   e) Administering
   f) Monitoring
   g) Education
   h) Reconciliation
   i) Uncertain
   j) None – exclude

4) Please classify the article to the relevant categories below (mandatory to answer this question, and can choose more than one). These correspond with the 5 Key Questions being addressed in the review
   a) Related to patient outcomes
   b) Deals with costs, benefits etc of the system
   c) Deals with values proposition to any of the users *(value issues that users consider when deciding to use the system "what benefit is there for me?")*
   d) Reports on system characteristics with related outcomes *(e.g. usability, validity, use, satisfaction etc)*
   e) Deals with issues relating to sustainability of the system *(maintenance, ...)*
   f) Reports on computerized decision support in medication management

Instructions for Key Questions algorithm to determine which KQ the article pertains to and if the article has comparison groups and is hypothesis driven to be applicable to KQ1.

1. First fill in the article UI and your initials at the top of the page.
2. Make sure the article fits our criteria thus far:
    a. It is about an integrated technology (EXCEPT for PDAs or insulin pumps-they need to take individual patient data and provide MM support) that enables the management of the medication process-across all phases
    b. It contains data from a study, which can be numerical (quantitative) or text data from a qualitative study where focus groups, delphi method, interviews etc were conducted and transcribed.
    c. **If the article is to be excluded, please state the specific failing (review article, no data, not integrated, not MM) and draw a line through the blue sheet.**
3. Start on the left-hand algorithm.
4. Does the study assess the values people consider when determining whether or not a particular application is useful to them? They must have data on this (qualitative or quantitative).
    a. These will likely be survey or interview studies with people's opinions, and can be patients, clinicians, pharmacists, hospital administrators etc.
    b. If yes, make sure you circle the KQ3 box.
    c. For **all** articles continue to the next question.
5. Does the study assess decisions to purchase, implement or use a system? They must have data on this (qualitative or quantitative).
    a. If yes, does it further describe the systems characteristics (such as proprietary, home-grown), or information about certification or conformity, or flexibility in the system (ability to customize) etc?
    b. If yes, make sure you circle the KQ4 box.
    c. For **all** articles continue to the next question.
6. Does the study discuss sustainability of the system? OR does the study report on a system that is proven sustainable, ie. it has been in use for 3+ years, in a real practice setting. Discussion of sustainability could include financial sustainability, maintenance and updating issues, adaptability of the system. It can relate to financial, technological, socio-political or organizational factors. They must have data on this (qualitative or quantitative).
    a. If yes, make sure you circle the KQ5 box.
    b. For **all** articles continue to the next question.
7. Does the study address the electronic communication between the clinician and the pharmacy? They must have data on this (qualitative or quantitative).
    a. If yes, make sure you circle the KQ6 box.
    b. For **all** articles continue to the **next algorithm**
8. Does the study measure one of the following? Please refer to the outcomes rubric for guidance. If you have an unusual measurement and you don't know where it falls, make a note of it at the bottom of the assessment page: (see table on p 3 for guidance)
        i. Process (about providing care)
        ii. Other outcomes (satisfaction, skills etc)

iii. Cost
iv. Clinical (patient related) outcomes
v. Population level (eg screening rates)
vi. Composite outcomes (are formed by combining individuals' scores on a collection of singular measures-usually in trials with a range of treatment effects)

b. If no, STOP and circle on the far right the KQ that are addressed by the study that you found in the left-column of the algorithm. If there are NO KQ addressed, make sure you give the article to Cynthia.
c. Indicate the methodology used in the box at the bottom of the blue page
d. If yes, continue

9. Does the study have a comparison group?
   a. Assess if it has a comparison group. This can be a different time-point, a before-after, a control group, another intervention group. But they must be comparing one set of data to another.
   b. If no, is the study qualitative? – If yes, circle KQ1 and continue to the bottom of the page and make a note in the outcomes section and methodology box.
   c. If NO, STOP and circle on the far right the KQ that are addressed by the study that you found in the left-column of the algorithm. If there are NO KQ addressed, make sure you give the article to Cynthia.
   d. If yes, continue
10. Is the study hypothesis driven? This means that they will state in their introduction the effect they think they will see based on their intervention, or they will statistically analyze/compare the groups. The presence of p-values or confidence intervals (CI) is another indicator that the study was hypothesis driven.
   a. If no, STOP and circle on the far right the KQ that are addressed by the study that you found in the left-column of the algorithm. **Please circle 'list for KQ1'.**
   b. If yes, continue
11. Does the article report on a CDSS (clinical decision support system) defined as: "Clinical Decision Support systems link health observations with health knowledge to influence health choices by clinicians for improved health care"—we need them to be computerized and providing health information related to medication management.
   a. If no, Circle KQ1. Also circle on the far right all of the KQ that are addressed by the study that you found in the left-column of the algorithm. Continue to the bottom of the page and make a note in the outcomes section and methodology box.
   b. If yes, continue
12. Is it a Randomized controlled trial?
   a. If no, Circle KQ1. Also circle on the far right all of the KQ that are addressed by the study. Continue to the bottom of the page and make a note in the outcomes section and methodology box.
   b. If yes, circle KQ7, and KQ1 and ensure that all KQs addressed by the study are indicated in the far right. Continue to the bottom of the page and make a note in the outcomes section and methodology box.

Outcomes: follow the outcomes table for guidance. Indicate with 1° the primary outcomes if the authors make the distinction.

Methods: Follow the methods algorithm to determine the methodology used in the study.

Broadly, we will categorize outcomes into the following categories. The table gives some specific measures/examples to help guide you. There will be measures that are difficult to classify. Please make a note at the bottom of the blue page.

<table>
<tr><th>Process</th><th>Other</th><th>Clinical</th></tr>
<tr><td rowspan="5">Errors
Error rates
Types of errors
Potential ADEs
Number of errors
Efficiency
Time related outcomes
Utilization of care
Provider time
Time to dispensing
Compliance/adherence
To guidelines
To order sets
Care related
Changes in prescribing decisions
Altering dosages
Changing preparation
Changing Rx pattern
Monitoring/surveillance
Change in test ordering
Inappropriate test ordering
Screening rates
Preventative care
Vaccinations
Population screening</td><td>Satisfaction/Usability

K/S/A
Knowledge
Skills
Attitudes
Usage

Other</td><td>Other clinical:
Infection rate
Length of stay
Compliance
Error effects:
Adverse Drug Events (ADE)
QoL
Physiological measures:
Hb1Ac
BP
INR</td></tr>
<tr><th>Cost</th><th>Population</th></tr>
<tr><td>Change in utilization
Costs
Length of stay assoc costs</td><td>Screening</td></tr>
<tr><th>Qualitative</th><th>Composite</th></tr>
<tr><td>Themes
Text excerpts</td><td>One index that encompasses a number of measures eg. risk assessment values etc.</td></tr>
</table>

Data Abstraction Form with Instructions

Data abstraction instructions
General Study Information:

Question	General Study Information	Options	Instructions
1.1	First Author	(text)	Type in the last name of the first author
1.2	Year of publication	(text)	enter the year of publication
1.3	What phase of medication management is being reported on?		can select more than 1
	Prescribing	CheckBox	The process of a clinician deciding and ordering a medication for a patient
	Transmission, order communication	CheckBox	The bi-directional communication of the prescription and it's fine-tuning between clinician and pharmacist. Includes electronic data exchange
	Dispensing	CheckBox	The preparation of the prescription in the pharmacy and getting it to the patient
	Administering	CheckBox	The patient taking the drug. Can be administered by nurse, other clinician, patient or caregiver.
	Monitoring including patient adherence and compliance	CheckBox	Monitoring of patient taking drug for adverse events, reactions, compliance, adherence, and efficacy. **Include lab monitoring or ordering of tests to monitor drug levels etc.**
	Education of patients and clinicians but not pre-professional education	CheckBox	Pre-professional education includes nursing, medical, dental etc students learning their profession--they are excluded. Interns and residents are included as well as patients. Need to include the issue of medication as well as education around taking and reviewing medications.
	Other e.g. discharge summaries. MM in general, etc	CheckBox	Discharge summaries are provided when the patient transitions from one level of care to another including home. For example, from the surgical ward to home or a nursing home. Reconciliation can go here as well where clinicians and patients check that lists of drugs for a particular patient is complete and up to date.
1.3.1	Specify Other	text box	
1.4	What is the country address of the first author?	Manual Text Entry	Please use: US, Can, UK, NL, Eur, Asia, Aus, NZ, other
1.5	Select funding information		This can usually be found just before the reference section or on the first page of the paper in small print, sometimes in the methods section.
	Internal funding	Radio--start off	This would be a statement that the division or group provided funding or if the study says things like "no external funding was used".
	External funding by grants, projects, contracts	Radio--start off	Funding section will indicate funding agency name
	External funding by industry, companies	Radio--start off	Funding section will indicate sponsoring company name
	Both internal and external	Radio--start off	

Question	General Study Information	Options	Instructions
	Not specified	Radio--start off	Use this when no funding information is provided in the paper.
	Other	Radio--start off	
1.5.1	Indicate Funding agency	textbox	Please note name of funding agency OR company
1.6	Is the article a general or systematic review summarizing a number of studies or the evidence on their question?	yes/no	If it is an original study, answer no. An original study reports first hand observations of a STUDY-having some kind of data. If this article is not about an original study, and it summarizes the evidence or is a systematic review with many studies included, then answer yes. If yes, STOP If no, continue to next question.
1.6.1	Is the article an original study, in which the authors report first hand observations, either qualitative or quantitative?	Yes/no.	
1.6.1.1	If the article is an original study, is it ONLY qualitative?	Yes/no	
1.6.1.1.1	If the article is an original study, is it ONLY quantitative? Does it report numerical findings?	Yes/no.	
1.6.1.1.1.1	Does the article reports mixed methods--both qualitative and quantitative?	Yes/no.	
1.6.1.2	Provide a clear description of the study, including all PICOM components	Open text	Here we need a very clear description of the study intervention, include the type of intervention(s), the groups involved. Try to be concise as possible. Often the aim of the study can help. Please include PICOM if possible (people, intervention, comparison, outcomes, method/design). Put this in paragraph form using 3-4 sentences.
1.6.1.3	Does the study have a comparison group	y/n	A comparison group can be the same population at a different time (e.g. before and after or time series), or it can be different groups of doctors (specialists vs. GPs etc) or it can be different groups of patient, different hospitals, clinic types, systems etc.
1.6.1.3.1	What is the intervention group being compared to?		
	Usual care	Checkbox	Pre-implementation or baseline would be considered usual care, where care has not changed from the usual
	A control group	Checkbox	This does not include the 'before' for a pre-post implementation study or baseline in a time series study.
	Another technology/system	Checkbox	
	Other	Checkbox	
1.6.1.3.1.1	Specify Other	text box	describe the other comparison groups here

Question	General Study Information	Options	Instructions
1.7	What is the study design?		
	RCT	Checkbox	"experimental design that studies the effect of an intervention or treatment using at least two groups: one that received the intervention and one that did not; participants **ARE** randomly assigned to a group (therapy, prevention)"
	Non-randomized trial	Checkbox	"experimental design that studies the effect of an intervention or treatment using at least two groups: one that received the intervention and one that did not; participants **ARE NOT** randomly assigned to a group (therapy, prevention)"
	Cohort study	Checkbox	Cohort study: involves establishing groups, often people, one of which is "exposed" (e.g. HIT) and one is not exposed. Both groups followed forward in time to determine if the outcomes of interest develop.
	Case control	Checkbox	A study where groups of people are formed, one of which has the outcome of interest (e.g. better prescribing) and one of which does not (not better prescribing). Often members in the groups are "matched" in relation to things like age or experience. People in both groups are evaluated to assess if the exposure of interest (e.g. EHRs) were present in the past.
	Time series	Checkbox	A study in which periodic measurements are obtained prior to, during, and following the introduction of an intervention or treatment in order to reach conclusions about the effect of the intervention. This usually has more than 2 time points. If only 2 points, 1 pre- and 1 post-implementation, then it is a before-after study.
	Before-after	Checkbox	A type nonrandomized study where data are collected before and after patients receive an intervention. Before-after studies can have a single arm where the before group is usual care or it can include a control group.
	Cross-sectional	Checkbox	involve observation of some subset of a population of items all at the same time, in which, groups can be compared
	Qualitative	Checkbox	Research that derives data from observation, interviews, or verbal interactions and focuses on the meanings and interpretations of the participants. Must say they are doing qualitative work-words like qualitative, themes, narrative, ethnography, phenomomology.
	Mixed methods	Checkbox	an approach to professional research that combines the collection and analysis of quantitative and qualitative data
	Case series	CheckBox	"A medical research study that tracks patients or other participants with a known exposure given similar treatment or examines their medical records for exposure and outcome."

Question	General Study Information	Options	Instructions
	Survey	CheckBox	A research method involving the use of questionnaires and/or statistical surveys to gather data about people and their thoughts and behaviors.
	Observational study	CheckBox	
1.8	Do you have any comments about the study/article not captured in the data?	text box	If there is something you cannot find/is wonky/you want to clarify etc. Use this comment box
1.9	Does this article have a companion(s)?	y/n	A companion is an article of the SAME study, with the SAME participants, that reports on different data. E.g. your article may have the economic data but they refer to another article reporting the clinical data. It does not include a study of the same system in the same setting but done with other patients/doctors/interventions.
1.9.1	if yes, provide the citation details:	text box	from the reference section, cut and past the reference for any companion article(s)

Study Population:

Question	Study Population	Options	Instructions
2.1	What is the primary unit of study and analysis? (select one of the following)		info: this is the unit they report their data/numbers and analysis on
	Health care providers	CheckBox	
	Patients	CheckBox	if they're measuring a patient's blood, ADEs, admissions --unhitching that happens to the patient, select this
	Institutions	CheckBox	
	IT Systems	CheckBox	
	Medications, prescriptions, orders	CheckBox	
	Geographic regions	CheckBox	
	Other	CheckBox	
2.1.1	Specify other (text)	text box	
	Not answered	CheckBox	
2.2	Are people being measured as the unit of study?	y/n	
2.2.1	Are clinicians being studies?	y/n	Who is being studied? Select as many groups as long as they represent at least 10% of the sample or data presented.
2.2.1.1	Please Select the types of clinicians being studied.		can select more than 1
	Physicians undifferentiated or cannot sort out	CheckBox	
	Primary care physicians/GPs, Family physicians	CheckBox	
	Specialists	CheckBox	
	Hospitalists	CheckBox	
	Other Physicians	CheckBox	

Question	Study Population	Options	Instructions
	Mid level practitioners (PAs, NPs, APN, midwives)	CheckBox	
	Nurses	CheckBox	
	Psychologists, counselors	CheckBox	
	Pharmacists	CheckBox	
	Dentists	CheckBox	
	Hospital administrators	CheckBox	
	Other health professionals	CheckBox	
2.2.2	Are caregivers being studied?	y/n	
2.2.3	Are patients being studied?	y/n	
2.2.3.1	Please select the types of patients being studied.		
	Infants (0 to 2 years)	CheckBox	
	Children (2 to 12)	CheckBox	
	Adolescents (13 to 18)	CheckBox	
	Adults (19 to 44)	CheckBox	
	Middle age (45 to 64)	CheckBox	
	Geriatric (65 plus)	CheckBox	
	Undifferentiated	CheckBox	
	Not Specified	CheckBox	
2.3	How many groups were studied?--not subgroups but original study groups e.g., number of groups randomized in an RCT or number of groups in a cohort study.	text box	How many groups were studied?--not subgroups but original study groups e.g., number of groups randomized in an RCT or number of groups in a cohort study.
2.4	Were the inclusion criteria given?	yes/no	Did they define the people/participants/population that was included in their sample?
2.4.1	What were the Inclusion criteria for the study (usually reported in the methods, copy and paste)	text box	copy and paste from methods when applicable
2.5	Were the exclusion criteria given?	yes/no	Did they define the people/ participants/population that were purposely EXCLUDED from their sample?
2.5.1	What were the exclusion criteria for the study (usually reported in the methods, copy and paste)	text box	copy and paste from methods when applicable

Setting:

Question	Setting	Options	Instructions
4.1	Did the study take place in a hospital?	y/n	(can select more than one setting)
4.1.1	Indicate the type(s) of hospital(s):		
	Acute care/tertiary	CheckBox	
	Critical care units (CCU, ICU, NICU)	CheckBox	
	Emergency department	CheckBox	
	General hospital	CheckBox	
	Palliative/hospice	CheckBox	
	Pediatric stand alone hospital	CheckBox	

Question	Setting	Options	Instructions
	Other specialty hospital (rehab, oncology)	CheckBox	
	Not specified	CheckBox	
	Do the authors report the number of beds?	y/n	
4.1.2.1	How many beds were reported?	text box	This should be the total of the beds for a multiple hospital study
4.2	Select any other settings in which the study took place:		
	Ambulatory care (clinic, doctor's office, etc.)	CheckBox	
	Long term care (nursing homes)	CheckBox	
	Home	CheckBox	
	Community (school, community centre, etc.)	CheckBox	
	Pharmacy	CheckBox	
	None	CheckBox	
	Other	CheckBox	
4.2.1	Specify Other	text box	
	Not specified	CheckBox	
4.3	Is there a pharmacy involved?	y/n	A pharmacy or pharmacist must be directly involved in the study. (can select more than one).
4.3.1	Specify the type(s) of pharmacy:		
	Inpatient hospital based	CheckBox	An inpatient pharmacy is located in a hospital and is the pharmacy system that serves patients while they are hospitalized--usually patients who are staying overnight in the hospital.
	Outpatient hospital based	CheckBox	This pharmacy is located in a hospital but provides drugs for those patients who are not hospitalized overnight.
	Other institution based	CheckBox	For example, in a nursing home setting.
	HMO pharmacy	CheckBox	
	Veterans Affairs Pharmacy	CheckBox	
	Pharmacy chain	CheckBox	
	Stand alone non chain store (e.g. family run)	CheckBox	
	Health insurance company based and Pharmacy Benefit Management (PBM) pharmacies	CheckBox	
	Other mail/email in pharmacies	CheckBox	
	Nuclear pharmacies (radioactive drugs)	CheckBox	
	Compounding pharmacies (*those that produce their own products using various chemicals and binders)*	CheckBox	
	Not specified	CheckBox	
	Other	CheckBox	
4.3.1.1	Specify other	text box	
4.4	Was the study conducted in an academic setting? Answer yes if at least 1 setting was academic e.g. University Hospital.	y/n/uncertain	look for names of Universities, or 'academic hospital' ,' teaching hospital', "university hospital" etc

Diseases/Drugs studied:

Question	Drug/disease	Options	Instructions
3.1	Were any disease(s) or condition(s) studied?	y/n	they might not 'measure' the disease, but if they are looking at a specific population of patients with a certain disease or the intervention is to improve treatment for a certain disease, then select this. E.g. flu vaccines =flu; diabetes PHR=diabetes; CDSS for DVT prevention=DVT
3.1.1	Please indicate information about the disease(s)/condition(s) studied:		
	All diseases and conditions	Radio--start off	articles that don't specify a condition but is about MM in any patient
	One disease or condition	Radio--start off	Articles specifically patients with 1 condition e.g. cancer, hypertension etc
	Not answered	Radio--start off	Articles that are not focused on patient MM e.g. articles about systems, settings etc
3.1.1.1	Which disease was specified		
	Asthma	Radio--start off	
	Diabetes	Radio--start off	
	Heart diseases	Radio--start off	
	Deep venous thrombosis, pulmonary embolism, other clotting issues	Radio--start off	
	Depression/schizophrenia/all mental health	Radio--start off	
	Other	Radio--start off	
3.1.1.1.1	Specify Other	text box	
3.2	Were certain drugs or classes of drugs the focus of the study?	y/n	the study must focus on certain drugs or classes of drugs rather than MM in general
3.2.1	Specify the drugs, classes or families of drugs	textbox	
3.2.2	Were the drugs		
	Toxic drugs/drugs with narrow therapeutic index (e.g. warfarin, digoxin)	Radio--start off	
	Controlled substance	Radio--start off	
	Both	Radio--start off	
3.2.2.1	Indicate the controlled substance:	text box	
	None of the above	Radio--start off	
	Not answered	Radio--start off	
3.2.3	Did the article focus on generic vs. brand names of drugs	y/n	
3.2.3.1	Indicate which drugs	text box	
3.2.4	Did the article focus on sound-alike or look-alike drugs?	y/n	
	Indicate which drugs	text box	
3.3	Did the article report on the preparation of a drug (the form in which it is administered)?	y/n	(can select more than one)
3.3.1	Indicate the preparations included:		
	Oral	CheckBox	

Question	Drug/disease	Options	Instructions
	Intravenous	CheckBox	
	Injection	CheckBox	
	Inhaled	CheckBox	
	Parenteral	CheckBox	
	Topical	CheckBox	
	Rectal	CheckBox	
	Not Specified	CheckBox	
	Other	CheckBox	
3.3.1.1	Specify Other	TextBox	

The technology:

Question	Technology	Options	Instructions
5.1	Please indicate the nature of the producer of the Health IT system used:		Health IT systems can be built by various people or groups. Early ones were built by an individual clinician who could program personal computers. Modern ones are often built/developed by commercial companies such as GE or Seimans. (can select more than one)
	Commercial	CheckBox	Is it a company--often for profit companies
	Home grown	CheckBox	Was it developed by those who are using it--e.g. by clinicians on the wards or by others working under clinicians, such as onsite programmers.
	Both	CheckBox	Can be a mix of commercial and home grown. Often a system might be started by an individual or group of individuals in a hospital or ward and when it shows promise and needs further development a commercial company may take over development and production of the system.
	Not specified	CheckBox	Check this if the article does not say who developed the system.
	Other	CheckBox	This could be a non-profit organization such as the World Health Organization.
5.1.1	specify other	text box	
5.2	Please indicate the nature of the MMS used:		(can select more than one). This question is designed to look at the “ownership” issue in relation to the MMS. For example, is it Open Source so anyone can implement the system. (can select more than one)

Question	Technology	Options	Instructions
	Open source	CheckBox	From: Wikipedia. Software whose source code is published and made available to the public, enabling anyone to copy, modify and redistribute the source code without paying royalties or fees. Open source code evolves through community cooperation. These communities are composed of individual programmers as well as very large companies. Some examples of open source initiatives are Linux, Eclipse, Apache, Tomcat web server, Mozilla, and various projects hosted on SourceForge and elsewhere. For eHealth, one of the most prevalent is OSCAR for EHRs
	Proprietary-commercial	CheckBox	A commercial company "owns" the software and users need to buy or lease the product and its code
	Proprietary-academic	CheckBox	An academic institution "owns" the software/ product and users need to buy or lease the product and its code.
	Not Specified	CheckBox	Check yes if not specified
	Other	CheckBox	Should be very few of these…
5.2.1	Specify Other	text box	
5.3	What kind of conformity standards did the MMS meet (can select more than 1)		MMSs must "interact" or integrate with many other information systems. Standards need to be implemented to insure that when the systems interact/interoperate they both function accurately and efficiently. MMSs that will be used by multiple users in multiple settings need to be developed based on standards. These standards can come from the computing, health, business, etc communities. HL7 is one often encountered standard. A good hint on the presence of standards will be the use of CAPITALS to describe things like standards and conformity. (can select more than one)
	Not specified	CheckBox	You will see this most often in articles.
	Local	CheckBox	This would be hospital wide system conformity with local standards and local IT and MMS components, systems.
	State/provincial	CheckBox	Some state/provincial standards exist. Most will be National although some like the BC, MB, AB, and ON HISC (Health Information Standards Council) standards exist.
	National-US	CheckBox	National standards include ANSI (American National Standards Institute) standards, HIPPA, PHIPPA

Question	Technology	Options	Instructions
	National-other	CheckBox	You may need to list stuff here. the UK, Australia, the Netherlands, Canada have National standards in place.
	International	CheckBox	Groups like ISO and HL7 go here
	Certification Commission for Healthcare Information Technology (CCHIT)	CheckBox	This is a US based standard and is one that needs to be addressed by the final report.
	Other	CheckBox	
5.3.1	Specify other	text box	
5.4	Did the system have a specific name?	y/n	
5.4.1	If so, What was the name of the MMS used?	text box	What was the system called?
5.5	Did the MMS system replace an existing system?	Yes/No/don't know	
5.6	What kind of MMS system is being studied in the article? Can select more than 1		Select the kind of system(s) used in the article. (can select more than one)
	Bacoding-medication administering	CheckBox	
	Bacoding-dispensing	CheckBox	
	eMedication administration system (eMAR, eTAR)	CheckBox	
	CPOE/POE system	CheckBox	
	CDSS/CDS/CCDS/reminders	CheckBox	
	Eprescribing	CheckBox	
	eTransmission-of the prescription to/from doctor to pharmacy	CheckBox	
	AMDD anesthesia medication dispensing system	CheckBox	
	Pharmacy information system	CheckBox	
	None	CheckBox	
	Other	CheckBox	
5.6.1	Specify Other	text box	
5.7	Is the system described as:		can select more than 1
	Stand alone	CheckBox	
	Integrated with another system or set of systems	CheckBox	
	a PDA/handheld access	CheckBox	
	Not Specified	CheckBox	
	Other	CheckBox	
5.7.1	specify other	text box	
5.8	What other system(s) is the MMS integrated with? (can select more than 1)		can select more than 1. A strong (i.e. effective) MMS will integrate (i.e. talk to) multiple other systems. We need to know which systems that the MMS is integrated with.
	EHR/EMR system	CheckBox	
	Personal health records systems	CheckBox	
	CPOE/POE system	CheckBox	
	CDSS/CDS/CCDS/reminders	CheckBox	
	Billing/administration system	CheckBox	
	Laboratory system	CheckBox	
	Imaging systems	CheckBox	
	Patient decision support system	CheckBox	
	Pharmacy	CheckBox	

Question	Technology	Options	Instructions
	Formulary	CheckBox	
	Insurance	CheckBox	
	Barcoding system	CheckBox	
	Hospital information system	CheckBox	
	Other	CheckBox	
5.8.1	Specify Other	text box	
	not specified	CheckBox	
5.9	Is the MMS web-based?		
	Fully we based	Radio--start off	
	Partly web based	Radio--start off	
	Not web based (internal system)	Radio--start off	
	not reported	Radio--start off	
5.10.	What kind of computer equipment does the system use?		can select more than 1
	PCs for clinicians-including COWs (computers on wheels)	CheckBox	
	PCs for patients	CheckBox	
	PDAs for clinicians	CheckBox	
	PDAs for patients and caregivers	CheckBox	
	Touchscreens for clinicians	CheckBox	
	Touchscreens for patients and caregivers	CheckBox	
	Mobile carts	CheckBox	
	Kiosks	CheckBox	
	Robots	CheckBox	
5.10.1	Other	text box	
	Not Specified	CheckBox	
5.11	What is the source of patient data for processing by the technology?		Where does the patient data come from that is used by the IT system? can select more than one. (can select more than one)
	EHRs/EMRs	CheckBox	
	Other internal-e.g. lab data, pharmacy records, PHRs	CheckBox	
	Third party vendor-e.g.. insurance database	CheckBox	
	Personal health records systems	CheckBox	
	Medical devices such as glucometers	CheckBox	
	Manual entry	CheckBox	
	Not specified		
5.12	When was the system implemented	text box for date/not reported	enter the date of original implementation of the original system. Note the system could have been built upon and developed since that date. Month/year 00/0000
5.13	What was the start date of the study?	text box for date/not reported	enter the Month/year the study began. 00/0000
5.14	What was the end data of the study?	text box for date/not reported	enter the Month/year the study ended. 00/0000. for a survey, beginning and end date often the same
5.15	Was the system in use for more than 3 years?	y/n/can't determine	Is end of study date at least 3 years since the initial implementation?

Outcomes:

Question	Outcomes	Options	Instructions
7.1	Did the authors clearly declare their primary outcome?	y/n	
7.2	What was the sample size of the study?	text box for number	
7.3	What was the unit for the sample size?	text box	
7.4	Were costs associated with the use of the MMIT system assessed?	y/n	
7.4.1	State the costs in as much detail as possible.	text box	
7.5	Were adverse effects of the HIT assessed?	yes/no/ unstated/	this would be a separate measurement of any negative impact of the technology on the MM process. Unintended consequences could be 1 example. See article 37. A negative effect on your primary outcome does NOT go here.
7.5.1	State the findings, including any assessment of clinical impact/relevance. State the findings in terms of % change among comparison groups, for the primary outcome only.	text box	if not statistically analyzed do not include this here
7.5.2	What was the p value of the analysis above?	options: ns/ $p<.05/P<.001$	
7.6	Were the impacts of the MMIT on PROCESS outcomes measured?	y/n	report only on the primary outcome, or if not clear, then abstract the medication management outcomes. Process outcomes are associated with the care given to patients, relating to errors, efficiencies, adherence to guidelines, prescribing changes, monitoring of patients e.g. labs, ordering preventative care etc.
7.6.1	Indicate the process outcomes measured:		
	Errors	checkbox	
	Efficiency	checkbox	
	Adherence/compliance with guidelines	checkbox	
	Changes in prescribing patterns	checkbox	
	Changes in monitoring/surveillance activities (e.g. lab test ordering)	checkbox	
	Preventative care	checkbox	
	Other	checkbox	
7.6.1.1	Specify other	text box	
7.6.2	State the general findings for process outcomes	text box	provide a general statement about the process outcomes results. Include details such as …a reduction in inappropriate prescribing, less time to administration, etc.
7.6.3	Define outcome 1-usually the primary outcome	text box	the primary outcome is the one of most importance. Primary outcome can be determined by the aim/objective/ purpose or if there is a power calculation for it or if they say it is the 1° outcome

Question	Outcomes	Options	Instructions
7.6.4	provide RRR statement-outcome 1	text box	% vs. %, RRR, p
7.6.5	Was there a second outcome?	y/n	what was the second outcome/sequential important outcome
7.6.5.1	Define outcome 2	text box	% vs. %, RRR, p
7.6.5.2	Provide RRR statement-outcome 2	text box	% vs. %, RRR, p
7.6.5.3	Was there a third outcome?	y/n	what was the third outcome/sequential important outcome
7.6.5.3.1	Define outcome 3	text box	% vs. %, RRR, p
7.6.5.3.2	Provide RRR statement-outcome 3	text box	% vs. %, RRR, p
7.6.5.3.3	Was there a fourth outcome?	y/n	what was the fourth outcome/sequential important outcome
7.6.5.3.3.1	Define outcome 4	text box	% vs. %, RRR, p
7.6.5.3.3.2	Provide RRR statement-outcome 4	text box	% vs. %, RRR, p
7.6.5.3.3.3	Was there fifth outcome?	y/n	what was the fifth outcome/sequential important outcome
7.6.5.3.3.3.1	Define outcome 5	text box	% vs. %, RRR, p
7.6.5.3.3.3.2	Provide RRR statement-outcome 5	text box	% vs. %, RRR, p
7.6.6	Was the PROCESS outcome improved on the primary outcome measure (or more that 50% of the measures of process were improved if no primary outcome measure indicated)	y/n	
7.7	Were the impacts of the MMIT on 'OTHER' outcomes measured?	y/n	Again, the "other" outcome must be the primary outcomes, or if not indicated, related to medication management.
7.7.1	Indicate the 'other' outcomes measured:		
	Use/usage	checkbox	
	Knowledge/skills/attitude	checkbox	
	Satisfaction	checkbox	
	Usability	checkbox	
	Other	checkbox	
7.7.1	Specify Other	text box	
7.7.2	State the general findings for other outcomes	text box	
7.7.3	Define outcome 1 - usually the primary outcome	text box	What was the primary outcome/most important outcome
7.7.4	Provide RRR statement-outcome 1	text box	% vs. %, RRR, p
7.7.5	Was there a second outcome?	y/n	
7.7.5.1	Define outcome 2	text box	What was the second outcome/sequential important outcome
7.7.5.2	Provide RRR statement-outcome 2	text box	% vs. %, RRR, p
7.7.5.3	Was there a third outcome?	y/n	
7.7.5.3.1	Define outcome 3	text box	What was the third outcome/sequential important outcome

Question	Outcomes	Options	Instructions
7.7.5.3.2	Provide RRR statement-outcome 3	text box	% vs. %, RRR, p
7.7.5.3.3	Was there a fourth outcome?	y/n	
7.7.5.3.3.1	Define outcome 4	text box	What was the fourth outcome/sequential important outcome
7.7.5.3.3.2	Provide RRR statement-outcome 4	text box	% vs. %, RRR, p
7.7.5.3.3.3	Was there a fifth outcome?	y/n	
7.7.5.3.3.3.1	Define outcome 5	text box	What was the fifth outcome/sequential important outcome
7.7.5.3.3.3.2	Provide RRR statement-outcome 5	text box	% vs. %, RRR, p
7.7.6	Was the other outcome improved on the primary outcome measure (or more that 50% of the measures of process were improved if no primary outcome measure indicated)?	yes/no/not tested	
7.8	Where the impacts of MMIT on patient CLINICAL outcomes measured?	y/n	This would apply for studies where patients are the unit of study. Measurements could be physiological e.g. blood pressure, Hb1ac etc, or adverse events, length of stay, mortality, quality of life etc. Again, the "other" outcome must be the primary outcomes, or if not indicated, related to medication management.
7.8.1	Indicate the patient clinical outcomes measured:		
	Physiological measure	checkbox	
	Adverse drug events	checkbox	
	Length of stay	checkbox	
	Mortality	checkbox	
	Quality of Life	checkbox	
	Other patient events	checkbox	List anything else here that would be important (i.e. felt or appreciated) by patients including things like improved conception rates.
	Other	checkbox	
7.8.1.1	Specify Other	text box	
7.8.2	State the general findings for the patient clinical outcomes	text box	
7.8.3	Define outcome 1-the primary outcome	text box	The primary outcome is the one of most importance. Primary outcome can be determined by the aim/objective/ purpose or if there is a power calculation for it or if they say it is the 1° outcome
7.8.4	Provide RRR statement-outcome 1	text box	% vs. %, RRR, p
7.8.5	Was there a second outcome?	y/n	
7.8.5.1	Define outcome 2	text box	What was the second outcome/sequential important outcome
7.8.5.2	Provide RRR statement-outcome 2	text box	% vs. %, RRR, p
7.8.5.3	Was there a third outcome?	y/n	

Question	Outcomes	Options	Instructions
7.8.5.3.1	Define outcome 3	text box	What was the third outcome/sequential important outcome
7.8.5.3.2	Provide RRR statement-outcome 3	text box	% vs. %, RRR, p
7.8.5.3.3	Was there a fourth outcome?	y/n	
7.8.5.3.3.1	Define outcome 4	text box	What was the fourth outcome/sequential important outcome
7.8.5.3.3.2	Provide RRR statement-outcome 4	text box	% vs. %, RRR, p
7.8.5.3.3.3	Was there a fifth outcome?	y/n	
7.8.5.3.3.3.1	Define outcome 5	text box	What was the fifth outcome/sequential important outcome
7.8.5.3.3.3.2	Provide RRR statement-outcome 5	text box	% vs. %, RRR, p
7.8.6	Was the CLINICAL outcome improved on the primary outcome measure (or more that 50% of the measures of process were improved if no primary outcome measure indicated)	y/n	
7.9	Where the impacts of MMIT on population level outcomes measured?	y/n	Again, the population outcome must be the primary outcomes, or if not indicated, related to medication management.
7.9.1	How was this measured?	text box	
7.9.2	What did the study conclude?	text box	
7.10.	Where the impacts of MMIT on composite outcomes measured?	y/n	Again, the composite outcome must be the primary outcomes, or if not indicated, related to medication management.
7.10.1	How was this measured?	text box	
7.10.2	What did the study conclude?	text box	
7.11	Did the study address decisions to buy/implement or use for any of the stakeholders?	y/n	
7.11.1	How was this measured?	text box	Include the measurement and method
7.11.2	What did the study conclude?	text box	
7.12	Did the study address values propositions for any of the stakeholders?	y/n	
7.12.1	How was this measured?	text box	
7.12.2	What did the study conclude?	text box	
7.13	Did the qualitative study produce codes or themes?	y/n	
7.13.1	Describe the resulting codes/themes	text box	
7.13.2	What did the study conclude?	text box	
7.14	Was the study about electronic communication between physicians and pharmacists?	y/n	
7.14.1	How was this measured?	text box	
7.14.2	What did the study conclude?	text box	

Methods Quality Assessment:

Question	Methods Assessments	Options	Instructions
6.1	the study contains quantitative data?	yes/no	if yes, continue to next question, if no, no need to complete this form
6.1.1	Is the quantitative study a Randomized controlled trial?	Yes/no	Is the quantitative study a Randomized controlled trial? [info button “experimental design that studies the effect of an intervention or treatment using at least two groups: one that received the intervention and one that did not; participants ARE randomly assigned to a group (therapy, prevention)”].
6.1.1.1	1. Was the assignment to the treatment groups really random?	Yes/no.	look for methods of randomization (random number generator, coin flip etc)
6.1.1.2	2. Was the treatment allocation concealed?	Yes/no.	This means that the people involved in getting the people into the study did not have any information or knowledge of what group the person might be going into. Look for things like:
6.1.1.3	3. Were the groups similar at baseline in terms of prognostic factors?	Yes/no.	did the groups have similar characteristics at baseline?
6.1.1.4	4. Were the eligibility criteria specified?	Yes/no.	Were there clear criteria for inclusion/exclusion for the study population?
6.1.1.5	5. Were outcome assessors blinded to the treatment allocation?	Yes/no.	Were the people measuring or analyzing data blinded to what groups the data came from?
6.1.1.6	6. Was the care provider blinded?	Yes/no.	Did the clinician know what group the study sample belonged to?
6.1.1.7	7. Was the patient blinded?	Yes/no.	(were the people blinded to the group they were in?)
6.1.1.8	8. Were the point estimates and measure of variability presented for the primary outcome measure?	Yes/no.	This is a 2 part question. The first--point estimates means that we have some sort of summary number like average minutes per prescription or rate of errors with the new/old system. The second issue is the measure of variability. Look for SDs (standard deviation measures usually in the form of mean 20 minutes per patient +-23 cm) or confidence intervals--for example mean 24 minutes (95% CI 21 to 25 minuets).
Not asked	9. Did the analyses include an intention to treat analysis	Yes/no.	Look for the phrase “Intention to treat” or ITT. It refers to analyzing people as they were randomized. For example patients allocated to surgery would be analyzed within the surgery group even if they had been too sick, say, to get the surgery and got the drug instead).
	Sum quality score from the above 8 questions	(automatic summation of 9 items “yes”)	[don’t worry about this]
6.1.2	If not an RCT, does the article report a cohort study?	Yes/No	Cohort study: *involves establishing groups, often people, one of which is “exposed” (e.g. HIT) and one is not exposed. Both groups followed forward in time to determine if the outcomes of interest develop.*
6.1.2.1	1. Is there sufficient description of the groups and the distribution of prognostic factors?	Yes/no.	This question should be answered yes if you see a table of data on the study participants, usually Table 1 at the front end of the article.

Question	Methods Assessments	Options	Instructions
6.1.2.2	2. Are the groups assembled at a similar point in their disease progression?	Yes/no.	This question only applies to studies of people who have a condition. The question needs to state how long the people in each of the groups had the disease or condition in question--e.g. the mean number of years since diagnosis.
6.1.2.3	3. Is the intervention/treatment reliably ascertained?	Yes/no.	Is there a description of the medication management or health information technology--answer yes if more than a paragraph on each.
6.1.2.4	4. Were the groups comparable on all important confounding factors?	Yes/no.	Again look for data in Tables that gives data on how comparable the groups were.
6.1.2.5	5. Was there adequate adjustment for the effects of these confounding variables?	Yes/no.	You will not likely see this information as it refers to adjustment in the analyses. Look for terms like adjustment, adjusted, regression analyses.
6.1.2.6	6. Was a dose-response relationship between intervention and outcome demonstrated?	Yes/no.	You will not likely find this information so say no.
6.1.2.7	7. Was outcome assessment blind to exposure status?	Yes/no.	This means that the people analyzing/assessing the data don't know which group the data came from –that way they are not biased thinking that people in this group should do better than the other group
6.1.2.8	8. Was follow-up long enough for the outcomes to occur?	Yes/no.	Use common sense here--for example, were the errors assessed say within the first month, or 6 months of implementing a new system. Say no if there is not time for the intervention (or new system) to have an effect on the situation.
6.1.2.9	9. Was the proportion of follow-up >80%?	Yes/no.	This question is looking for an assessment of the number of people who were initially enrolled into the study AND the number who were available for assessment at the end of the study. Also called follow up rate or proportion or just follow up.
6.1.2.10	10. Were drop-out rates and reasons for drop-out similar across intervention and unexposed groups?	Yes/no.	This question is asking "why" did people drop out or why they were "lost" to the study.
	Sum quality score for above 10 questions	(automatic summation of 10 items "yes")	[this will not show in the interface, but be done by the computer system independently)
6.1.3	If not an RCT or cohort study, does the article report on a case control study?	Radio--start off	Case control study: *A study where groups of people are formed, one of which has the outcome of interest (e.g. better prescribing) and one of which does not (not better prescribing). Often members in the groups are "matched" in relation to things like age or experience. People in both groups are evaluated to assess if the exposure of interest (e.g. EHRs) were present in the past.*
6.1.3.1	1. Is the case (people with the outcome) definition explicit?	Yes/no.	See the question and methods section to ascertain if the people who are the cases (e.g. those with errors in prescriptions) are described.

Question	Methods Assessments	Options	Instructions
6.1.3.2	2. Has the disease state of the cases been reliably assessed and validated?	Yes/no.	If a disease or disorder mentioned, did they tell how it was ascertained--often using rules or standard definitions.
6.1.3.3	3. Were the controls randomly selected from the source of population of the cases?	Yes/no.	This is often hard to tell. Look for the word "random" or some mention of how the controls were selected. Often this will be no.
6.1.3.4	4.How comparable are the cases and controls with respect to potential confounding factors?	Yes/no.	Look for Table 1 or in the first paragraph of the results section. If some information on the comparability of the groups is listed answer yes.
6.1.3.5	5. Were interventions and other exposures assessed in the same way for cases and controls?	Yes/no.	Were measurements taken the same for the controls and the case groups?
6.1.3.6	6. How was the response rate defined?	Yes/no/n/a	Not applicable
6.1.3.7	7. Were the non-response rates and reasons for non-response the same in both groups?	Yes/no/n/a	Not applicable
6.1.3.8	8. Is it possible that over-matching has occurred in that cases and controls were matched on factors related to exposure?	Yes/no/n/a	Not applicable
6.1.3.9	9. Was an appropriate statistical analysis used (matched or unmatched)?	Yes/no/n/a	Not applicable
	Sum score	(automatic summation of 9 items "yes")	[this will not show in the interface, but be done by the computer system independently)
6.1.4	If not an RCT, cohort study or case control, does the article report on a case series?	Radio--start off	If not an RCT, cohort study or case control, does the article report on a case series?[info button "a medical research study that tracks patients with a known exposure given similar treatment or examines their medical records for exposure and outcome."]
6.1.4.1	1. Is the study based on a representative sample selected from a relevant population?	Yes/no.	Answer yes if the article explains why and how these cases were chosen.
6.1.4.2	2. Are the criteria for inclusion explicit?	Yes/no.	Answer yes if they list what the criteria for choosing the sites listed?
6.1.4.3	3. Did all individuals enter the survey at a similar point in their disease progression?	Yes/no.	Answer yes if a disease is present and they provide any information on how long the disease had been diagnosed.
6.1.4.4	4. Was follow-up long enough for important events to occur?	Yes/no.	Likely not applicable .
6.1.4.5	5. Were outcomes assessed using objective criteria or was blinding used?	Yes/no.	The outcomes such as error rates need to be assessed in a blinded manner to suit methodologists. Look for the terms blind:, mask:, placebo:, etc.
6.1.4.6	6. If comparisons of sub-series are being made, was there sufficient description of the series and the distribution of prognostic factors?	Yes/no .	Answer yes if any information is given. If the analysis of the cases was down broken down into subcategories, such as men and women, children and adolescents, young or old….

Question	Methods Assessments	Options	Instructions
	Sum score	(automatic summation of 6 items "yes")	[[this will not show in the interface, but be done by the computer system independently)
6.1.5	If not any of the above, is this a before-after study?	Yes/No	A before-after study will have measures taken before and after implementation of a change.
6.1.6	If not any of the above, is the study a time-series?	Yes/No	
6.1.7	If not any of the above, is this an observational study? (can include a case study with data, survey etc).	Yes/No	An observational study is one where the researchers have no control over exposures and instead observe what happens to groups of people.

Appendix C. Evidence Tables

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Abboud (2006) (Abboud et al. 187-198) Design: Before-after N = 336 orders Implementation: 04/2002 Study Start: 10/2003 Study End: 03/2004	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders EHR/EMR system, Formulary, Hospital information system, Imaging systems, Laboratory system, Pharmacy	Pediatric stand alone hospital, 423 Beds	antibiotics courses with no lab order*	no significant differences between the baseline and the corollary order periods on courses of antibiotics associated with no laboratory monitoring 31 (19.5%) vs. 31(17.5%), p = NS.	-

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: A1c = hemoglogin A1c; ACE = Angiotensin Converting Enzyme; ACEI = Angiotensin-Converting Enzyme Inhibitor; ADEs = Adverse Drug Events; ALT = Alanine Aminotranceferase; AMI = Acute Myocardial Infarction; AR = Absolute Reduction; ARB = Angiotensin-II-Receptor Blocker; ARI = Acute respiratory infection; AST = Aspartate Aminotransferase; CC = Care Considerations; CCDS = Computerized Clinical Decision Support; CDS = Clinical / Computerized Decision Support; CDSS = Clinical Decision Support System; CHF = Congestive Heart Failure; CI = Confidence interval; CIT = Clinical information technology; COPD = Chronic Obstructive Pulmonary Disease; CPG = Clinical Practice Guidelines; CPOE = Computerized Provider Order Entry; DDI = Drug-drug Interaction; DS = Decision Support; DSS = Decision Support System; ED = Emergency Department; EHR = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; EP = Electronic Prescribing; e-RX = Electronic Prescribing; e-TAR = Electronic Treatment Authorization Request; GP = General Practitioner; h = Hour; HIT = Health Information Technology; HIV = Human Immunodeficiency Virus; hr = Hour; hrs = Hours; ICU = Intensive Care Unit; K = Potassium; LVSD = Left Ventricular Systolic Dysfunction; ME = Medication Error; Mg = Magnesium; min = Minute; MMR = Measles; Mumps and Rubella; N = Sample Size; n/a = Not Applicable; Np = Nurse Practitioner; NR = not reported; NS = NS; NSAID = Nonsteroidal anti-inflammatory drug; NSAIDS = Nonsteroidal anti-inflammatory drugs; OR = Odds ratio; OSUH = Ohio State University Health System; p = Probability; PCA = Patient-Controlled Analgesia; PDA = Personal Digital Assistants; PICU =; Pediatric Intensive Care Unit; POE = Provider Order Entry; PONV = Postoperative Nausea and Vomiting; PRN = *pro re nata;* RCT = Randomized Controlled Trial; RR = Relative Risk; RRR = Relative Risk Reduction; RV = rule violation; UDDS = Unit Dose Drug Dispensing System; UTI = Urinary tract Infection; vs. = Versus; VTE = Venous Thromboembolism

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Achtmeyer (2002) (Achtmeyer, Payne, and Anawalt 277-281) Design: Before-after N = 1,405 orders for supplemental insulin Implementation: 12/1998 Study Start: 12/1998 Study End: 07/1999	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/ tertiary, 290 Beds Academic	rate of traditional sliding scale orders for supplemental insulin*	rate of traditional sliding scale orders for supplemental insulin in hospitalized patients was reduced when a quick-order CPOE/CDSS system was put in place (97.1% vs. 63.8%, RRR 34%, p <0.001).	+
Agostini (2007) (Agostini, Shang, and Inouye 43-48) Design: Before-after N = 24,509 patients Implementation: 04/2002 Study Start: 04/2002 Study End: 03/2003	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Formulary	Acute care/tertiary, 944 Beds Academic	rate of prescribing of sedative-hypnotics*	Prescribing of sedative-hypnotics decreased from 2,208 per 12,356 (18%) patients preintervention to 1,832 per 12,153 (15%) postintervention (OR for the intervention = 0.82, 95% CI = 0.76–0.87), an 18% risk reduction (p <0.001 for pre/post difference).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Ali (2005) (Ali et al. 110-114) Design: Before-after N = 91 patients Implementation: 02/2000 Study Start: 05/2000 Study End: 05/2002	**CPOE/POE system**	Critical care units (CCU, ICU, NICU) 25 Beds Academic	mean number of orders for vasoactive drips per patient, mean number of orders for sedative infusions per patient	Compared to the initial CPOE, the redesign of the CPOE system to incorporate more complex order sets resulted in significantly fewer orders placed per patient (means) for vasoactive drips (4.8 vs. 2.2, p <0.01) and sedative infusions (6.4 vs. 2.9, p <0.01), as a measure of improved workflow efficiency.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Bailey (2007) (Bailey et al. 586-590). Design: RCT N = 853 patients Implementation: 00/0000 Study Start: 02/2000 Study End: 05/2001	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system, Laboratory system	Acute care/tertiary, 1,385 Beds Inpatient hospital based, Academic	compliance rates: - patients discharged on a full complement regimen of secondary prevention medications* -ACE inhibitor*, -statins*, -aspirin -beta-blockers.	When individual drug class exclusions were considered, compliance rates increased for patients discharged on a full-complement regimen of secondary prevention medications (70.3% vs. 83.6%, RRR - 19%, p <0.001). Compliance rates for ACE inhibitor (83.6 vs. 89.9, RRR - 8%, p = 0.01) and statin use (89.3 vs. 94.2%, RRR - 5%, p = 0.02) were significantly higher, while rates for aspirin (96.5% vs. 96.4%, RRR 0%, p = 0.95) and beta-blockers (91.8% vs. 95.9%, RRR - 5%, p = 0.08) remained the same.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Bates (1999) (Bates et al. 313-321) Design: Time series N = 1,817 admissions Implementation: 05/1993 Study Start: 10/1992 Study End: 04/1997	**CDSS/CDS/CCDS/ reminders** Integrated Billing/administration system Hospital information system	Acute care/tertiary 700 Beds Academic	Rate of non-missed dose errors per 1,000 patient-days over 4 time periods*, Rate of non-missed dose errors per admission*	The rate of errors (other than missed dose) per 1000 patient-days fell from baseline across all time points for medication errors: non-missed-dose medication errors (142, 51.2, 74, 2666; p = 0.0001). The results were similar for non-missed-dose error rate per admission (0.64, 0.27, 0.28, 0.11, p = 0.0001). Non-intercepted serious medication errors declined significantly over time (7.6, 7.3, 1.7, 1.1, p = 0.0003).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Bates (1994) (Bates, Boyle, and Teich 996) Design: Before-after N = 62 Physicians (Medical Interns and 1st and 2nd year surgical residents) Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CPOE/POE system** Integrated Hospital information system	Unspecified Hospital	Time spent ordering by medical interns*, Time spent ordering by surgical residents*, Time spent on daily and one-time orders*, Time spent on sets of orders*	When time spent ordering was compared between pre-order entry and post-order entry periods, the percent for medical interns increased from 5.3% to 10.5% (p <0.001) representing 44 additional minutes per day, while for surgical house officers the corresponding figures were an increase from 6.4% to 15.5% (p <0.001), 73 minutes per day. Daily and one-time orders accounted for the majority of this change, increasing almost threefold in percent total time (2.2% before, vs. 7.2% after order entry). However, sets of orders took less total time after order entry (1.7% vs. 3.1%).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Bates (1998) (Bates et al. 1311-1316) Design: RCT N = 4,220 patients Implementation: 00/0000 Study Start: 02/1993 Study End: 07/1995	**CPOE/POE system** Integrated Billing/administration system, Formulary, Hospital information system	Acute care/tertiary, 726 Beds Academic	the rate of nonintercepted serious medication errors/1,000 patient days -phase 1 to 2*, the rate of nonintercepted serious medication errors/1,000 patient days -CPOE vs. CPOE+team, Transcription errors	In paired analyses comparing phase 1 and phase 2 (Table 2), the rate of nonintercepted serious medication errors fell 55%, from 10.7 events per 1,000 patient-days to 4.86 events ($p = 0.01$). For the RCT in the post-CPOE phase, comparing CPOE alone with CPOE plus team showed no significant difference in error rates (4.81 vs. 6.01, $p = 0.49$). Transcription errors (CPOE to paper in pharmacy) fell 84%, $p < 0.001$.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Bell (2010) (Bell et al. e770-e777) Design: RCT N = 19,450 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 04/2008	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care, Academic	proportion of children with asthma having at least 1 prescription for controller medication*, proportion of children with asthama having an up-to-date asthma care plan*, proportion of children with asthma having spirometry performed*	Increases in the number of prescriptions for controller medications, over time, was 6% greater (p = 0.006) and 3% greater for spirometry (p = 0.04) in the intervention urban practices. Filing an up-to-date asthma care plan improved 14% (p = 0.03) and spirometry improved 6% (p = 0.003) in the suburban practices with the intervention.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Berner (2006) (Berner et al. 171-179) Design: RCT N = 59 internal medicine residents Implemgentation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Handheld	Ambulatory care, Academic	proportion of unsafe NSAID prescribing per physician at followup	The proportion of cases per physician with unsafe NSAID prescriptions were similar at baseline for control (0.29) and intervention residents (0.27). At followup, the rates were statistically different, with lower proportions for intervention residents after adjustment for baseline rates (0.45 control vs. 0.23 intervention, $p < 0.05$). Note that the control group prescribing degraded over time while the intervention group was stable.	-
Bernstein (2005) (Bernstein et al. 225-231) Design: Before-after N = 1,158 prescriptions Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Emergency department, Academic	percentage of proprietary antibiotics prescribed*	The percentage of proprietary antibiotics prescribed before and after insertion of the electronic prompt was 26.6% vs. 20.7%, RRR 22%, $p = 0.03$.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Bertoni (2009) (Bertoni et al. 678-686) Design: RCT N = 8,878 patients Implementation: 00/0000 Study Start: 06/2001 Study End: 04/2006	**CDSS/CDS/CCDS/ reminders** Handheld	Ambulatory care	adherence to guideline-screening*, adherence to guideline-appropriate lipid management*	There was no difference in screening rates between the CDSS-PDA group and the control. The control group had a 10.8% drop in appropriate management from baseline, while the PDA group had a 1.1% drop, p <0.01. Stable adherence was observed in the PDA intervention group, whereas a decline in guideline adherence was observed in the control group.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Bloomfield (2005) (Bloomfield et al. 258-263) Design: RCT N = 9,105 patients Implementation: 04/2002 Study Start: 10/2001 Study End: 10/2003	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	rate of prescription lipid therapy (before-after)	rate of lipid therapy prescriptions increased significantly after implementation of the prompts in the intervention clinics (8.3% vs. 39.1%, RRR -371, p <0.0001) no statistically significant difference in prescription rates (40.7% for progress notes, 36.9% for patient letters, and 39.4% for reminders, p = 0.60) alternative logistic regression analysis, significant interaction between group and site, indicating that the efficacy of the prompts differed by site.	+
Bogucki (2004) (Bogucki et al. 278-280) Design: Before-after N = 2,124 orders for parenteral corticosteroids Implementation: 04/2002 Study Start: 04/2003 Study End: 07/2003	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system EHR/EMR system, e-MAR	Pediatric stand alone hospital, 324 Beds	rate of methylprednisone ordering*	There was a significant reduction in methylprednisone prescribing following the implementation of the alert in relation to the total number of parenteral corticosteroids ordered (21.5% vs. 9.7%, RRR 55%, p <0.0001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Bouaud (2001) (Bouaud et al. 1-4) Design: Before-after N = 127 decisions/orders Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care Other	rate of compliance with CPG	Before using OncoDoc, phyicians compliance with CPG was 61.42%. Using the system significantly increased actual compliance to 85.03% ($p < 0.0001$).	+
Buising (2008) (Buising et al. 35) Design: Time series N = 740 patients Implementation: 01/2005 Study Start: 04/2003 Study End: 09/2006	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Acute care/tertiary, 350 Beds Academic	proportion of patients receiving appropriate antibiotic therapy*	proportion of patients receiving appropriate antibiotic therapy increased significantly between each time period (61.9% baseline vs. 68.7 academic detailing vs. 89.7 CDSS, pairwise comparisons $p < 0.01$) associated ORs for having received the recommended empiric antibiotic therapy were 2.58 between baseline and CDSS periods and 2.03 between academic detailing and CDSS.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Butler (2006) (Butler et al. 643-653) Design: Before-after N = 1,827 patients (1,251 with CHF and 576 with AMI) Implementation: 07/2002 Study Start: 07/2001 Study End: 0.9/2003	**CDSS/CDS/CCDS/ reminders CPOE/POE system**	Acute care/tertiary, Academic	compliance rate: ACEI for LVSD*, compliance rate: ACEI for AMI*, compliance rate: aspirin for AMI*, compliance rate: beta-blocker for AMI*	Aspirin (95% vs. 95%, RRR 0%, NS), betablocker (88% vs. 95%, RRR -8%, NS), and ACEI (77% vs. 81%, RRR -5%, NS) use for AMI patients at the time of discharge in the pre-CPOE era was high and remained so in the CPOE period. Similarly for ACEI for CHF patients (74% vs. 87%, RRR -18%, NS). When examining indicators in the post-CPOE phase, rates were higher in patients for which the tool was used, vs. not used for all 4 medication related indicators (p <0.001).	-
Chertow (2001) (Chertow et al. 2839-2844) Design: Time series N = 19,982 admissions Implementation: 00/0000 Study Start: 09/1997 Study End: 04/1998	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Hospital information system Imaging systems	Acute care/tertiary, 720 Beds Academic	rate of appropriate prescribing*, rate of appropriate prescribing involving dosage alterations*, rate of appropriate prescribing involving frequency alterations*	The rate of appropriate prescribing was increased with CPOE/CDSS for all orders (51% intervention vs. 30% control, RRR 70%, p <0.001) by dose (67% vs. 54%, RRR 43%, p <0.001), or by frequency (59% vs. 35%, RRR 69%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Chisholm (2003) (Chisholm et al. 199-206) Design: Before-after N = 790 children admitted to hospital with asthma exacerbations Implementation: 10/2002 Study Start: 11/2001 Study End: 12/2003	**CPOE/POE system** Integrated Billing/administration system, EHR/EMR system, Laboratory system	Pediatric stand alone hospital, 323 Beds	systemic corticosteroids use*, metered-dose inhaler use*	More use was made of systemic corticosteroids (OR 5.61, 95% CI 3.46 to 9.11) and of metered-dose inhalers (OR 1.42, CI 1.04 to 1.94) after implementation of standard order sets in the CPOE for asthma patients.	+
Choi (2004) (Choi et al. 1-6) Design: Before-after N = 307 patients Implementation: 02/2003 Study Start: 12/2002 Study End: 04/2003	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system	Ambulatory care	Error rates per patient*	Error rates per patient significantly declined in the intervention site following implementation of the nurse CPOE with CDSS (17.4% vs. 3.1%, RRR 82%, p = 0.0075). In the control group, error rates remained unchanged (8.6% vs. 6.9%, NS). At baseline, the control group rate was statistically lower than the intervention group (8.6% vs. 17.4%, p = 0.04).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Christakis (2001) (Christakis et al. e15) Design: RCT N = 38 providers Implementation: 00/0000 Study Start: 03/0000 Study End: 05/0000	**CDSS/CDS/CCDS/ reminders** Integrated online prescription writer	Ambulatory care, Academic	change in the frequency of antibiotic prescription*	For the primary outcome, providers in the intervention arm had a 44% change in the frequency with which they prescribed antibiotics for <10 days, whereas providers in the control arm had a 10% change, this change in behavior was significantly related to the intervention, although both groups improved (p <0.01).	+
Clancy (1992) (Clancy, Gelfman, and Poses 14-18) Design: Before-after N = 1,013 patients Implementation: 02/1985 Study Start: 11/1984 Study End: 05/1985	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Acute care/tertiary, Academic	pneumococcal vaccination rate per admission*	Preimplementat ion of the reminder pneumococcal vaccination rate was 3.4% compared 45% post (p <0.0001).	+
Cobos (2005) (Cobos et al. 421-432) Design: RCT N = 2,221 patients Implementation: 04/2000 Study Start: 04/2000 Study End: 05/2002	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	proportion of patients prescribed lipid lowering drugs (secondary)	The proportion of patients prescribed lipid lowering drugs was significantly lower in the CDSS guideline intervention group (59.1% vs. 40.8%, RRR 31%, p <0.0001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Colpaert (2006) (Colpaert et al. R21) Design: RCT N = 2,510 prescriptions Implementation: 00/0000 Study Start: 03/2004 Study End: 04/2004	**CPOE/POE system** Integrated Billing/administration system,CPOE/POE system, Hospital information system, Laboratory system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 22 bed unit Beds Academic	rate of medication prescribing errors*, minor MPEs*, Intercepted MPEs *, Serious MPEs *	The incidence of MPEs was significantly lower in the computerized unit (C-U) compared with the paper based unit (PBU) [44/1,286 (3.4%) vs. 331/1,224 (27.0%); p <0.001]. There were significantly fewer minor MPEs in the C-U than in the PB-U [9 (0.7%) vs. 225 (18.4%); p <0.001)]. Intercepted MPEs were also lower in the C-U [12 (0.9%) vs. 46 (3.8%); p <0.001].Serious MPEs were also lower in C-U than PBU [23 (1.8%) vs. 60 (4.9%), p <0.001].	+
Cordero (2004) (Cordero et al. 88-93) Design: Before-after N = 211 infants Implementation: 02/2000 Study Start: 10/2001 Study End: 09/2002	**CPOE/POE system** Integrated Imaging systems, Pharmacy	Acute care/tertiary, Critical care units (CCU, ICU, NICU) Academic	medication turn-around times-caffeine*, medication error rate-gentamicin	The turn-around times for the pre- and post-CPOE loading dose of caffeine were 10.5 ± 9.8 and 2.8 ± 3.3 hours p <0.01, respectively. In the pre-CPOE period, there were 14 (13%) gentamicin prescription dosage errors, in the post-CPOE period there were 0	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Cote (2008) (Cote et al. 1097-1103) Design: Before-after N = 601 adult patients Implementation: 00/0000 Study Start: 12/2005 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Unspecified Hospital	rate of gastroprotection at discharge*, control vs. physician education vs. alert vs. alert plus education	The study sought the change in rate of gastroprotection at discharge for all patients; changes only occurred for the group that had both education and alerts compared to control (43% vs. 61%, RRR -42%, p <0.001). Education alone (42%) or alerts alone (39%) did not change rates of gastroprotection.	-
Cunningham (2008) (Cunningham, Geller, and Clarke 546-554) Design: Before-after N = 1,040 order sets Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders	Acute care/tertiary, General Hospital 667 Beds	compliance to medication order sets*, minutes to first dose of antibiotics	Medication orders placed using CPOE were significantly more compliant with hospital protocols (80%) than paper based medication orders at both the CPOE hospital (63%) and the control hospital (64%), and first doses of antibiotics were delivered significantly faster when ordered with CPOE (180 min) than when placed using the standard paper-based system (326 min, p <.01).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	Settings	Outcomes Measured	Results	Outcome
Davis (2007) (Davis et al. e25) Design: RCT N = 44 health care providers Implementation: 11/1999 Study Start: 11/1999 Study End: 12/2003	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Ambulatory care, Academic	changed physician behavior in accordance with the intervention message screens*	Prescribing behavior in accordance with the evidence improved only marginally, by 1% in control group and 4% in the intervention group (absolute difference 3%, 95% CI 1%, 15%).	+
de Jong (2009) (de Jong et al. 9-20) Design: Cross-sectional N = 749,811 contacts Implementation: 00/1998 Study Start: 01/2001 Study End: 12/2001	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	proportion of prescriptions in accordance with DSS*, Herfindahl-Hirschman Index	GPs who use the DSS daily prescribe more according to the advice given in the DSS (89%) than GPs who do not use the DSS (75%, RRR 19%, p = 0.04). There was no significant difference between the Herfindahl-Hirschman Index for both groups (40.3 for daily users and 41.4 for non users, p = 0.3) the variation in prescriptions for a given diagnoses was comparable between groups.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Devine (2010) (Devine et al. 928) Design: Before-after N = 10,169 prescriptions Implementation: 03/2003 Study Start: 03/2002 Study End: 04/2006	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system	Ambulatory care	errors	Frequency of errors declined from 18.2% (Pre-CPOE) to 8.2% (post-CPOE), a reduction in adjusted odds of 70% (OR: 0.30; 95% CI 0.23 to 0.40), p <0.001.	+
Dexter (2001) (Dexter et al. 965-970) Design: RCT N = 3,416 patients Implementation: 00/0000 Study Start: 05/1997 Study End: 10/1998	**CDSS/CDS/CCDS/ reminders** Integrated Pharmacy	General Hospital Academic	proportion compliance: -pneumococcal vaccination*, -influenza vaccination* -subcutaneous heparin -aspirin at discharge	The use of the reminders led to a higher ordering rate all 4 preventive therapies for eligible patients; pneumococcal vaccination (0.8% vs. 35.8%, RRR -4375%, p <0.001), influenza vaccination (1.0% vs. 51.4%, RRR -5040%, p <0.001), subcutaneous heparin (18.9% vs. 32.2%, RRR -70%, p <0.001) and aspirin at discharge (27.6% vs. 36.4%, RRR -32%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Dexter (2004) (Dexter et al. 2366-2371) Design: RCT N = 1,677 patients Implementation: 11/1998 Study Start: 11/1998 Study End: 12/1999	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	General Hospital, Academic	rate of receipt of vaccination -influenza*, rate of receipt of vaccination - pneumococcal*	Patients in the standing order group received both vaccinations more often than patients in the pop-up reminder group; for the influenza vaccine 30% reminder vs. 42% standing order, p <0.001; for the pneumococcal vaccine 51% vs. 31%, p <0.001.	+
Durieux (2000) (Durieux et al. 2816-2821) Design: Time series N = 1,971 patients Implementation: 00/0000 Study Start: 12/1997 Study End: 07/1999	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system	Acute care/tertiary, 1,000 Beds Academic	rate of appropriate anticoagulant prescribing*	Physicians complied with guidelines in 82.8% of cases during control periods and in 94.9% of cases during intervention periods (RRR - 15%, p <0.001). During each intervention period, the proportion of appropriate prescriptions ordered increased significantly. Each time the CDSS was removed, physician compliance with guidelines reverted to that observed before initiation of the intervention.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Eslami (2006) (Eslami et al. 803-809) Design: Cross-sectional N = 392 orders Implementation: 00/2002 Study Start: 05/2002 Study End: 12/2004	**CPOE/POE system** Integrated EHR/EMR system, Laboratory system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 28 in 3 units Beds	Dosing error*	The dose was wrong (i.e. there was >10% deviation from the guideline) in 73% (165/227) of the orders that used the default value (essentially as suggested by the CPOE) and in 77% (127/165) of the orders in which the default value was not administered (p = 0.4).	-
Evans (1998) (Evans et al. 232-238) Design: Before-after N = 1,681 patients Implementation: 00/0000 Study Start: 07/1992 Study End: 06/1995	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, 520 Beds Academic	mean number of days with excessive antibiotic dosing*, usage rate of antiinfectives*	During the intervention period, there were significantly fewer days when doses of antiinfective agents were excessive than during the preintervention period (2.7 days vs. 5.9 days per patient, respectively; p <0.002). There was an increase in the use of antiinfectives following the intervention reminder (67% vs. 73%, RRR 9%, p <0.03).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Evans (1990) (Evans et al. 351-354) Design: Before-after N = 7,656 patients Implementation: 00/0000 Study Start: 06/1985 Study End: 09/1986	**CDSS/CDS/CCDS/ reminders Hospital information system** Integrated Laboratory system, Pharmacy	Unspecified Hospital	mean number of antibiotic doses per patient, proportion of patients receiving preoperative antibiotics, proportion of patients receiving antibiotics for too long,	Surgical patients received an average of 19 antibiotic doses before implementation of the implementation of the 'stop orders' and 13 after (p <0.001). There were non significant changes in the proportion of patients receiving preoperative antibiotics (64% vs. 66%, NS) or those receiving antibiotics for too long (40% vs. 35%, NS).	+
Evans (1994) (Evans et al. 878-884) Design: RCT N = 482 cultures Implementation: 00/000 Study Start: 07/1990 Study End: 01/1991	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system	Acute care/tertiary 520 Beds	rate of prescribing antibiotics to which all of the isolated pathogens were susceptible	The computer group had a higher rate of prescribing antibiotics to which all of the isolated pathogens were susceptible (77% vs. 94%, RRR 22%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Feldstein (2006) (Feldstein et al. 1009-1015) Design: RCT N = 9,910 patients with 239 care providers in 15 primary care clinics Implementation: 12/2002 Study Start: 01/2000 Study End: 08/2004	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system, EHR/EMR system	Ambulatory care	interacting prescription rate (/10,000 warfarin users/month), slope for interacting prescription rate	When baseline trends were controlled for, the overall interacting prescription rate decreased immediately after the alerts were implemented, with an estimated reduction of 329.7 interacting prescriptions per 10, 000 warfarin users in the first month (p = 0.002). The alerts also significantly changed the trend in the interacting prescription rate, with a preintervention increasing rate of 1.1 and a postintervention decreasing rate of 21.3 (slope change -22.4; p = 0.01). Academic detaining did not have an effect on interacting prescription rates.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Feldstein (2006) (Feldstein et al. 450-457) Design: RCT N = 311 women Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system	Ambulatory care	rate of completion of BMD or medication for osteoporosis, The same pattern was evidence for medication only	control group had fewer women who had BMD completer or medication for osteoporosis compare with the reminder and reminder plus education groups (5.9% control, 51.5% reminders, and 33% reminders and education, p <0.01 for both comparisons with control RRR for reminders alone 690% and RRR for reminders and education 460%). The same pattern was evidence for medication only (5.0% control, 27.7% reminders and 20.2% reminders plus education; p <0.01 for comparisons with control.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Field (2009) (Field et al. 480-485) Design: RCT N = 833 patients (10 physicians and 213,967 patient days) Implementation: 00/000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders CPOE/POE** system Integrated EHR/EMR system	Long term care (nursing homes)	proportion of appropriate orders*, proportion of inappropriate drugs avoided	The proportion of appropriate antidepressant order rates for patients with renal insufficiency was higher in the CDSS group (52% vs. 63%, OR 1.2, 95% CI 1.0 to 1.4). More inappropriate drugs were avoided (15% vs. 46%, OR 2.6, CI 1.4 to 5.0). Improvements were seen in frequency and missing information but not for doses in the CDSS group.	+
Fiks (2009) (Fiks et al. 159-169) Design: RCT N = 22,586 patients Implementation: 00/0000 Study Start: 10/2006 Study End: 05/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system	Ambulatory care, Academic	rates of up-to-date influenza vaccination*, rates of captured opportunities for vaccination*	Rates of up-to-date influenza vaccination increased from 44.2% to 48.2% (control) and from 45.0% to 53.0% (intervention), a 4.0% (95% CI: -1.3% to 9.1%) greater but NS. Overall rates of captured opportunities for vaccination increased 3.8% (12.3% to 16.1%) control practices and 4.8% (14.4% to 19.2%) intervention sites, difference 1% (95% CI: -2.4% to 4.9%).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Filippi (2003) (Filippi et al. 1497-1500) Design: RCT N = 15,343 patients Implementation: 00/0000 Study Start: 05/2001 Study End: 11/2001	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system	Ambulatory care	Antipletlet drug treatment	number of treated patients significantly increased in the intervention group (OR 1.99, 95% CI 1.79 to 2.22).	+
Fischer (2003) (Fischer et al. 2585-2589) Design: Before-after N = 1,045 orders Implementation: 00/00 Study Start: 00/00 Study End: 00/00	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, Inpatient hospital based Academic	defined daily dose -IV, defined daily dose –oral DDD	After implementation the use of IV medication (DDD) decreased by 11.1%, p = 0.002 and the oral drug use (DDD) increased by 3.7%, p = 0.002.	+
Fischer (2008) (Fischer et al. 2433-2439) Design: Before-after N = 12,625,276 prescriptions Implementation: 10/2003 Study Start: 10/2003 Study End: 5/2005	**e-Rx** Integrated Formulary, Insurance	Not specified	rates of prescribing, tier 1*, rates of prescribing, tier 2*, rates of prescribing, tier 3*	20% of prescriptions written by intervention physicians completed using e-Rx intervention group prescribed 1.4% more (95% CI, 0.6% to 2.0%) tier 1 medications, 0.3% fewer (95% CI, –0.8% to 0.2%) tier 2 medications, and 1.0% fewer (95% CI, –1.4% to –0.7%) tier 3 medications than the control group.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Flottorp (2002) (Flottorp et al. 367) Design: RCT N = 26,826 Consultation Implementation: 00/0000 Study Start: 01/2000 Study End: 01/2001	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Use of antibiotics for sore throat, use of antibiotics for UTI	sore throat group 3% less likely to receive antibiotics after the intervention (49.5% vs. 43.8%, p = 0.032) UTI (43.4% vs. 46.3%, p = 0.639) Women with symptoms of UTI in the intervention group were 5.1% less likely to have a laboratory test ordered (55% vs. 49.8%, p = 0.046) For sore throat, the numbers were 39.7% vs. 42.0%, p = 0.638 proportion of telephone consultations sore throat: 1.2% greater in the control group than in the intervention group (14.1% vs. 12.9%, p = 0.128) proportion decreased for UTI (18.9% vs. 19.8%, p = 0.874)	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Fontan (2003) (Fontan et al. 112-117) Design: Cross-sectional N = 4,532 prescriptions Implementation: 00/1988 Study Start: 02/1999 Study End: 03/1999	**Computerized unit dose drug dispensing system (UDDS)** Integrated Hospital information system	Other specialty hospital (rehab, oncology) Pediatric stand alone hospital 510 Beds	prescribing error rate administering error rate	Errors were decreased with the use of the eRX and computerized dispensing system compared with the hand-written prescriptions and ward distribution system. Prescribing errors were reduced from 87.9% to 10.6%, RRR 88%, $p < 0.00001$. Administrative errors with time errors were reduced from 29.3% to 22.5%, RRR 23%, $p < 0.001$.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Fortuna (2009) (Fortuna et al. 897-903) Design: RCT N = 257 clinicians Implementation: 00/1997 Study Start: 03/2006 Study End: 03/2008	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, e-Rx	Ambulatory care, Academic	relative risk of prescribing heavily marketed medications*	The relative risk of prescribing heavily marketed medications in the alert-group during the intervention period was less than in the usual-care group (RRR 0.74; 95% CI 0.57 to 0.96; p = 0.02). The RR of prescribing heavily marketed hypnotics in the alert-plus-education group was less than in the usual-care group (RRR 0.74; 95% CI 0.58 to 0.97, p = 0.03). The prescribing of heavily marketed medications was similar in the alert-only group and the alert-plus-education group (RRR 1.02; 95% CI 0.80 to 1.29; p = 0.90).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Frances (2001) (Frances et al. 165-166) Design: RCT N = 63 physicians and 730 patients Implementation: 00/0000 Study Start: 03/1997 Study End: 06/1997	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Pharmacy	Ambulatory care	Receiving aspirin*, History of MI and receiving beta-blocker,*, Receiving cholesterol-lowering agent*	proportion of patients had an active prescription for aspirin 37.9% vs. 35.1%, RRR 7%, p = 0.440, NS; proportion of patients with MI who had an active beta-blocker prescription 22.2% vs. 33.3%,RRR - 50%,p = 0.465, NS; proportion of patients receiving a cholesterol-lowering agent (73.2 % vs. 71.0%,RRR - 15%, p = 0.512)	-
Frank (2004) (Frank, Litt, and Beilby 87-90) Design: RCT N = 10,507 patients Implementation: 00/0000 Study Start: 03/1998 Study End: 03/1999	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	proportion of opportunities taken for preventive activity*	Reminders did not improve adherence to MMR and flu vaccinations, but there was a significant increase in tetanus immunization (1.5% vs. 2.8%, relative change 1.89, 95% CI 1.59, 2.25). and pneumococcal immunization rates (1.6% vs. 2.8%, relative change 1.70, 95% CI 1.10, 2.62). Two of 8 non-medication related preventive care recommendatio ns were significantly improved as well.	+
Franklin (2007) (Franklin et al.	**Automated Dispensing**	Acute care/tertiary,	error rate for new prescriptions*, error rate	The prescription	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
279-284) Donyai (2008) (Conyai et al. 230-237) Barber (2007) (Barber, Cornford, and Klecun 271-278) Franklin (2008) (Franklin, Jakclin, and Barber 375-379) Franklin (2007) (Franklin et al. 133-139) Design: Before-after N = 4,803 medication orders Implementation: 06/2003 Study Start: 00/0000 Study End: 00/0000	**Machine, e-Medication administration system (e-MAR, e-TAR) e-Rx** Integrated Pharmacy	28 bed surgery ward of a teaching hospital Inpatient hospital based Academic	for drug administrations*, %administered <1hr (Franklin, Jacklin, and Barber 375-379), rate of pharmacist interventions (Donyai et al. 230-237), total pharmacy time taken on study ward	error rate for new orders dropped significantly after implementation of the system (3.8% vs. 2.0%, RRR 47%, p = 0.0004). Medication administration error rate also significantly declined (8.6% vs. 4.4%, RRR 49%, p = 0.0003). (Franklin, Jacklin, and Barber 375-379) Post-intervention medication timeliness was improved (% administered <1hr, 79% vs. 89%, p <0.001). (Donyai et al. 230-237) The rate of pharmacist interventions declined significantly after implementation (3.0% vs. 1.9%, AR 1.1 (95% CI 0.2,2.0). (Franklin et al. 133-139) Total pharmacy time taken on study ward increased after implementation (1h 8 min vs. 1h 38 min, p = 0.001). Pharmacists were required to endorse fewer orders (50% vs. 21%,	

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
				RRR 58%, p <0.0001) and endorsed fewer orders (55% vs. 30%, RRR 45%, p <0.0001).	
Fretheim (2006) (Fretheim, Aaserud, and Oxman e216) Fretheim (2006) (Fretheim et al. e134) Design: RCT N = 139 practices and 501 physicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	thiazides prescription rates*, rates of cardiovascular risk assessment, proportion of patients achieving treatment goal at 3 months	Prescribing of thiazides increased in the reminders + group (11% vs. 15%, RRR 54%, p <0.001, RR 1.94 95% CI 1.49 to 2.49). The groups did not differ for cardiovascular risk assessment (RR 1.04, CI 0.60 to 1.71) or proportion that achieved treatment goal at 3 months (RR 0.98, CI 0.93 to 1.02).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Galanter (2004) (Galanter, Polikaitis, and Didomenico 270-277) Design: Before-after N = 620 patients Implementation: 00/0000 Study Start: 02/2001 Study End: 03/2002	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system Laboratory system	Acute care/tertiary, Academic	compliance with digoxin monitoring guidelines - synchronous alerts*, compliance with hypokalemia and hypomagnesemia treatment guidelines - synchronous alerts*, compliance with hypokalemia and hypomagnesemia treatment guidelines - asynchronous alerts*	Post implementation, synchronous alerts significantly increased test ordering for digoxin levels, K levels and Mg levels at 1 hr and 24 hrs (p <0.01 for all). Supplementation of Mg at 1 hour was significantly improved, but not at 24 hrs. Supplementation of K was not improved at 1 or 24 hrs. Synchronous alerts resulted in improved compliance at 1 hr and 24 hrs for both K and Mg supplementation (p <0.01).	+
Galanter (2005) (Galanter, Didomenico, and Polikaitis 269-274) Design: Before-after N = 410 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, Academic	likelihood of a patient receiving contraindicated medication, compliance rates- housestaff compared to other clinicians	The likelihood of a patient receiving at least one dose of the contraindicated medication decreased from 89% to 47% after alert implementation (p <0.0001), RRR 47%. For the 226 alerts received by housestaff, the alert compliance rate was 42%; for the remaining clinicians the compliance rate was 38% (p = 0.54).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Gerard (2008) (Gerard et al. 776-779) Design: Time series N = 907 orders for flu vaccination Implementation: 00/2001 Study Start: 00/2003 Study End: 00/2007	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	General Hospital 464 Beds	acceptance rate of pre-selected orders, year 1 vs. year 2, acceptance rate of pre-selected orders, year 2 vs. year 3, vaccination rate, year 1 vs. year 2, vaccination rate, year 2 vs. year 3	During the intervention, physicians were significantly more likely to accept pre-selected vaccination orders, Year 1 (47%), Year 2 (77%), Year 3 (83%); however vaccine administration by nurses was suboptimal. EMR functionality improved, patient receipt of vaccine increased significantly, Year 1 [0/36; 0%], Year 2 [8/66; 12%], Year 3 [286/805; 36%].	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Gill (2009) (Gill et al. 221-226) Design: RCT N = 64,150 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 10/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Up-to-date lipid test*, Lipid medication if not at goal (high risk patients only)*	Outcomes improved for most measures from before to 1 year after the intervention (univariate analysis). However, after controlling for confounding variables and for clustering in multilevel modeling, only up-to-date lipid testing for high-risk patients was statistically better in the intervention group as compared to the control group (adjusted OR 15.0, p <0.05). Intervention status was NS	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Gilutz (2009) (Gilutz et al. 23-29) Design: RCT N = 7,448 patients from 56 control and 56 intervention clinics Implementation: 00/0000 Study Start: 01/2000 Study End: 12/2003	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system, Laboratory system, Pharmacy	Ambulatory care Academic	rate of adequate monitoring Positive treatment trend, overall up-titration rate in patients with LDL = 110 mg/dl	higher rate of adequate monitoring documented in intervention arm (54.8% vs. 48.7%, p <0.001). Medication initiation or up-titration recommended for patients with LDL levels above 110 mg/dl results showed overall positive trends were minimally more prominent in the intervention arm (59.1% vs. 53.7%, p <0.003). This difference constitutes a higher rate of drug initiation (2.5%), up-titration (1.8%) and avoiding drug cessation (1.1%). However, overall up-titration in patients with LDL = 110 mg/dl was poor, both in the intervention arm and in the control arm (8.6% vs. 7.4%,NS).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Ginzburg (2009) (Ginzburg et al. 2037-2041) Design: Before-after N = 540 Patients Implementation: 00/0000 Study Start: 01/2005 Study End: 12/2005	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Medication error*	Significantly more medication errors were found in the preintervention group than in the postintervention group [(32.6% (n = 103) vs. 20.5% (n = 46), p = 0.002]. Significantly fewer strength overdosing errors occurred in the postintervention group (8.9% vs. 4.0%, p = 0.028).	+
Goethe (1997) (Goethe, Schwartz, and Szarek 553-558) Design: Time series N = 1,604 alerts Implementation: 00/0000 Study Start: 01/1994 Study End: 12/1996	**CDSS/CDS/CCDS/ reminders**	Other specialty hospital (rehab, oncology) 130 Beds	alert rate, physician response rate to alerts*, compliance with alerts*	The rate of alerts went down in the second year (29% vs. 15%, RRR 48%, p <0.001), as did the rate of physician responses to the alerts (67% vs. 55%, RRR 18%, p <0.001) change in practice to comply with guidelines occurred 28% (year 1) compared to 21% (year 2)	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Griffey (2009) (Griffey 265) Design: Time series N = 2,419 orders Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Stand-Alone, CPOE/POE system	Emergency department, Academic	During use of the CDSS system, agreement with recommended doses was increased.	During use of the CDSS system, agreement with recommended doses was increased (23.0% for off and 31.4% for on, RRR 37%, p = 0.03) reduction similar for benzodiazepines (p = 0.03), opiates (p = 0.04), and NSAIDS (p = 0.0009).	+
Halkin (2001) (Halkin et al. 260-265) Design: Time series N = 775,186 prescriptions Implementation: 11/1997 to 00/1998 Study Start: 01/1998 Study End: 06/1999	**CDSS/CDS/CCDS/ reminders** Integrated Pharmacy	Pharmacy, HMO pharmacy	rate of drug interaction prescriptions 90% pharmacies and 50% physicians compared with baseline, rate of drug interaction prescriptions 95% pharmacies and 90% physicians compared with baseline	Dispensing of drug interaction prescriptions was reduced by 21.1% and by 67.5% in periods II and III compared with period I (OR, 0.79; 95% CI, 0.75 to 0.83 and OR, 0.28; 95% CI, 0.26 to 0.30, respectively).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Hicks (2007) (Hicks et al. 429-441) Design: RCT N = 1,422 patients Implementation: 00/0000 Study Start: 07/2003 Study End: 02/2005	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Other, Academic	blood pressure controlled, receiving a recommended drug class medication within 1 week of the clinic visit adjusted	This study had 4 groups: usual care, CDS, NPs, and NPs+CDS. No difference was seen across all 4 groups for blood pressure readings: Usual care vs. CDS: 45% vs. 48% controlled, OR 0.96 (CI 0.78 to 1.19). Patients in the CDS group were more likely to have received a recommended drug class medication within 1 week of the clinic visit than patients in the usual care group: adjusted OR 1.32 (CI 1.09 to 1.61).	+
Hollingworth (2007) (Hollingworth et al. 722-730) Devine (2010) (Devine et al. 152-171) Design: Cross-sectional N = 146 health care providers (69 in phase 1 and 77 in phase 2) Implementation: 00/2003 Study Start: 02/2005 Study End: 01/2006	**e-Rx** Integrated EHR/EMR system	Ambulatory care	time spent on writing tasks (min/hr), paper vs. desktop vs. laptop, time spent on computer tasks (min/hr) paper vs. desktop vs. laptop, time spent on computer and writing tasks (min/hr), paper vs. desktop vs. laptop, More time in phase 2 compared with handwritten prescriptions for all prescriptions and new prescriptions but not for renewed prescriptions. (Devine et al. 152-171)	Prescribers at e-RX sites, both desktop and wireless laptops, spent significantly less time (minutes/hour) on writing tasks that their paper-based colleagues (8.7 paper vs. 5.5 desktop vs. 5.9 laptops, p <0.05), but more time on computer based tasks (3.8 vs. 7.4. vs. 8.1, p <0.05). Overall time on writing tasks and computer tasks together were not different among	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
				the three formats (12.4 vs. 12.9. vs. 14.0, NS) and should not greatly disrupt workflow.[In the second phases (Deveine et al. 152-171) (point of care prescribing) the clinicians spend more time than handwritten prescribing for all prescriptions: 25 seconds more (99.5% CI 12 to 38), and more time for new prescriptions: 29 seconds more (CI 14 to 44) but not more time for renewed prescriptions: 13 seconds more (CI -13 to 39).	
Hulgan (2004) (Hulgan et al. 349-357) Design: Time series N = 15,194 quinolone orders Implementation: 02/2002 Study Start: 02/2001 Study End: 01/2003	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, Academic	change in weekly proportion of oral quinolone orders*	55.5% orders were for oral quinolones before the intervention orders compared with 62.4% after (RRR -12%, p = NR). In the time-series analysis, the intervention increased the proportion of oral quinolone orders per week by 5.6% (95% CI 2.8 to 8.4%; p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Hwang (2002) (Hwang, Park, and Bakken 213-223) Design: Time series N = 171 patients Implementation: 10/1999 Study Start: 06/1999 Study End: 05/2000	**CPOE/POE system** Integrated Hospital information system Imaging systems	Acute care/tertiary, 1,000 plus Beds Academic	number of daily orders per patient, number of daily medication orders, number of changed orders, number of cancelled orders, number of daily PRN orders	daily orders per patient significantly increased following POE system introduction compared to both 3- and 6-months post (10.9 vs. 17.4 vs. 19.9, p </0.0001) similar pattern observed for number of daily medication orders (4.2 vs. 6.6 vs. 6.1, p <0.0001) and PRN orders (2.9 vs. 7.9 vs. 8.3, p <0.0001) difference between 3 and 6 months after POE was NS for either measure. The number of changed orders (2.2 vs. 0.2 vs. 0.03, NS) and cancelled orders (3.3 vs. 2.3 vs. 2.2, NS)	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Igboechi (2003) (Igboechi et al. 227-231) Design: Before-after N = 10,134 medication errors Implementation: 06/2001 Study Start: 06/1999 Study End: 05/2002	**CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders EHR/EMR system, Pharmacy	Acute care/tertiary, 350 Beds Inpatient hospital based	total potential errors*, Illegible orders, incomplete orders, incorrect orders, drug therapy problems	The number of documented medication errors decreased postimplementation for total potential errors (p <0.001), illegible orders (p <0.001), incomplete orders, (p <0.001) and incorrect orders (p <0.001) but not for drug therapy problems (p = 0.289). Annual numbers were compared for each of the 2 years before implementation of CPOE and the year after CPOE.	+
Jacques (2005) (St Jacques et al. 215-221) Design: Before-after N = 287 procedures Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Acute care/tertiary, Academic	antibiotic redosing rate*	On-time antibiotic redosing increased significantly after the implementation of the computer reminder system (20% vs. 57%, RRR -185%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Jani (2008) (Jani et al. 214-218) Design: Before-after N = 2,222 prescribed drugs Implementation: 03/2006 Study Start: 07/2005 Study End: 07/2006	**e-Rx** Integrated EHR/EMR system, e-MAR, Pharmacy	Pediatric stand alone hospital, Ambulatory care	error rate*, error free visit rate	The overall prescribing error rate was 77.4% (95% CI = 75.3% to 79.4%) for handwritten items and 4.8% (95% CI = 3.4% to 6.7%) with e-Rx (RRR, 94%, p <0.001). Pre-e-Rx, 1153 items (73.3%; 95% CI = 71.1% to 75.4%) were missing essential information, and 194 items (12.3%; 95% CI = 10.8% to 14%) were judged to be illegible. Post-EP, only 9 items (1.4%; 95% CI = 0.7% to 2.6%) were missing essential information, and illegibility errors were eliminated. The number of patient visits that were error-free increased from 21% to 90% (69% difference; 95% CI = 64% to 73.4%; RRR - 324%, p <0.001) after the implementation of e-Rx.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Javitt (2008) (Javitt, Rebitzer, and Reisman 585-602) Design: RCT N = 39,508 patients Implementation: 01/2001 Study Start: 01/2001 Study End: 12/2001	**CDSS/CDS/CCDS/ reminders** Integrated Billing/administration system Laboratory system, Pharmacy	Ambulatory care	resolution rate-add a drug alert*, resolution rate-stop a drug*, resolution rate -do a test*	Resolution rate for "add a drug" CCs was 8.6 % higher in the study group than the control group (p <0.05). There was, however, no significant difference in the resolution rates for "stop a drug" CCs (change -6%, NS). Resolution rates for "do a test" CCs were 5.8% higher in the study group, p <0.05.	+
Johnson (2010) (Johnson et al. 321-325) Design: RCT N = 3,285 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 08/2007	**CDSS/CDS/CCDS/ reminders** **e-Rx** Integrated EHR/EMR system	Ambulatory care, Pharmacy, Not specified, Academic	rate of callbacks generated*	There was no significant difference in the callback rates between the "SYW off" and the "SYW on "periods (0.4% vs. 0.45%; p = 0.47).	-
Kadmon (2009) (Kadmon, et al. 935-940) Design: Time series N = 5,000 Medication orders Implementation: 11/2004 Study Start: 09/2004 Study End: 09/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 12 bed PICU unit	total prescription error rate(combination of the 3 error types)*, pADE*, rule violations*, medication prescription errors*	Among the 5,000 prescriptions reviewed, 273 (5.5%) contained prescription errors. Implementation of CPOE associated with a slight, nonsignificant decrease in prescription error rate (between periods 1 and 2; 8.2% vs. 7.8%, p = 0.66). Decreases in rate of	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
				prescription errors after CDSS implementation were statistically significant between periods 2 and 3 (7.8% vs. 4.4%, p = 0.0004) and after prescription authorization between period 3 and 4 (4.4% vs. 1.4%, p <0.0001). The rate of potential ADEs decreased slightly between periods 1 and 2 (from 2.5% to 2.4%, p = 0.9) and significantly in periods 3 and 4 (to 0.8% and 0.7%, respectively; p <0.005). Rate of MPEs decreased slightly between periods 1 and 2 (from 5.5% to 5.3%, p = 0.79), but new types of MPEs appeared. A significant decrease in period 3 (to 3.8%; p <0.05) and a dramatically significant decrease in period 4 (to 0.7%; p <0.0005) was noted. 3 RVs were found	

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
				between period 1 and 2 (0.002% vs. 0.001%, p = 0.3). No RVs were found in period 3 and 4.	
Kaplan (2006) (Kaplan et al. 461-467) Design: Time series N = n/a orders Implementation: 04/2002 Study Start: 12/2001 Study End: 01/2004	**CPOE/POE system** Integrated Formulary, Hospital information system, Imaging systems, Pharmacy	Pediatric stand alone hospital, 423 Beds	rate of verbal orders*, rate of unsigned verbal orders*	Overall, there was a significant decrease in the rates of verbal orders (from 22% to 10%) and unsigned verbal orders (from 43% to 9%) between the period before CPOE implementation and 21 months after CPOE implementation (p = 0.0001 for both).	+
Karson (2007) (Karson et al. 1004) Design: Time series N = 74,494 verbal orders Implementation: 0/0000 Study Start: 01/2005 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 900 Beds Academic	compliance with co-signing within 24 hours, compliance with co-signing by month end	At baseline, 49% of verbal orders were co-signed within 24 hours. This increased to 63% after the first intervention and 93% after the second intervention (p <0.001). At month end, the compliance rate was 61% at baseline, 94% after the first intervention and 98% after the second (p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Kazemi (2010) (Kazemi et al. e5) Design: Observational study N = 158 patients (neonates) Implementation: 00/2007 Study Start: 12/2007 Study End: 09/2008	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, 400 Beds Academic	rate of non-intercepted errors for orders (POE Errors vs. NOE Errors)*, rate of nonintercepted errors for ordered medication*, rate of nonintercepted errors for patient days*, rate of nonintercepted errors medication-days *,	The rate of nonintercepted errors for orders decreased from 22.7% to 14.5% (RR 0.64; 95% CI 0.53 to 0.77, p <0.001). For ordered medication it dropped from 12.8% to 7.6% respectively (RR 0.60; 95% CI 0.50 to 0.71, p <0.001). However, the highest rate difference (9.5%) was seen when calculated according to patient days (24.5% vs. 15%, RR 0.61; 95% CI 0.49 to 0.77; p <0.001). The rate difference for medication-days were 5.8% (14.4% vs. 8.6%, RR 0.60; 95% CI 0.49 to 0.74;p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Kim (2006) (Kim et al. 495-498) Design: Before-after N = 2,375 chemo orders Implementation: 02/2003 Study Start: 07/2001 Study End: 02/2004	**CPOE/POE system** Integrated EHR/EMR system	Other specialty hospital (rehab, oncology) Academic	rate of improper dosing on treatment plans, rate of improper dosing on orders, rate of treatment plans and orders not matching, rate of missing cumulative dose calculations, rate of incorrect dosing calculations	After CPOE deployment, daily chemotherapy orders were less likely to have improper dosing on orders (2.3% vs. 0.1%, RRR 97%, p <0.05), incorrect dosing calculations (5.8% vs. 0.5%, RRR 91%, p <0.05), missing cumulative dose calculations (18% vs. 5.7%, RRR 68%, p <0.05), and incomplete nursing checklists (4.8% vs. 2.5%, RRR 48%, p <0.05). There was no difference in the likelihood of improper dosing on treatment plans (4.0% vs. 2.6%, RRR 35%, NS) and a higher likelihood of not matching medication orders to treatment plans (1.1% vs. 6%, RRR -445%, p <0.05).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	Settings	Outcomes Measured	Results	Outcome
Kim (2008) (Kim et al. 416-421) Design: Time series N = not given not given Implementation: 00/2002 Study Start: 02/2004 Study End: 04/2006	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 750 Beds Academic	3rd generation cephalasporin use (daily doses/1,000 patient days)	The use of third generation antibiotic cephalosporin use decreased significantly from 103.2 doses/1,000 patient days to 84.9 postimplementation. It increased once the feedback element was stopped (84.9 vs. 115.1, p <0.05).	+
Kirk (2005) (Kirk et al. 817-824) Design: Observational study N = 4,274 prescriptions Implementation: 00/2000 Study Start: 03/2003 Study End: 08/2003	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, Ambulatory care Academic	error rate	The computer calculated dose error rate was 12.6% compared with the traditional prescription error rate of 28.2% (RRR 55%, p <0.001).	+
Kitahata (2003) (Kitahata et al. 803-811) Design: Time series N = 1,204 patients with HIV Implementation: 04/1998 Study Start: 03/1996 Study End: 09/1999	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Ambulatory care, Academic	rate of prophylaxis for mycobacterium avium complex infection, rate of prophylaxis for pneumocystis cairnii pheumonia	After implementation of the CDSS patients were more likely to be given prophylaxis for mycobacterium avium complex infection (Hazard Ratio 3.84, CI 1.58 to 9.32, = 0.003) but not for pneumocystis cairnii pheumonia (Hazard Ratio 1.14, CI 0.84 to 1.59, NS).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Koide (1999) (Koide et al. 11-19) Design: Before-after N = 1,024 prescriptions for 111 patients and 68 physicians Implementation: 09/1994 Study Start: 09/1994 Study End: 09/1996	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system, Laboratory system	Acute care/tertiary, 1,040 Beds Academic	rate of 'appropriate' prescribing (normal value of ALT or AST within 3 mon)ths	127/491 (25.9%) preintervention prescriptions were classified as 'appropriate'. 353/533 (66.2%) postintervention prescriptions were classified as 'appropriate'. This sudden increase in level of 40.3% occurring immediately after the start of the intervention was highly significant (p <0.0001).	+
Kooij (2008) (Kooij et al. 893-898) Design: Time series N = 1,565 patients Implementation: 00/0000 Study Start: 11/2005 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	General Hospital, Academic	rate of prophylaxis, control vs. CDSS, r ate of prophylaxis, CDSS vs. stopping CDSS	Patients who needed PONV prophylaxis were more likely to be prescribed medication if clinicians were provided with electronic DS (73%) than before DS (38%) or after the electronic DS was stopped (37%), p <0.001.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Kooij (2009) (Kooij et al. 187-191) Design: Before-after N = 5,652 patients Implementation: 00/0000 Study Start: 11/2005 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary, Academic	percentage of patients who received dexamethasone*,percentage of patients who received granisetron*, percentage of patients who received both dexamethasone and granisetron*	Dexamethasone was given to 46% of the control period. In the decision support period, rate increased significantly to 95% and after deactivating the automated reminders, it decreased to 47% in the post decision support period (p <0.001) For granisetron, these percentages were 53%, 81%, and 51%, respectively (p <0.001). Percentage of patients receiving both medications was 39% in the control period, increased to 79% in the decision support group and decreased to 41% in the post decision support group (p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Kralj (2003) (Kralj et al. 197-203) Design: Case control N = 11,644 patient-physician encounter Implementation: April 2000 Study Start: 12/1999 Study End: 11/2001	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	changes in prescribing rates of erythropoietin between clinics at baseline compared with during the intervention group	The mean difference in prescribing rates between experimental and control clinic at baseline was 0.36 (p = 0.044). Whereas in the intervention period the difference in the rates between them almost tripled to .093 (p = 0.000). The rate of erythropoietin prescribing increased by 14.2% (p = 0.05) at the experimental clinic. It declined by 15.9% (p = 0.12, NS) in the control clinic.	+
Krall (2004) (Krall, Traunweiser, and Towery 1-9) Design: RCT N = 1,076 patients Implementation: 00/1994 Study Start: 01/2000 Study End: 02/2000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary	proportion of patients no longer eligible for alerts at the end of the month*	Following implementation of the alert, more patients were ‘no longer eligible for alerts at the end of the month’ (25.8% pre vs. 54.3% post, RRR - 103%, p <0.001).	+
Kucher (2005) (Kucher et al. 969-977) Design: RCT N = 2,506 patients Implementation: 00/0000 Study Start: 09/2000 Study End: 01/2004	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system	Acute care/tertiary Academic	received pharmacological interventions	More patients in the CDSS group received pharmacological interventions. (13% vs. 24%, RRR 69%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Lapane (2008) (Lapane et al. 442-446) Design: Mixed methods N = 276 primary care prescribers and their staff Implementation: 00/2003 Study Start: 04/2006 Study End: 08/2006	**e-Rx**	Ambulatory care	self reported drug alert overrides*	22/145 prescribers (15%) reported overriding drug-allergy alerts most of the time or 'always' with variation in frequency of overriding drug alerts by e-Rx software system ranging from 9% to 50% (p = 0.656 for overall comparison by e-Rx software system). Nearly 1 in 4 respondents reported overriding drug–dose alerts 'most of the time 'or 'always' (range 13% to 33%; p = 0.006). More than 40% indicated they override drug–drug interactions 'most of the time' or 'always' (range, 25% to 50%; p = 0.374).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Lecumberri (2008) (Lecumberri et al. 699-704) Design: Time series N = 19,338 patients Implementation: 09/2005 Study Start: 01/2005 Study End: 06/2007	**CDSS/CDS/CCDS/ reminders** Integrated hospital guidelines	Unspecified Hospital Academic	number of alerts, proportion of alerted patients receiving thromboprophy-laxis	an electronic alert was sent to 32.8% and 32.2% of all hospitalized patients, respectively. Appropriate prophylaxis among alerted patients was ordered in 89.7% (2006) and 88.5% (in 2007) of surgical patients, and in 49.2% (in 2006) and 64.4% (in 2007) of medical patients.	-
Ledwich (2009) (Ledwich et al. 1505-1510) Design: Before-after N = 2,477 vaccine possibilities (patients) Implementation: 00/0000 Study Start: 10/2006 Study End: 12/2007	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care, Academic	influenza vaccination rates, pneumococcal vaccination rates*	PostBPA influenza vaccination rates significantly increased (47% to 65%; p <0.001), at both sites. PostBPA pneumococcal vaccination rates likewise significantly increased (19% to 41%; p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Lesprit (2009) (Lesprit et al. 1058-1063) Design: Observational study N = 932 prescriptions Implementation: 11/2006 Study Start: 11/2006 Study End: 10/2007	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system	Acute care/tertiary, 960 Beds Academic	actual duration of treatment in days compared to prescribed*	Of the 482 prescriptions requiring intervention, the physicians complied with 80.3% of the recommendations. There was a significant reduction in the actual duration of antibiotic treatment compared to the originally prescribed duration (8 to 7 days (p <0.0001).	+
Lester (2005) (Lester et al. 22-29) Design: RCT N = 235 patients and 14 clinicians Implementation: 07/2003 Study Start: 07/2003 Study End: 07/2004	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care Academic	proportion of patients receiving statins*, proportion of patients receiving statins at 1 yr*	At 1 month, more patients in the email group had received statins than control patients (3% vs. 15%, RRR 400, p <0.001). At 1 year the difference in receipt of statins had disappeared (17% vs. 25%, NS).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Lin (2008) (Lin et al. 620-626) Design: Time series N = 1,123 high severity order checks Implementation: 00/1997 Study Start: 01/2001 Study End: 01/2006	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, General Hospital, 444 Beds Ambulatory care, Long term care (nursing homes)	override rates-severe drug-drug alerts*, override rates-severe drug-allergy alerts*	There were 215 high severity order checks in 2001 (0.5% of orders) and 908 in 2006 (2.5% of orders). Rate of overrides for drug-drug checks remained the same between 2001 and 2006 (88% vs. 87%, NS). Rate of overrides for drug-allergy order checks increased significantly from 2001 to 2006 (69% vs. 81%, RRR - 17%, p <0.005).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Linder (2009) (Linder et al. 231-240) Design: RCT N = 111,820 patients Implementation: 00/0000 Study Start: 11/2005 Study End: 05/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Imaging systems, Laboratory system	Ambulatory care	Rate of antibiotic prescribing to patients with ARI *	In the intent-to-intervene analysis, clinicians prescribed antibiotics to 43% of patients with ARI diagnoses in control clinic compared to 39% in the intervention clinic (OR. 0.8; 95% CI 0.6 to 1.2; p = 0.30). The ARI Smart Form did not significantly reduce overall antibiotic prescribing, was used by 33% of intervention clinicians (86/262) at least once. Appropriate antibiotic prescribing rate was 88% (n = 990 visits) in the as-used analysis.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Liu (2008) (Liu et al. 1109-1112) Design: Time series N = 858 patients Implementation: 00/1989 Study Start: 01/2005 Study End: 12/2006	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary	percentage of no prophylactic antibiotic after clean surgery, mean number of days of antibiotic treatment	In clean procedures, the percentage of no prophylactic antibiotic after surgery increased in the long run (overall 76% vs. 84% vs. 93%, no analysis); the increase was significant for 2 of the 4 surgery types (p <0.005). In clean-contaminated procedures, the duration of prophylactic antibiotic after surgery (mean number of days) was significantly reduced in 2 of the 3 surgery types (p <0.001).	+
Madaras-Kelly (2006) (Madaras-Kelly et al. 155-169) Design: Time series N = not reported Implementation: 00/0000 Study Start: 07/2001 Study End: 06/2004	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, 87 Beds	use of antibiotics*	Use of aminopenicillin beta-lactam inhibitors, all fluoroquinolones and levofloxacin decreased while use of first-generation cephalosporins and trimethoprim sulfamethoxazole increased (p <0.05 for each).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Mahoney (2007) (Mahoney et al. 1969-1977) Design: Before-after N = 2,843,135 inpatient medication orders Implementation: 02/2002 Study Start: 02/2002 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders CPOE/POE system Pharmacy information system** Integrated EHR/EMR system, Hospital information system	General Hospital, Pediatric stand alone hospital, 966 in 2 hospitals Beds Pharmacy, Inpatient hospital based, Academic	rate of: -drug allergy violations*, -excessive doses*, -incomplete or unclear orders*, -therapeutic duplication*	Medication errors decreased after implementation of the CIT with respect to drug allergy violations (OR 0.14, 95% CI 0.11 to 0.17, p <0.001), excessive doses (OR 0.68, 95% CI 0.62 to 0.74, p <0.001) and incomplete or unclear orders (0.35, 95% CI 0.32 to 0.38, p <0.001), but no decease in therapeutic duplications. Turnaround time between drug ordering and administration decreased from 90 minutes to 11 minutes. The override rate also decreased (7.1 to 2.9%, RRR 59%, p = 0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Martens (2007) (Martens et al. S403-S416) Design: RCT N = 77 physicians (GPs) Implementation: 04/2004 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated, EHR/EMR system	Ambulatory care	quinolone prescriptions, inhaled corticosteroids for newly diagnosed COPD in patients >40 years, first choice drugs for sore throats GPs got either reminders on antibiotics, asthma, and COPD or cholesterol. Reminders were either to stop prescribing drugs or to prescribe a specific first-line drug.	No differences were seen for either group to prescribe a drug or in the cholesterol reminder group. GPs in the antibiotics, asthma and COPD group showed changes in 3 of 8 drug categories. Outcome measures were sum scores for drug volume: lower scores were improvements in prescribing. Reminder physicians prescribed fewer quinolones (4.6 (95% CI 2.8 to 8.1) vs. 1.5 (95% CI 0.8 to 2.2); fewer inhaled corticosteroids for newly diagnosed COPD in patients >40 yr (0.5 (95% CI 0.3 to 0.9) vs. 0.0 (95% CI 0 to 0.1), p = 0.00); and better first choice drugs for sore throats (0.8 (95% CI 0.3 to 2.4) vs. 0.2 (95% CI 0.0 to 9.4), p = 0.03.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Mattison (2010) (Mattison et al. 1331-1336) Design: Before-after N = not reported medication orders Implementation: 10/2004 Study Start: 06/2004 Study End: 08/2008	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 621 Beds Academic	rate of prescribing not-recommended medications*, rate of prescribing medications with recommended dosage reductions*	In before-and-after comparisons, the mean (SE) rate of prescribing not-recommended medications dropped from 11.56 (0.36) to 9.94 (0.12) orders per day (difference, 1.62 [0.33]; p <0.001).There were no appreciable changes in the rate of ordering medications for which only dose reduction was recommended or that were not targeted after CPOE implementation.	+
Maynard (2010) (Maynard et al. 10-18) Design: Time series N = 3,285 patients Implementation: 04/2006 Study Start: 00/2005 Study End: 00/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 350 Beds Academic	percent of patients on adequate prophylaxis*	The percent of patients on adequate prophylaxis improved in each of the 3 years from a baseline of 58% in 2005 to 78% in 2006 (unadjusted relative benefit = 1.35; 95% CI 1.28 to 1.43), and 93% in 2007 (unadjusted relative benefit =1.61; 95% CI 1.52 to 1.69).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
McCluggage (2010) (McCluggage et al. 70-75) Design: Before-after N = 522 patients Implementation: 02/2007 Study Start: 08/2006 Study End: 04/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, Academic	optimal regimen prescribed*	The percentage of patients whose initial vancomycin regimen matched the nomogram recommendation was higher in the postimplementation group compared with the preimplementation group (35.8% vs. 23.7%, p = 0.0028).	+
McGregor (2006) (McGregor et al. 378-384) Design: RCT N = 4,507 patients Implementation: 00/000 Study Start: 05/2004 Study End: 08/2004	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system, Pharmacy	Acute care/tertiary 648 Beds Inpatient hospital based, Academic	mean time spent on antimicrobial management	Team members spent 3.2 hours per day on management of antimicrobials with the decision support system compared with 4 hours per day without. No statistical testing was done.	+
McMullin (1999) (McMullin et al. 2077-2082) Design: Before-after N = 265 patients Implementation: 01/1996 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system, Pharmacy	Acute care/tertiary, Pharmacy, Inpatient hospital based	rate of concomitant orders for contraindicated medications with cisapride*	The rate of ordering contraindicated drugs with cisapride was reduced with COPE (9% vs. 3.1%, RRR 65%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Miskulin (2009) (Miskulin et al. 1081-1088) Design: Cohort study N = 8,941 patients Implementation: 00/2005 Study Start: 11/2005 Study End: 04/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	EPO use*, time spent on anemia management (hours per month)	After adjustment for center and baseline differences, the log weekly EPO dose in patients treated using CDS was 4% less than those dosed manually (RR 0.96; 95% CI, 0.77 to 1.18, NS). CDS was associated with a nearly 50% decrease (p <0.001) in the time spent by dialysis unit staff on anemia management. Units using the computerized protocol spent a median of 3 hours per month on anemia management units using manual dosing spent a median of 6.5 hours per month.	+
Montgomery (2000) (Montgomery et al. 686-690) Design: RCT N = 552 patients Implementation: 00/0000 Study Start: 09/1996 Study End: 09/1998	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	probability of patients taking 2 drugs, probability of patients taking 3 drugs	risk chart group alone compared to computer support group had a lower probability of patients taking 2 drugs (OR 0.5, 95% CI 0.2 to 0.9) p <0.05) or 3 drugs (OR 0.3, 95% CI 0.1 to 0.6, p <0.05).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Morrison (2006) (Morrison et al. 1033-1039) Design: Time series N = 3,864 patients Implementation: 00/0000 Study Start: 02/2001 Study End: 02/2003	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, 1171 Beds Academic	meperidine prescription rate, rate of patients receiving a concomitant laxative with an opioid	rate of patients receiving a concomitant laxative with an opioid did not change with the introduction of the CDSS system (data for 5 groups, 24.7% of patients who needed a laxative, 27.8%, 32.1%, 26.8%, and 34.0%, all comparisons NS). Fewer patients received meperidine with the introduction of the CDSS system. For group 4 (CDSS and enhanced assessment compared with Group 1 control 44.2% vs. 25.4%, RRR 20%, p <0.05). For Group 5 vs. Group 1 the rate of meperidine use was even lower (44.4% vs. 11.9%, RRR 73%, p = 0.01).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Mullett (2001) (Mullett et al. e75) Design: Before-after N = 1,758 patients Implementation: 02/1999 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Hospital information system	Critical care units (CCU, ICU, NICU) Pediatric stand alone hospital, 232 Beds Inpatient hospital based, Academic	per patient anti-infective doses, per patient number of anti-infectives, per patient anti-infective orders per course, mean subtherapeutic anti-infective days/100 patient days, mean excessive dosage anti-infective days/100 patient days	The rate of per person use of anti-infective agents did not differ for PICU doses (12.8 vs. 13.4, NS), PICU number of doses (1.85 vs. 1.97, NS) but did differ for PICU anti-infective orders per patient-anti-infective course (1.56 vs. 1.38, p <0.01). The mean number of subtherapeutic risk days decreased (7.35 vs. 4.7, p <0.001) as did the mean excessive dosage risk days (8.45 vs. 6.1, p <0.001).	+
Nash (2005) (Nash et al. 64-69) Design: Time series N = 39,440 doses Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**Medication safety reporting system** Integrated Hospital information system Laboratory system	Acute care/tertiary, 1171 Beds Academic	reduction in excessive dosing for the nursing intervention, reduction in excessive dosing for the pharmacist intervention	There was a reduction in the rate of excessive dosing in the participating units compared to the control unit in the nurse intervention (23% for baseline for the control group with 17% for the nurse intervention and 17% for the pharmacist interventions (p <0.05).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Newby (2003) (Newby, Fryer, and Henry 210-213) Design: Cross-sectional N = 1,667 prescriptions Implementation: 00/0000 Study Start: 10/0000 Study End: 11/0000	**e-Rx** Integrated Pharmacy	Pharmacy, Stand alone (e.g. family run)	rate of repeat ordering	The rate of repeat ordering was higher for all antibiotics if the original was written using an e-Rx system (40% for paper vs. 69% for initial e-Rx, adjusted OR 3.82, 95% CI 2.55 to 5.72, p <0.05). This same significant affect was seen for all 4 study antibiotics. The rate of filling prescriptions NS as reported by patients (69% if the prescription was on paper vs. 61% by e-Rx, NS).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Niemi (2009) (Niemi et al. 389-397) Design: Before-after N = 5,076 patients Implementation: 00/0000 Study Start: 10/2006 Study End: 03/2007	**CDSS/CDS/CCDS/ reminders** Integrated Billing/administration system, Imaging systems, Laboratory system, Pharmacy	Acute care/tertiary	antibiotic administration within four hours*, pneumonia vaccination status documentation*, appropriate pneumonia antibiotic selection*, ACE or ARB initiation*, provision of discharge instructions to patients*	Compliance with the medication related indicators for pneumonia measures were NS; antibiotic administration within four hours (83% vs. 87%, RRR -5%), pneumonia vaccination status documentation (82% vs. 92%, RRR-12%), appropriate pneumonia antibiotic selection (93% vs. 92%, RRR 1%). After implementation, heart failure medication related quality indicators measures were not significantly for ACE or ARB initiation (95% vs. 98%, RRR -4%) but there was a significant increase in compliance with the provision of discharge instructions to patients (84% vs. 95%, RRR -13%, p <0.01).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Niiranen (2008) (Niiranen and Yli-Hietanen 4330-4332) Design: Time series N = 18,818 patient followups Implementation: 03/2005 Study Start: 04/2005 Study End: 12/2007	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Ambulatory care, Home	proportion of patient followups assigned by nurses, year 1 to 2, proportion of patient followups assigned by nurses, year 2 to 3	In general, the share of patient followups assigned by nurses was similar in year 1 and 2 (56.7% vs. 55.1%, RRR 3%, NS), and increased significantly between year 2 and 3 (55.1% vs. 58.7%, RRR -7%, p <0.001).	+
Novis (2010) (Novis et al. 648-654) Design: Before-after N = 800 patients Implementation: 08/2007 Study Start: 03/2007 Study End: 03/2008	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary	percentage of patients receiving pharmacological prophylaxis, percentage of patients receiving sequential compression devices and pharmaprophy-laxis	The proportion of patients receiving the recommended pharmacological prophylaxis preoperatively more than doubled (14% to 36%, p <0.001) Overall, the percentage of at-risk patients receiving the recommended combined DVT prophylaxis of SCD and pharmacological prophylaxis increased nearly seven-fold (5% to 32%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Oliven (2005) (Oliven et al. 377-386) Design: Cross-sectional N = 1,350 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Drug order database EHR/EMR system, Hospital information system, Laboratory system	Acute care/tertiary, 88 Beds Academic	Type 1 PEs per 100 hospitalization days, Type 2 PEs per 100 hospitalization days	The incidence of Type 1 PEs was 5.21 and 1.36 per 100 hospitalization days in the HW dept and CDOE dept, respectively (p <0.0001). Type 2 PEs were more common, 7.20 and 3.02 per 100 hospitalization days in the HWdept and CDOEdept, respectively (p <0.0001), and about 75% of them were due to few drug laboratory interactions.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Overhage (1996) (Overhage, Tierney, and McDonald 1551-1556) Design: RCT N = 24 practice teams Implementation: 10/1991 Study Start: 10/1992 Study End: 03/1993	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Hospital information system, Laboratory system, Pharmacy	General Hospital Academic	rates of compliance with preventive care recommend-ations*	control teams complied with 24% of the reminders compared with 23% for intervention teams (p = 0.78) When preventive care measures were analyzed individually, 2 significant differences were seen in compliance (24-hour urine protein and angiotensin-converting enzyme [ACE] inhibitor) between control and intervention teams. Assumed to be due to chance with multiple testing and because they were in the opposite directions.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Overhage (1997) (Overhage et al. 364-375) Design: RCT N = 86 physicians on 6 services (services randomized) Implementation: 00/0000 Study Start: 10/1992 Study End: 04/1994	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Laboratory system	General Hospital, Academic	immediate compliance with corollary ordering*, 24 hour compliance*, hospital stay compliance*	Intervention physicians ordered the corollary orders required by the guidelines twice as often as control physicians did when measured by immediate compliance (46.3% vs. 21.9%, RRR - 111%, p <0.0001). Significant differences between study and control physicians also appear in 24 hour compliance (50.4% vs. 29.0%, RRR - 74%, p <0.0001) and hospital-stay compliance (55.9% vs. 37.1%, RRR 51%, p <0.0001).	+
Overhage (2001) (Overhage et al. 361-369) Design: RCT N = 34 physicians Implementation: 00/1984 Study Start: 09/1996 Study End: 02/1998	**CPOE/POE system** Integrated Billing/administration system CPOE/POE system, Imaging systems	Ambulatory care, Academic	mean time spent in direct care per patient, minutes*, mean time spent in writing tasks per patient, minutes*	Time spent in direct care with a patient in minutes remained the same in the control (paper-based) and CPOE groups (15.8 vs. 16.1, NS). Time spent on writing tasks in minutes remained the same between groups (6.2 vs. 6.9, NS).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Ozdas (2006) (Ozdas et al. 188-196) Design: Before-after N = 540 patients Implementation: 04/2003 Study Start: 08/2002 Study End: 09/2003	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system EHR/EMR system	Acute care/tertiary, 630 Beds Academic	rate of order set use for sensitive to AMI patients*, rate of order set use for confirmed AMI patients*	There was a significant increase in ACS order set use after the implementation of the Admission Advisor for ‘sensitive to AMI’ admissions (60% vs. 70%, RRR -17%, p = 0.009), and a non-significant increase for confirmed AMI patients (46% vs. 64%, RRR -39%, p = 0.07). For all suspected AMI admissions, ACS order set use yielded a significant increase in early aspirin ordering (77% vs. 91.2%, RRR -17%, p = 0.001) and an increase in trend toward significance in beta-blocker ordering (70% vs. 76%, RRR -9%, p = 0.07). A similar non-significant trend in aspirin (89% vs. 97%, RRR -9%, p = 0.07) and beta-blocker (81% vs. 88%, RRR -9%, p = 0.18) ordering behavior associated with a confirmed diagnosis of AMI.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Palen (2006) (Palen et al. 389-395) Design: RCT N = 26,586 index dispensings Implementation: 00/0000 Study Start: 11/2002 Study End: 10/2003	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system EHR/EMR system, Pharmacy	Ambulatory care	compliance rate	Difference between the control and intervention group physicians in the overall rate of compliance with ordering the recommended laboratory monitoring for prescribed study medications (NS). Laboratory monitoring was performed as recommended 56.6% of the time in the intervention group compared with 57.1% of the time in the control group (p = 0.31). Improved compliance favored the intervention group (71.2% vs. 62.3% [p = 0.003] for gemfibrozil; 75.7% vs. 73.9% [p = 0.05] for statins, 52.8% vs. 46% for colchicine [p = 0.05]; 42.9% vs. 0% for methotrexate [p = 0.03]).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Paterno (2009) (Paterno et al. 40-46) Design: Cohort study N = 71,350 alerts Implementation: 00/1996 Study Start: 02/2004 Study End: 02/2005	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 1633 beds in 2 hospitals Academic	compliance rate with DDI alerts: -overall, -severe alerts, -moderately severe alerts	71,350 alerts were reviewed, of which 39,474 occurred at the non-tiered site and 31,876 at the tiered site. Compliance with DDI alerts was significantly higher at the site with tiered DDI alerts compared to the non-tiered site (29% vs. 10%, p <0.001). At the tiered site, 100% of the most severe alerts were accepted, vs. only 34% at the non-tiered site (p <0.001); moderately severe alerts were also more likely to be accepted at the tiered site (29% vs. 10%, p <0.001).	+
Patterson (1998) (Patterson 573-576) Design: Before-after N = 2,013 Patients (cases) Implementation: 00/0000 Study Start: 00/0000 Study End: 01/1998	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Acute care/tertiary, 520 Beds Academic	rate of DVT prophylaxis *	The preintervention rate of deep vein thrombosis (DVT) prophylaxis was 85.2%. With the introduction of the computerized reminder, compliance with DVT prophylaxis increased to 99.3% (85.2% vs. 99.3%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Paul (2006) (Paul et al. 1238-1245) Design: RCT N = 3,529 patients in the RCT and 1,203 in the cohort study Implementation: 00/0000 Study Start: 05/2004 Study End: 11/2004	**CDSS/CDS/CCDS/ reminders**	Acute care/tertiary, 424 Beds Academic	appropriate antibiotic prescribing increased	Appropriate antibiotic prescribing increased for both intention to treat analyzes (64.5% vs. 72.7%, RRR 13%, p <0,05) and for per protocol analyzes (64.5% vs. 85.1%, RRR 32%, p <0.05). The cohort study showed similar increases in improved prescribing (57% vs. 70%, p <0.001).	+
Peterson (2005) (Peterson et al. 802-807) Design: Cohort study N = 7,456 Medication orders Implementation: 00/0000 Study Start: 10/2001 Study End: 05/2002	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 720 Beds Academic	agreement with system recommended daily dose of psychotropic drugs for control vs. CPOE, incidence of dosing that was 10-fold greater than recommended for control vs. CDSS	The CDSS increased the prescription of the recommended daily dose (29% vs. 19%; RRR 58% p <0.001) reduced the incidence of dosing that was 10-fold greater than recommended (2.8% vs. 5.0%, RRR 48%; p <0.001).	+
Peterson (2007) (Peterson et al. 2-40) Design: RCT N = 9,111 medication orders Implementation: 00/0000 Study Start: 12/2005 Study End: 08/2006	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary Critical care units (CCU, ICU, NICU) Emergency department, Not specified Academic	ratio between prescribed and recommended doses	Ratio between the prescribed dose and recommended dose showed that compared to controls the intervention group (reminders) received lower doses (3.0 vs. 2.5, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Prescription in Ischaemic Stroke Management (PRISM) Study Group (2003) (Weir) et al. 143-153) Design: RCT N = 1,640 Patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Unspecified Hospital	relative risk reduction (RRR) in ischemic and hemorrhagic vascular events	Actual therapy prescribed vs. the option of 'no antiplatelet or anticoagulant therapy. Estimated RRR(%) for the control and intervention in the first phase was 16.7 (13.2 to 23.7) vs. 16.3 (15.2 to 21.2) (not significantly different) For the second phase it was 16.3 (13.1 to 23.8) vs. 16.7 (13.5 to 22.9) (NS).	-
Quinn (2008) (Quinn et al. 160-168) Design: RCT N = 30 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders Daibetes Management Tool** Integrated Web-based data analytics and therapy optimization tools	Ambulatory care	changes in medication (medication intensified)	Patients using WDS were more likely to have physicians intensify diabetes medications (84.6% vs. 23.08%, p = 0.002).	+
Quinzler (2009) (Quinzler et al. 30-35) Design: Before-after N = 20,031 prescribed drugs Implementation: 00/2003 Study Start: 08/2006 Study End: 03/2007	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders Pharmacy	Acute care/tertiary 1680 Beds Academic	proportion of prescriptions with inappropriate tablet splitting	The CDSS alert resulted in a significant reduction in prescriptions for inappropriate tablet splitting (2.7% vs. 1.4%, RRR 48%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Raebel (2005) (Raebel et al. 2395-2401) Design: RCT N = 10,169 dispensings Implementation: 00/0000 Study Start: 09/2002 Study End: 12/2003	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system, Pharmacy	Ambulatory care, HMO pharmacy	percentage of dispensings with baseline monitoring	Recommended laboratory monitoring was completed in 74.7% (n=7,598) of dispensings at initiation of therapy. Compared to the usual care group, monitoring was higher in the intervention group (70% vs. 79%, RRR -13%, p <0.001).	+
Raebel (2007) (Raebel et al. 977-985) Design: RCT N = 59,680 patients Implementation: 00/0000 Study Start: 05/2005 Study End: 05/2006	**CDSS/CDS/CCDS/ reminders Pharmacy information system** Integrated EHR/EMR system	Ambulatory care, HMO pharmacy	new dispensings of targeted medications*, dispensings of targeted medications considered inappropriate*	In the analysis of all dispensings of targeted medications, there was a significant reduction of new dispensings of at least one targeted medication (2.2% vs. 1.8%, RRR 16%, p <0.002). For dispensings of targeted medications considered inappropriate, there was also a significant reduction with the use of the alerting system (1.5% vs. 1.1%, RRR 27%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Raebel (2007) (Raebel et al. 440-450) Design: RCT N = 11,100 women Implementation: 00/0000 Study Start: 01/2003 Study End: 04/2003	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system Pharmacy	Ambulatory care HMO pharmacy	the proportion of pregnant women dispensed a category D or X medication*, the total number of first dispensings of targeted medications	The alerts resulted in a 47% reduction in the proportion of pregnant patients receiving category D or X drugs (p <0.001) Intervention patients received 238 dispensings of unique targeted medications and usual care patients received 361 dispensings (p = 0.03). The study was stopped primarily due to 2 false-positive alert types: Misidentification of medications as contraindicated in pregnancy by the pharmacy information system and misidentification of pregnancy related to delayed transfer of diagnosis information.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Rasmussen (2005) (Rasmussen et al. 1137-1142) Design: RCT N = 253 patients Implementation: 00/0000 Study Start: 00/2001 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Internet based electronic diary	Ambulatory Care Academic	good compliance (use of medication always or almost always) Internet vs. specialist group	A significant improvement in compliance was observed for all groups, but good compliance was significantly higher (p <0.001) for both the Internet vs. the GP group and the specialist vs. the GP group. 4 of 4 measures of improve prescribing was noted in the internet group and the specialist group. The GP group also improved but to a lesser extent.	+
Riggio (2009) (Riggio et al. 124-131) Design: Before-after N = 100 patients with heparin induced thrombocytopeni a Implementation: 06/2005 Study Start: 03/2004 Study End: 09/2006	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, 728 Beds Academic	time from platelet count criterion until heparin/ enoxaparin stop* Time from platelet count criterion until 1st HIT laboratory test drawn* Time from platelet count criterion until direct thrombin inhibitor started*	Counter to expectations, the time (in days) taken from alert to heparin stop order was significantly higher after implementation (1.3 vs. 2.9, p = 0.04). There were no significant differences in time (in days) from alert to lab test (2.3 vs. 3.0, NS), nor time to start of treatment with direct thrombin inhibitor (19.3 vs. 15.0, NS).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Riggio (2009) (Riggio et al. 1719-1726) Design: Before-after N = 2,151 discharge measures Implementation: 00/2001 Study Start: 07/2005 Study End: 03/2008	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system	Acute care/tertiary, 690 Beds Academic	overall compliance rate*	CDSS yielded a 26% increase in overall compliance with the cardiac discharge measures, from 76.8% in the preintervention period to 96.8% (p <0.001) in the postintervention period.	+
Rohrig (2008) (Rohrig et al. 63-68) Design: Before-after N = 156 patients Implementation: 00/1999 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Critical care units (CCU, ICU, NICU) 14 bed unit Beds Academic	rate of adequate treatment, rate of inadequate treatment	The frequency of adequate treatment increased from an average 47.8% in the pre-period to 66.5% in the post-period (p <0.01). Rate of inadequate treatment decreased from 34.2% to 18.5%.	+
Rollman (2002) (Rollman et al. 493-503) Design: RCT N = 200 Patients with documented major depression Implementation: 00/0000 Study Start: 04/1997 Study End: 12/1998	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	antidepressant prescribing rate (secondary)	Prescribing antidepressants (continuous use of change in prescriptions) did not differ across the 3 groups at 3 or 6 months.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Rood (2005) (Rood et al. 172-180) Design: RCT N = 484 patients Implementation: 04/2001 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Critical care units (CCU, ICU, NICU) 18 Beds Academic	adherence to glucose measurement timing recommend-ations*, adherence to insulin dose advice*	Rate of compliance with glucose measurement timing recommendations control-intervention-control (29% vs. 38% vs. 41% with period 2 and 3 greater than period 1, p = 0.05). During the intervention period, the rate for computerized group was higher than the control (36% vs. 40%, p = 0.05). Rate of compliance with insulin dose advice was higher in period 2 than 1, and then decreased significantly in period 3 (56% vs. 70% vs. 42%, p = 0.05). During the intervention period the rate for computerized group was higher than the control (64% vs. 77%, p = 0.05).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Ross (2005) (Ross et al. 410-415) Design: Cohort study N = 190 physicians Implementation: 00/0000 Study Start: 08/2001 Study End: 07/2002	**e-Rx** Integrated Formulary	HMO pharmacy	Formulary compliance ratio*, Absolute generic utilization ratio,* Adjusted generic utilization ratio *	No differences between predominantly traditional prescribers and e-prescribers for formulary compliance (82.8% vs. 83.2%, p = 0.32) or absolute generic drug utilization (36.9% vs. 37.3%, p = 0.18) or adjusted generic drug utilization (74.3% vs. 74.7%, p = 0.27).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Rosser (1992) (Rosser et al. 911-917) Design: RCT N = 8,069 patients Implementation: 00/0000 Study Start: 04/1985 Study End: 03/1986	**CDSS/CDS/CCDS/ reminders**	Ambulatory care, Academic	rate of tetanus toxoid vaccination*	The rates of tetanus toxin given were 3.2% in control, 22.8% in physician reminder, 24% in telephone reminder, and 30.6% in the letter reminder. The differences in the recorded vaccination rate between the randomized control group and the three reminder groups are as follows: 19.6% in the physician reminder group (95% CI 17.1% to 22.2%, p <0.00001), 20.8% in the telephone reminder group (CI 18.3% to 23.5%, p <0.00001) and 27.4% in the letter group (CI 24.8% to 30.2%, p <0.00001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Rubin (2006) (Rubin et al. 627-634) Design: Observational study N = 99 primary care physicians Implementation: 01/2002 Study Start: 01/2002 Study End: 03/2004	**CDSS/CDS/CCDS/ reminders** Integrated Handheld, Stand-Alone	Ambulatory care	change in rate of antibiotic prescribing according to recommend-ations*,change in rate of adherence to NOT prescribe antibiotic recommend-ations*	Adherence with CDSS recommendations increased from 79.3% in the first one-third of provider's cases to 82.0% in the second two-thirds (an increase of 2.7%; p <0.016) .Total adherence was higher with diagnoses for which an antibiotic was not indicated (84.8% vs. 75.7% for diagnoses warranting antibiotics), and providers showed a significant improvement in adherence over time for cases not requiring antibiotics (an increase of 2.7%; p <0.039).	+
Safran (1995) (Safran et al. 341-346) Safran (1993) (Safran et al. 224-228) Design: RCT N = 349 patients with HIV Implementation: 00/0000 Study Start: 05/1992 Study End: 09/1993	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system	Ambulatory care, Academic	mean response time to alerts* mean response times to reminders*	Physicians who got alerts responded more quickly to them (mean 52 vs. 11 days, p <0.0001). Physicians who got reminders responded more quickly to them (mean 500 vs. 114 days, p = 0.0001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Schnipper (2008) (Schnipper et al. Symposium) Design: Before-after N = 30 clinicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Antiplatelet prescribed or contraindication documented*, Beta-blocker prescribed *, Change in diabetic therapy if A1c >7.0 *	Antiplatelet prescribed or contraindication documented improved from 3.2% in the preintervention to 31.0% in the postintervention period, p <0.001. Beta-blocker prescribed or contraindication documented was 4.2 % in the preintervention compared to 66.7% in the post period, p = 0.03. Change in diabetic therapy if A1c >7.0 was 10.7% in the pre-period and 16.9% in the post period, p = 0.11.	+
Scotton (2009) (Scotton et al. 71-76) Design: Before-after N = 283 patients Implementation: 12/2003 Study Start: 03/2003 Study End: 01/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary, 606 Beds	proportion of cases with guideline violations	Contrary to expectations, the prescribing guidelines were violated significantly less frequently during baseline (27.4%) than after implementation of the reminder (34.3%), p <0.01.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Segarra-Newnham (2003) (Segarra-Newnham 758-762) Design: Before-after N = 211 Patients Implementation: 00/1997 Study Start: 00/1995 Study End: 07/2001	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Vaccination rate for pneumococcal vaccine*, Vaccination rate for tetanus vaccine*	Vaccination rates for enrolled before 1997 and after 1997 were 100% vs. 97% for pneumococcal vaccine (NS).However the vaccination rate for the same time period for tetanus vaccine was 100% vs. 61% due to national shortage of vaccine after 1997 (p <0.001).	-
Sellier (2009) (Sellier et al. 203-210) Design: Time series N = 942 prescriptions Implementation: 00/0000 Study Start: 08/2006 Study End: 08/2007	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system, Pharmacy	Acute care/tertiary, 827 Beds Academic	rate of inappropriate first prescriptions*, overall rate of inappropriate prescriptions, rate of cancellation of prescriptions if no eGFR lab result was available	The rate of inappropriate first prescriptions did not differ significantly between intervention and control periods (19.9% vs. 21.3%, RRR 7%, p = 0.63); nor did the overall rate of inappropriate prescriptions (20.4% vs. 18.5%, RRR 9%, p = 0.37). The rate of cancellation of prescriptions if no eGFR lab result was available also did not differ between control and intervention periods (31.3% vs. 35%, RRR-12%, p = 0.62).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Shiffman (2000) (Shiffman et al. 767-773) Design: Before-after N = 9 physicians Implementation: 00/0000 Study Start: 09/1996 Study End: 10/1998	**CDSS/CDS/CCDS/ reminders** Handheld	Ambulatory care	Adherence rate with metered-dose inhaler/ nebulization*, rate of systemic corticosteroid prescriptions*	Adherence with metered-dose inhaler/nebulization rates did not differ between control and intervention (73% vs. 91%, NS), nor did rate of prescribing systemic corticosteroids (43% vs. 57%, NS).	-
Shojania (1998) (Shojania et al. 554-562) Design: RCT N = 396 physicians Implementation: 00/0000 Study Start: 06/1996 Study End: 03/1997	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Imaging systems, Laboratory system, Pharmacy	Acute care/tertiary, 720 Beds Academic	number of vancomycin orders/ prescriber*, mean duration of treatment prescribed per physician*, mean number of days of vancomycin per course of treatment*	The total number of orders for vancomycin for physicians in the control group was higher than in the intervention group (16.7 vs. 11.3 orders per physician, $p = 0.04$). Physicians in the intervention group prescribed vancomycin for 36% fewer days than physicians in the control group (26.5 vs. 41.2, $p = 0.05$). The number of days of vancomycin per course of treatment was also lower for the physicians in the intervention group, mean of 1.8 vs. 2.0 for the control group ($p = 0.05$).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Shu (2001) (Bates et al. 965) Design: Before-after N = 44 Physicians (Interns) Implementation: 11/01998 Study Start: 09/1998 Study End: 06/1999	**CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, 820 Beds	time spent ordering*	The percentage of total time spent writing orders by medical interns between pre-CPOE and post-CPOE period increased from 2.1% to 9.0% (p <0.001).	-
Shulman (2005) (Shulman et al. R516-R521) Design: Time series N = 3,465 prescriptions over 4 times points Implementation: 04/2002 Study Start: 09/2001 Study End: 12/2002	**CPOE/POE system** Integrated Hospital information system	Critical care units (CCU, ICU, NICU) 22 (in the ICU) Beds Academic	rate of ME*	The proportion of MEs before CPOE was 6.7% and 4.8% after CPOE introduction (RRR 28%, p <0.04) The proportion of MEs with CPOE varied over time after its introduction (p <0.001). Evidence also indicated the strong linear trend of a declining proportion of MEs over time (p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Silveira (2007) (Delgado et al. 223-230) Design: Before-after N = 4,814 orders (treatment lines) Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**e-Rx** Integrated EHR/EMR system, Pharmacy	General Hospital, 53 beds in 2 wards of the hospital Beds	rate of errors: -medication data, -dose, -administration frequency/time, -route of administration, -nursing transcription	The EP system was associated with a lower rate of errors compared with the manual system for medical data (38% vs. 8%, RRR 79%, p <0.05), dosage (29% vs. 2%, RRR 92%, p <0.05), administration frequency/time (6% vs. 1%, RRR 83%, p <0.05) and route of administration (17% vs. 0%, RRR 99%, p <0.05). Nursing transcription errors were increased (18% vs. 21%, RRR 17% p <0.05) while drug interaction (2% vs. 3%) and treatment duration errors (1% vs. 1%) remained the same.	+
Sintchenko (2005) (Sintchenko et al. 398-402) Design: Before-after N = not reported n/a Implementation: 10/2002 Study Start: 04/2002 Study End: 03/2003	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 800 (18 bed ICU) Beds Academic	antibiotic consumption (defined daily doses/1,000 patient days)*	Consumption of antibiotics in defined daily doses/1,000 patient days decreased significantly after implementation of the hand-held decision support tool (1,767 vs. 1,458, p = 0.04).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Small (2008) (Small, Barrett, and Price 181-187) Design: Cross-sectional N = 1,941 prescriptions Implementation: 01/2003 Study Start: 01/2005 Study End: 09/2005	**CPOE/POE system**	Acute care/tertiary, Academic	error rate*, types of errors, severity of errors, error rates among prescribers	For error rates using computerized vs. spreadsheets indicated a relative risk reduction of 42% (20% vs. 12%, RRR 42%, p <0.0001) The distribution of type of error differed significantly according to prescription method (p <0.001) and the distribution of severity of errors also differed significantly according to prescribing method (p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Smith (2006) (Smith et al. 1098-1104) Design: Time series N = no sample size given number of dispensings Implementation: 09/2000 Study Start: 10/1999 Study End: 12/2002	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system EHR/EMR system	Ambulatory care	number of dispensing of non-preferred drugs/10,000 population in elderly patients, number of dispensing of preferred drugs/10,000 population in elderly patients, number of dispensing of non-preferred drugs/10,000 population in non-elderly patients	Following the implementation of the drug-specific alerts, a large and persistent reduction (5.1 prescriptions per 10,000, p = 0.004) a 22% relative decrease from the month before alert implementation, in the exposure of elderly patients to nonpreferred medications was observed. We found no evidence of a decrease in use of nonpreferred agents for nonelderly patients. There was an upward, though non-significant trend in the use of preferred agents in elderly patients following the intervention (p = 0.66).	-
Sobieraj (2008) (Sobieraj 1755-1760) Design: Before-after N = 101 patients Implementation: 03/2007 Study Start: 07/2006 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated CPOE/POE system	Acute care/tertiary, 819 Beds Academic	compliance with ordering VTE prophylaxis	The addition of alerts for patients at risk of VTE and an education program resulted in a significant improvement in compliance with ordering VTE prophylaxis (49% vs. 93%, RRR -90%, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Spencer (2005) (Spencer et al. 416-419) Design: Before-after N = 5,063 medication errors Implementation: 10/2002 Study Start: 01/2002 Study End: 05/2003	**CPOE/POE system**	Acute care/tertiary, 688 Beds Academic	reported errors per discharge	Implementation of CPOE on the two units was associated with a significant increase in reported errors, from 0.068 per discharge before CPOE implementation to 0.088 per discharge afterward ($p = 0.01$).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Steele (2005) (Steele et al. e255) Design: Before-after N = 54,206 patient visits Implementation: 12/2002 Study Start: 08/2002 Study End: 04/2003	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Laboratory system	Ambulatory care	percentage of: -time provider ordered the rule-associated laboratory test (for which alert was triggered and message displayed), - times medication order triggered but not completed (for an abnormal laboratory value), -times the provider ordered the rule-associated laboratory test (for alert that was triggered for a missing laboratory test)	Medication orders for which an alert was presented shows an increase in the percentage of time the provider ordered the rule-associated laboratory test (38.5% vs. 51.1%, p, 0.001) .When alert was for an abnormal laboratory value, percentage of times medication order triggered but was not completed increased from 5.6% at baseline to 10.9% during the intervention (p = 0.03). The largest effect was noticed when the alert was triggered for a missing laboratory test, the percentage of times the provider ordered the rule-associated laboratory test increased from 43.0% at baseline to 62.0% (p <0.001). All other outcomes did not have statistically significant change.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Stone (2009) (Stone et al. 960-967) Design: Before-after N = 18,884 procedures Implementation: 05/2007 Study Start: 12/2006 Study End: 05/2008	**CPOE/POE system**	Unspecified Hospital	medication error rates, Mean total time from placement of order to nurse receipt	Medication error rates did not decrease significantly from preimplementation to 6 or 12 months postimplementation (0.22% vs. 0.16 % vs. 0.21%, p = NS). Mean total time from placement of order to nurse receipt before implementation was significantly reduced (41.2 minutes vs. 27 seconds, p <0.01).	-
Tamblyn (2003) (Tamblyn et al. 549-556) Design: RCT N = 12,560 Patients Implementation: 00/0000 Study Start: 01/1997 Study End: 02/1998	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	rate of initiation of inappropriate drugs per 1,000 visits, Rate of discontinuation of inappropriate drugs per 1,000	During the study the number of new potentially inappropriate prescriptions per 1,000 visits was lower (52.2 v 43.8) in the CDS group than in the control group (RR 0.82, 95% CI 0.69 to 0.98). The rate of discontinuation of inappropriate drugs per 1,000 was not different: 67.4 vs. 71.4, (RR 1.06, 95% CI 0.089 to 1.26).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Tamblyn (2010) (Tamblyn et al. 176-188) Design: RCT N = 2,293 patients Implementation: 00/0000 Study Start: 04/2006 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Insurance, provincial beneficiary and prescription databases	Ambulatory care	rate of drug profile review, Changes in therapy	Significant increase in drug profile review in the intervention compared to the control group (44.5% vs. 35.5%;p <0:001). There was no statistically significant difference between the intervention and control group in the proportion of patients who had increases in therapy (28.5% vs. 29.1%; OR 0.98; p = 0.86).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Tang (1999) (Tang et al. 115-121) Design: Time series N = 2,484 patient visits Implementation: 07/1996 Study Start: 10/1995 Study End: 01/1998	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care, Academic	compliance rates with vaccination guidelines*-computer users compliance rates with vaccination guidelines*-paper users	Compliance rates did not increase in the first year for either group. For the computer users, compliance rates steadily increased year 2 to year 3 to year 4 (38.7% vs. 60.9%, RRR -57%, p = 0.001; 60.9% vs. 68.2%, RRR -12%, p = 0.02). For the paper group, year 2 to 3 saw a significant increase (28.5 vs. 37.0, p = 0.02), but year 3 to 4 saw a significant decrease (37.0% vs. 30.6%, p = 0.03). No comparisons between paper and computer were performed by the authors.	+
Tang (2009)[162] Design: Before-after N = 1,762 patients Implementation: 01/2005 Study Start: 09/2004 Study End: 06/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Laboratory system, Pharmacy	Ambulatory care	overall compliance rate, pregnancy test ordering, Charting of cumulative dose, liver function and lipid profile test ordering	Introduction of e-isotretinoin chart resulted in marked improvement in physician compliance to all steps of the isotretinoin prescription process, with the overall compliance rate increasing from 57.5% to 97.8% (p <0.05) in the first year post-implementation. Of the female patients, 100%	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
				were tested for pregnancy prior to starting isotretinoin therapy, an increase of 66.0% compared with the pre-implementation period (p <0.05). Charting of cumulative dose improved (an increase of 13.5% to 99.5%, p <0.05) so did liver function tests and lipid investigations (an increase of 3.8% to 100%). The results demonstrated close to 100% compliance with charting of cumulative dose of isotretinoin, pregnancy testing, liver function and lipid profile tests. The results sustained for more than 2 years from January 2005 to June 2007 [no analysis given past 1 year].	
Teich (2000)[163] Design: Time series N = not reported orders Implementation: 10/1993 Study Start: 00/0000 Study End:	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system, Imaging systems, Laboratory system	Acute care/tertiary, 720 Beds Academic	H2-blocker orders, variability in dosages, frequency of administration and exceeding maximum dosages, proportion of orders for 3x IV ondansetron, compliance with heparin ordered consequent to	Study 1: Nizatidine was used for <20% of all oral H2-blocker orders before implementation of the alert, vs. >95% after wards (p <	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
00/0000			bed rest	0.001); this was sustained for year 1 and 2. The use of IV ranitidine increased from 0% before the intervention to 71% of intravenous H2-blocker orders (32/45) in the first week and to 97% or more from the fourth week onward. Study 2: Variability in standard deviation dosages across medications reduced by 11% following implementation of the dosage guidance application (p <0.001). Maintained over 3 years followup. Standard deviation of frequency of administration reduced by 30% post-implementation (p <0.001) and proportion of orders exceeding maximum dose decreased significantly from 2.1% to 0.56% post-implementation (p <0.001). Study 3: Orders for 3x IV ondansetron increased significantly after the	

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
				preferred order was highlighted in the dosing list (5.9% vs. 93.5%, RRR -1485%, p <0.001). Study 4: heparin ordering with bed rest increased from 23.9% to 46.9%.	
Terrell (2009)[164] Design: RCT N = 5,162 Patients Implementation: 00/0000 Study Start: 01/2005 Study End: 07/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 450 Beds Academic	proportion of ED visits by seniors with an inappropriate medication, proportion of medications that were potentially inappropriate was also reduced	The decision support reduced the proportion of ED discharges that resulted in potentially inappropriate prescriptions (3.9% vs. 2.6%; p = 0.02; OR 0.55, 95% CI 0.34 to 0.89). The proportion of medications that were potentially inappropriate was also reduced, from 5.4% to 3.4% (p =.006; OR 0.59, CI 0.41 to 0.85).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Terrell (2009)[165] Design: RCT N = 5,162 patient visits to 63 physicians Implementation: 00/0000 Study Start: 01/2005 Study End: 07/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, 450 Beds Academic	visits with an inappropriate medication prescription*, prescriptions that were inappropriate, n (%)	Primary Outcome: Decision support significantly reduced the proportion of ED discharges that resulted in a potentially inappropriate prescription (3.9% vs. 2.6%; p = 0.02; OR 0.55, 95% CI 0.34 to 0. 0.89. This difference represents an absolute RR of 1.3% (95% CI 0.4 to 2.3). Secondary Outcome: When analyzed as a percentage of all medications prescribed by physician subjects, the proportion of medications that were potentially inappropriate was significantly reduced, from 5.4% to 3.4% (p = 0.006; OR 0.59, 95% CI 0.41 to 0.85), with an absolute reduction of 2.0% (95% CI 0.7 to 3.3).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Tierney (2003)[166] Design: RCT N = 706 patients, 20 pharmacists, 94 physicians and 1 nurse practitioner Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Pharmacy	Ambulatory care, Outpatient hospital based Academic	compliance with cardiac care suggestions*	Neither the physician nor the pharmacist intervention had any significant effect on whether patients' cardiac care was compliant with the suggestions (p >0.8 across the 4 intervention groups by analysis of variance, with p > 0.7and p >0.4 when testing the physician and pharmacist interventions separately).	-
Tierney (2005)[167] Design: RCT N = 706 patients Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Pharmacy	Ambulatory care, Pharmacy Outpatient hospital based Academic	adherence to the care suggestions*	There were no differences between the four study groups in either adherence to the care suggestions, combined or individually (32% control, 32% physician intervention, 32% pharmacist intervention, 37% both interventions, NS).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	HIT Studied Integrated system	Settings	Outcomes Measured	Results	Outcome
Upperman (2005)[168] Design: Before-after N = Not reported ADE/1,000 doses Implementation: 00/2002 Study Start: 01/2002 Study End: 0/0000	**CPOE/POE system Integrated** EHR/EMR system	Acute care/tertiary, Pediatric stand alone hospital, Academic	ADE rates per 1,000 before and after CPOE implementation	All ADEs before CPOE were 0.3 per 1,000 doses, whereas after CPOE ADEs were 0.37 per 1,000 doses (p = 0.3).	+
Uttaro (2007)[169] Design: Cohort study N = 23 psychiatrists Implementation: 01/2004 Study Start: 01/2004 Study End: 03/2005	**CDSS/CDS/CCDS/ reminders** Stand-Alone, New York State Office of Mental Health intranet, pharmacology resources	Other specialty hospital (rehab, oncology)	percentage of caseloads on 2 or more antipsychotics*, overall percentage of patients on 2 or more antipsychotics	Overall, there were moderately large reductions for most psychiatrists in the percentage of caseloads on 2 or more antipsychotics (56% vs. 36%, RRR 36%, p <0.01). There were significantly greater reductions in March 2005 for psychiatrists who had higher percentages of their caseloads on two or more concurrent antipsychotics in January 2004.The overall percentage of patients on 2 or more antipsychotics dropped significantly (54% vs. 36%, RRR 33%, p <0.01).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
van Doormaal (2009)[170] Design: Time series N = 1,195 patients Implementation: 00/0005 Study Start: 07/2005 Study End: 05/2008	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Barcoding system, Pharmacy	Acute care/tertiary, 1,300 (Groningen); 600 (Tilburg and Waalwijk) Beds Academic	medication errors (ME)* preventable adverse drug events (pADEs)*	During the baseline period, 55% of all medication orders (MOs) contained at least one or more MEs, whereas during the postintervention period this was 17%; a significant immediate absolute reduction of 40.3% (95% CI: -45.13% to 35.48%). In the baseline period, 15.5% of admitted patients experienced one or more pADE, as opposed to 7.3% in the postintervention period. Decrease could not be attributed to CPOE/CDSS. The immediate change was NS (-0.42%, 95% CI: -15.52% to 14.68%) because of the observed underlying negative trend during the pre-CPOE period of -4.04% [95% CI: -7.70% to 0.38%] per month.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Van Wyk (2007)[171] Design: RCT N = 87,860 Patients Implementation: 00/0000 Study Start: 05/2004 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Percentage of patient treated	Of the patients requiring treatment, 66% were treated in the alerting arm, 40% in the on-demand arm, and 36% in the control arm. After adjustment for differences between arms, the likelihood of being treated was 40% higher in the alerting arm (adjusted RR = 1.40; 95% CI 1.15 to 1.70) and 19% higher (NS) in the on-demand arm in comparison to the control arm (adjusted RR = 1.19; 95% CI 0.94 to 1.50). A similar pattern was shown for the need for screening within the 3 groups.	+
Varkey (2007)[172] Design: Cross-sectional N = 4,527 prescriptions Implementation: 00/0000 Study Start: 00/1996 Study End: 00/2002	**CPOE/POE system** **Integrated** CDSS/CDS/CCDS/ reminders	Ambulatory care, Other institution based	frequency of intercepted prescription errors*	Statistically significant decrease in frequency of intercepted prescription errors among handwritten and computerized prescriptions was observed (7.4% vs. 4.9%, p = 0.0048).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	Settings	Outcomes Measured	Results	Outcome
Voeffray (2006)[173] Design: Before-after N = 2,445 prescriptions Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Pharmacy	Acute care/tertiary, 850 Beds Pharmacy, Inpatient hospital based, Academic	Rate of error*	The average monthly error rate was 15% (95% CI 13% to 18%). After introduction of the CPOE system, the average monthly error rate (which included both computer orders and handwritten, amounted to 13% (95% CI 10% to 16%). This decrease in rate was not statistically different from the rate observed in the first period (p = 0.36). Postimplementation errors in the computerized group only was 0.6% (95% CI 0.3% to 1.4%).	-
Walsh (2008)[174] Design: Time series N = 627 admissions Implementation: 04/2002 Study Start: 09/2001 Study End: 05/2003	**CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders	Critical care units (CCU, ICU, NICU) General Hospital, 59 Pediatric beds Beds	rates non-intercepted serious medical errors*	The rates of errors did not differ for all errors (44.7 before vs. 50.9 errors per 1,000 patient days after COPE, NS), non-intercepted serious medical errors (23.1 before vs. 20.6 per 1,000 patient days after CPOE, NS), or serious medical errors (31.7 before vs. 33.0 per 1,000 patient days after CPOE, NS).	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Were (2009)[175] Design: Before-after N = 40 Patients Implementation: 00/0000 Study Start: 12/2007 Study End: 04/2008	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, 264 Beds Academic	acceptance of all recommendations, rate of acceptance of pharmacological recommendations	More recommenda-tions were implemented in the reminders group (59% vs. 78%, RRR 32%, p = 0.01) The rate of acceptance of pharma-cological recommenda-tions was similar (51% vs. 77%).	+
Wilkes (2009)[176] Design: Before-after N = 84 patients Implementation: 06/2005 Study Start: 06/2005 Study End: 05/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system	Acute care/tertiary, Pediatric stand alone hospital, 418 Beds	prescription rate among eligible patients, prescription rate -off-label	The rate of oseltamivir prescription did not change significantly for patients eligible for the drug (40% vs. 25%, RRR 38%, p = NS), or for off-label prescribing for patients not eligible for the drug (4% vs. 5%, RRR -24%, p = NS) following the implementation of a computerized reminder.	-

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Wrona (2007)[177] Design: Observational study N = 536 PCA patients Implementation: 00/2003 Study Start: 01/2003 Study End: 03/2004	**CPOE/POE system,** Integrated EHR/EMR system, Imaging systems, Laboratory system	Pediatric stand alone hospital	rates of respiratory monitoring rates of oxygen saturation monitoring	Compared to the control group of 'no order set', patients in the Acute Pain Team Service had a higher rate of respiratory monitoring (43% vs. 66.3%, RRR - 54%, p <0.05) and oxygen saturation monitoring (86.1% vs. 98.6%, RRR - 15%, p <0.05). Compared to the control group of 'no order set', patients in the prescriber initiated PCA had higher respiratory rate monitoring (43% vs. 57.8%, RRR - 34%, p <0.05). No other comparisons were significant.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Xamplas (2010)[178] Design: Before-after N = 96 patients Implementation: 02/2008 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, e-MAR, Pharmacy	Acute care/tertiary, 465 Beds Inpatient hospital based, Academic	Piperacillin–tazobactam days per 1,000 patient-days*, Piperacillin–tazobactam doses per 1000 patient-days*	While the number of piperacillin–tazobactam days per 1,000 patient days did not significantly change (124 ± 6.3 vs. 121 ± 12.6, p = 0.389) during the preintervention and postintervention periods, there was a significant reduction in the number of piperacillin–tazobactam doses per 1,000 patient-days during the postintervention period (457 ± 33.3vs. 341 ± 35.7, p <0.001).	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Yu (2009)[179] Design: Cross-sectional N = 3,364 hospitals Implementation: 00/0000 Study Start: 07/2003 Study End: 06/2004	CPOE/POE system	Unspecified Hospital, Not specified	11 medication quality indicators*	Among the 11 medication-related measures for acute myocardial infarction, heart failure and pneumonia, the mean performance on 6 cardiovascular-related measures was higher among CPOE hospitals (p <0.001) vs. the comparison (nonCPOE) hospitals. Also, for one pneumonia measure, administering “Antibiotics within 4 hours of arrival for patients with pneumonia,” performance was lower for hospitals with full CPOE implementation (p <0.001). Four quality indicators were not significantly different among the groups; 3 for pneumonia and administration of thrombolytic agent within 30 minutes for AMI. The differences are maintained when hospital teaching status and ownership and number of beds are taken into account.	+

Evidence Table 1. KQ1: Articles assessing primary process outcomes for all technologies assisting the prescribing phase of medication management (continued)

Article Information	**HIT Studied** Integrated system	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Zanetti (2003)[180] Design: RCT N = 273 patients Implementation: 00/0000 Study Start: 03/2000 Study End: 06/ 2000	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Acute care/tertiary, Academic	appropriate redosing of antibiotics*	More patients in the alarm plus reminder group received appropriate redosing of antibiotics after > 240 minutes in surgery (adjusted OR 3.31, 95% CI 1.97 to 5.56, p <0.0001).	+
Zhan (2006)[181] Design: Mixed methods N = 138,922 number of errors/100,000 doses Implementation: 00/0000 Study Start: 01/2003 Study End: 12/2003	**CPOE/POE system**	Unspecified Hospital	number of errors reported per 100,000 doses-inpatients*, number of errors reported per 100,000 doses-outpatients*	The number of errors reported per 100,000 doses was not different among non-CPOE (n=339) and CPOE facilities (n=120) for inpatients (mean 56 vs. 55, p = 0.9) or outpatients (mean 60 vs. 57, p = 0.8).	-

Evidence Table 2. KQ1: primary process outcomes for all technologies assisting order communication

Article Information	HIT Integrated systems	Settings	Outcomes Measured	Results	Outcome
Astrand (2009)[182] Design: Cross-sectional N = 14,365 prescriptions Implementation: 00/0000 Study Start: 02/2006 Study End: 03/2006	**e-Rx, e-Transmission-of the prescription to/from doctor to pharmacy**	Pharmacy, Other mail/email in pharmacies	proportion of new prescriptions needing clarification*	Clarification contacts were made for 2.0% (147/7532) of new e-Prescriptions and 1.2% (79/6833) of new non-electronic prescriptions. RR 1.7 (95% CI 1.3 to 2.2) Increased RR was mainly due to 'Dosage and directions for use', RR 7.6 (95% CI 2.8 to 20.4) when compared to other clarification contacts. In all, 89.5% of the suggested pharmacist interventions were accepted by the prescriber, 77.7% (192/247) as suggested and an additional 11.7% (29/247) after a modification during contact with the prescriber.	-

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: CCDS = Computerized Clinical Decision Support; CDIX = Critical Drug Interaction Alert Program; CDS = Clinical / Computerized Decision Support; CDSS = Clinical Decision Support System; CI = Confidence interval; CPOE = Computerized Provider Order Entry; EHR = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; e-RX = Electronic Prescribing; e-TAR = Electronic Treatment Authorization Request; GP = General Practitioner; HIT = Health Information Technology; HMO = Health Maintenance Organization; N = Sample Size; NS = Not specified; OSUH = Ohio State University Health System; p = Probability; POE = Provider Order Entry; RCT = Randomized Controlled Trial; RR = Relative Risk; RRR = Relative Risk Reduction; vs. = Versus

Evidence Table 2. KQ1: primary process outcomes for all technologies assisting order communication (continued)

Article Information	**HIT** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Beer (2002)[183] Design: Cross-sectional N = 836 Medication orders Implementation: 00/0000 Study Start: 06/2002 Study End: 06/2002	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Hospital information system	Pharmacy, Outpatient hospital based Academic	mean time required to complete prescription review for OpTx order *	The mean time required to complete the prescription review for an OpTx order was 11.11 min (95% CI 10.1 to 12.1; n = 140) compared to the mean time to review a paper order of 5.96 min (95% CI 5.6 to 6.4, p <0.001; n = 696). Therefore, the mean time required to review an order was increased by 5.15 min with the implementation of the direct electronic order entry system.	-
Ekedahl (2004)[184] Design: Cross-sectional N = 24,6991 prescriptions Implementation: 00/0000 Study Start: 05/2000 Study End: 10/2001	**e-Rx** Integrated Pharmacy	Pharmacy, Not specified	rate of non compliance (unclaimed “all other” prescriptions vs. unclaimed e-Prescriptions)	Rate of non compliance between unclaimed “all other” prescriptions 369/322754 (0.01%) vs. unclaimed e-Prescriptions 2,171/91,704 (2.37%).	-
Halkin (2001)[65] Design: Time series N = 775,186 prescriptions Implementation: 11/1997 to 00/1998 Study Start: 01/1998 Study End: 06/1999	**CDSS/CDS/CCDS/ reminders** Integrated, Pharmacy	Pharmacy, HMO pharmacy	rate of drug interaction prescriptions when 90% of pharmacies and 50% of physicians compared with baseline, rate of drug interaction prescriptions when 95% of pharmacies and 90% of physicians compared with baseline	Dispensing of drug interaction prescriptions reduced by 21.1% and by 67.5% in periods II and III compared with period I (OR, 0.79; 95% CI 0.75 to 0.83 and OR, 0.28; 95% confidence limit, 0.26 to 0.30, respectively).	+
Humphries (2007)[185] Design: Before-after N = not given prescriptions Implementation: 02/2002 Study Start: 07/2000 Study End: 05/2005	**CDSS/CDS/CCDS/reminders** Integrated EHR/EMR system Pharmacy	Ambulatory care, Outpatient hospital based	proportion of co-dispensings for interacting drugs per 10,000 prescriptions	The proportion of prescriptions of any of the 8 drug pairs decreased after implementation of CDIX for all 8 drugs (21.3 to 14.7 per 10,000 prescriptions, RRR 31%, (CI 12.7 to 49.5, p = 0.01).	+

Evidence Table 2. KQ1: primary process outcomes for all technologies assisting order communication (continued)

Article Information	HIT Integrated systems	Settings	Outcomes Measured	Results	Outcome
Johnson (2010)[75] Design: RCT N = 3,285 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 08/2007	**CDSS/CDS/CCDS/ reminders** **e-Rx** Integrated EHR/EMR system	Ambulatory care, Pharmacy, Not specified, Academic	rate of callbacks generated*	There was no significant difference in the callback rates between the "SYW off" and the "SYW on" periods (0.4% vs. 0.45%; p = 0.47).	-
Mahoney (2007)[99] Design: Before-after N = 2,843,135 inpatient medication orders Implementation: 02/2002 Study Start: 02/2002 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system, Pharmacy information system** Integrated EHR/EMR system Hospital information system	General Hospital, Pediatric stand alone hospital, 966 in 2 hospitals Beds Pharmacy Inpatient hospital based Academic	rate of -drug allergy violations*, -excessive doses*, -incomplete or unclear orders*, -therapeutic duplication*	Medication errors decreased after implementation of the CIT with respect to drug allergy violations (OR 0.14, CI 0.11 to 0.17, p <0.001), excessive doses (OR 0.68, CI 0.62 to 0.74, p <0.001) and incomplete or unclear orders (0.35, CI 0.32 to 0.38, p <0.001), but no decease in therapeutic duplications. Turnaround time between drug ordering and administration decreased from 90 minuets to 11 minutes, NR. The override rate also decreased (7.1 to 2.9%, RRR 59%, p = 0.001).	+
Mekhjian (2002)[186] Design: Before-after N = 28,898 patients Implementation: 05/2000 Study Start: 02/2000 Study End: 01/2001	**CPOE/POE system, e-Medication administration system (e-MAR, e-TAR)** Integrated Dietary system EHR/EMR system Imaging systems Laboratory system	Acute care/tertiary, Other specialty hospital (rehab, oncology) Academic	medication turn-around time, proportion of verbal orders countersigned, rate of transcription errors	Combining the data showed that time from initiation of the prescription and administration was reduced after POE: mean 5:28 hours before vs. 1:51 hours after, RRR 64%, p <0.001. The proportion of signed verbal orders increased for both hospitals: OSUH 56.4% vs. 76%, RRR 76%, p <0.001 and James Cancer 72.8% vs. 99.0, RRR 36%, p <0.001. The volume of transcription errors was reduced after POE from 11.3% to 0%, RRR 100%, p <0.001.	+

Evidence Table 2. KQ1: primary process outcomes for all technologies assisting order communication (continued)

Article Information	**HIT** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Mitchell (2004)[187] Design: Cross-sectional N = 4,297 prescriptions Implementation: 0/1999 Study Start: 09/2002 Study End: 12/2002	**e-Medication administration system (e-MAR, e-TAR)** **e-Rx** Integrated Formulary Pharmacy	Acute care/tertiary, Academic	15 aspects of data completeness for e-MAR were sought with implementation of the e-MAR.	e-MAR was more accurate (more inclusion of important information) for nurses 9 of the 15 were statistically significantly improved including presence of dosing recommendations (30% v3 99%, RRR 230%, p <0.01) Errors detected by the pharmacist did not differ before and after implementation of the e-Rx system. Only minor errors were redueced with the system.	+
Murray (1999)[188] Design: Cohort N = 11,102 observations of 28 pharmacists Implementation: 03/1995 Study Start: 11/1995 Study End: 01/1996	**Pharmacy information system** Integrated EHR/EMR system Imaging systems Laboratory system	Acute care/tertiary, Pharmacy, Inpatient hospital based	distribution of pharmacist time on activities, functions and contacts*.	The electronic guidelines and reminders were associated with the overall distribution of activities (more time discussing information and less time checking and preparing prescriptions) p <0.001; overall functions (more time advising or discussing information or problem solving and less time filling prescriptions) p <0.001 and distribution of contacts (more time with other pharmacy personnel, patients, and clinicians and less time working alone) p <0.001.	+
Nam (2007)[189] Design: Before-after N = 39 Patients Implementation: 00/0000 Study Start: 06/2003 Study End: 05/2005	**CPOE/POE system** Integrated EHR/EMR system Laboratory system	Emergency department	Time to arrival to tPA treatment in minutes*	Time from arrival to tPA treatment was reduced by 23 minutes (from 79 to 56 minutes; p <0.01).	+
Nilsson (2007)[190] Design: Cohort study N = 2,563 prescriptions (acute) Implementation: 00/0000 Study Start: 02/2005 Study End: 03/2005	**e-Rx** Integrated Pharmacy	Pharmacy, Other	rate of prescription pick up by patients within 5 days*	e-RX accounted for 84% of the prescriptions. Among the patients with e-prescriptions 91% picked up their prescriptions in 5 days compared to 85% in the paper group, (RRR -7%, p <0.01).	+

Evidence Table 2. KQ1: primary process outcomes for all technologies assisting order communication (continued)

Article Information	**HIT** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Pearce (2010)[191] Design: Before-after N = 332 medication refill orders Implementation: 05/2006 Study Start: 02/2006 Study End: 03/2007	**e-Rx** Integrated EHR/EMR system Pharmacy	Ambulatory care, Pharmacy, Pharmacy chain	time to a response for refill request*	The average time to a response to a pharmacy refill request decreased from 1.57 days to 1.04 days (p <0.004).	+
Senholzi (2003)[192] Design: Before-after N = 349 pharmacist interventions Implementation: 11/2001 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated e-MAR: Nursing Medication Administration Record	Acute care/tertiary, 633 Beds Inpatient hospital based, Academic	Number of pharmacist interventions	The number of pharmacist interventions remained the same before and after CPOE implementation in the control unit (80 before and 84 after) In the CPOE unit the number of pharmacist interventions increased from 76 to 109, p <0.01.	+
Varkey (2007)[172] Design: Cross-sectional N = 4,527 prescriptions Implementation: 00/0000 Study Start: 00/1996 Study End: 00/2002	**CPOE/POE system** Integrated CDSS/CDS/CCDS/reminders	Ambulatory care, Other institution based	frequency of intercepted prescription errors*	Statistically significant decrease in frequency of intercepted prescription errors among handwritten and computerized prescriptions was observed (7.4% vs. 4.9%, p = 0.0048).	+
Wess (2007)[193] Design: Before-after N = 3,791 medication orders Implementation: 06/2005 Study Start: 00/0000 Study End: 00/0000	**CPOE/POE system** Integrated EHR/EMR system Hospital information system	General Hospital, Inpatient hospital based, Academic	mean time from provider order entry to pharmacist verification, -community hospital, - university hospital, proportion of clarification calls placed, -community hospital, -university hospital	The mean time from provider order entry to pharmacist verification decrease for both community (152 vs. 32 minutes, p <0.0001) and university hospitals (108 vs. 50 minutes, p <0.0001) The call back percentage also decreased for both community (2.8 vs. 0.4%, RRR 86%, p <0.0001) and university hospitals (2.8% vs. 0.5%, RRR 82%, p <0.0001).	+

Evidence Table 2. KQ1: primary process outcomes for all technologies assisting order communication (continued)

Article Information	HIT Integrated systems	Settings	Outcomes Measured	Results	Outcome
Wietholter (2009)[194] Design: Before-after N = 2,988 medication orders Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CPOE/POE system** Integrated Pharmacy	Acute care/tertiary, 761 Beds Inpatient hospital based	mean order-processing time (min)*	The mean order-processing time before CPOE implementation was 115 minutes from prescriber composition to pharmacist verification. After CPOE implementation, the mean order-processing time was reduced to 3 minutes (p <0.0001).	+

Evidence Table 3. KQ1: primary process outcomes for all technologies assisting dispensing

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Alvarez Diaz (2009)[195] Design: Observational study N = 54,169 opportunities for error (the number of medication order lines validated) Implementation: 00/0000 Study Start: 02/2008 Study End: 10/2008	**3 medication dispensing systems** Integrated CPOE/POE system Pharmacy	General Hospital, 1070 Beds Pharmacy Inpatient hospital based	validation errors *, filling errors*	Error rate and OR for validation errors in unit dose distribution system (UDDS) without CPOE (No-CPOE-UDDS) in relation to the UDDS with CPOE (CPOE-UDDS) was 146/13,645 (1.1) vs. 63/20,240 (0.3), (OR 0.289, 95% CI 0.215 to 0.388). For No-CPOE-UDDS in relation to automated dispensing system with CPOE (CPOE-ADS), it was 146/13,645 (1.1) vs. 83/13,932 (0.6), (OR 0.554, 95%CI 0.423 to 0.726) Error rate and OR for filling errors No-CPOE-UDDS in relation to CPOE-UDDS was 265/13,645 (1.9) vs. 345/20,240 (1.7), (OR 0.876, 95% CI 0.745 to 1.029). For No-CPOE-UDDS in relation to CPOE-ADS it was 265/13,645 (1.9) vs. 309/13,932 (2.2), (OR 1.145, 95% CI 0.97 to 1.352).	+
Halkin (2001)[65] Design: Time series N = 775,186 prescriptions Implementation: 11/1997 to 00/1998 Study Start: 01/1998 Study End: 06/1999	**CDSS/CDS/CCDS/ reminders** Integrated Pharmacy	Pharmacy, HMO pharmacy	drug interaction rate prescriptions 90% pharmacies and 50% of physicians compared with baseline drug interaction rate prescriptions 95% pharmacies and 90% physicians compared with baseline	Dispensing of drug interaction prescriptions was reduced by 21.1% and by 67.5% in periods II and III compared with period I (OR 0.79; 95% CI 0.75 to 0.83 and OR 0.28; 95% CI 0.26 to 0.30, respectively).	+

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).
*indicates outcomes noted as being the primary outcome by the paper's authors
Abbreviations: ADS = Automated Dispensing System; CDS = Clinical / Computerized Decision Support ; CDSS = Clinical Decision Support System; CIT = clinical information technology; CPOE = Computerized Provider Order Entry; EHR = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; e-TAR = Electronic Treatment Authorization Request; HIT = Health Information Technology; HMO = Health Maintenance Organization; OR = Odds ratio; N = Sample Size; NS = Not specified; p = Probability; RCT = Randomized Controlled Trial; RRR = Relative Risk Reduction; UDDS = Unit Dose Druge Dispensing System; vs. = Versus

Evidence Table 3. KQ1: Primary Process outcomes for all technologies assisting dispensing (continued)

Article Information	**HIT Studied** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Mahoney (2007)[99] Design: Before-after N = 2,843,135 inpatient medication orders Implementation: 02/2002 Study Start: 02/2002 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system,** **Pharmacy information system** Integrated EHR/EMR system Hospital information system	General Hospital, Pediatric stand alone hospital, 966 in 2 hospitals Beds Pharmacy Inpatient hospital based Academic	rate of -drug allergy violations*, -excessive doses*, -incomplete or unclear orders*, -therapeutic duplication*	Medication errors decreased after implementation of the CIT with respect to drug allergy violations (OR 0.14, CI 0.11 to 0.17, p <0.001), excessive doses (OR 0.68, CI 0.62 to 0.74, p <0.001) and incomplete or unclear orders (0.35, CI 0.32 to 0.38, p <0.001) but no decease in therapeutic duplications. Turnaround time between drug ordering and administration decreased from 90 minutes to 11 minutes, no stats given. The override rate also decreased (7.1 to 2.9%, RRR 59%, p = 0.001).	+
Murray (1999)[188] Design: Cohort N = 11,102 observations of 28 pharmacists Implementation: 03/1995 Study Start: 11/1995 Study End: 01/1996	**Pharmacy information system** Integrated EHR/EMR system Imaging systems Laboratory system	Acute care/tertiary, Pharmacy, Inpatient hospital based	distribution of pharmacist time on activities, functions and contacts*	The electronic guidelines and reminders were associated with the overall distribution of activities (more time discussing information and less time checking and preparing prescriptions) p <0.001; overall functions (more time advising or discussing information or problem solving and less time filling prescriptions) p <0.001, and distribution of contacts (more time with other pharmacy personnel, patients, and clinicians and less time working alone) p <0.001.	+
Pearce (2010)[191] Design: Before-after N = 332 medication refill orders Implementation: 05/2006 Study Start: 02/2006 Study End: 03/2007	**e-Pprescribing** Integrated EHR/EMR system Pharmacy	Ambulatory care, Pharmacy Pharmacy chain	time to a response for refill request*	The average time to a response to a pharmacy refill request decreased from 1.57 days to 1.04 days (p <0.004).	+

Evidence Table 3. KQ1: Primary Process outcomes for all technologies assisting dispensing (continued)

Article Information	**HIT Studied** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Raebel (2007)[130] Design: RCT N = 59,680 patients Implementation: 00/0000 Study Start: 05/2005 Study End: 05/2006	**CDSS/CDS/CCDS/ reminders Pharmacy information system** Integrated EHR/EMR system	Ambulatory care, HMO pharmacy	new dispensings of targeted medications*, dispensings of targeted medications considered inappropriate*	In the analysis of all dispensings of targeted medications, there was a significant reduction of new dispensings of at least one targeted medication (2.2% vs. 1.8%, RRR 16%, p <0.002) For dispensings of targeted medications considered inappropriate, there was also a significant reduction with the use of the alerting system (1.5% vs. 1.1%, RRR 27%, p <0.001).	+
Reeve (2007)[196] Design: RCT N = 2,396 clinical interventions by pharmacists Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**Pharmacy information system**	Pharmacy, Other, Stand alone non chain store (eg family run)	Rate of pharmacist interventions /100 diabetic patients-aspirin therapy for diabetic patients * The total rate of pharmacist intervention/100 patients *	The rate of targeted interventions for aspirin therapy for high risk diabetic patients was 0 for the control group and 4.82/100 diabetic patients (p <0.05) .Clinicians who received the prompts had a higher rate of intervening with patients overall (1.74 per 100 patients) compared with pharmacists who did not receive the prompts (mean 0.91 per 100 patients), p <0.001. When the prompts were stopped the rate of aspirin interventions fell to pre-prompt levels.	+
Wilson (1997)[197] Design: Before-after N = 00 not stated number of medications, etc Implementation: 02/1994 Study Start: 07/1993 Study End: 06/1995	**e-Medication administration system (e-MAR, e-TAR)** Integrated Formulary, Hospital information system	Acute care/tertiary, 362 Beds Inpatient hospital based Academic	Medication occurrences per admission*, Medication occurrences per patient day*, Medication occurrences per order, Medication occurrences per dose	Self-reported medication occurrences (errors) per admission (11% vs. 7%, RRR 39%, p <0.001), per patient day (1.4% vs. 7%, RRR 34%, p <0.001), per order (0.4% vs. 0.3%, RRR 34%, p <0.001), and per dose (0.05% vs. 0.03%, RRR 40%, p <0.001) were all significantly reduced following implementation of a shared electronic medication record for pharmacists and nurses.	+

Evidence Table 4. KQ1: primary process outcomes for all technologies assisting drug administration

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Banet (2004)[198] Design: Before-after N = 55 nurses Implementation: 05/2003 Study Start: 00/0000 Study End: 00/0000	**CPOE/POE system, e-MAR, e-Medication administration system (e-MAR, e-TAR)** Integrated Imaging systems Laboratory system Pharmacy	Emergency department Academic	distribution of nurses' time on activities, functions and contacts*	Time-motion study demonstrated that after implementing the information system changes, nurses spent less time (mean percent of total time) on paper documentation (17% vs. 2%, RRR 90%, p <0.05) and searching for charts (0.4% vs. 0.1%, RRR 75%, p <0.05). They spent more time using computers (10% vs. 26%, RRR -157%, p <0.05), and charting in patients rooms (0.2% vs. 2.1%, RRR -950%, p <0.05). They spent the same amount of time on documentation tasks overall (27% vs. 28%, RRR 3%, NS) and direct patient care (41% vs. 39%, RRR 4%, NS).	+
Climent (2008)[199] Design: Cross-sectional N = 2,242 opportunities for error Implementation: 00/0000 Study Start: 05/2005 Study End: 06/2006	**3 different drug delivery systems, e-Medication administration system (e-MAR, e-TAR), e-Rx**	Acute care/tertiary, 1,500 Beds Academic	medication error rate*, medication error rate-reaching patients*	The integrated MMIT unit dose delivery system with e-Rx (DUPEA) had an error rate similar to the non-integrated unit dose system (DUTI), and the ward stock system (9.5% stock vs. 7.8% DUPEA vs. 4.7% DUTI) .The error rate reaching patients with the DUPEA was lower than stock but higher than DUTI (8.1% stock vs. 5.5% DUPEA vs. 0.4% DUTI, p <0.05).	-

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).
*indicates outcomes noted as being the primary outcome by the paper's authors
Abbreviations: AR = Absolute Reduction; BCMA = Bar Code Medication Administration ; CCDS = Computerized Clinical Decision Support; CCU = Critical Care Unit; CDS = Clinical / Computerized Decision Support ; CDSS = Clinical Decision Support System; CI = CI; CPOE = Computerized Provider Order Entry; EHR = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; e-RX = Electronic Prescribing; e-TAR = Electronic Treatment Authorization Request; hr = Hour; ICU = Intensive Care Unit; MMIT = Medication Management Information Technology; N = Sample Size; NICU = Neonatal Intensive Care Unit; NS = Not specified; OR = OR; OSUH= Ohio State University Health System; p = Probability; POE = Provider Order Entry; RRR = Relative Risk Reduction; SD = Standard deviation; UDDS = Unit Dose Drug Dispensing System; vs. = Versus

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
DeYoung (2009)[200] Design: Before-after N = 1,465 medication administrations in 92 patients Implementation: 01/2007 Study Start: 12/2006 Study End: 05/2007	**BCMA (BCMA)** Integrated e-MAR	Critical care units (CCU, ICU, NICU) 38 in ICU, 744 in hospital Beds Academic	error rate-overall*, -excluding documentation errors*, -wrong administration time*	The medication error rate was reduced by 56% after the implementation of BCMA (19.7% vs. 8.7%, p <0.001). This rate increased to 63% when documentation orders were excluded (p <0.001). The benefit was related to a reduction associated with errors of wrong administration time. Wrong administration time errors decreased from 18.8% during preimplementation to 7.5% postimplementation (p <0.001). There were no significant differences in other error types.	+
Fontan (2003)[46] Design: Cross-sectional N = 4,532 prescriptions Implementation: 00/1988 Study Start: 02/1999 Study End: 03/1999	**Computerized UDDS** Integrated Hospital information system	Other specialty hospital (rehab, oncology) Pediatric stand alone hospital, 510 Beds	Prescribing error rate, Administering error rate	Errors were decreased with the use of the e-RX and computerized dispensing system compared with the hand-written prescriptions and ward distribution system. Prescribing errors were reduced from 87.9% to 10.6%, RRR 88%, p <0.00001 Administrative errors with time errors were reduced from 29.3% to 22.5%, RRR 23%, p <0.001.	+

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Franklin (2007)[50] Donyai (2008)[51] Barber (2007)[52] Franklin (2008)[53] Franklin (2007)[54] Design: Before-after N = 4,803 medication orders Implementation: 06/2003 Study Start: 00/0000 Study End: 00/0000	**Automated Dispensing Machine, e-Medication administration system (e-MAR, e-TAR) e-Rx** Integrated Pharmacy	Acute care/tertiary, 28 surgery bed ward of a teaching hospital Beds Inpatient hospital based, Academic	error rate for new prescriptions*, error rate for drug administrations*, %administered <1hr[53], rate of pharmacist interventions[51] Total pharmacy time taken on study ward	The prescription error rate for new orders dropped significantly after implementation of the system (3.8% vs. 2.0%, RRR 47%, p = 0.0004) Medication administration error rate also significantly declined (8.6% vs. 4.4%, RRR 49%, p = 0.0003).[53] Postintervention medication timeliness was improved (%administered <1hr, 79% vs. 89%, p <0.001).[51] The rate of pharmacist interventions declined significantly after implementation (3.0% vs. 1.9%, AR 1.1 (95% CI 0.2,2.0).[54] Total pharmacy time taken on study ward increased after implementation (1h 8min vs. 1h 38min, p = 0.001). Pharmacists were required to endorse fewer orders (50% vs. 21%, RRR 58%, p <0.0001) and endorsed fewer orders (55% vs. 30%, RRR 45%, p <0.0001).	+

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Helmons (2009)[201] Design: Before-after N = 2,353 opportunities for error Implementation: 05/2007 Study Start: 09/2007 Study End: 04/2008	**BCMA** Integrated Handheld CPOE/POE system EHR/EMR system, e-MAR, Pharmacy	Critical care units (CCU, ICU, NICU) 386 Beds Academic	error rate-surgical medical unit*, error rate-ICU*	The total medication administration error rates did not significantly decrease on the medical–surgical units (11% vs. 8%, RRR 23%, NS) the ICU (13% vs. 14% RRR -7%, NS) or overall (13% vs. 14% RRR -7%, NS) Accuracy measured by 6 indicators of accuracy reflecting error-prone process variations. Baseline medication administration accuracy higher in medical–surgical units compared with the ICUs. On the medical– surgical units, 3 accuracy indicators changed after the introduction of BCMA; improved compliance with checking patient identity after BCMA implementation was offset by more distractions and interruptions and less explanation of the medication to the patient. These 3 indicators did not change in the ICUs However, implementation of BCMA resulted in improved charting and labelling of medications administered in the ICUs.	-
Low (2002)[202] Design: Before-after N = not reported prescriptions Implementation: 03/2000 Study Start: 03/1999 Study End: 03/2001	**BCMA** Integrated Hospital information system	Acute care/tertiary, Pharmacy Inpatient hospital based	rate of errors per 1,000 doses	The rate of errors per 1,000 doses did not differ across the 24 month periods before and after BCMA (0.125 vs. 0.145, p = 0.6).	-

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	**HIT Studied** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Mahoney (2007)[99] Design: Before-after N = 2,843,135 inpatient medication orders Implementation: 02/2002 Study Start: 02/2002 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders, CPOE/POE system, Pharmacy information system** Integrated EHR/EMR system, Hospital information system	General Hospital, Pediatric stand alone hospital, 966 in 2 hospitals Beds Pharmacy Inpatient hospital based, Academic	rate of -drug allergy violations*, -excessive doses*, -incomplete or unclear orders*, -therapeutic duplication*	Medication errors decreased after implementation of the CIT with respect to drug allergy violations (OR 0.14, CI 0.11 to 0.17, p <0.001) excessive doses (OR 0.68, CI 0.62 to 0.74, p <0.001) and incomplete or unclear orders (0.35, CI 0.32 to 0.38, p <0.001) but no decease in therapeutic duplications. Turnaround time between drug ordering and administration decreased from 90 minuets to 11 minutes, no stats given. The override rate also decreased (7.1 to 2.9%, RRR 59%, p = 0.001).	+
Mekhjian (2002)[186] Design: Before-after N = 28,898 patients Implementation: 05/2000 Study Start: 02/2000 Study End: 01/2001	**CPOE/POE system, e-Medication administration system (e-MAR, e-TAR)** Integrated Dietary system, EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, Other specialty hospital (rehab, oncology) Academic	medication turn-around time, proportion of verbal orders countersigned, rate of transcription errors	Combining the data showed that time from initiation of the prescription and administration was reduced after POE: mean 5:28 hours before vs. 1:51 hours after, 64% relative reduction, p <0.001. The proportion of signed verbal orders increased for both hospitals: OSUH 56.4% vs. 76%, RRR 76%, p <0.001 and James Cancer 72.8% vs. 99.0, RRR 36%, p <0.001. The volume of transcription errors was reduced after POE from 11.3% to 0%, RRR 100%, p <0.001.	+
Mitchell (2004)[187] Design: Cross-sectional N = 4,297 prescriptions Implementation: 0/1999 Study Start: 09/2002 Study End: 12/2002	**e-Medication administration system (e-MAR, e-TAR), e-Rx** Integrated Formulary, Pharmacy	Acute care/tertiary, Academic	15 aspects of data completeness for e-MAR were sought with implementation of the e-MAR.	e-MAR was more accurate (more inclusion of important information) for nurses 9 of the 15 were statistically significantly improved including presence of dosing recommendations (30% v3 99%, RRR 230%, p <0.01), Errors detected by the pharmacist did not differ before and after implementation of the e-Rx system. Only minor errors were reduced with the system	+

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Morriss (2009)[203] Design: Cohort study N = 958 patients; 92,398 doses administered Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated Pharmacy	Critical care units (CCU, ICU, NICU) 36 beds NICU Beds Academic	Medication Error*, Potential ADEs*, preventable ADEs*	When the BCMA system was not operative, the unadjusted medication error rates were 69.5/1,000 doses and mean 0.53 (SD 0.98)/subject/day. The unadjusted medication error rates increased in the study NICU when the BCMA system was operative to 79.7/1,000 doses and mean 0.60 (SD 0.99)/subject/day (p <0.001). The increase in medication error was associated with a 117% increase in detected wrong-time errors from 1412 before the BCMA system to 3075 when the system was operative. Significant decrease in potential ADEs [0.11 (0.47) vs. 0.033 (0.20), p <0.001], or unadjusted targeted, preventable ADEs [00.0065 (0.082) vs. 0.0032 (0.060) p <0.008] for subjects cared for in the BCMA system-equipped beds.	+
Paoletti (2007)[204] Design: Before-after N = 1,868 Doses observed Implementation: 08/2003 Study Start: 00/0000 Study End: 00/0000	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated Hospital information system, Pharmacy	General Hospital, 521 Beds	error rate*	The error rate compared between pre and postimplementation period in the three groups were: 19.6% vs. 20.6%, p = 0.762 (control); 25.3% vs. 19.2%, p = 0.065 (Intervention Group 1) and 15.6% vs. 10%, p = 0.035 (Intervention Group 2). Group 1 and 2 were noted to have different practices during baseline measurement. [unsure if this would be considered a positive trial].	+

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Persell (2008)[205] Design: RCT N = 242 patients Implementation: 00/0000 Study Start: 10/2004 Study End: 03/2005	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care, Academic	self-reported aspirin use* by all patients, self-reported aspirin use* by patients excluding long-term aspirin users and patients reporting medical contraindication	The control rate (reminders only) of self-reported aspirin use was not significantly different than the intervention (reminders plus clinician emails and patient phone calls) group (39% vs. 46%, p = 0.20). Excluding long-term aspirin users and patients reporting medical contraindication (30% vs. 43%, p = 0.013).	-
Poon (2006)[206] Design: Before-after N = 232 observation sessions Implementation: 00/0000 Study Start: 02/2005 Study End: 10/2005	**BCMA**	Acute care/tertiary, 735 Beds	proportion time on medication administration, proportion time nurses spent on direct care	The proportion of time nurses spent on the major activity groups remained stable. Before BCMA implementation, nurses spent 26.5% of their time on medication administration. After BCMA implementation, this proportion remained statistically unchanged at 24.5% (RRR 8%, p = 0.22). The proportion of time nurses spent on direct care activities unrelated to medication administration remained statistically unchanged (20.1% vs. 23.7%, RRR -18%, p = 0.15).	-
Poon (2010)[207] Design: Before-after N = 14041 medication administration Implementation: 04/2005 Study Start: 02/2005 Study End: 10/2005	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated EHR/EMR system, Pharmacy	Acute care/tertiary, 735 Beds Academic	Non-timing errors in medication administration*, Timing errors in medication administration*, transcription error (2ndary outcome)	On units without the bar-code e-MAR, 776 (11.5%) non-timing medication-administration errors was observed compared to 495 (6.8%) on units with the bar-code e-MAR (p <0.001). The overall incidence of medication doses directly observed to be administered either early or late decreased from 16.7% without the bar-code e-MAR to 12.2% with its use (p = 0.001). The units without bar-code e-MAR observed 110 (6.1%) transcription errors while those with it observed no errors (p <0.001).	+

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Shirley (1999)[208] Design: Before-after N = 163 medication administrations Implementation: 00/0000 Study Start: 05/1997 Study End: 08/1997	**Automated drug dispensing system** Integrated, Pharmacy	Acute care/tertiary, 270 Beds	proportion of medications administered as scheduled*, mean time deviation between actual and scheduled administration times*,	Before implementation of the automated dispensing system, 59% of 76 medication doses were administered as scheduled, after 77% of 87 doses were administered as scheduled (RRR -31%, p = 0.02). The mean time deviation between actual and scheduled administration times did not change significantly postimplementation (130 minutes vs. 101 minutes, p = 0.157).	-
Taylor (2008)[209] Design: Before-after N = 521 medication administrations Implementation: 07/2005 Study Start: 09/2004 Study End: 04/2006	**CPOE/POE system** Integrated e-MAR, Pharmacy	Critical care units (CCU, ICU, NICU)	variance in medication administration	Medication variances were detected for 19.8% of administrations during the pre-CPOE period, compared with 11.6% with CPOE (RRR 41%, p <0.05). The reasons for medication administration variances during the pre-CPOE and CPOE were not statistically different. Overall, administration mistakes, pharmacy problems and prescribing problems accounted for 74% of all variances observed.	+
Wax (2007)[210] Design: Before-after N = 14,465 patients Implementation: 02/2005 Study Start: 06/2004 Study End: 12/2005	**Anesthesia information management system (AIMS), CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary, Academic	overall compliance with antibiotic administration before surgery, noncompliance due to late administration, noncompliance due to early administration	Compliance (antibiotics 60 min before surgery) for the entire data set increased from 82.4% to 89.1% (RRR -8%, p <0.01) following the event icon implementation. Noncompliance rates decreased following implementation for late administration (15.2% vs. 8.1%, RRR 47%, p <0.01), but remained unchanged for early administration (2.4% vs. 2.8%, RRR -17%, p = 0.07).	+

Evidence Table 4. KQ1: Primary Process outcomes for all technologies assisting drug administration (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Wilson (1997)[197] Design: Before-after N = 00 not stated number of medications, etc Implementation: 02/1994 Study Start: 07/1993 Study End: 06/1995	**e-Medication administration system (e-MAR, e-TAR)** Integrated Formulary, Hospital information system	Acute care/tertiary, 362 Beds Inpatient hospital based, Academic	Medication occurrences per admission*, Medication occurrences per patient day*, Medication occurrences per order, Medication occurrences per dose	Self-reported medication occurrences (errors) per admission (11% vs. 7%, RRR 39%, p <0.001), per patient day (1.4% vs. 7%, RRR 34%, p <0.001), per order (0.4% vs. 0.3%, RRR 34%, p <0.001), and per dose (0.05% vs. 0.03%, RRR 40%, p <0.001) were all significantly reduced following implementation of a shared electronic medication record for pharmacists and nurses.	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring

Article Information	**HIT Studied** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Abboud (2006)[1] Design: Before-after N = 336 orders Implementation: 04/2002 Study Start: 10/2003 Study End: 03/2004	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders EHR/EMR system, Formulary, Hospital information system, Imaging systems, Laboratory system, Pharmacy	Pediatric stand alone hospital, 423 Beds	Antibiotics courses with no lab order*	There were no significant differences between the baseline and the corollary order periods on courses of antibiotics associated with no laboratory monitoring [31(19.5%) vs. 31(17.5%), p = NS].	-
Bertoni (2009)[12] Design: RCT N = 8,878 patients Implementation: 00/0000 Study Start: 06/2001 Study End: 04/2006	**CDSS/CDS/CCDS/ reminders** Integrated Handheld	Ambulatory care	adherence to guideline-screening*, adherence to guideline-appropriate lipid management*	There was no difference in screening rates between the CDSS-PDA group and the control. The control group had a 10.8% drop in appropriate management from baseline, while the PDA group had a 1.1% drop, p <0.01. Stable adherence was observed in the PDA intervention group, whereas a decline in guideline adherence was observed in the control group.	-

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: A1c = haemoglobin A1c; ACE = Angiotensin Converting Enzyme; ALT = Alanine Aminotranceferase; AST = Aspartate Aminotransferase; CCDS = Computerized Clinical Decision Support; CCU = Critical Care Unit; CDS = Clinical / Computerized Decision Support ; CDSS = Clinical Decision Support System; CI = CI; CPOE = Computerized Provider Order Entry; DM = Diabetes Mellitus ; EHR = Electronic Health Record; EMR = Electronic Medical Records; GP = General Practitioner; HIT = Health Information Technology; HIV = Human Immunodeficiency Virus; HMO = Health Maintenance Organization; ICU = Intensive Care Unit; K = Potassium; Mg = Magnesium; N = Sample Size; NICU = Neonatal Intensive Care Unit; NPs = Nurse Practitioners; NS = Not statistically significant; NSAID = Nonsteroidal anti-inflammatory drug; OR = Odds Ratio; p = Probability; PCA = Patient-Controlled Analgesia PDA = Personal Digital Assistants ; PHR = Patient Health Record; POE = Provider Order Entry; RCT = Randomized Controlled Trial; RRR = Relative Risk Reduction; vs. = Versus; yr = Year

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Bertsche (2009)[211] Design: Before-after N = 100 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Formulary	Acute care/tertiary, 1621 Beds Academic	number of patients with at least one deviation from international guidelines*	At discharge, the number of patients with at least one deviation from international guidelines decreased by the intervention from 37 (74%) in control group to 7 (14%) in the intervention group (p <0.001).	+
Chambers (2008)[212] Design: Before-after N = 87 patients Implementation: 00/0000 Study Start: 01/2005 Study End: 06/2006	**CDSS/CDS/CCDS/ reminders** **Computer-Based Antimicrobial Monitoring System** Integrated EHR/EMR system, Laboratory system, Pharmacy	Unspecified Hospital	Vancomycin de-escalation rates*, Mean duration of Vancomycin therapy (days)*, Combination-Antimicrobial de-escalation rate*, Mean duration of Combination-Antimicrobial therapy (days)*	Vancomycin de-escalation rates significantly improved from 33% to 68% with intervention (p = 0.001). In addition, the average duration of therapy was decreased from 10.4 ± 7.3 days to 7.7 ± 2.4 days (p = 0.014). Combination-Antimicrobial de-escalation rates were not statistically improved upon (67% vs. 63%, p = 0.763). The average duration of therapy was decreased from 12.8 ± 5.5 days to 9.5 ± 2.5 days, p = 0.335).	+
Chisholm (2003)[19] Design: Before-after N = 790 children admitted to hospital with asthma exacerbations Implementation: 10/2002 Study Start: 11/2001 Study End: 12/2003	**CPOE/POE system** Integrated Billing/administration system, EHR/EMR system, Laboratory system	Pediatric stand alone hospital, 323 Beds	systemic corticosteroids use*, metered-dose inhaler use*	More use was made of systemic corticosteroids (OR 5.61, 95% CI 3.46 to 9.11) and of metered-dose inhalers (OR 1.42, 95% CI 1.04 to 1.94) after implementation of standard order sets in the CPOE for asthma patients.	-

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Cobos (2005)[23] Design: RCT N = 2,221 patients Implementation: 04/2000 Study Start: 04/2000 Study End: 05/2002	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	proportion of patients prescribed lipid lowering drugs (secondary)	The proportion of patients prescribed lipid lowering drugs was significantly lower in the CDSS guideline intervention group (59.1% vs. 40.8% RRR 31%, p <0.0001).	+
Demakis (2000)[213] Design: RCT N = 12,989 patients Implementation: 00/0000 Study Start: 01/1995 Study End: 06/1996	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Ambulatory care Academic	adherence rates for 5 medication management standards of care*, monitoring warfarin treatment; treatment of atrial fibrillation with warfarin, aspirin or ticlopidine; treatment of myocardial infarction with beta-blockers or switching NSAID therapy for gastrointestinal bleeds, pneumococcal vaccination	Adherence rates for medication management standards of care were not significantly different for 4 of the 5 medication management standards of care. There was a large effect for pneumococcal vaccination (12.7% vs. 4.3%; OR 3.26; 95% CI, 2.09 to 5.09). adherence was significantly improved for 13 standards (53.5% vs. 58.8%, OR 12.4 (95% CI 1.08 to 1.42, p = 0.002).	-
Evans (1990)[36] Design: Before-after N = 7,656 patients Implementation: 00/0000 Study Start: 06/1985 Study End: 09/1986	**CDSS/CDS/CCDS/ reminders** **Hospital information system** Integrated Laboratory system, Pharmacy	Unspecified Hospital	mean number of antibiotic doses per patient, proportion of patients receiving perioperative antibiotics, proportion of patients receiving antibiotics for too long	Surgical patients received an average of 19 antibiotic doses before implementation of the ‘stop orders’ and 13 after (p <0.001). There were non significant changes in the proportion of patients receiving perioperative antibiotics (64% vs. 66%, NS) or those receiving antibiotics for too long (40% vs. 35%, NS).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Evans (1999)[214] Design: Before-after N = 13,384 Patients Implementation: 01/1005 Study Start: 04/2005 Study End: 03/2006	**CDSS/CDS/CCDS/ reminders** Integrated Pharmacy	Critical care units (CCU, ICU, NICU) 12 beds in the shock/trauma/respiratory intensive care unit. of a 520 bed academic hospital Beds Not specified, Inpatient hospital based, Academic	The mean number of days with excessive antibiotic dosing*	The mean number of days with excessive antibiotic dosing was lower after the intervention (4.7 days vs. 2.9 days, p <0.001).	+
Feldstein (2006)[215] Smith (2009)[216] Design: RCT N = 961 patients Implementation: 09/2004 Study Start: 09/2003 Study End: 01/2005	**CDSS/CDS/CCDS/ reminders** Integrated Billing/administration system, EHR/EMR system, Pharmacy	Ambulatory care HMO pharmacy	rates of completing lab monitoring*	Patients in the EMR group were 2.5 times more likely than patients in the Usual Care group to complete laboratory monitoring (p <0.001), patients in the automated telephone voice message group were 4.1 times more likely (p <0.001), and patients in the pharmacy team outreach group were 6.7 times more likely (p <0.001).	+
Field (2009)[40] Design: RCT N = 833 patients (10 physicians and 213,967 patient days) Implementation: 00/000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated EHR/EMR system	Long term care (nursing homes)	proportion of appropriate orders*, proportion of inappropriate drugs avoided	The proportion of appropriate antidepressant order rates for patients with renal insufficiency was higher in the CDSS group (52% vs. 63%, OR 1.2, 95% CI 1.0 to 1.4). More inappropriate drugs were avoided (15% vs. 46%, OR 2.6, 95% CI 1.4 to 5.0). Improvements were seen in frequency and missing information but not for doses in the CDSS group.	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Galanter (2004)[57] Design: Before-after N = 620 patients Implementation: 00/0000 Study Start: 02/2001 Study End: 03/2002	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system, Laboratory system	Acute care/tertiary, Academic	compliance with digoxin monitoring guidelines - synchronous alerts*, compliance with hypokalemia and hypomagnesemia treatment guidelines - synchronous alerts*, compliance with hypokalemia and hypomagnesemia treatment guidelines - asynchronous alerts*	Postimplementation, synchronous alerts significantly increased test ordering for digoxin levels, K levels and Mg levels at 1 hr and 24 hrs (p <0.01 for all). Supplementation of Mg at 1 hour was significantly improved, but not at 24 hrs. Supplementation of K was not improved at 1 or 24 hrs. Synchronous alerts resulted in improved compliance at 1 hr and 24 hrs for bot K and Mg supplementation (p <0.01).	+
Gill (2009)[60] Design: RCT N = 64,150 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 10/2006	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Up-to-date lipid test*, Lipid medication if not at goal (high risk patients only)*	Outcomes improved for most measures from before to 1 year after the intervention (univariate analysis). However, after controlling for confounding variables and for clustering in multilevel modeling, only up-to-date lipid testing for high-risk patients was statistically better in the intervention group as compared to the control group (adjusted OR 15.0, p <0.05). Intervention status was NS for any other analysis.	-
Gilutz (2009)[61] Design: RCT N = 7,448 patients from 56 control and 56 intervention clinics Implementation: 00/0000 Study Start: 01/2000 Study End: 12/2003	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system, Laboratory system, Pharmacy	Ambulatory care Academic	rate of adequate monitoring, Positive treatment trend, overall up-titration rate in patients with LDL = 110 mg/dl	A higher rate of adequate monitoring was documented in the intervention arm (54.8% vs. 48.7%, p <0.001). Medication initiation or up-titration was recommended for patients with LDL levels above 110 mg/dl. The results showed that overall positive trends were minimally more prominent in the intervention arm (59.1% vs. 53.7%, p <0.003). Difference constitutes a higher rate of drug initiation (2.5%), up-titration (1.8%) and avoiding drug cessation (1.1%). Overall up-titration in patients with LDL = 110 mg/dl was poor, both in the intervention arm and in the control arm (8.6% vs. 7.4%, NS).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Grant (2008)[217] Design: RCT N = 244 patients Implementation: 00/2002 Study Start: 09/2005 Study End: 03/2007	**PHR** Integrated Billing/administration system, EHR/EMR system, Imaging systems, Laboratory system, Patient decision support system	General Hospital, Ambulatory care Home	Proportion of followup visits with DM related medication changes.	For the secondary outcome, significantly more followup visits included DM related medication changes in intervention patients than the control group, 15% vs. 53%, RRR 253%, p <0.001.	+
Hicks (2007)[66] Design: RCT N = 1,422 patients Implementation: 00/0000 Study Start: 07/2003 Study End: 02/2005	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Other, Academic	blood pressure controlled, receiving a recommended drug class medication within 1 week of the clinic visit adjusted This study had 4 groups: usual care, CDS, NPs, and NPs+CDS.	No difference was seen across all 4 groups for blood pressure readings: Usual care vs. CDS: 45% controlled vs. 48% controlled, OR 0.96 (95% CI 0.78 to 1.19). Patients in the CDS group were more likely to have received a recommended drug class medication within 1 week of the clinic visit than patients in the usual care group: adjusted OR 1.32 (95% CI 1.09 to 1.61).	+
Javitt (2005)[218] Design: RCT N = 39,462 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Insurance	Ambulatory care	Compliance with recommendations to add-a-drug*	Physicians complied with 24% of these “add-a-drug” recommendations in the intervention group. In the control group, physicians spontaneously instituted the treatment that would have been recommended in 17% of instances in which the recommendation was triggered but not issued. This 42% relative difference in compliance was statistically significant (p = 0.007).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Koide (1999)[84] Design: Before-after N = 1,024 prescriptions for 111 patients and 68 physicians Implementation: 09/1994 Study Start: 09/1994 Study End: 09/1996	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system, Laboratory system	Acute care/tertiary, 1040 Beds Academic	rate of appropriate prescribing	Of 491 preintervention prescriptions, 127 (25.9%) were classified as appropriate because they were accompanied by a normal value of ALT or AST within 3 months. Of 533 postintervention prescriptions, 353 (66.2%) were classified as appropriate. Sudden increase occurred immediately after the start of the intervention (p <0.0001).	+
Kucher (2005)[89] Design: RCT N = 2,506 patients Implementation: 00/0000 Study Start: 09/2000 Study End: 01/2004	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system	Acute care/tertiary, Academic	received pharmacological interventions	More patients in the CDSS group received pharmacological interventions. (13% vs. 24%, RRR 69%, p <0.001).	+
Kuilboer (2006)[219] Design: RCT N = 32 primary care practices (78,926 patients of whom 9,798 had asthma or related symptoms) Implementation: 07/1998 Study Start: 07/1998 Study End: 05/1999	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	rate of prescribing for cromoglycate-12 to 39yr, rate of prescribing for cromoglycate-40-59yr	Of 20 potential changes in measurement rates, 8 were observed: The AsthmaCritic group had more contacts for the 12 to 39 year group (p = 0.03), more measurement of peak flow total for the 0 to 11 year group (p = 0.02), more FEV1 total peak flow ratio measurement in the 12-59 year groups (p = 0.04 and 0.009), and more measurement of FEV1 rates in the 3, 12 and older groups (p = 0.01, 0.01, and 0.016) Prescribing for cromoglycate was reduced in the 12 to 39 year and 40 to 59 year groups (12 to 39: 9.9/1000 patients vs. 4.1, p = 0.03) and (40 to 59: 9.0/1000 patients vs. 4.2, p = 0.05). Other prescribing (3 drugs or drug classes and 4 age groups) did not differ across groups.	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Lester (2005)[94] Design: RCT N = 235 patients and 14 clinicians Implementation: 07/2003 Study Start: 07/2003 Study End: 07/2004	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care Academic	proportion of patients receiving statins*, proportion of patients receiving statins at 1 yr*	At 1 month more patients in the email group had received statins than control patients (3%, 15%, RRR 400, p <0.001). At 1 year the difference in receipt of statins had disappeared (17% vs. 25%, NS).	+
Lo (2009)[220] Design: RCT N = 3,673 potential alert trigger events (prescriptions) Implementation: 00/2000 Study Start: 07/2003 Study End: 01/2004	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders Imaging systems	Ambulatory care Academic	proportion of events resulting in lab testing	3,673 total events where baseline lab tests would have been advised: 1,988 events in the control group and 1,685 in the intervention group. In the control group, baseline labs were requested for 771 (39%) of the medications. In the intervention group, baseline labs were ordered by clinicians in 689 (41%) of the cases. Overall, no significant association existed between the intervention and the rate of ordering appropriate baseline laboratory tests (RRR 5%, p = 0.782).	-
Matheny (2008)[221] Design: RCT N = 2,507 outpatient visits in 1,922 geriatric patients and 303 primary care physicians Implementation: 00/0000 Study Start: 01/2004 Study End: 06/2004	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders Laboratory system	Ambulatory care Academic	rate of receiving appropriate laboratory testing within 14 days of the clinical encounter/ 10 medication-lab reminder categories	Reminders for appropriate laboratory monitoring had no impact on rates of receiving appropriate testing for creatinine, potassium, liver function, renal function, or therapeutic drug level monitoring for patients overdue for lab monitoring NSAIDs; Angiotensin Receptor Blockers ; Metformin; Potassium Supplements; Potassium Sparing Diuretics, Thiazide Diuretics; ACE Inhibitors; HMG Co-A Reductase Inhibitors; Thyroxine; (or the following therapeutic drugs combined: Carbamazapine; Cyclosporine, Phenobarbital, Phenytoin, Proc-NAPA, Valproate).	-

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
McDonald (1976)[222] Design: RCT N = 601 patient visits Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	General Hospital, Academic	compliance with drug monitoring test alerts*, compliance with recommendations to change therapeutic regimens*	Alerts to patients overdue for drug monitoring tests resulted in an increased number of tests ordered (11% vs. 36%, RRR -227%, p <0.0001). Recommendations for changes to therapeutic regimens were followed in 28% of study events compared to 13% of control events (p <0.026).	+
McGregor (2006)[104] Design: RCT N = 4,507 patients Implementation: 00/000 Study Start: 05/2004 Study End: 08/2004	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system, Pharmacy	Acute care/tertiary, 648 Beds Inpatient hospital based, Academic	mean time spent on antimicrobial management	Team members spent 3.2 hours per day on management of antimicrobials with the decision support system compared with 4 hours per day without. No statistical testing was done.	+
McMullin (1999)[105] Design: Before-after N = 265 patients Implementation: 01/1996 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system, Pharmacy	Acute care/tertiary, Pharmacy, Inpatient hospital based	rate of concomitant orders for contraindicated medications with cisapride*	The rate of ordering contraindicated drugs with cisapride was reduced with COPE (9% vs. 3.1%, RRR 65%, p <0.001).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Montgomery (2000)[107] Design: RCT N = 552 patients Implementation: 00/0000 Study Start: 09/1996 Study End: 09/1998	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	probability of patients taking 2 drugs, probability of patients taking 3 drugs	Adjusted data showed that compare with those in the risk chart group alone, those with computer support had a lower probability of patients taking 2 drugs (OR 0.5, 95% CI 0.2 to 0.9)< p <0.05) or 3 drugs (OR 0.3, CI 0.1 to 0.6, p <0.05).	-
Niiranen (2008)[113] Design: Time series N = 18,818 patient followups Implementation: 03/2005 Study Start: 04/2005 Study End: 12/2007	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Ambulatory care Home	proportion of patient followups assigned by nurses, year 1 to 2, proportion of patient followups assigned by nurses, year 2 to 3	In general, the share of patient followups assigned by nurses was similar in year 1 and 2 (56.7% vs. 55.1%, RRR 3%, NS), and increased significantly between year 2 and 3 (55.1% vs. 58.7%, RRR -7%, p <0.001).	+
Okon (2009)[223] Design: Before-after N = 51,619 severe pain events Implementation: 09/2005 Study Start: 10/2005 Study End: 06/2007	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, nurse charting system	Acute care/tertiary, 504 Beds	rate of reassessment errors, time to resolution of pain events-minutes (4 time periods)	Aggregate delayed reassessment error postintervention rate of 35.8% compared with preintervention (56.2%, p <0.0001) for relative error reduction of 36%. Observed median time to resolution of severe pain events among all hospitalized patients decreased from 195 (T0) to 117 minutes (T1), 106 minutes (T2), and 101 minutes (T3) (all p <0.0001).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Overhage (1997)[117] Design: RCT N = 86 physicians on 6 services (services randomized) Implementation: 00/0000 Study Start: 10/1992 Study End: 04/1994	**CDSS/CDS/CCDS/ reminders** Integrated, CPOE/POE system, EHR/EMR system, Laboratory system	General Hospital, Academic	immediate compliance with corollary ordering*, 24 hour compliance*, hospital-stay compliance*	Intervention physicians placed corollary orders twice as often as control physicians did when measured by immediate compliance (46.3% vs. 21.9%, RRR -111%, p <0.0001). Significant differences between study and control physicians also appear in 24 hour compliance (50.4% vs. 29.0%, RRR -74%, p <0.0001) and hospital stay compliance (55.9% vs. 37.1%, RRR 51%, p <0.0001).	+
Palen (2006)[120] Design: RCT N = 26,586 index dispensings Implementation: 00/0000 Study Start: 11/2002 Study End: 10/2003	**CDSS/CDS/CCDS/ reminders** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system, EHR/EMR system, Pharmacy	Ambulatory care	compliance rate	There was no significant difference between the control and intervention group physicians in the overall rate of compliance with ordering the recommended laboratory monitoring for patients prescribed study medications. Laboratory monitoring was performed as recommended 56.6% of the time in the intervention group compared with 57.1% of the time in the control group (p = 0.31). In cases in which a statistically significant difference was demonstrated, improved compliance favored the intervention group 71.2% vs. 62.3% (p = 0.003) for gemfibrozil; 75.7% vs. 73.9% (p = 0.05) for statins, 52.8% vs. 46% for colchicine (p = 0.05); 42.9% vs. 0% for methotrexate (p = 0.03)	-
Patel (2009)[224] Design: Before-after N = 25,503 patients Implementation: 00/2001 Study Start: 00/2001 Study End: 00/2007	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Hospital information system	Acute care/tertiary, 617 Beds Academic	percent compliance*	There were no statistical differences in percent compliance for all outcomes at 2001 baseline between hospitals (p >0.05). Adherence to all outcome criteria in the 5 high-risk populations over the 6-year time frame resulted in a 119% change compared with 91% at the non-REACH® hospital (p = 0.470).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Quinn (2008)[127] Design: RCT N = 30 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** **Diabetes Management Tool** Integrated Web-based data anlytics and therapy optimization tools	Ambulatory care	Changes in medication (medication intensified)	Patients using WellDoc System were more likely to have physicians intensify diabetes medications (84.6% vs. 23.08%, p = 0.002).	+
Raebel (2005)[129] Design: RCT N = 10,169 dispensings Implementation: 00/0000 Study Start: 09/2002 Study End: 12/2003	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system, Pharmacy	Ambulatory care HMO pharmacy	percentage of dispensings with baseline monitoring	Recommended laboratory monitoring was completed in 74.7% (n=7,598) of dispensings at initiation of therapy. Compared to the usual care group, monitoring was higher in the intervention group (70% vs. 79%, RRR -13%, p <0.001)	+
Riggio (2009)[133] Design: Before-after N = 100 patients with heparin induced thrombocyte-penia Implementation: 06/2005 Study Start: 03/2004 Study End: 09/2006	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, 728 Beds Academic	Time from platelet count criterion until heparin/enoxaparin stop*, Time from platelet count criterion until 1st HIT laboratory test drawn*, Time from platelet count criterion until direct thrombin inhibitor started*	Counter to expectations, the time (in days) taken from alert to heparin stop order was significantly higher after implementation (1.3 vs. 2.9, p = 0.04). There were no significant differences in time (in days) from alert to lab test (2.3 vs. 3.0, NS), nor time to start of treatment with direct thrombin inhibitor (19.3 vs. 15.0, NS).	-

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Rind (1994)[225] Design: Time series N = 562 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Formulary, Hospital information system, Laboratory system, Pharmacy	Acute care/tertiary, 504 Beds Academic	mean time interval between event and medication change*	The mean interval between the occurrence of an event and discontinuation of a medication or a change in its dosage was 97.5 hours during the control period and 75.9 hours during the intervention period, a difference of 21.6 hours (p <0.0001).	+
Rollman (2002)[136] Design: RCT N = 200 Patients with documented major depression Implementation: 00/0000 Study Start: 04/1997 Study End: 12/1998	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	antidepressant prescribing rate (secondary)	Prescribing of antidepressants (continuous use of change in prescriptions) did not differ across the 3 groups at 3 or 6 months.	-
Rood (2005)[137] Design: RCT N = 484 patients Implementation: 04/2001 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Critical care units (CCU, ICU, NICU) 18 Beds Academic	adherence to glucose measurement timing recommendations*, adherence to insulin dose advice*	Rate of compliance with glucose measurement timing recommendations control-intervention-control (29% vs. 38% vs. 41% with period 2 and 3 greater than period 1, p = 0.05). During the intervention period the rate for computerized group was higher than the control (36% vs. 40%, p = 0.05) Rate of compliance with insulin dose advice was higher in period 2 than 1, and decreased significantly in period 3 (56% vs. 70% vs. 42%, p = 0.05). During the intervention period the rate for computerized group was higher than the control (64% vs. 77%, p = 0.05).	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Roumie (2006)[226] Roumie (2007)[227] Design: RCT N = 871 patients Implementation: 00/0000 Study Start: 06/2004 Study End: 12/2004	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care Outpatient hospital based	prescribing changes*	No differences were seen comparing the groups who had provider education alone vs. those who had provider education and computer alerts for prescribing of any medication, changing doses, or adding medications (all data adjusted for multiple variables).	-
Safran (1995)[141] Safran (1993)[142] Design: RCT N = 349 patients with HIV Implementation: 00/0000 Study Start: 05/1992 Study End: 09/1993	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated EHR/EMR system	Ambulatory care Academic	mean response time to alerts*, mean response times to reminders*	Physicians who got alerts responded more quickly to them (mean 52 vs. 11 days, p <0.0001). Physicians who got reminders responded more quickly to them (mean 500 vs. 114 days, p = 0.0001).	+
Schnipper (2008)[143] Design: Before-after N = 30 clinicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Antiplatelet prescribed or contraindication documented*, Beta-blocker prescribed *, Change in diabetic therapy if A1c > 7.0 *	Antiplatelet prescribed or contraindication documented improved from 3.2% in the preintervention to 31.0% in the postintervention period (p <0.001). Beta-blocker prescribed or contraindication documented was 4.2 % in the preintervention compared to 66.7% in the post period (p = 0.03). Change in diabetic therapy if A1c >7.0 was 10.7% in the pre-period and 16.9% in the post period, p = 0.11.	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Sequist (2005)[228] Design: RCT N = 6,243 Patients Implementation: 07/2000 Study Start: 10/2002 Study End: 04/2003	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, General Hospital, Ambulatory care Community (school, community centre etc) Academic	compliance rate with Diabetes reminders*, compliance rate with Coronary Artery Disease reminders*	Diabetes reminders resulted in the recommended action in 19% in the intervention group vs. 14% in the control group. After adjusting for baseline patient and physician characteristics, patients in the intervention group were more likely than control patients to receive recommended diabetes care based on the composite outcome (OR 1.30, 95% CI 1.01 to 1.67). Coronary artery disease reminders resulted in the recommended action for overdue items in 22% in the intervention group vs. 17% in the control group. Using the composite outcome, patients in the intervention group received recommended coronary artery disease care more often than those in the control group (OR 1.25, 95% CI 1.01 to 1.55) after adjusting for baseline differences.	+
Shiffman (2000)[147] Design: Before-after N = 9 physicians Implementation: 00/0000 Study Start: 09/1996 Study End: 10/1998	**CDSS/CDS/CCDS/ reminders** Integrated Handheld	Ambulatory care	adherence rate with metered-dose inhaler/nebulization*, rate of systemic corticosteroid prescriptions*	Adherence with metered-dose inhaler/nebulization rates did not differ between control and intervention (73% vs. 91%, NS), nor did rate of prescribing systemic corticosteroids (43% vs. 57%, NS).	-

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Tierney (2003)[166] Design: RCT N = 706 patients, 20 pharmacists, 94 physicians and 1 nurse practitioner Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Pharmacy,	Ambulatory care Outpatient hospital based, Academic	compliance with cardiac care suggestions*	Neither the physician nor the pharmacist intervention had any significant effect on whether patients' cardiac care was compliant with the suggestions ($p > 0.8$ across the 4 intervention groups by analysis of variance, with $p > 0.7$ and $p > 0.4$ when testing the physician and pharmacist interventions separately).	-
Tierney (2005)[167] Design: RCT N = 706 patients Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system, Pharmacy	Ambulatory care Pharmacy, Outpatient hospital based, Academic	adherence to the care suggestions*	There were no differences between the four study groups in either adherence to the care suggestions, combined or individually (32% control, 32% physician intervention, 32% pharmacist intervention, 37% both interventions, NS).	-
White (1984)[229] Design: RCT N = 396 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, Academic	physician actions*	Physicians were 1.22 times as likely to take action in the alert group as compared to the non-alert group ($p < 0.003$). Actions included medication and lab monitoring changes.	+

Evidence Table 5. KQ1: primary process outcomes for all technologies assisting monitoring (continued)

Article Information	**HIT Studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Wrona (2007)[177] Design: Observational study N = 536 PCA patients Implementation: 00/2003 Study Start: 01/2003 Study End: 03/2004	**CPOE/POE system** Integrated EHR/EMR system, Imaging systems, Laboratory system	Pediatric stand alone hospital	Rates of respiratory monitoring. Rates of oxygen saturation monitoring	Compared to the control group of ‘no order set’, patients in the Acute Pain Team Service had a higher rate of respiratory monitoring (43% vs. 66.3%, RRR -54%, p <0.05) and oxygen saturation monitoring (86.1% vs. 98.6%, RRR -15%, p <0.05). Compared to the control group of ‘no order set’, patients in the prescriber initiated PCA had higher respiratory rate monitoring (43% vs. 57.8%, RRR -34%, p <0.05). No other comparisons were significant.	+

Evidence Table 6. KQ1: Primary Process outcomes for all technologies assisting education and other aspects of medication management

Article Information	**HIT Studied** Integrated systems	Settings	Outcomes Measured	Results	Outcome
Agrawal (2009)[230] Design: Before-after N = 19,356 MedRecon events Implementation: 06/2006 Study Start: 08/2006 Study End: 12/2007	**CDSS/CDS/CCDS/ reminders medication reconciliation at admission, transfer and discharge** Integrated CPOE/POE system, EHR/EMR system	Unspecified Hospital, 630 Beds Other, Academic	compliance with performing medication reconciliation*	On a monthly basis, clinicians performed medication reconciliation more often after the MedRec system and its reminder system were in place. Compliance improved from approximately 34% to 98% to 100%, statistically significant improvement.	+
Grasso (2002)[231] Design: Before-after N = 200 discharge summaries Implementation: 04/2001 Study Start: 06/2000 Study End: 07/2001	**PDA use to construct discharge summaries Handheld** Integrated EHR/EMR system, Pharmacy	Other specialty hospital (rehab, oncology), Inpatient hospital based	errors rate	The rate of errors in discharge summaries from a psychiatric hospital decreased after the implementation of PDAs to produce the summaries (22% vs. 8%, RRR 64%, $p < 0.05$).	+

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).
*indicates outcomes noted as being the primary outcome by the paper's authors
Abbreviations: GP = General Practitioner; HIT = Health Information Technology; N= Sample Size; p = Probability; PDA = Personal Digital Assistants ; PDMW = Physician Discharge Medication Worksheet; RRR = Relative Risk Reduction; vs. = Versus

Evidence Table 6. KQ1: Primary Process outcomes for all technologies assisting education and other aspects of medication management (cont'd)

Article Information	HIT Studied Integrated systems	Settings	Outcomes Measured	Results	Outcome
Poole (2006)[232] Design: Before-after N = 100 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**Medication Reconciliation Discharge System** Integrated e-MAR, Hospital information system	General Hospital, Inpatient hospital based	frequency discrepancies *, Dose discrepancies*, Therapeutic drug duplication discrepancies*	The PDMW was found to be effective in reducing discrepancies in frequency and dose and reducing therapeutic drug duplication at the time of discharge. Resolution of discrepancies in frequency improved by 65% with the tool (18% vs. 76%, p <0.001).. Resolution of discrepancies in dosages improved by 60% (28% vs. 82%, p <0.001), and therapeutic drug duplication was addressed in 58% more cases (p <0.001).	+
Quinn (2008)[127] Design: RCT N = 30 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	**CDSS/CDS/CCDS/ reminders Diabetes Management Tool** Integrated Web-based data analytics and therapy optimization tools	Ambulatory care	changes in medication (medication intensified)	Patients using WellDoc System were more likely to have physicians intensify diabetes medications (84.6% vs. 23.08%, p = 0.002).	+
van der Kam (2001)[233] Design: Cohort study N = 1,149 medications Implementation: 00/0000 Study Start: 02/1998 Study End: 05/1998	**e-Rx, Pharmacy information system** Integrated Pharmacy	Unspecified Hospital, Pharmacy, Not specified	Agreement of GP and pharmacist with patient for drug reported on admission, Agreement of GP and pharmacist with patient for drug reported on 10 days after discharge	Agreement of GP and pharmacist with patient for drugs reported was 31% for paper-based group compared to 49% for electronic group on admission (RRR 58%, p <0,001). The figures on 10 days after discharge were 33% and 53% respectively (RRR 61%, p <0.001). Total number of drugs reported by patients on admission was 38% and 29% for paper-based and electronic groups respectively. The figures on 10 days after discharge were 38% and 28% respectively.	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Chan (2008)[234] Design: Survey N = 1,174 nursing homes Implementation: 00/0000 Study Start: 09/2004 Study End: 12/2004	Administering, Dispensing	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated EHR/EMR system, Pharmacy	Long term care (nursing homes)	factors associated with use of electronic drug dispensing systems*, factors associated with use of electronic medication administration records*	nursing home facility characteristics associated with use of electronic information systems for drug dispensing: northwest region (OR 0.45 95% CI 0.31 to 0.67), west region (OR 1.63 (95% CI 1.10 to 2.43), administrator in place 5-9 years, (0.54, 95% CI 0.37 to 0.78) and number of services offered (OR 1.23 (95% CI 1.13 to 1.34). Factors associated with medication administration records use in nursing homes included northwest (OR 0.43, 95% CI 0.27 to 0.66) and west (OR 1.85, 95% CI 1.24 to 2.75) regions, urban centers (0.7, 95% CI 0.50 to 0.97), occupancy rates of 70 to 79% (OR 0.41, 95% CI 0.23 to 0.72), administrator in place <5 years (OR 0.49, 95% CI 0.33 to 0.71) and number of services offered (OR 1.21, 95% CI 1.10 to 1.31).	-

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: ASyMS = Advanced Symptom Management System; BCMA = Bar Code Medication Administration; BPOC = Barcode-enabled Point of Care; CCDS = Computerized Clinical Decision Support; CCU = Critical Care Unit; CDS = Clinical / Computerized Decision Support; CDSS = Clinical Decision Support System; CI = CI; CPOE = Computerized Provider Order Entry; DDI = drug drug interaction; DHCp = Decentralized Hospital Computer Program; HER = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; e-RX = Electronic Prescribing; e-TAR = Electronic Treatment Authorization Request; GP = General Practitioner; HIT = Health Information Technology; ICU = Intensive Care Unit; MAS-NAS = Medication Administration System-Nurses Assessment of Satisfaction; MM = Medication Management; mos = Months; N = Sample Size; NICU = Neonatal Intensive Care Unit; NPs = Nurse Practitioners; OR = OR; p = Probability; PHR = Patient Health Record; POE = Provider Order Entry; PWS = Physician Workstation; r = Correlation Coefficient; RCT = Randomized Controlled Trial; RR = Relative Risk; RRR = Relative Risk Reduction; SES = Socioeconomic; SYW = Show Your Work (program); vs. = Versus

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Ghahramani (2009)[235] Design: Survey N = 413 health professionals working in a hospital Implementation: 05/2005 Study Start: 11/2005 Study End: 00/0000	Prescribing	**CPOE/POE system**	Acute care/tertiary, Academic	factors associated with user satisfaction*, Frequency of use	User satisfaction was negatively associated with age (p <0.0001) and positively associated with system familiarity (p <0.0001), frequency of use (p <0.0001) and system characteristics (p <0.0001). Frequency of use was negatively associated with age (p <0.001) and training (p = 0.002) and was positively associated with user satisfaction (p <0.0001), user friendliness (p <0.0001), system familiarity (p = 0.0002), and system characteristics (p <0.0001).	+
Glassman (2006)[236] Design: Survey N = 97 clinic physicians and NPs (prescribers) Implementation: 03/2000 Study Start: 12/2000 Study End: 12/2002	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Hospital information system	Ambulatory care	knowledge of DDI*, perceptions towards CPOE*	The groups differed for knowledge for 19 drug interactions, improved for 3 and decreased for 1. Knowledge did not differ by specialty. At year 1, 45% of clinicians preferred CPOE for prescriptions. By year 3 this had increased to 63%, p <0.001. the other 4 reported perceptions had not changed. 8 barriers were assessed with both surveys. 6 did not differ between the 2 time periods. The perception that important alerts were missing (15% vs. 29%, p = 0.01) and poor visual presentation (7% vs. 21%, p = 0.02) differed.	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Graumlich (2009)[237] Graumlich (2009)[238] Design: RCT N = 631 patients Implementation: 00/0000 Study Start: 11/2004 Study End: 01/2007	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system**	Acute care/tertiary, 730 Beds Academic	patient mean score for discharge preparedness*, patient score for satisfaction with medication information, outpatient physicians perception of discharge software	When comparing patients assigned to discharge software vs. usual care, patient mean (SD) scores for discharge preparedness were higher (17.7 [4.1] vs. 17.2 [4.0]; p = 0.042), patient score for satisfaction with medication information were unchanged (12.3 [4.8] vs. 12.1 [4.6]; p = 0.567) and their outpatient physicians scored higher quality discharge (17.2 [3.8] vs. 16.5 [3.9]; p = 0.027). Hospital physicians found mean effort to use discharge software was more difficult than the usual care (6.5 [1.9] vs. 7.9 [2.1]; p = 0.011) and discharge software users had satisfaction (7.4 [1.4] vs. 7.9 [1.4]; p = 0.129) for usual care physicians	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Holden (2008)[239] Design: Mixed methods N = 215 nurses Implementation: 12/2006 Study Start: 11/2006 Study End: 11/2007	Administering	**BCMA** Integrated CDSS/CDS/CCDS/ reminders CPOE/POE system, EHR/EMR system	Pediatric stand alone hospital, Academic	perceived ease of use*, perceived usefulness*, satisfaction with process*	The predicted process acceptance model was supported pre-BCMA (F(12,88) = 5.13, MSE = 0.67, p <0.05) and post-BCMA (F(12,61) = 5.00, MSE = 0.61, p <0.05). Perceived ease of use of the process was significantly and uniquely associated with process acceptance both pre-BCMA (ß = 0.28, p <0.05) and post-BCMA (ß = 0.49, p <0.05). Perceived usefulness was significantly associated with process acceptance pre-BCMA (ß = 0.40, p <0.05) but not post-BCMA (ß = 0.18, p = 0.10). These two process beliefs accounted for 31.3% and 32.2% of the variance in process acceptance pre- and post-BCMA, respectively.	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Holden (2010)[240] Design: Survey N = 294 nurses Implementation: 07/2007 Study Start: 10/2006 Study End: 08/2007	Administering	**BCMA** Integrated CPOE/POE system	Acute care/tertiary, Pediatric stand alone hospital, Academic	perceptions of accuracy, usefulness, consistency, time-efficiency, ease of performance, error likelihood, error detection likelihood	Nurses perceptions of the administration process changed at the hospital that implemented BCMA, whereas perceptions of nurses at the control hospital did not. BCMA appeared to improve the safety of the processes of matching medications to the medication administration record and checking patient identification. The accuracy, usefulness, and consistency of checking patient identification improved as well. In contrast, nurses perceptions of the usefulness, time efficiency, and ease of the documentation process decreased post-BCMA.	+
Hurley (2007)[241] Design: Mixed methods N = 1,087 nurses Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated CPOE/POE system, EHR/EMR system, Pharmacy	Acute care/tertiary, Academic	satisfaction -The Medication Administration System-Nurses Assessment of Satisfaction Scale (MAS-NAS)	Overall scores on The Medication Administration System-Nurses Assessment of Satisfaction (MAS-NAS) Scale, significantly increased following implementation of the BCMA/e-MAR system (4.1 vs. 5.0, $p < 0.001$). There were significant increases in each of the 3 subscales of efficacy, safety and access ($p < 0.001$).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Johnson (2010)[75] Design: RCT N = 3,285 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 08/2007	Prescribing, Transmission, order communication	**CDSS/CDS/CCDS/ reminders** **e-Rx** Integrated EHR/EMR system	Ambulatory care, Pharmacy, Not specified, Academic	perceptions*	When asked if SYW helped avoid callbacks the majority of respondents agreed or strongly agreed (69%). Pharmacists found the allergy override information helpful (69% agree or strongly agree). A majority of pharmacists (79%) felt that information about patient's insurance eligibility was less helpful; 41% of pharmacists were neutral, 31% were in disagreement, and 7% were in strong disagreement with the statement ‘‘SYW was helpful with insurance eligibility".	+
Kawasumi (2006)[242] Design: Cross-sectional N = 28 primary care physicians caring for 4,096 patients Implementation: 00/0000 Study Start: 03/2003 Study End: 11/2003	Prescribing	**drug management system, e-Rx** Integrated EHR/EMR system, Insurance	Ambulatory care	rate of use of electronic medication histories, rate of use of e-Rx	Physicians differed in their use of electronic medication histories for patients based on their SES: 10.8% for high SES, 14.6% for middle SES (comparing middle and high, RR 1.55, 95% CI 1.15 to 2.47), and 17.9% for low SES (comparing high and low SES RR 1.70, 95%CI 1.15 to 2.47). Use of e-Rx did not differ by SES (36.1% for high, 39.0% for middle and 37.2% for low SES, NS).	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Kirking (1986)[243] Design: Survey N = 218 pharmacists Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Transmission, order communica-tion	**CDSS/CDS/CCDS/ reminders** **Pharmacy information system** Integrated Pharmacy	Pharmacy, Other	reported frequency of DDI per week, reported number of daily contacts with prescribers, proportion of contacts with prescribers related to DDI and allergies	computer users reported potential drug interactions an average of 16.1 interactions detected per week compared to 8.7 for non-users (p>0.05). As a group, computer users compared to non-users were found to have more contacts per day with prescribers (21.5 vs. 16.0, respectively, p <0.05), and a higher percentage of their reported contacts were related to interaction and allergy problems (3.9% vs. 2.8% respectively, p <0.05).	+
Kralewski (2008)[244] Design: Survey N = 93 physicians Implementation: 00/0000 Study Start: 09/2006 Study End: 10/2006	Prescribing	**e-Rx**	Ambulatory care, Academic	proportion of prescriptions sent electronically	Practice-level variables explain most of the variance in the use of e-scripts by physicians, although there are significant differences in use among specialties as well. General internists have slightly lower use rates for e-Rx and pediatricians have the highest rates. Larger practices and multispecialty practices have higher use rates, and five practice culture dimensions influence these rates; two have a negative influence and three (organizational trust, adaptive, and a business orientation) have a positive influence.	

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Kramer (2007)[245] Design: Before-after N = 283 patients Implementation: 00/0000 Study Start: 09/2004 Study End: 10/2005	reconciliation	**electronic medication reconciliation system** Integrated EHR/EMR system	Unspecified Hospital, 760 beds plus 102 bassinets Beds Inpatient hospital based	improved self-reported perceptions, satisfaction; self-reported perceptions of clear instructions on what medications to take, how much and how often the medications were to be taken, other instructions on taking the medication, potential side effects, and general understanding of the medications	Patients reported satisfaction with the reconciliation system (better knowledge of their discharge medications) for 5 of 5 factors. Improved self-reported perceptions of clear instructions on what medications to take ($p = 0.007$), how much and how often the medications were to be taken($p = 0.007$), other instructions on taking the medication($p = 0.006$), potential side effects ($p = 0.001$), and general understanding of the medications($p = 0.001$). Healthcare provider Physician assistants and nurse practitioners reported that patients had clearer instructions on discharge ($p = 0.01$); how much, how often, and when to take their medications at home ($p = 0.05$); and the medication discharge process was views as being sufficient for them as care givers ($p = 0.0003$).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Lee (1996)[246] Design: Survey N = 205 physicians and nurses Implementation: 05/1993 Study Start: 00/1993 Study End: 00/1995	Prescribing	**CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders	Acute care/tertiary, 720 Beds Academic	correlates of satisfaction*	Overall satisfaction was most strongly correlated with characteristics related to the efficiency of POE, such as impact on productivity (r = 0.69) and ease of use (r = 0.67). Characteristics related to the quality of care, such as reducing error or giving information, were less strongly correlated with overall satisfaction (r = 0.32 and r = 0.36, respectively), although these correlations were still significant.	+
Li (2006)[247] Design: Qualitative N = 2 qualitative researchers (nurse and human factors psychology) Implementation: 02/2004 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated Hospital information system	Acute care/tertiary	usability The 2 researchers used heuristic methods and identified 5 major problem areas with the CPOE system. These problems centered on text presentation, too much information/too many decisions at one time, color scheme (monochromatic blue/grey with red used as accent and not to note caution or problems).	Problems were given to the developers who addressed them in the next redesign of the system.	

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	**MM Phase(s)**	**HIT Studied** Integrated System	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Lindenauer (2006)[248] Design: Mixed methods N = 356 physicians at 2 hospitals. Implementation: 00/0000 Study Start: 05/2003 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Imaging systems, Pharmacy	Acute care/tertiary, 725 Beds Academic	use	The physician users of CPOE were categorized as being low (n = 109), intermediate (n = 88), or high (n = 141) users. Groups did not differ for use by gender, use of a computer in outpatient practice, years since graduate from medical school, practice at study institution, or total number of orders placed. Specialty was associated with use: more anesthesiolgists, pediatricians, and surgeons used CPOE (p <0.0001). Physicians who trained with CPOE (p = 0.045) and those who used computers daily were more likely to use CPOE (p = 0.04). High and intermediate users were 3 times as likely to believe that the user interface of the system supported their work flow. Similarly, 19% of low users, 31% of intermediate users, and 45% of high users believed that entering orders into the system was faster than writing orders.	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Liu (2004)[249] Design: Survey N = 154 hospitalized patients Implementation: 07/2002 Study Start: 10/2002 Study End: 12/2007	Education of patients and clinicians but not pre-professional education	**Pharmacy information system** Integrated Hospital information system	Acute care/tertiary, Academic	patient knowledge*	Patients reported improved drug knowledge: improved abilities to use their prescriptions, avoid adverse drug events, know contraindications and side effects of their drugs, and acquire needed information, p <0.001 for each before and after comparison.	+
McAlearney (2005)[250] Design: Observational study N = 1,010 patients Implementation: 04/2002 Study Start: 11/2001 Study End: 11/2003	Prescribing	**CPOE/POE system, order sets** Integrated CDSS/CDS/CCDS/ reminders Laboratory system, Pharmacy	Pediatric stand alone hospital, 328 Beds Academic	order set utilization*	Order set utilization varied significantly by condition (X2 = 339.2, p <0.001). The asthma order set use rate (88.1%) was highest, followed by appendectomy order set use (79.4%), followed by a relatively low CAP order set use rate (21.1%).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	**MM Phase(s)**	**HIT Studied** Integrated System	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
McCann (2008)[251] Design: Mixed methods N = 53 patients Implementation: 0 Study Start: 03/2006 Study End: 09/2006	Monitoring including patient adherence and compliance	**symptom management system** Integrated Handheld	Ambulatory care	preintervention perceptions, postintervention perceptions	Preintervention, patients' expectations of participating were largely positive: 87% anticipated that using the ASyMS© handset would help them communicate with their doctors and nurses; 79% thought using the ASyMS© handset to record symptoms would help manage symptoms; and patients reported positive expectations about the alerting system, frequently using terms such as 'reassuring', 'excellent idea', 'confident' and 'comforting'. Patients anticipated they would find their overall experience of being involved in the study challenging (32%), rewarding (62%), educational (41%) and interesting (63%). Postintervention, patients reported positive experiences of being involved in the study, describing their experience as interesting (80%), valuable (77%) and educational (34%).	

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Musser (2006)[252] Design: RCT N = 51 anesthesiologists Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system**	Unspecified Hospital	time used in CPOE sessions in seconds (text-based (OS) vs. graphical format (IF))*, rate of miscellaneous orders placed per session (text-based vs. graphical format)*	Users predominately chose to use the IF format: used for 70% of the orders in the free-choice phase, and 17/24 (71%) of survey respondents preferred IF. OS format gained substantial support, 15 of 26 (58%) answered that they would choose to keep either both formats or the OS alone; and those users initially assigned to the IF format were more likely than their counterparts (36% vs. 21%) to prefer the OS format. Experience level (based on number of orders placed) had a small but significant (p = 0.02) correlation with preference of format, with more experienced users preferring for the OS format. According to time measurements from the usage logs, CPOE sessions in which the IF format was used averaged 27 seconds shorter (162 vs. 189 seconds, p <0.01). No statistically significant differences between IF and OS formats were found for length of stay, rate of mistakes made, or the number of orders for diagnostic tests or medications; miscellaneous orders were placed slightly more frequently (5.44 vs. 5.14 orders per session, p = 0.03) from the OS format.	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Niazkhani (2009)[253] Design: Before-after N = 211 nurses Implementation: 12/2001 Study Start: 09/2003 Study End: 10/2004	Administering, Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Hospital information system	Acute care/tertiary, 1237 Beds Academic	Overall mean scores of medication process attitudes* Kardex vs. TIMED, correlates of attitudes toward CPOE*. Overall mean scores of attitudes were summed across the 15 questionnaire items (relating to regarding medication process, characteristics of medication orders, registration of drug administration, learning and speed of process and managing non-stock medications) and compared pre- and post for Kardex and TIMED units.	Following implementation of CPOE, there was an increase in scores for the Kardex system (3.2 vs. 3.6, p <0.001) but not for the TIMED units (3.4 vs. 3.5, NS). Overall score with the CPOE was strongly correlated with user satisfaction (r=0.75, p <0.001), clarity of administration record (r=0.66, p <0.001), ease of the process (r=0.63, p <0.001), and clarity of the drug review form (r=0.63, p <0.001) but not with professional status, computer experience or ward.	+
O'Morrow Snyder (2003)[254] Design: Before-after N = 17 nurses Implementation: 07/2002 Study Start: 01/2003 Study End: 05/2003	Administering	**BCMA** Integrated CPOE/POE system, Hospital information system, Imaging systems, Laboratory system, Pharmacy	General Hospital, 457 Beds	nurses attitudes toward BPOC	No differences in responses about attitudes toward the BPOC system before or after training and implementation took place (p >0.05) for any of the 7 factors included in the survey: patient care, charting, computer benefit, computer capability, computer characteristics, legal issues or management tools.	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Onzenoort (2008)[255] Design: Observational study N = 15,162 drug administrations Implementation: 09/2005 Study Start: 00/0000 Study End: 00/0000	Administering	**BCMA** Integrated CPOE/POE system, EHR/EMR system	Acute care/tertiary, Academic	variables related to use of BCMA	Nurses verified the bar codes of about half of medications administered. Variables that increased the use of bar code verification were department (more in rheumatology and metabolic and infectious diseases and less in oncology, hematology, and gastronerterology and neurology and neurosurgery); oral administration (and not parenteral, inhalation, rectal or other); more with more than 46 nurses; more with nurses younger than 30 years; more with 6-7 shifts worked per month.	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Pirnejad (2008)[256] Pirnejad (2009)[257] Design: Mixed methods N = 149 nurses Implementation: 09/2003 Study Start: 11/2003 Study End: 06/2007	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system, Hospital information system	Acute care/tertiary, 1237 Beds Academic	nurses attitudes toward paper based system vs. CPOE*	[256] The first question asked nurses whether their current medication system supported their work process and showed a statistically significant difference between nurses' attitudes in pre- and postimplementation (60.5% agreed for the paper-based system and 68.5% for the CPOE system, p = 0.048). More in the paper group said 'no' (32.9% vs. 2.7%), while fewer were unsure (3.9% vs. 28.8%).[257] Questions about the perceived physical appearance of the prescription and administration registrations system were analyzed; The analysis showed that nurses judged CPOE system prescriptions to be significantly better than those from the paper-based system with regard to legibility (p <0.001) and completeness (p <0.001). However, there was no statistically significant difference between prescription layout in the two systems (p > 0.006).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Porteous (2003)[258] Design: Mixed methods N = 787 General practitioners, opinion leaders, computing experts, pharmacists, and patients Implementation: 00/0000 Study Start: 01/2000 Study End: 05/2000	Transmission, order communica-tion	**electronic communication between physicians and pharmacists, e-Rx**	Pharmacy	percentage of responders supporting electronic transfer	Responders in all three groups (68% of patients [95% CI 64% to 72%], 83% of GPs [95% CI 77% to 89%], and 87% of community pharmacists [95% CI 82% to 92%]) thought that electronic transfer of prescription related information was a good idea in principle. All groups were concerned about security and sharing confidential patient information.	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Rahimi (2009)[259] Design: Survey N = 310 healthcare providers Implementation: 00/2008 Study Start: 02/2009 Study End: 00/2009	Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Formulary, medication administration, Pharmacy	Unspecified Hospital, Ambulatory care	Perceptions Data analyzed physicians and nurses' experiences related to the adoption of a CPOE system, structuring the analyses according to three attributes of diffusion of innovation theory, i.e. the relative advantage of the system, its compatibility with professional values and needs, and its complexity of use.	More nurses (56.7%) than physicians (31.3%) stated that the CPOE system introduction had worked well in their clinical setting (p <0.001). Similarly, more physicians (73.9%) than nurses (50.7%) reported that they found the system not adapted to their specific professional practice (p = < 0.001). Also more physicians (25.0%) than nurses (13.4%) stated that they did want to return to the previous system (p = 0.041). Relative advantages of the CPOE system were estimated to be significantly (p <0.001) higher among nurses (39.6%) than physicians (16.5%). Physicians' agreements with the compatibility of the CPOE and with its complexity were significantly higher than the nurses (p <0.001). An important reason behind the reluctance of physicians and nurses to use the CPOE system was that the system was not adapted to their work routines.	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Rogers (1999)[260] Design: Before-after N = 42 practices Implementation: 10/1995 Study Start: 04/1997 Study End: 10/1997	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	use of the decision support system in 2 time periods	More clinicians used the decision support system in phase 2 as compared with phase 1: 9.3% vs. 27%, RRR 186, p <0.001.	+
Rohrig (2007)[261] Design: Cross-sectional N = 40 physicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Critical care units (CCU, ICU, NICU) Academic	usability of Antibiotic Wizard*	In a survey physicians compared Antibiotic Wizard with Microsoft Word on 6 scales. 3 of the scales showed no difference in comparison (suitability for the task, conformity with user expectations, and suitability for individualization). For the other 3 scales, Antibiotic Wizard was perceived as being better than Word: self descriptiveness, controllability, and error tolerance (p <0.01 for all 3 comparisons).	+
Rosenbloom (2005)[262] Design: RCT N = 418,739 opportunities to access an information item Implementation: 00/1995 Study Start: 04/19999 Study End: 03/2000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Acute care/tertiary, 609 Beds Academic	access rate for educational opportunities	Study physicians accessed educational opportunities for 278 of 240,504 (0.12%) vs. 18 of 178,235 opportunities (0.01%), RRR 1100, p <0.05.	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Ross (2004)[263] Design: RCT N = 107 patients Implementation: 00/0000 Study Start: 08/2001 Study End: 09/2002	Monitoring including patient adherence and compliance	**Patient accessible Medical Record** Integrated messaging system	Acute care/tertiary, Ambulatory care, Academic	change in the self-efficacy domain of the Kansas City Cardiomyopathy Questionnaire*	A change of 7.7 was set to be minimal clinically significant difference. There was a trend towards an improvement in the intervention group, with scores of 85 at baseline, 88 at 6 mos and 91 at 12 mos (p = 0.08); but the improvement of 6 points did not reach the threshold value set as a standard for this outcome.	-
Rotman (1996)[264] Design: RCT N = 34 Physicians Implementation: 00/0000 Study Start: 07/1994 Study End: 06/1995	Prescribing	**CDSS/CDS/CCDS/ reminders e-Rx** Integrated Hospital information system, Laboratory system	Ambulatory care	User Satisfaction Rating*	After the physicians used the PWS, their user-satisfaction, score decreased by 0.34 Likert-scale units (approximately one half of one SD of the mean score, p = 0.008). In contrast, the mean satisfaction in the control group (DHCP) increased by 0.49 Likert-scale units (p <0.0001). Overall, the two groups diverged with a difference of 0.83 Likert-scale units between the two groups (p <0.0001).	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	**MM Phase(s)**	**HIT Studied** Integrated System	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Rupp (2008)[265] Design: Survey N = 1,094 pharmacy staff Implementation: 00/0000 Study Start: 04/2006 Study End: 07/2006	Dispensing, Transmission, order communication	**e-Rx** Integrated Pharmacy	Pharmacy Pharmacy chain	satisfaction with e-Rx	Pharmacy personnel reported general satisfaction but also perceived key weaknesses with electronic prescribing (e-Rx). Pharmacists, considered e-Rx technology to be significantly more positive in terms of safety, efficacy, and efficiency than pharmacy technicians. Effect on pharmacy efficiency was the most influential predictive variable for determining staff satisfaction with e-Rx; followed by communications with the physician and patient safety (final model retained were as follows: satisfaction = 0.6071+ 0.3562 efficiency + 0.2075 communications with physician + 0.1720 safety + 0.1698 relations with patient + 0.I487 effectiveness).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Schectman (2005)[266] Design: Survey N = 84 physicians Implementation: 09/2003 Study Start: 00/0000 Study End: 00/0000	Prescribing	**e-Rx** Integrated, CDSS/CDS/CCDS/ reminders	Ambulatory care, Academic	correlates of use* System utilization rate was strongly associated with perceived actual ease of use and usefulness; perceptions that their patients liked them to use the system; perceived efficiency; and feeling comfortable. Interestingly, use was not associated with satisfaction with ease of use or system capabilities since even high utilizers felt that the system should be easier to use. Utilization was also not associated with the amount of prior computer experience or with clinical practice satisfaction.	There was a strong association between self reported rate of recent system use and the actual number of prescriptions written in the two months prior to the survey based on electronic utilization data ($r = 0.70$, $p < 0.0001$). There was no association between respondent age, gender, or level of training and utilization. There was no overall association between the mean score on the scale of attitudes toward computers' effect (beneficial vs. detrimental) on the practice of medicine and utilization of the expert system ($p = 0.18$). However, there was an association between prescription writing and the specific beliefs that computers enhanced the enjoyment of the practice of medicine ($p = 0.04$) and the quality of health care ($p = 0.004$).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	**MM Phase(s)**	**HIT Studied** Integrated System	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Schmidt (2008)[267] Design: Cohort study N = 62 patients with CHF Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**patient adherence reporting** Integrated EHR/EMR system	Ambulatory care	association between self report and pill container	Clinicians could not assess patient adherence. Patients' self reports of adherence were similar to what was measured using the automated pill boxes and response to the EHRs. 51% wanted to continue after 6 months of monitoring. No changes were noted in physical health but both groups reported improved levels of mental health. p <0.001 at 2 months p <0.01 at 6 month association between self report and pill container (NS).	+
Shannon (2005)[268] Design: Cohort study N = 9 physicians Implementation: 00/1999 Study Start: 00/0000 Study End: 00/0000	Prescribing	**e-Rx** Integrated, Hospital information system	Emergency department	rate of use of e-Rx*	The addition of wireless handheld computers resulted in a statistically significant increase in prescription-writing by physicians. The mean of the observed rates of prescribing was 52% during the control period and 64% during the intervention period, a 12.5% increase (SE 0.057, p = 0.03).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Sittig (2006)[269] Design: Survey N = 110 PCPs Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Ambulatory care, Academic	factors affecting CDS system acceptance	Younger clinicians appreciated the system more than those who had been practicing longer in the hospital, most respondents liked the system (helped take care of patients better (3.5), work the time it takes (3.5), and reminds me of something I had forgotten (3.1)), cost. safety and health maintenance reminders were valued about the same; clinicians were more likely to look up patient information (3.9), enter orders for patients (3.8), show patient data (2.9); they wanted fewer alerts and noted that they came at an inappropriate time.	
Tan (Woan Shin Tan) (2009)[270] Design: Survey N = 179 health care providers Implementation: 00/2006 Study Start: 10/2007 Study End: 00/0000	Prescribing	**CPOE/POE system, e-Rx** Integrated CDSS/CDS/CCDS/ reminders Pharmacy	Ambulatory care, Other institution based	physician satisfaction with e-Rx*	85% of physicians were satisfied with the e-Rx system. Their satisfaction was associated with the ability to prescribe a new medication (p = 0.002) or change an existing one (p = 0.05), and the amount of time taken to enter prescription information (p = 0.04). 77% of pharmacists were satisfied with the system. their satisfaction was associated with the amount of time spend on processing standard purchases (p = 0.05).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Tierney (1994)[271] Design: Survey N = 212 Physicians and Medical students Implementation: 00/0000 Study Start: 04/1990 Study End: 10/1991	Prescribing	**CPOE/POE system** Integrated EHR/EMR system	General Hospital	overall attitude score	Factor analysis created an overall attitude score of 16 items loading into 3 factors that explained 57% variance. The score was significantly different between groups (p = 0.0002) declining progressively from juniors (mean 47.1, SD 7.0) interns (mean 44.3, SD 7.1), and residents (40.9, 6.9). Junior students sig dif from all other groups. Gender, typing ability and computer ownership not factors.	-
Topps, (2005)[272] Design: Mixed methods N = 313 Healthcare provider Implementation: 11/2002 Study Start: 05/2002 Study End: 06/2003	Administering	**BCMA** Integrated Billing/administration system,Hospital information system, Pharmacy	Pediatric stand alone hospital	perceived effect of new system on medication errors*, perceived staff time using system*	The comparison of pre and post tests revealed that statistically significant pre vs. post differences were observed for perceived effect of new system on medication errors". Mean pre bar-code was 1.91; mean post-score-2.23 with difference between means statistically significant (F=6.55; df = 1, 308; p = 0.011); however the score was higher post bar-code than pre bar-code, indicating that the staff felt errors had not decreased as much as they thought they would. For staff time using system, mean pre bar-code was 3.55; mean postbar-code was 3.95 with difference between means statistically significant (F = 8.80; df = 1, 312; p = 0.003).	-

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Wang (2009)[273] Design: Mixed methods N = 228 physicians (139 e-Rx users and 89 non-users) Implementation: 09/2006 Study Start: 10/2006 Study End: 12/2006	Prescribing	**e-Rx** Integrated Stand-Alone	Ambulatory care	predictors of use of e-Rx*	Specialty (p = 0.05) and practice setting (smaller practices) (p = 0.002) were associated with use but not age, attitude towards computer, practice size, or use of EMRs. Performance measures were associated with volume of use of e-Rx (p <0.001) and usability issues were associated with stopping use of e-Rx (p = 0.03).	
Weiner (1999)[274] Design: Survey N = 271 clinicians Implementation: 06/1996 Study Start: 11/1996 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated Imaging systems, Laboratory system, Pharmacy	Acute care/tertiary, Academic	perceptions of nurses and physicians towards CPOE*	More nurses reported the POE system easier to use than house officers and attendings (78% vs. 63% vs. 37%, p <0.03). House officers and attendings were more likely than nurses to report the use of POE decreased their time with patients (9% for nurses, 44% for house officers, and 34% for attendings, p <0.05). House officers were more likely than nurses to state that POE was associated with more tests and more errors in ordering. More nurses felt that the system improved the quality of care (56%) compared with 29% for house officers and 34% for attendings, p <0.03).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Weingart (2008)[275] Design: Cohort study N = 267 patients Implementation: 09/2000 Study Start: 04/2001 Study End: 06/2002	Monitoring including patient adherence and compliance	**patient messaging via PHR** Integrated Billing/administration system, EHR/EMR system, Imaging systems, Laboratory system	Ambulatory care, Academic	patient usage of MedCheck messages*	Patients opened 79% of MedCheck messages and responded to 12%; 77% responded within 1 day. Patients often identified problems filling their prescriptions (48%), problems with drug effectiveness (12%), and medication symptoms (10%). Clinicians responded to 68% of patients' messages; 93% answered within 1 week. Clinicians often supplied or requested information (19%), or made multiple recommendations (15%).	
Wilson (2000)[276] Design: Survey N = 112 prescribers and pharmacy staff Implementation: 00/1990 Study Start: 05/1998 Study End: 06/1998	Prescribing	**CPOE/POE system** Integrated Billing/administration system, Hospital information system, Imaging systems, Laboratory system, Pharmacy	Unspecified Hospital, 48 Beds Ambulatory care	correlates of satisfaction*	Overall, users were satisfied with the CHCS POE system. Satisfaction was significantly positively correlated with ratings of the POE system's impact on productivity, ease of use, effect on the quality of care, reliability, and provision of information to help providers write better orders ($p < 0.05$).	+

Evidence Table 7. KQ1: primary intermediate outcomes for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Zaidi (2006)[277] Design: Survey N = 115 clinicians Implementation: 00/0000 Study Start: 02/2005 Study End: 08/2005	Prescribing	**antibiotic approval program, CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary, Inpatient hospital based, Academic	clinicians' perceptions of ease of use and usefulness of a web-based antibiotic approval system*	Use of the iApprove CDSS system was negatively associated with number of years of experience (p = 0.004). Use was positively associated with self-rated computer sophistication (p = 0.03), frequency of accessing laboratory data (p = 0.012), the system was perceived to be easy to learn (p = 0.001) or easy to show others how to use the system (p = 0.014), or if they perceived the system to be integrated into daily work flow (p = 0.028), the perceived ease of finding additional information related to recommendation (p = 0.009), and ease of logging out of the system (p = 0.034).	+

Evidence Table 8a. Summary of full economic evaluation studies

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Perspective (Time horizon)	Currency (year) Cost elements	Effective-ness measure	Intervention and alternative being evaluated	Main economic findings
Fretheim (2006)[55] Fretheim (2006)[56] Norway	Cost-effective-ness analyses	Compared costs and effects of a multifaceted intervention aimed at improving prescribing of anti-hyperten-sive and cholesterol lowering drugs compared with usual care.	Using data from a cluster-RCT of private practices, the cost-effectiveness included the cost incurred per additional patient started on a thiazide rather than another anti-hypertensive drug.	Intervention: 73 practices with 70 included in analysis; control: 73 with 69 included in analysis	Perspec-tive of the health care system, (1 year)	2002 USD (used 2002 avg. exchange rate from Norwegian kroner) Development of software; training of outreach visitors; printed material; travel; cost of pharmacists doing outreach; admin costs; opportunity cost of physician time; technical support; drug expenditure; number of consultations per patient; laboratory tests	Number of patients prescribed thiazides for hypertension, number of patients that had a cardiovas-cular risk assess-ment done, number of patients who achieved treatment target goal (BP, LDL, total cholesterol)	multifaceted intervention: (1) educational outreach visits to clinics; (2) audit & feedback on current adherence to guidelines & recommendations; (3) computerized reminders to physicians during pt encounter vs. passive dissemination of guidelines through national medical journal	The cost-effectiveness of the intervention was USD$454 per additional patient started on thiazides.

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: ADE = adverse event; BP = blood pressure; BWH = Bringham and Women's Hospital; CDSS = computerized decision support system; CPOE = computerized physician order entry; CVR = cardiovascular risk; ESCHM = European Society of Cardiology and other societies for Hypercholesterolemia Management; GINA = Global Initiative for Asthma; LOS = length of stay; MAR = medication administration record; MOE = medication ordering entry; pADE = preventable adverse drug events; QOL = quality of Life; RCT = randomized controlled trial; SADC = system of clinical decision support; SGRQ = St. George Respiratory Questionnaire; USD = United States Dollars

Evidence Table 8a. Summary of full economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Perspective (Time horizon)	Currency (year) Cost elements	Effective-ness measure	Intervention and alternative being evaluated	Main economic findings
Karnon (2008)[278] U.K.	Cost-utility analysis	To estimate the net benefits of interventions that aim to reduce the impact of medication errors, either through prevention or detection.	A decision tree model to describe a series of error points and subsequent error detection points in pathways through the medication process in a generic secondary care setting. Assumed an acute hospital size of 400 beds	populated model with quantitative estimates to describe the incidence and impacts of medication errors. The effective-ness of potential interventions was estimated by describing impact of interventions on error incidence and detection rates, which feed through to alter the estimated frequency of medication errors and pADEs.	Five years to represent the predicted useful life of the IT-based interventions.	U.K. sterling (2006) Monetary values were assigned to the interventions, efficiency savings, treatment of, and the health effects of pADEs.	Quality of life utility decrements associated with experiencing a pADE	CPOE vs. additional ward pharmacists vs. bar coding	The fully estimated net benefits of the three interventions are dominated by the estimated monetary valuations of the health effects of pADEs, with mean net benefits of £31.5, £27.25, and £13.1 million over a five year time horizon for CPOE, ward pharmacists and bar coding, respectively.

Evidence Table 8a. Summary of full economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Perspective (Time horizon)	Currency (year) Cost elements	Effective-ness measure	Intervention and alternative being evaluated	Main economic findings
Plaza, V. (2005)[279] Spain	Cost-effectiveness	To evaluate the cost-effective-ness of an intervention to promote the recommen-dation of the Global Initiative for Asthma compared with standard practice	Physicians were randomized to CDSS offering recommendations or no CDSS groups in a multicenter, prospective, pragmatic study. Eligible patients were followed for 1 year. The incremental cost-effective-ness ratio was defined as the increase in total cost per patient divided by the change in QoL score	20 physicians (10 pulmonolo-gists and 10 primary care physicians) & (included 198 asthmatic patients)	Societal perspective & national health system (i.e. payer)	Euros (2001) Direct (resource x unit cost, treatment costs) and indirect (time off work due to medical visits) costs for societal perspective and direct costs for payer perspective	Difference in QOL using St. Georges Respiratory Questionnaire. GRQ, healthcare resources consumed, number of medical visits, hospitali-zations, asthma treatment, blood analysis, spirometry, chest radiographs	CDSS vs. no CDSS	Not clear what currency the results are presented in. Hard to decipher but it may be that from the societal perspective the intervention was dominant (less costly and more effective) and from the payer perspective the ICER was $61/ percentage point reduction in SGRQ scale
Rosser (1992)[139] Canada	Cost-effectiveness analysis	To assess the effect of three computer-ized reminder systems on compliance with tetanus vaccination.	Prospective randomized controlled trial (4 arms). Setting: Hospital Family Medicine Centre over 1 year	5242 randomiza-tion patients and 2369 non-randomized patients ≥ 20 years of age not in a hospital or institution	Health care practice (1 year)	CDN (1985/1986) Physician time, clerical and nurse time, stationary, stamps, prepaid envelope and clerical time, cost to set up computerized reminder system was not included.	Proportion of patients who received tetanus toxoid in the study year or who had a claim of vaccine-tion in the previous 10 years	Computer-generated physician reminder, vs. telephone reminder to patient, vs. letter reminder to patient to recommend tetanus vaccination vs. control group	cost to practice per additional vaccination recorded was 22¢ to 43¢ for physician reminders, $4.43 to $5.43 for telephone reminders; and $6.05 for the letter reminders.

Evidence Table 8a. Summary of full economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Perspective (Time horizon)	Currency (year) Cost elements	Effective-ness measure	Intervention and alternative being evaluated	Main economic findings
Wu, RC. (2007)[280] Canada	Cost-effectiveness analysis	To determine the potential incremental cost-effective-ness of an electronic MOE/MAR system.	Incremental cost-effectiveness analysis comparing mean effective-ness of electronic MOE/MAR vs. Standard paper ordering for prevention of ADEs. Setting: Three tertiary care teaching hospitals	N/A	Health care institution (10 years with 5% discount rate)	USD (2004) Implementation costs (software, project management, clinical team involvement and training); operating costs (support for new interface, training))	Reduction of preventable ADEs and mortality (rates obtained by review of literature)	MOE/MAR (i.e. CPOE) compared with conventional paper-based system	Incremental costs for CPOE system vs. paper was $12,700 per ADE averted This value is sensitive to the ADE rate, system effectiveness of ADE reduction, system cost, and costs due to possible increase in doctor workload.

Evidence Table 8b. Summary of partial economic evaluation studies

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Chertow (2001)[18] U.S.	Cost-analysis	To determine if a system application for adjusting drug dose and frequency in patients with renal insufficiency, when merged with a computerized order entry system, improves drug prescribing and patient outcomes	Four consecutive 2-month intervals consisting of control (usual computerized order entry) alternating with intervention (computerized order entry plus decision support system) conducted in September 1997–April 1998 at a 720-bed urban tertiary care teaching hospital.	Hospitalized patients with renal insufficiency, 7,887 admissions during the 2 intervention periods (2 months each) 9,941 admissions in the 2 control periods (2 months each)	?? assumed 1997/1998 Hospital and pharmacy charges	Rates of appropriate prescription by dose and frequency, length of stay, and changes in renal function, compared among patients with renal insufficiency	Real-time computerized decision support system for prescribing drugs in patients with renal insufficiency. During intervention periods, the adjusted dose list, default dose amount, and default frequency were displayed to the order-entry user and a notation was provided that adjustments had been made based on renal insufficiency. During control periods, these recommended adjustments were not revealed to the order-entry user, and the unadjusted parameters were displayed.	There were no significant differences in estimated hospital and pharmacy costs. USD$4,881 vs. USD$4,968 in total costs and USD$168 vs. USD$166 for the intervention and the control groups, respectively LOS was shorter for the intervention group 4.3 days vs. 4.5 days, p = 0.009 even after adjusting for sex, age and DRG there remained a significant difference p = 0.002.

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations = ADE = adverse drug event, AMI = acute myocardial infarction; CC = care considerations; CDSS=computerized decision support system; CHF = congestive heart failure; CMS = Center for Medicare and Medicaid Services; COPD = Chronic Obstructive Pulmonary Disease; CPOE=computerized physician order entry; CPR computer-based patient record; CVR = cardiovascular risk; DRG = diagnosis related group; EMR = electronic medical record; ER = emergency room; ESCHM = European Society of Cardiology and other societies for Hypercholesterolemia Management; HF=heart failure; HMO = health maintenance organization; ICU=intensive care unit; IHD=ischemic heart disease; IQR = *interquartile range* JCAHO = Joint Commission for Accreditation of Healthcare Organizations; LOS = length of stay; pmpm = per member per month; POE = physician order entry; QALY = Quality Adjusted Life Year; QOL = quality of life; RCT = randomized controlled trial; Rx = treatment; SD = standard deviation; USD = United States Dollars

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Barenfanger (2001)[287] U.S.	Cost-analysis	To assess the impact of improved interventions facilitated by (i) a computer software program which electronically notifies pharmacists of potential problems with a patient's antimicrobial therapy, and (ii) the education of pharmacists making interventions and notification of the medical staff of the program.	Quasi RCT (2 arm) of hospitalized patients prospective study in a 450-bed community teaching hospital over a 5 month time period	Patients: (i) infected with a bacterial isolate with no order for antimicro-bial therapy, (ii) infected with bacteria resistant to current antimicrobial therapy, (iii) on therapy not tested, and (iv) on antimicro-bial therapy but from whom no sample for culture had been taken. Analysis A: 24 patients in control group, 52 patients study group; Analysis B&C: (DRG) matched samples study group: 188, control group: 190	?? assumed 1998/1999 Total costs, fixed costs (overhead) variable direct (pharmacy costs, supplies, lab tests, radiology tests) fixed indirect costs	Mortality, length of stay	Compared patients whose microbiologic data were processed in the normal manual manner in the pharmacy to patients whose microbiological data were processed using the computer software, TheraTrac 2, a computer software program which electronically links susceptibility testing results immediately to the pharmacy and alerts pharmacists of potential interventions	Analysis A: study group had average total standard cost of $21,189 per patient; control group had average total standard cost of $51,790 per patient, a decrease of $30,601 per patient in study group (p = 0.41) Analysis B (DRG-matched patients for whom susceptibility testing was done): study group had average total standard cost of $13,294 per patient; control group had average total standard cost of $18,601 per patient, a decrease of $5,308 per patient in study group (p = 0.008). Analysis C:(severity adjustment) study group had average total standard cost of $13,294 per patient; severity-adjusted control group had average total standard cost of $16,106 per patient, a decrease of $2,812 per patient in study group (no statistical analyses performed) By using these severity-adjusted data (that the data management team relies on), estimated variable cost savings annually from the improvement of interventions is $2,932,000 (2,000 in patients for whom

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
								susceptibility testing is done X $1,466). If the list price of TheraTrac 2 ($44,500) is subtracted from the expected annual cost savings from the use of our program to improve interventions ($2,932,000), the resulting savings ($2,887,500) is still substantial in the first year. The present study demonstrates the financial benefits of improved interventions involving antimicrobial agents, namely, statistically significant differences in lengths of stay, total costs, variable costs, and radiology costs.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Chisolm (2006)[19] U.S.	Cost analysis	To assess the relationship between use of a computerized order set within a CPOE and processes of care pediatric asthma treatment	Before/after. 'Pre-set' patients: those admitted prior to order set implementation; 'no set': those admitted after implementation when asthma order set not used; 'set' patients admitted after implementation and the order set was used. Inpatient pediatric teaching hospital	Asthma patients between the age of 2 and 20 years admitted to hospital between November 2001 and November 2003 (excluded those admitted to ICU). N=790 (261 'pre–set'; 63 'no set'; 466 'set' cases)	USD (year not stated) Length of stay, total inpatient charges and pharmacy charges	Use of systemic cortices-teroids, use of pulse oximetry, and use of metered-dose inhalers.	Computerized order set within a CPOE system before and after implementation of the asthma order set	No significant difference in costs or lengths of stay among the three groups. Total charges were $3,620, $3,567, $3,759; pharmacy charges were $416, $373, $429; and LOS was 1.94, 1.93 and 1.77 for the 'no set', 'pre-set', and 'set' groups respectively.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Cobos (2005)[23] Spain	cost analysis	To assess the cost and effectiveness of a CDSS based on recommendations of the ESCHM in comparison with usual care for patients with hypercholes-terolaemia	A multi-centre cluster-randomized, unblinded, pragmatic trial. (Primary care) Perspective not stated (1 year time horizon)	Patients with hypercholes-terolaemia, which was defined as total cholesterol concentra-tions >200 mg/dL. Patients were excluded if they had triglyceride concentra-tions >400 mg/dL or were participating in another study. 44 practices, 2,221 patients (1,161 usual care, 1,060 CDSS)	Euros (2002) Direct costs only: physician visits, lab analyses, lipid-lowering drugs	Achievement of LDL-C reduction goals in patients with CVR of >20% over 10 yrs or keeping it <20% when patient baseline was <20%	CDSS vs. usual care	The treatment costs were €214,683 in the usual care group and €125,569 in the intervention group. The total costs were €264,658 in the usual care group and €170,061 in the intervention group. The adjusted means of the treatment costs per patient were €237 in the usual care group and €178 in the intervention group. The difference was €59 (95% CI: €34 to €83; p <0.0001). The adjusted means of the total costs per patient were €283 in the usual care group and €223 in the intervention group. The difference was €60 (95% CI: €33 to €86; p = 0.001). The CDSS did not alter the effectiveness of usual care but induced considerable savings.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Evans (1992)[283] U.S.	quasi cost analysis	To use a hospital information system to help identify ADEs and to create a database of ADEs to prevent specific types of ADE	Pre-post design using a computerized ADE surveillance system vs. a control group with no ADEs	Hospital-ized patients	USD (not stated) Hospitalization costs	Reduction in ADEs and LOS	Computerized surveillance with physician notification only of verified ADEs if classified as server or life-threatening vs. physician immediately notified of all ADEs when they were verified. Either the clinical pharmacist of ADE study nurse contacted the prescribing physician and recommended a change in drug or dosage vs. a control populatin of patients who received drugs but did not have ADEs	The average cost of hospitalization was $38,007 for patients with severe ADEs compared to $22,474 (p <0.002) for patients with moderate ADEs and $6,320 for patients without ADEs.
Evans (1998)[35] U.S.	Cost analysis	To evaluate a CDSS to improve the use of and reduce the cost of antibiotics	Prospective study in a 12 bed Shock/Trauma/Respiratory ICU. (before/after) 12 months	398 patients in intervention (divided into those who got the recom-mended treatment and those who did not); 766 patients in control. # of physicians not stated	USD (1995) Cost of antibiotics and cost of hospitalization	# of ADEs, # of days of excessive antibiotic dosage, LOS, and mortality	Antibiotics ordered using CDSS by physicians during the study period compared to the control period	The cost of anti-infective agents was $102 vs. $340 and $427 (p <0.001) and the total cost of hospitalization was $26,315 vs. $35,283 and $44,865, (p <0.001). for control, regimen followed, and regimen overridden, respectively.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Evans (1999)[214] U.S.	Cost analysis	To examine the effect of a computer-assisted antibiotic dose monitor used to reduce the number of days that patients receive excessive dosages of antibiotics and the number of ADEs secondary to antibiotics.	Descriptive epidemiologic study of a two-year preintervention period and one-year intervention period. 12 month intervention period	All patients ≥18 years, admitted to Hospital from April 1 1993 to March 31 1996, who received ≥1 of 5 targeted antibiotics who had a serum creatinine or a urine creatinine clearance test result before antibiotic therapy, and who were never admitted or transferred to the ICU. # of physicians not stated	USD (1996) Cost of antibiotics	# of ADEs, # of days of excessive antibiotic dosage	Antibiotics ordered using CDSS by physicians during the study period compared to the control period	The intervention group had a lower and at a lower mean cost ($80.62 vs. $92.96; p <0.02) of antibiotics than patients during the preintervention period.
Evans (1994)[37] U.S.	Cost analysis	To evaluate a CDSS to assist physicians in the selection of appropriate empiric antibiotics	Two-stage random-selection study (tertiary, private hospital and major teaching centre associated with a university). 12 month time frame	28 physicians, 482 cultures	USD (1994) Cost of antibiotics	Computer-suggested antibiotics with results of suscepti-bility tests of cultures and antibiotics selected by physician	Antibiotics ordered using CDSS by randomized physicians were then compared between crossover periods of antibiotic consultant use.	The average cost for 24 hours of therapy for the computer-suggested antibiotics was $41.08 per patient, compared with an average of $51.93 (p <0.001) for the antibiotics actually prescribed by physicians.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Evans (1995)[284] U.S.	Cost analysis	To evaluate a CDSS to improve the use of and reduce the cost of antibiotics	A 7-month pilot was compared with 12-months previous in a 12-bed Shock/Trauma/Respiratory ICU. 7 months	588 orders for antibiotics, # of physicians not stated	USD (1994) Cost of antibiotics	# of ADEs and LOS	Antibiotics ordered using CDSS by physicians during the study period compared to the control period	The mean cost of antibiotics was $87.03 (p <0. 04) less per patient during the study period as compared to the control period.
Javitt (2005)[218] U.S.	Cost analysis	To demonstrate the potential effect of deploying a sentinel system that scans administrative claims information and clinical data to detect and mitigate errors in care and deviations from best medical practices	RCT, members of an HMO were randomly assigned to an intervention or a control group. Care considerations (CC) generated by the CDSS for subjects in the intervention group were relayed to treating physicians, and those for the control group were deferred to study end.	Intervention and control group members consisted of all health plan enrollees who were between the ages of 12 and 64 years and had incurred at least 1 physician claim or 1 pharmacy claim in the 12 months before enrollment	USD (not specified) Total charges, in-patient charges; out-patient charges; Rx charges; professional charges	CCs generated by group; physician compliance with recom-mendation; and hospital utilization	CDSS tool that produces an electronic record from administrative data and runs it through a set of decision rules identifies "issues" and sends a CC message to the physician in the intervention group but nothing sent to the control group until the end of the study.	Charges for those whose recommendations were communicated were $77.91 per member per month (pmpm) lower and paid claims were $68.08 pmpm lower than controls compared with the baseline (p = 0.003 for both). Paid claims for the entire intervention group (with or without recommendations) were $8.07 pmpm lower than those for the entire control group. In contrast, the intervention cost $1.00 pmpm, suggesting an 8-fold return on investment.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Javitt (2008)[74] U.S.	Cost analysis	To determine whether a CDSS tool improves quality of care and the effect of the intervention on average charges per member per month.	RCT, participants randomized to study group had the software turned on. Software was not turned on for patients in the control group until the 1-year experiment was over. Conducted in a large HMO	Patients all had medical charges in the previous year, all patients <65 yrs n = 19,719 intervention group, n = 19,792 control group	USD (2001) Total charges, in-patient charges; out-patient charges; Rx charges; professional charges	Rate at which CC are resolved	CDSS tool that produces an electronic record from billing records, lab feeds and pharmacies then runs the record through a set of decision rules, identifies “issues” and sends a CC message, 3 levels of CCs; level 1 contains potentially life-threatening situations, level 2 might have an important effect on clinical outcomes, level 3 are preventative care issues. All CCs reviewed by doctors employed by software company. HMOs medical director received level 1 messages and called the appropriate physician. Level 2 and 3 were received by an HMO nurse who then decided whether to send message to physician. Data collected in control group but CCs turned off.	The intervention reduced the average of total charges in the study group by 6.1%; average charge for the control group ($327.54 vs. $352.31 pmpm)

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Kaushal (2006)[286] U.S.	Cost analysis	To assess the costs and benefits associated with the implementa-tion of a CPOE and CDSS system over 10 years (1993-2002)	Cost and benefit estimates of a hospital CPOE system in a 720-adult bed, tertiary care academic hospital. With 7% discounting	Patients admitted to the hospital over the 10 year timeframe	USD (2002) Capital and operational costs, drug costs, hospital costs	Reductions in ADEs, LOS, proportion of appropriate prescript-tions, laboratory & radiology tests (some measures from the literature)	CPOE with graduated CDSS over 10 years compared to estimates of what it might have been like without the CPOE	$11.8 million to develop, implement, and operate CPOE; over 10 yrs, the system saved the hospital $28.5 million. It took over 5 years to realize a net benefit and over 7 years to realize an operating budget benefit.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Macdonald (2002)[285] Canada	Cost analysis	Evaluation of the safety and potential cost savings of a computerized, laboratory-based program to manage inpatient warfarin thrombopro-phylaxis after major joint arthroplasty.	A consecutive-case study of adults admitted over a 54-month period (July 1994–December 1998) in a tertiary care orthopedic institution compared with Patients who underwent similar procedures in the 18-month period before the program was introduced (<1994) served as historical controls. These patients received the identical loading doses of warfarin and were individually managed by staff surgeons or internists.	Patients requiring joint arthroplasty who had no recent episodes of thrombo-embolic disease, no mechanical heart valve, atrial fibrillation, severe liver disease or baseline inter-national normalized ratio [INR] greater than 1.3 (n = 4,729, intervention vs. n = 279, control)	CAD (year not stated) Pharmacy and comparative nursing care costs associated with the program	Test results maintained within the desired therapeutic range (INR 2.0–3.0), clinically severe bleeding episodes, readmis-sion rates, clinically symptom-atic and veno-graphically proven episodes of venous thrombosis or pulmonary embolism	Major joint arthroplasty with warfarin therapy administered through the computerized program compared with an historical control group Patients who underwent similar procedures in the 18-month period before the program was introduced served as historical controls. These patients received the identical loading doses of warfarin and were individually managed by staff surgeons or internists.	The potential savings per patient would be 11 minutes of nursing time or $5.50/patient daily for a total annual figure, based on 10,152 patient days per yr of $55,836. NOTE: The cost estimates and potential cost savings are speculative and are meant to be illustrative and not conclusive in nature.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
McGregor (2006)[104] U.S.	Cost-analysis	To evaluate the effectiveness and cost effectiveness of a web-based, computerized CDSS for the management of antimicrobial utilization	RCT (2 arm), in-patients a 648-bed tertiary care, academic hospital over a 3 month period	n = 4,507 (n = 2,237 intervention arm & n = 2,270 control)	USD (2004) Hospital antimicrobial costs (primary outcome)	Mortality, LOS, frequency of tests for C. difficile, time spent managing antimicro-bial utilization	Antimicrobial utilization was managed by an existing antimicrobial management team (AMT) using the system in the intervention arm and without the system in the control arm. The system was developed to alert the AMT of potentially inadequate antimicrobial therapy. This is a "back-end" or post-prescription review.	Hospital antimicrobial expenditures were $285,812 for intervention vs. $370,006 in the control arm, for a savings of $84,194 (23%), or $37.64 per patient
McMullin (2004)[281] U.S.	Cost analysis	To evaluate the impact on prescription costs of a computerized decision support system (CDSS)	Retrospective cohort study (before-after) using pharmacy claims database in primary care. Clinicians using CDSS were matched to controls with 6 month followup	19 physicians in each group	USD (not stated) New prescription costs	NIL	CDSS that provides evidence-based recommendations to clinicians during the electronic prescribing process before and after implementation	Average cost for intervention group per new prescription $4.16 lower (p = 0.02); for new and refilled prescriptions $4.99 lower (p = 0.01). The 6 month savings from new prescriptions and their refills were estimated to be $3,450 (95% CI, $1,030 to $5,863) per clinician.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
McMullin (2005)[282] U.S.	Cost analysis	To evaluate the impact on prescription costs of a computerized decision support system (CDSS)	Retrospective cohort (before-after) study using pharmacy claims database in primary care. Clinicians using CDSS matched to controls. 12 months (extension of the 6-month study described above)	19 physicians in each group	USD (not stated) New and existing prescription costs	NIL	CDSS that provides evidence-based recommendations to clinicians during the electronic prescribing process before and after implementation	The average cost per new prescription decreased by $1.00 (-2.4%) in the intervention group while it increased by $3.75 (9.0%) in the control group. The 12 month savings on new prescriptions were $109,897
Mekhjian (2002)[186] U.S.	Cost-analysis	To evaluate the benefits of computerized physician order entry (POE) and electronic medication administration record (e-MAR) on the delivery of health care	Cohort of inpatient nursing units in an academic health system (3 sites Cancer hospital, state hospital, rehab centre), before-and-after POE The study comprised before-and-after comparisons between phase 1, preimplementation of POE (pre-POE) and phase 2, postimplementation of POE (post-POE) and, within phase 2, a comparison of POE and the combination of POE plus e-MAR	Cohort of inpatient nursing units	USD (2002) Total costs per patient	LOS, medication turn-around time, radiology turn-around time, laboratory test turn-around time, medication transcription errors	phase 1, preimplementation of POE (pre-POE) and phase 2, postimplementation of POE (post-POE) and, within phase 2, a comparison of POE and the combination of POE plus e-MAR	State hospital total costs for the heart transplant service (pre-POE, $5,264; post-POE, $4,871; p = 0.013) and organ transplant service (pre-POE, $8,382; post-POE, $7,711; p = 0.043) showed a statistically significant decrease, whereas costs for general surgery (pre-POE, $4,995; post-POE, $5,567; p = 0.008) showed a statistically significant increase. There were no statistically significant changes in other services. Cancer: services such as surgical oncology (pre-POE, $6,087; post-POE, $5,631; p = 0.008) and neurology/ neurosurgery (pre-POE, $5,600; post-POE, $5,125; p = 0.045) showed statistically

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
			for a period of 10 to 12 months across all services in the respective hospitals.					significant reductions in total costs, whereas the POE, $5,821; p <0.001) showed a statistically significant increase in total costs and thoracic surgery (pre=POE, $5,181; post=POE, $5,946; p = 0.055) showed a nonsignificant increase. When all the services were combined, severity adjusted total cost per admission did not change significantly in either state (pre-POE, $5,697; post-POE, $5,661; p = 0.687) or in the cancer hospital (pre-POE, $6,427; post-POE, $6,518; p = 0.502).
Mullett (2001)[109] U.S.	Cost-analysis	To evaluate the impact of a pediatric anti-infective CDSS.	Cohort, patients in a 26-bed pediatric intensive care unit in an academic 232-bed hospital 6-month pre- vs. postimplementa-tion	N=1758 (809 control, 949 intervention)	USD (1999) Hospital costs, anti-infective drug charges	Number of anti-infective drugs used, total doses used, LOS, mortality	CDSS vs. pre-CDSS (all patient care orders from the physicians were handwritten. Antibiotic and other medication orders typically were interpreted by the clerk and rewritten onto the bedside medication administration record. Carbon copies of the handwritten order were physically sent to the pharmacy and read by a pharmacist, who entered the order via the keyboard into the HELP system's pharmacy module.	no difference in hospital costs $28,257.67 (control) vs. $25,032.11 (intervention) no difference in mean anti-infective cost/patient $274.79 (control) vs. $289.60 (intervention)

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Ornstein (1999)[288] U.S.	Cost-analysis	To determine the impact of displaying prescription cost information in a computer-based patient record (CPR) system on decreasing drug costs by family physicians	During a 6-month period, cost information was not displayed; during the subsequent 6-month intervention period, costs were displayed at the time of prescribing. Academic family practice setting.	10 physicians, 36 residents	USD (1995/1996) Prescription costs	Nil	CPR system that displays drug cost information at time of prescription order compared to no cost information being displayed during the control period	This study failed to detect an impact of CPR-based prescription drug cost information on overall drug costs to patients among family physicians in an academic family medicine ambulatory clinical practice The mean (SD) cost per prescription in the control period was \$21.83 (\$27.00), and in the intervention period was \$22.03 (\$28.12), (p = 0.61). The mean (SD) cost/contact control \$12.49 (\$29.35) vs. intervention \$13.03 (\$30.06) (p = 0.12).

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Paul (2006)[123] Israel, Germany, Italy	Cost analysis	Cohort study: the aim was to compare CDSS advice with physician performance for antibiotic treatment and antibiotic costs. In the RCT, the goal was to assess whether the CDSS improved physician performance and patient-related outcomes	Prospective cohort study comparing a CDSS for antibiotic treatment advice to physician's treatment followed by a multicentre, cluster randomized trial comparing wards using the CDSS vs. antibiotic monitoring without the CDSS. (Cohort-6-month time period between 2002/2003 in each of the 3 countries; RCT-6-month period in 2004) 3 university affiliated primary and tertiary hospitals (Israel, Germany, Italy)	Patients suspected of harboring bacterial infections in 3 university affiliated primary and tertiary hospitals (Israel, Germany, Italy) Cohort:1,203 patients RCT: 2,326 patients	Euros (2002/ 2004) Antibiotic costs including: (1) direct drug & administration, (2) ADE (rates from the literature and assigned costs in hospital days and QALYs), (3) ecological costs (patient costs, probability of infection and antibiotic failure; costs to eco-system for loss of antibiotic efficacy, penalty cost for drugs of last resort (antibiotic costs, including costs related to future antibiotic resistance)	Appropriate antibiotic treatment, mortality, LOS	CDSS recommends treatment by highlighting the 3 top-ranked antibiotic regimens, with the highest cost-benefit difference, including no antibiotic treatment wards using the CDSS vs. antibiotic monitoring without CDSS). CDSS advises antibiotic therapy for inpatients using data available at the time of empirical antibiotic treatment.	COHORT: All cost components, except those related to expected adverse events, were significantly lower for the treatments suggested by the CDSS compared with those used by physicians. Total antibiotic costs were €289 lower per patient for CDSS compared with physicians, a relative decrease of 48%. RCT: the use of the CDSS resulted in significantly lower antibiotic costs in intervention vs. control wards, the difference originating from lower ecological costs in intervention wards in Israel and Italy. Direct antibiotic costs, as well as costs incurred by observed adverse events, were similar -mean total antibiotic costs per patient €623.2 (control) vs. €565.4 (intervention) p = 0.007 Total projected costs for the appropriate CDSS regimens were lower than physician's treatment by €262 per patient, a relative decrease of 44%, with the reduction originating mainly from lower ecological costs

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Piontek (2010)[290] U.S.	Cost analysis	The effects of an adverse-ADE alert system on cost and quality outcomes in community hospitals were evaluated.	Retrospective observational study evaluated the effects of an ADE alert system in seven hospitals in a health network. Outcomes after, and one year before, the deployment of an ADE alert system were evaluated. Inpatients in two hospitals without any computerized ADE alert system constituted the control group. Administrative data were gathered for patients from these facilities for the same time frames as for the pre-implementation and post-implementation groups.	All inpatients admitted to one of seven hospitals in a health network	USD (not indicated) Primary outcomes evaluated included pharmacy department costs, variable drug costs. Secondary outcomes included total hospitalization costs	Primary outcomes included mortality rates. Secondary outcomes included LOS, rate of readmis-sion, and case-mix index	Pre-post ADE alert system. Four distinct groups were evaluated: (1) preimplementation of the ADE alert system (internal control group), (2) postimplementation group, (3) external control group matching internal control time frame, and (4) external control group matching ADE postimplementation time frame.	Statistically significant decreases were observed in average pharmacy department costs per patient ($867 vs. $826, p <0.001) from preimplementation to post –implementation. In contrast, the external control group had a significant increase in pharmacy department costs ($734 vs. $797, p = 0.029). Drug costs decreased significantly from baseline ($360 vs. $337, p <0.001) in the study group. Conversely, there were significant increases in drug costs in the external control group ($401 vs. $429, p = 0.029).

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Stone (2009)[158] U.S.	Cost-analysis	Presentation of the implementation of a CPOE system in the management of surgical patients	Retrospective and prospective analyses of patient-safety measures 6 months pre- and 6 months post-CPOE institution, respectively. Inpatients of a multispecialty hospital academic surgical practice	Paper only provides the number of surgical procedures pre and post: 6,815 procedures in the pre period and 5,963 in the first post 6 month and 6,106 in the second 6 months postimple-mentation	USD (2007/2008) Personnel requirements (efficiencies) and capital costs of implementation	Patient safety, medication errors, order implementa-tion time	CPOE compared to no CPOE	-total capital costs for implementation $2.9 million and operating costs of $2.3 million -decrease in the number of unit secretaries (clarified orders and transcribed the orders to a required format); -savings of $445,500 (personnel changes occurred as a consequence of work-load redistribution). Considerable gains in efficiency were noted, which included the time necessary to have orders accessible to nursing, radiology, and laboratory. This gain in efficiency will likely result in long-term cost savings and increased quality of care. Additionally, personnel needs were reduced, which subsequently resulted in additional financial benefit for our institution.

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Tierney (2005)[167] U.S.	Cost analysis	To assess whether guideline-based care suggestions delivered via physicians' and pharmacists' computer (CDSS) workstations could improve the outpatient management and outcomes among patients with asthma or COPD	1-year, 2x2 factorial, 4 arm RCT, academic general internal medical practice in a hospital	246 physicians and 20 outpatient pharmacists randomized (706 patients included)	USD (1994-1996) Total health care charges (Outpatient charges + inpatient charges)	Adherence to treatment guidelines, QOL, patient satisfaction with physician & pharmacists, ER visits, hospital-izations.	Care recommendations provided electronically to physicians, pharmacists, both physician & pharmacist vs. no care recommendations/ intervention	Patients in the group receiving only the physician intervention had significantly elevated total health care charges, possibly because of just a small number of extremely high-cost hospitalizations costs Control (n=80):$5,800 (SD: 8,536) Physician only (n=81):$8,006 (SD: $18,720) Pharmacist only (n=80):$5,333 (SD:$9,400) Both physician & pharmacist (n=82):$5,652 (SD: $10,579)

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Tierney (2003)[166] U.S.	Cost analysis	To assess the effects of an established EMR system containing a CPOE with a guideline-based CDSS for managing patients with IHD and chronic HF	1-year, 2x2 factorial, 4 arm RCT, academic, primary care group practice (targeting physicians and pharmacists)	11 full time & 9 part-time outpatient pharma-cists, ?? physicians; 32 practice sessions (706 patients included)	USD (1994-1996) Total health care charges (Outpatient charges + inpatient charges)	Adherence to recom-mendation, health-related QOL, exacerba-tion of heart disease, patient satisfaction with physician and pharmacist, medication compli-ance, satisfaction with care, physician attitude toward intervention	Evidence-based cardiac care recommendations displayed electronically to physicians, pharmacists, physician & pharmacists vs. no recommendations for enrolled patients	No difference in total costs across groups Costs: Control (n=181): $7,025 (SD $17,024) Physician only (n=197): $6,302 (SD 10,928) Pharmacist only (n=158); $7,387 (SD: $13,206) Both physician and pharmacist (n=170): $7,639 (SD:$16,921)

Evidence Table 8b. Summary of partial economic evaluation studies (continued)

Author (year) Country	Type of economic evalua-tion	Study objective	Study design (include setting)	Population (n)	Currency (year) Cost elements	Effect measure	Intervention and alternative being evaluated	Main economic findings
Tierney (1993)[289] U.S.	Cost analysis	To assess the effects on health care resource utilization of a network of microcomputer workstations for writing all inpatient orders (CPOE) that encourage cost effective ordering. Aim of increasing cost consciousness and reducing costs	RCT in an inpatient internal medicine service of an urban public hospital over 6 months	6 medical services were randomly assigned to intervention or control: 5,219 patients (1,859 intervention from 22 teams & 3,360 controls from 46 teams)	USD (1990/1991) Inpatient charges (bed, tests and drugs)	LOS, time in motion	Microcomputer workstations, linked to a comprehensive EMR system for all inpatient order vs. hand-written orders	Total charges per admission were significantly less (mean difference: $887, 12.7% reduction) for intervention teams than for control teams, with similar differences in bed charges, test charges, and drug charges. Hospital stays for intervention admissions were 0.89 day (10.5%) shorter than for controls (p = 0.11). This would amount to more than $3 million in charges annually for that hospital's medicine service
Weingart (2009)[291] U.S.	Cost analysis	To understand the potential benefits of medication safety alerts in ambulatory care using a (CPOE)	A multifaceted study from January 1 through June 30 2006. An expert panel reviewed a sample of common drug interaction alerts, estimating the likelihood and severity of ADEs associated with each alert, the likely injury to the patient, and the health care utilization required to address each ADE	279, 476 alerted prescriptions written by 2,321 ambulatory care clinicians	USD (2006) Hospitalization, emergency room visit, office visit, filled prescription	ADEs and related injuries	Potential benefit of electronic prescribing with decision support based on expert panel estimates	Alerts potentially resulted in a cost savings of $402,619 (IQR, $141,012 to $1,012,386). Drug alerts have the potential to prevent harm and reduce health care costs

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases

Article Information	**MM Phase(s)**	**HIT Studied** Integrated System	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Ali (2005)[4] Design: Before-after N = 91 patients Implementation: 02/2000 Study Start: 05/2000 Study End: 05/2002	Prescribing	**CPOE/POE system**	Critical care units (CCU, ICU, NICU) 25 Beds Academic	LOS - Secondary Outcome	LOS did not differ between patients cared for with the initial CPOE vs. the modified CPOE (9.9 days vs. 9.0 days, NS)	-

The HIT system studied is in **bold**, followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: A1c = hemoglobin A1c; ADE = Adverse Drug Event; AHR = Airway Hyper-responsiveness; aPTT = Activated Partial Thromboplastin Time; AQLQ = Asthma Quality of Life Questionnaire; ARR = Adjusted Relative Risk; BMI = Body Mass Index; BG = blood glucose; BP = Blood Pressure; CAGES = computer assisted guideline enhancement system; CCDS = Computerized Clinical Decision Support; CDS = Clinical / Computerized Decision Support; CDSS = Clinical Decision Support System; CI = Confidence IntervalI; CPOE = Computerized Provider Order Entry; DBP = Diastolic Blood Pressure; DVT = Deep Vein Thrombosis; EHR = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; e-TAR = Electronic Treatment Authorization Request; FEV1 = Forced Expiratory Volume in the first second.; GHb = Glycohemoglobin; GP = General Practitioner; HbA1c = Glycated hemoglobin; HF = Hear Failure; HIT = Health Information Technology; ICU = Intensive Care Unit; INR = International Normalized Ratio; Kg/m^2 = Kilogram per square metre; LDL = Low density Lipoprotein; LOS = Length of Stay; mg/dL = milligrams per decilitre; micro-moL/L = micro moles per litre; mL/min = millilitre per minute; MM = Medication Management; MMC = Montefiore Medical Center; mmHg = millimeter of mercury; mmol/l = millimoles per litre; N or n = Sample Size; NS = Not Statistically Significant; OR = OR; OSUH = Ohio State University Health System; p = Probability; PADEs = Potential Adverse Drug Events; PANSS = Positive and Negative Syndrome Scale PCA = Patient-Controlled Analgesia; PE = Pulmonary Embolism; PHR = Patient Health Record; POE = Provider Order Entry; PRISM = Pediatric Risk of Mortality; QoL = Quality of Life; RCT = Randomized Controlled Trial; RRR = Relative Risk Reduction; SBP = Systolic Blood Pressure; SD = Standard Deviation; SF-36 = Short Form 36; SICU = Surgical Intensive Care Unit; vs. or vs. = Versus; VTE = Venous thromboembolism

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Balcezak (2000)[292] Design: Cohort study N = 747 Patients Implementation: 00/0000 Study Start: 10/1996 Study End: 01/1997	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, 900 Beds Academic	aPPT exceeding therapeutic threshold by 24 hours, aPPT exceeding therapeutic threshold by 48 hours, aPPT within therapeutic threshold by 48 hours	Use of the nomogram was 10% (low). More patients who received the nomogram ordering exceeding the therapeutic threshold by 24 hours and by 48 hours were 79% vs. 56% (p <0.001), and 88% and 66% (p <0.001) respectively. More patients achieved a therapeutic range by 24 hours and 48 hours with the weight-based nomogram compared with physician-guided dosing were 47% vs. 39% (p = 0.027), and 69% and 52% (p = 0.019) respectively. Use of the nomogram also had a higher rate of being within the therapeutic range by 48 hours (69% vs. 52%, RRR 25%, p = 0.02).	+
Barenfanger (2001)[287] Design: Cohort study N = 450 patients Implementation: 00/0000 Study Start: 10/1998 Study End: 02/1999	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Pharmacy	Acute care/tertiary, 450 Beds Pharmacy, Inpatient hospital based, Academic	mortality rate, average length of stay	In matched patient analysis, the study patients did not differ for mortality (10% vs. 11%, p = 0.7). The control group patients stayed longer in the hospital (13.7 vs. 11.0 days, p = 0.04).	+
Baroletti (2008)[293] Design: Cohort study N = 9,527 patients Implementation: 00/000 Study Start: 01/2004 Study End: 07/2006	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Unspecified Hospital	symptomatic VTE or PE*	The primary end point of symptomatic DVT or PE at 90 days occurred in 5.1% of patients in the cohort group and 4.9% of patients in the historical alert group, respectively, p = 0.82	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Beccaro (2006)[294] Design: Before-after N = 2,533 patients Implementation: 11/2003 Study Start: 10/2002 Study End: 12/2004	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Hospital information system, Imaging systems, Laboratory system	Pediatric stand alone hospital, 270 Beds	unadjusted total mortality	Introduction of the CPOE system was not associated with changes in mortality rates measured 13 months after implementation. The unadjusted mortality rates before implementation was 4.2% and after 3.4%, RRR 18%, (95% CI -21% to 45%), NS. No mortality difference was seen either for transfer patients (7.8% before and 9.6% after, RRR 34%, 95% CI -47% to 71%, NS) or for children with congenital cardiovascular disease (4.4% before and 2.6% after, RRR 41%, 95% CI -63% to 79%, NS).	-
Boord (2007)[295] Design: Before-after N = 351 ICU patients Implementation: 11/2004 Study Start: 10/2004 Study End: 01/2005	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders, CPOE/POE system,** **e-Rx** Integrated EHR/EMR system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 21 Beds Academic	percentage of patients within ideal glucose range*, time spent in ideal glucose range (minutes)*	Patients were studied for 5 days in the SICU. The percentage of patients with their blood glucose in the ideal range increased with the CPOE insulin protocol (29.3% vs. 37.7%, RRR -29%, p = 0.006). Patients who were cared for under CPOE/CDSS also spent more time on average within normal glucose levels across all 5 days (mean difference 116 minutes, p = 0.029).	+
Chabot (2003)[296] Design: Cohort study N = 100 people with hypertension Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Pharmacy Computerized Prescription Management System	Pharmacy, Other	Mean BP (mm Hg), Adherence, Controlled BP (Measure based on Recommendation before 1999) or in 1999	The groups did not differ for blood pressure: mean SBP: 139 vs. 141, p = 0.747; DBP: 78 vs. 78, p = 0.357 or for adherence based on pharmacy recorded: 93% vs. 98%, p = 0.643 or self reported data: 83% vs. 68%, p = 0.085 or rates of controlled BP (recommendations before 1999) 81% vs. 78%, p = 0.684 (recommendations in 1999) 44% vs. 54%, p = 0.3	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Chen (2010)[297] Design: Case control N = 200 patients Implementation: 00/0000 Study Start: 08/2003 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Unspecified Hospital	LDL-C goal,	Among the first 200 consecutive patients followed up more than 1 year, 65% reached the LDL-C goal in 1 year. For those whose treatment followed CAGES, 74% reached the LDL-C goal. For those whose treatment was entered without CAGES, 57% reached the LDL-C goal. The OR is 2.1 (1.2, 3.8, 95% CI) (p = 0.022), patients whose treatment followed CAGES were twice as likely to reduce their LDL-C	+
Chertow (2001)[18] Design: Time series N = 19,982 admissions Implementation: 00/0000 Study Start: 09/1997 Study End: 04/1998	Prescribing	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Hospital information system Imaging systems	Acute care/tertiary, 720 Beds Academic	length of stay, percentage of patients with a decline of creatinine clearance >10 mL/min	Length of stay decreased with CPOE/CDSS (mean 4.5 days vs. 4.3 days, p = 0.009). No changes in renal function were observed	+
Chisholm (2003)[19] Design: Before-after N = 790 children admitted to hospital with asthma exacerbations Implementation: 10/2002 Study Start: 11/2001 Study End: 12/2003	Monitoring including patient adherence and compliance, Prescribing	**CPOE/POE system** Integrated Billing/administration system, EHR/EMR system, Laboratory system	Pediatric stand alone hospital, 323 Beds	length of stay	No difference was seen in LOS (1.8 vs. 1.9 days) NS	-
Cobos (2005)[23] Design: RCT N = 2,221 patients Implementation: 04/2000 Study Start: 04/2000 Study End: 05/2002	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	proportion of patients achieving successful lipoprotein-cholesterol goals or cardiovascular risk reassessment*	Effectiveness was defined as success or failure for patients achieving either their LDL cholesterol goal or a reassessment of their cardiovascular risk maintained at <20%. The proportion of patients achieving success in the intention to treat analysis was similar between usual care and intervention groups (50.5% vs. 54%, NS).	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Cook (2004) [298] Design: Time series N = 334 paired visits Implementation: 11/2001 Study Start: 11/2001 Study End: 05/2002	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Handheld	Ambulatory care	fasting glucose levels*, random glucose*, A1c*	For 117 paired visits using fasting glucose for insulin adjustment, paired fasting glucose levels decreased from 220 ± 85 to 149 ± 61 mg/dL (p <0.0001). For 103 paired visits where random glucose was used for dosing, random glucose decreased from 249 ± 93 to 168 ± 69 mg/dL (p <0.0001). For 114 paired visits using A1c for insulin adjustment, A1c levels improved from 10.4 ± 2.9% to 7.9 ± 2.0% (p <0.0001).	+
Evans (1995)[284] Design: Before-after N = 962 patients Implementation: 07/1994 Study Start: 07/1993 Study End: 02/1995	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Critical care units (CCU, ICU, NICU)	ADE rate, Length of Stay	The rate of ADE did not differ before and after implementation (2.4% vs. 0.,9%, NS). The length of stay in the unit did not differ (mean 6.2 vs. 5.8 days, NS).	-
Evans (1998)[35] Design: Before-after N = 1,681 patients Implementation: 00/0000 Study Start: 07/1992 Study End: 06/1995	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, 520 Beds Academic	ADE*	ADE rate decreased significantly following the implementation of the reminder (3.7% vs. 1%, RRR 73%, p = 0.018)	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Evans (1992)[283] Design: Before-after N = 45,544 patients (May '89-Apr '91) Implementation: 05/1989 Study Start: 05/1989 Study End: 00/1991	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders surveillance system** Integrated EHR/EMR system, Hospital information system, Laboratory system, Pharmacy	Unspecified Hospital	rate of type B ADEs, rate of severe ADEs, length of stay	Rate of type B ADEs declined following the use of the surveillance system and the addition of computer alerts (15% vs. 1.4%, p <0.001). The rate of severe ADEs with early notification of physicians to all ADEs as soon as they were verified reduced from 7.6% to 2.2% (p <0.001). The average length of stay for patients with type B ADEs to hospital-administered drugs was 17 days compared to 14 days (p <0.013) for patients with type A ADEs and only five days for the control patients that did not have ADEs. The average length of hospitalization for patients with severe ADEs was 20 days compared to 13 days for patients with moderate (p <0.024).	+
Evans (1994)[299] Design: Time series N = 1,865 ADEs Implementation: 00/1980s Study Start: 05/1989 Study End: 04/1992	Monitoring including patient adherence and compliance	**Health Information System** Integrated Laboratory system, Pharmacy	Acute care/tertiary, 520 Beds Academic	ADE-known drug allergies*, ADE-rapid antibiotic administration rates*	The ADE surveillance system identified drug allergy and rapids antibiotic administration rates as areas of concern. In year 2 and 3, when clinicians were alerted to all ADEs and had in service for antibiotic admin rates, the number of known drug allergy ADEs declined to 0 (p <0.002) and there was a significant decrease in the number of ADEs related to antibiotic administration rates (p <0.01).	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Evans (1999)[214] Design: Before-after N = 13,384 Patients Implementation: 01/1005 Study Start: 04/2005 Study End: 03/2006	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Pharmacy	Critical care units (CCU, ICU, NICU), 12 beds in the shock/trauma/respiratory ICU. of a 520 bed academic hospital Beds Not specified, Inpatient hospital based, Academic	Rates of adverse drug events*	The rate of adverse drug events related to 5 antibiotics was lower in patients who were followed with the drug monitoring system (0.9% vs. 0.3%, RRR 67%, p <0.001).	+
Fiumara (2010)[300] Design: Cohort study N = 880 patients Implementation: 00/0000 Study Start: 07/2006 Study End: 05/2008	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system, Hospital information system	Unspecified Hospital	Symptomatic DVT or PE at 90 days*, PE at 90 days, DVT at 90 days, Death at 90 days, Major haemorrhage at 30 days	There was no significant difference in symptomatic 90-day VTE rates between the two cohorts (2.8% for the one-screen vs. 2.2% for the three-screen, p = 0.55). PE at 90 days was 1.1% vs. 0.9%,p = 0.25. DVT at 90 days was 1.1% vs. 1.9%,p = 0.14. Death at 90 days was less frequent among patients in the one-screen alert cohort than the three-screen alert cohort (14.6% vs. 22.2%, p = 0.004).The frequency of major haemorrhage was similar in both alert cohorts (1.3% vs. 1.8%, p = 0.51).	-
Frances (2001)[48] Design: RCT N = 63 physicians and 730 patients Implementation: 00/0000 Study Start: 03/1997 Study End: 06/1997	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Pharmacy	Ambulatory care	LDL level <100 mg/dL*	The proportion of patients with a level of LDL cholesterol in the desired range (< 100 mg/dL) Did not improve cholesterol management in patients (73.2 % vs. 71.0%, p = 0.512) with CAD.	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Garthwaite (2004)[301] Design: Cohort study N = 939 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary, Ambulatory care, Academic	Serum cholesterol, creatinine kinase, alkaline phosphatase levels, creatinine clearance, cyclosporine dose, cyclosporine trough levels, DBP, SBP	Serum cholesterol*, creatinine kinase, alkaline phosphatase levels*, creatinine clearance*, cyclosporine doses and trough levels, lipid-lowering drugs, and dia*- and SBP measurements were compared between baseline and 6 months. *indicates significant improvements.	+
Gill (2009)[60] Design: RCT N = 64,150 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 10/2006	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Lipids at goal*	After controlling for confounding variables and for clustering in multilevel modeling, the proportion of patients with lipids at goal was not significantly different between control and intervention groups.	-
Gilutz (2009)[61] Design: RCT N = 7,448 patients from 56 control and 56 intervention clinics Implementation: 00/0000 Study Start: 01/2000 Study End: 12/2003	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system, Laboratory system, Pharmacy	Ambulatory care, Academic	LDL level reduction*	In the group of patients with initial LDL levels above 120 mg/dl, a significant decrease in LDL levels was observed in the two groups, which was minimally more pronounced in the intervention arm from 145.5 ± 22.3 mg/dl to 121.9 ± 34.2, mg/dl, 16.2% reduction than in the control arm from 145.8 ± 22.9 to 124.3 ± 34.6, 14.8% reduction; (p <0.02).	+
Grant (2008)[217] Design: RCT N = 244 patients Implementation: 00/2002 Study Start: 09/2005 Study End: 03/2007	Monitoring including patient adherence and compliance	**PHR** Integrated Billing/administration system, EHR/EMR system, Imaging systems, Laboratory system, Patient decision support system	General Hospital, Ambulatory care, Home	HbA1c levels*	For the primary outcome, study participants had relatively good glycemic control (mean HbA1c levels) at baseline with modest improvement over the study period that did not differ by treatment arm (7.1% vs. 7.2%, p = 0.45), with nearly three-quarters of all patients at goal (73% vs. 68% among control patients; p = 0.53).	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Graumlich (2009)[237] Graumlich (2009)[238] Design: RCT N = 631 patients Implementation: 00/0000 Study Start: 11/2004 Study End: 01/2007	Prescribing	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system**	Acute care/tertiary, 730 Beds Academic	Readmitted within 6 months*, emergency department visit within 6 months, adverse events within 1 month	When comparing patients assigned to discharge software vs. usual care, there was no difference in hospital readmission within 6 months (37.0% vs. 37.8%; OR 0.005 [95% CI, - 0.074 to 0.065]; p = 0.894), emergency department visit within 6 months (35.4% vs. 40.6%; OR 0.052 [95% CI, -0.115 to 0.011]; p = 0.108), or adverse events within 1 month (7.3% vs. 7.3%; OR 0.003 [95% CI, -0.037 to 0.043]; p = 0.884)	-
Gurwitz (2008)[302] Design: RCT N = 1,118 residents Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system Laboratory system	Long term care (nursing homes)	ADE rates per 100 resident months*, Preventable ADE targeted by alerts	ADE rates per 100 resident months were similar for control and intervention units (10.4 vs. 10.8, NS). The same was found for the rate of preventable ADEs per 100 resident months (3.9 vs. 4.0, NS). Of the 152 preventable events on the intervention units, 59 (38.8%) might have been prevented as a result of one or more of the alerts. Of the 126 preventable events identified on the control units, 56 (44.4%) might have been prevented as a result of one or more of the alerts. NS.	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Han (2005)[303] Design: Before-after N = 1,942 patients Implementation: 10/2002 Study Start: 10/2001 Study End: 03/2003	Dispensing, Transmission, order communication	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, Pediatric stand alone hospital, Academic	mortality rate	The unadjusted mortality rate after implementation was 3.9%. A step-wise regression analysis was done using 19 variables. For the model that was adjusted for PRISM score 7 factors including use of CPOE were associated with mortality: shock, Glasgow Coma scale score, surgical referral, prematurity, cardiovascular problems, and PRISM score. The OR for mortality for the presence of CPOE is 3.71, 95% CI 2.13 to 6.46. Post CPOE mortality affected children and ICU admission most severely. In the primary regression model that adjusted for PRISM score, shock was highly associated with increased odds of mortality (OR: 6.24; 95% CI:2.94 to 13.26), followed by CPOE (OR: 3.71; 95% CI:2.13 to 6.46) and severe coma (OR: 3.43; 95% CI: 1.88 to 6.25).	+
Hetlevik (1999)[304] Design: RCT N = 1,998 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system	Ambulatory care	SBP mmHg, DBP mmHg, Serum cholesterol mmol/1, BMI kg/m2	The groups did not differ for BP, cholesterol levels or BMI: SBP was 155.6 vs. 156.8 mmHG (95 % CI -0.6 to 3.0) between the control and the intervention group. DBP was 89.8 vs. 88.8 mmHg (95% CI -1.9 to -0.2). Serum cholesterol was 6.57 mmol/l vs. 6.64 mmol/l (95% CI -0.1 to 0.2) between the two groups. BMI was 27.7 kg/m2 vs. 27.8 kg/m2 (95% CI -0.4 to 0.07).	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	**HIT Studied** Integrated System	Settings	Outcomes Measured	Results	Outcome
Holdsworth (2007)[305] Design: Before-after N = 2,407 patient admissions Implementation: 00/0000 Study Start: 00/0000 Study End: Oct 2004	Administering, Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Pharmacy	Acute care/tertiary, 50 Beds	Total ADEs per 100 admissions* Preventable ADEs per 100 admissions*, Potential ADEs per 100 admission*,	Patients were classified as having an ADE, a preventable ADE or potential ADE. All rates of ADEs were reduced after implementation of the CPOE system. Total ADEs per 100 admissions: 6.3 vs. 3.1 RRR 37%, 95% CI 0.05 to 0.57. Preventable ADEs per 100 admissions: 3.8 vs. 2.2, RRR 44%, 95% CI 0.09 to 0.66. Potential ADEs per 100 admissions: 7.9 vs. 2.2, RRR 63%, 95% CI 0.45 to 0.75.	+
Holman (1996)[306] Design: RCT N = 5 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering, Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Handheld	Home	Pre-prandial blood glucose levels*	Pre-prandial blood glucose levels* were significantly less during the ‘advice on’ period compared to the ‘advice off’ period (7.5 vs. 8.9 mmol/l, p = 0.015)	+
Hwang (2002)[70] Design: Time series N = 171 patients Implementation: 10/1999 Study Start: 06/1999 Study End: 05/2000	Prescribing	**CPOE/POE system** Integrated Hospital information system Imaging system	Acute care/tertiary, 1,000 plus Beds Academic	LOS (mean number of days)	LOS in mean number of days decreased over the three time periods (11.4 vs. 10.3 vs. 8.2), with a significant reduction before implementation to 6 months postimplementation (p = 0.049).	+
Janssen (2009)[307] Design: Observational study N = 522 patients Implementation: 00/0000 Study Start: 10/2000 Study End: 04/2002	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Ambulatory care	PANSS Positive score*, PANSS Negative score*	Pronounced group-effect was found when comparing the Düsseldorf group using the Decision-Support System and the control group (Munich 1) providing treatment-as-usual, 14.1 (6.5) vs. 13.8 (6.7), p = 0.004) with respect to positive symptoms. No group effects were apparent concerning negative symptoms. The interaction effect of time 9 group was significant with regard to the negative score (p <0.039) and the positive score (p <0.001) (Figs. 1, 2).	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Javitt (2005)[218] Design: RCT N = 39,462 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Insurance	Ambulatory care	Admissions per 1,000 persons*	Among those in both groups who triggered recommendations, there were 19% fewer hospital admissions in the intervention group compared with the control group (213.8 ± 5.7 vs. 264.6 ± 5.7, p <0.001).	+
Keene (2007)[308] Design: Before-after N = 1,291 patients Implementation: 00/2001 Study Start: 09/2000 Study End: 02/2003	Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Laboratory system, Pharmacy	Critical care units (CCU, ICU, NICU), Academic	mortality*	Overall, 29 (3.16%) patients admitted during the pre-CPOE period and nine (2.41%) patients admitted in the post-CPOE period died under MMC care (p = 0.466).	-
Kucher (2005)[89] Design: RCT N = 2,506 patients Implementation: 00/0000 Study Start: 09/2000 Study End: 01/2004	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, Hospital information system	Acute care/tertiary, Academic	Clinically diagnosed DVT at 90 Days, Clinically Diagnosed PE at 90 days	The primary end point for clinically diagnosed DVT at 90 days occurred in 103 (8.2%) in the control group as compared with 61 patients (4.9%) in the intervention group (RRR 40%, p = 0.001). For clinically diagnosed PE at 90 days the numbers were 35 (2.8%) in the control group as compared with 14 (1.1%) in the intervention group (RRR 61%, p = 0.004). The groups did not differ for proximal- or distal DVT, DVT of the arms, death, or hemorrhage.	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Lecumberri (2008)[91] Design: Time series N = 19,338 patients Implementation: 09/2005 Study Start: 01/2005 Study End: 06/2007	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated hospital guidelines	Unspecified Hospital, Academic	rate of VTE during hospitalization*, control to year 1, rate of VTE during hospitalization*, year 1 to year 2	A non-significant reduction of VTE during hospitalization was achieved. Compared with the first semester of 2005, before implementing the computer-alert program, the overall rate of VTE during hospitalization was reduced from 3.26/1,000 (21 episodes in 6,441 patients) to 1.74/1,000 patients, (relative reduction 46.6%) in 2006. During the first semester of 2007, the rate of VTE during hospitalization was 1.67/1,000. OR: 0.53, 95% CI 0.25 to 1.10 and OR: 0.51, 95% CI 0.24 to 1.05 during the first semesters of 2006 and 2007 respectively, the impact being significant (p <0.05) among medical patients in 2007, OR: 0.36, 95%CI 0.12 to 0.98.	-
Lesprit (2009)[93] Design: Observational study N = 932 prescriptions Implementation: 11/2006 Study Start: 11/2006 Study End: 10/2007	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system	Acute care/tertiary, 960 Beds Academic	mortality rate*, median LOS*, readmission rate*	Clinical outcomes mortality (5.6% vs. 4.1%, RRR 27%, p = 0.348) and readmission (15.2% vs. 15.4%, RRR -1%, p = 0.936) were similar between intervention and non-intervention patients, LOS was significantly longer for intervention patients (15 days vs. 19 days, p = 0.011).	-
Lester (2005)[94] Design: RCT N = 235 patients and 14 clinicians Implementation: 07/2003 Study Start: 07/2003 Study End: 07/2004	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care, Academic	LDL cholesterol	For the first assessment of LDL levels, the email group had lower levels of LDL cholesterol (138 vs. 119 mg/dL, p = 0.004). At the end of the study both groups had decreased their cholesterol levels and the difference between them was no longer seen (129 vs. 111 mg/dL, p = 0.055).	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Liu (2008)[97] Design: Time series N = 858 patients Implementation: 00/1989 Study Start: 01/2005 Study End: 12/2006	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system	Acute care/tertiary	post-operative wound infection rates-clean procedures, post-operative wound infection rates-clean-contaminated procedures	The post-operative wound infection rate did not change significantly among 3 groups. In clean procedures, the post-operative wound infection rates were 0.63, 0.72 and 0.71% in group 1, group 2 and group 3, respectively (p = 0.995). In clean-contaminated procedures, the postoperative wound infection rates were 8.5%, 12.0%, and 9.4% in group 1, group 2, and group 3, respectively (p = 0.736).	-
Macdonald (2002)[285] Design: Before-after N = 5,008 patients Implementation: 07/1994 Study Start: 07/1994 Study End: 12/1998	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Acute care/tertiary, Academic	proportion of time within normal INR range*, readmission rates*	Patients in the computer group spent more time with INRs in the normal range (52% vs. 62%, p <0.05). No difference is readmission rates were found (3.8% vs. 3.0%, p = 0.9).	-
Madaras-Kelly (2006)[98] Design: Time series N = not reported Implementation: 00/0000 Study Start: 07/2001 Study End: 06/2004	Prescribing	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, 87 Beds	nosocomial infections rates*	All nosocomial infections decrease after the implementation of computer prompts, requirement for justification, and suggestion of alternate antibiotics beyond fluoroquinolones (1.37 cases/100 patient days vs. 0.62 cases, p = 0.02)	+
McGregor (2006)[104] Design: RCT N = 4,507 patients Implementation: 00/000 Study Start: 05/2004 Study End: 08/2004	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system, Pharmacy	Acute care/tertiary, 648 Beds Inpatient hospital based, Academic	mortality, Length of stay	The groups did not differ form mortality. All patients 3.0% vs. 3.3%, p = 0.6) or for those patients who got alerts (8.2% vs. 7.8%, p = 0.5). Length of stay did not differ. All patients: 4.0 days vs. 3.8, p = 0.4 and 5 vs. 4 days for patients with alerts, p = 0.6	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Meigs (2003)[309] Design: RCT N = 598 patients Implementation: 05/1998 Study Start: 05/1997 Study End: 04/1999	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Ambulatory care	HbA1c levels*	The intervention had a modest but nonsignificant benefit on glycemic control; HbA1c levels tended to improve in the intervention group (change -0.23) and worsen in the control group (change +0.14). p = 0.09	-
Mekhjian (2002)[186] Design: Before-after N = 28,898 patients Implementation: 05/2000 Study Start: 02/2000 Study End: 01/2001	Administering, Transmission, order communication	**CPOE/POE system, e-Medication administration system (e-MAR, e-TAR)** Integrated Die-TARy system, EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, Other specialty hospital (rehab, oncology) Academic	severity-adjusted LOS *	After POE and e-MAR, severity-adjusted length of stay was reduced in OSUH (3.9 to 3.7 days, p = 0.002) but not James Cancer (3.7 to 3.6 days, NS)	+
Miskulin (2009)[106] Design: Cohort study N = 8,941 patients Implementation: 00/2005 Study Start: 11/2005 Study End: 04/2006	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Hb levels *	In the model adjusted for only center, average Hb levels were 11.8 ± 0.2 (SE) g/dL in patients treated using manual dosing and 0.11 ± 0.04 (SE) g/dL lower (p <0.001) in those treated with CDS.	+
Montgomery (2000)[107] Design: RCT N = 552 patients Implementation: 00/0000 Study Start: 09/1996 Study End: 09/1998	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	SBP, DBP	SBP and DBP was not reduced in the CDSS group (SBP 153. vs. 153 mmHg) (DBP 85 vs. 85 mmHg) compared to the usual care group (EMR alone)	-
Murray (2004)[310] Design: RCT N = 712 patients Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Pharmacy	Ambulatory care, Pharmacy, Outpatient hospital based, Academic	SF-36 QoL*	No intergroup differences were found for the primary endpoint the SF-36 QoL* scale (Table 3). No analysis presented.	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Niiranen (2008)[113] Design: Time series N = 18,818 patient followups Implementation: 03/2005 Study Start: 04/2005 Study End: 12/2007	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Ambulatory care, Home	proportion of patient followups with patients within p-INR, year 1 to 2	The share of patient followups with patients within p-INR target range was significantly lower in year 2 than year 1 (67.1% vs. 63.1%, RRR 6%, p <0.001), then was constant from year 2 to year 3 (63.1% vs. 63.1%, RRR 0%,NS)	-
Novis (2010)[114] Design: Before-after N = 800 patients Implementation: 08/2007 Study Start: 03/2007 Study End: 03/2008	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Acute care/tertiary	postoperative bleeds, 30-, 60-, and 90- day DVT rates	Despite the increase in preoperative prophylaxis administration, there was no significant change in postoperative bleeds, with the rate of confirmed bleeds actually decreasing from 4% to 3% after implementation of the risk assessment (p = 0.34; NS). Over the course of the study, there was a trend toward decreased DVT events. The 30-, 60-, and 90-day DVT rates prior to implementation were 1.5%, 1.8%, and 2.0% respectively. After implementation, the 30-, 60-, and 90-day DVT rates were 0.3%, 0.5%, 1.3% respectively. This represents an overall 80% decrease in the 30-day rate of DVT and a 36% decrease in the 90-day rate of DVT, NS (p <0.12, p <0.58 respectively). There were no confirmed PE events at 90 days postoperation in this study population.	-
Oliven (2005)[115] Design: Cross-sectional N = 1,350 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated Drug order database, EHR/EMR system, Hospital information system, Laboratory system	Acute care/tertiary, 88 Beds Academic	Hospital stays	The average hospital stay was significantly shorter in department with CDOE than the department where prescriptions were handwritten and transcribed (6.9 ± 6.2 vs. 8.9 ± 7.9, p <0.001).	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Overhage (1997)[117] Design: RCT N = 86 physicians on 6 services (services randomized) Implementation: 00/0000 Study Start: 10/1992 Study End: 04/1994	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system, Laboratory system	General Hospital, Academic	LOS	LOS was not different for intervention patients compared with control patients (8.12 vs. 7.62, a difference of -0.5 days, 95% CI -0.17 to 1.19; p = 0.94).	-
Peterson (2005)[124] Design: Cohort study N = 7,456 Medication orders Implementation: 00/0000 Study Start: 10/2001 Study End: 05/2002	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system	Acute care/ tertiary, Critical care units (CCU, ICU, NICU), 720 Beds Academic	LOS per 100 patient days, Fall per 100 patients days, Altered mental status per 100 patient days	There was no difference in the LOS between control and intervention period. (4 days for both, p = 0.43) or rate of altered mental status/100 patient days (21=% vs. 22%, p = 0.17). The rate of falls was reduced in the CPOE group (0.64 falls/100 patient days for control vs. 0.28/100 patient days for the CPOE group, p = 0.001.)	-
Pielmeier (2010)[311] Design: Before-after N = 10 patients Implementation: 00/0000 Study Start: 02/2009 Study End: 03/2009	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Critical care units (CCU, ICU, NICU)	Mean log-normal BG ± standard deviation (mmol/L)	Hypoglycemia (blood glucose [BG] b3.5 mmol/L) was not observed. Mean log-normal BG ± standard deviation was reduced from 8.6 ± 2.4 mmol/L preintervention to 7.0 ± 1.1 mmol/L during the Glucosafe intervention (p <0.01). Mean log-normal BG ± standard deviation was reduced from 7.0 ± 1.1 mmol/L Glucosafe intervention to 7.4 ± 1.5 mmol/L during the intervention (p <0.03)	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Piontek (2010)[290] Design: Before-after N = 229,463 patients Implementation: 05/2001 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Laboratory system, Pharmacy	Unspecified Hospital, For Study group: bed sizes ranged from 58 to 303 (Indiana), 237 to 442 (Ohio), and 371 (California).For external control group: 460 (Maryland) and 365 (Idaho) Beds Inpatient hospital based	Mortality rates	Simple mortality rates exhibited no statistically significant changes in either the study group(3.86% vs. 3.87%, p <=0.999) or the control groups (2.99% vs. 2.88%, p = 0.963).However, severity-adjusted mortality rates decreased significantly only in the study group (1.049% vs. 0.975%, p <0.001).	-
Plaza (2005)[279] Design: RCT N = 198 patients Implementation: 03/2000 Study Start: 10/1999 Study End: 02/2001	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Handheld	Ambulatory care	QoL-St George's Respiratory Questionnaire*	Scores on the St George's Respiratory Questionnaire were significantly lower for intervention patients (34.1 vs. 27.3, p = 0.002, difference 6.8 (95% CI 2.5 to 11.1).	+
Quinn (2008)[127] Design: RCT N = 30 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Education of patients and clinicians but not pre-professional education, Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders Daibetes Management Tool** Integrated Web-based data analytics and therapy optimization tools	Ambulatory care	Average decrease in A1c values	Average decrease in A1c for intervention patients was 2.03% compared to .68% for control patients (p <0.04)	+
Ralston (2009)[312] Design: RCT N = 83 patients Implementation: 00/0000 Study Start: 08/2002 Study End: 05/2004	Monitoring including patient adherence and compliance	**Patient accessible Medical Record** Integrated CDSS/CDS/CCDS/ reminders EHR/EMR system, Personal health records systems	Ambulatory care, Academic	Absolute change in GHb*	Absolute change in GHb declined significantly in the intervention group compared with the usual care group (0.2 vs. -0.9, change -0.7%; p = 0.01) at 12 months after adjusting for age, sex, and baseline GHb.	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Rasmussen (2005)[132] Design: RCT N = 253 patients Implementation: 00/0000 Study Start: 00/2001 Study End: 00/0000	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Internet based electronic diary	Ambulatory care (clinic, doctors office etc) Academic	Improved Symptoms, Improved Quality of Life (AQLQ), Improved lung function (FEV1>=300 mL), Improved Airway hyperresponsiveness (AHR)	The treatment and monitoring with the Internet-based management tool lead to significant improvement in the Internet group regarding: Improved Asthma symptoms: Internet vs. specialist: OR 2.64 (95% CI 1.43 to 4.88), p = 0.002 Internet vs. GP: OR 3.26 (95% CI 1.71 to 6.19); p <0.001 2) Improved QOL: Internet vs. specialist: OR 2.21 (95% CI 1.09 to 4.47), p = 0.03 Internet vs. GP: OR 2.10 (95% CI 1.02 to 4.31), p = 0.04 3) Lung function: Internet vs. specialist: OR 3.26 (95% CI 1.50 to 7.11), p = 0.002 Internet vs. GP: OR 4.86 (95% CI 1.97-11.94), p <0.001 4)Airway responsiveness: Internet vs. Specialist: OR 1.26 (95% CI 0.57-2.79), p = NS Internet vs. GP: OR 3.06 (95% CI 1.13 to 8.31), p = 0.02	+
Rind (1994)[225] Design: Time series N = 562 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Formulary, Hospital information system, Laboratory system, Pharmacy	Acute care/tertiary, 504 Beds Academic	difference in change in creatinine levels at 3 days*, difference in change of creatinine level at 7 days*, serious renal impairment	For medical service patients with changes in renal function, more patients had serious renal impairment in the control group compared (7.5% vs. 3.4%, p = 0.034). Difference in changes in creatinine levels at 3 days (14 mmol/L, p = 0.007) and 7 days (26 mmol/L, p <0.05) favored alerts medication event showed significant decreases for patients in the.	+
Rohrig (2008)[135] Design: Before-after N = 156 patients Implementation: 00/1999 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Critical care units (CCU, ICU, NICU) 14 bed unit Beds Academic	Delta-SOFA, length of stay ICU (hours) duration of ventilation (hours)	Delta-SOFA decreased from 1.9% in the pre-period to 1.4% in the post-period, p = 0.23; length of stay (ICU) hours decreased from 472 to 337, p = 0.07; duration of ventilation hours decreased from 254 to 178, p = 0.07.	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Rollman (2002)[136] Design: RCT N = 200 Patients with documented major depression Implementation: 00/0000 Study Start: 04/1997 Study End: 12/1998	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	mean depression scores*	All groups improved their mean depression scores at 3 and 6 months. However, the groups did not differ from each other in mean scores at 3 or 6 months.	-
Roumie (2006)[226] Roumie (2007)[227] Design: RCT N = 871 patients Implementation: 00/0000 Study Start: 06/2004 Study End: 12/2004	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care, Outpatient hospital based	the proportion of patients achieving goal blood pressure	Patients of providers who were randomly assigned to the patient education group had better blood pressure control (138/75 mm Hg) than those in the provider education and alert or provider education alone groups (146/76 mm Hg and 145/78 mm Hg, respectively). More patients in the patient education group had a systolic blood pressure of 140 mm Hg or less, compared with those in the provider education or provider education and alert groups RR 1.31 (95% CI, 1.06 to 1.62) p = 0.012. The proportion achieving goal blood pressure differed in the 3 groups: 107/255 (42.0%) vs. 148/362 (40.9%) vs. 213/358 (59.5%) (p = 0.003) in the provider education; provider education and alert; and provider education, alert, and patient education groups, respectively.	-
Safran (1995)[141] Safran (1993)[142] Design: RCT N = 349 patients with HIV Implementation: 00/0000 Study Start: 05/1992 Study End: 09/1993	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** **CPOE/POE system** Integrated EHR/EMR system	Ambulatory care, Academic	rate of hospitalizations, rate of mortality	Patients in the control group had a higher rate of hospitalizations than those in the intervention group (44% vs. 35%, RRR 20%, p = 0.04). No significant difference in mortality rate (p = 0.18)	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Schmidt (2008)[267] Design: Cohort study N = 62 patients with CHF Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**patient adherence reporting** Integrated EHR/EMR system	Ambulatory care	Sel-reported compliance, physical and mental health status in regard to health-related quality of life	The concordance between self-reported compliance (Yes/No) and telematic compliance monitoring was high; patients of the study group, who reported as noncompliant, highly significantly showed lower compliance scores, measured across a 2 month monitoring period with the telematic approach ($T = 9.71$, $p < 0.001$). The same effect was true to the 6 month period ($T = 3.51$, $p < 0.01$). Pre–post comparisons with respect to both physical and mental health status in regard to health-related quality of life showed significant differences between baseline and 1-month followup ($T = -3.09$, $p \leq 0.01$), as well as baseline and 6-month followup ($T = 1.81$, $p = 0.05$). However, there were neither significant increases nor decreases between 1-month followup and 6-month followup. The changes from baseline to 1-month followup were stronger with respect to mental health than to physical health. Changes were insignificant in the control group.	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Schnipper (2009)[313] Design: RCT N = 322 patients Implementation: 00/0000 Study Start: 05/2006 Study End: 06/2006	Medication Reconciliation	**medication reconciliation application** Integrated CPOE/POE system	Acute care/tertiary Academic	PADE rate per patient*, PADE rate per patient per hospital, rate of hospital readmission or emergency department visit within 30 days	Among 160 control patients, there were 230 PADEs (1.44 per patient), while among 162 intervention patients there were 170 PADEs (1.05 per patient) (ARR, 0.72; 95% CI, 0.52 to 0.99). A significant benefit was found at hospital 1 (ARR, 0.60; 95% CI, 0.38 to 0.97) but not at hospital 2 (ARR, 0.87; 95% CI, 0.57 to 1.32) (p = 0.32 for test of effect modification). Hospitals differed in the extent of integration of the medication reconciliation tool into computerized provider order entry applications at discharge. The rate of hospital readmission or emergency department visit within 30 days was 20% in the intervention arm and 24% in the usual care arm (clustered OR, 0.76; 95% CI, 0.43 to 1.35).	+
Schnipper (2009)[314] Design: Before-after N = 169 patients Implementation: 00/2006 Study Start: 07/2005 Study End: 06/2006	Monitoring including patient adherence and compliance	**CPOE/POE system** Integrated EHR/EMR system, Hospital information system, Laboratory system, Pharmacy	Acute care/tertiary, Academic	Mean percent glucose readings 60–180 mg/dL per patient*	Mean percent of glucose readings between 60 and 180 mg/dL per patient, was 59.1% in the preintervention period and 64.7% in the postintervention (p = 0.13 in unadjusted analysis). When adjusted for A1c, admission glucose, and insulin use prior to admission, the adjusted absolute difference in the percent of glucose readings within range was 9.7% (95% CI [CI], 0.6%-18.8%; p =0.04)	+
Sintchenko (2005)[152] Design: Before-after N = not reported n/a Implementation: 10/2002 Study Start: 04/2002 Study End: 03/2003	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 800 (18 bed ICU) Beds Academic	LOS, mean number of days*, mortality rate*	LOS decreased significantly from a mean of 7.12 days to 6.22 days (p = 0.02). Mortality rate was not different before and after the intervention (11.5% vs. 13.2%, NS)	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Steele (2005)[157] Design: Before-after N = 54,206 patient visits Implementation: 12/2002 Study Start: 08/2002 Study End: 04/2003	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system, Laboratory system	Ambulatory care	"definite" or "probable" ADE rate	There was a non-statistically significant difference towards less "definite" or "probable" adverse drug events defined by Naranjo scoring (10.3% at baseline vs. 4.3% during postintervention, p = 0.23).	-
Takada (2003)[315] Design: Before-after N = 374 patients Implementation: 00/1995 Study Start: 01/1998 Study End: 06/2002	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system	Other specialty hospital (rehab, oncology), 650 Beds	testing for renal function at 1 month*, 6 months*, decreased renal function at 1 month*, 6 months*	Introduction of the CDSS was not associated with testing for renal function at 1 month (43.8 vs. 48.3, p = 0.46 NS) or 6 months (85.3% vs. 84.5%, p = 0.84) or for having decreased renal function at 1 month (3.1% vs. 3.4%, p = 0.86) or at 6 months (5.4% vs. 5.1%, p = 0.92). NS at each stage.	-
Tierney (2003)[166] Design: RCT N = 706 patients, 20 pharmacists, 94 physicians and 1 nurse practitioner Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Pharmacy	Ambulatory care, Outpatient hospital based, Academic	QOL SF-36*, heart failure exacerbation*	Across the 4 groups (physician intervention, pharmacist intervention, both interventions, and controls) the SF-36 (8 subscales), or for Heart Failure exacerbation (4 subscales), and emergency department visits or hospitalizations (all or related to HF) were NS.	-
Tierney (2005)[167] Design: RCT N = 706 patients Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	Monitoring including patient adherence and compliance Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system, Pharmacy	Ambulatory care, Pharmacy, Outpatient hospital based Academic	QOL SF-36, Chronic Respiratory Disease Questionnaire, hospitalizations (Control vs. Physician intervention vs. Pharmacist Intervention vs. Both Intervention).	No significant change in QOL measures. Hospitalization was measured and not affected.	-

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	MM Phase(s)	HIT Studied Integrated System	Settings	Outcomes Measured	Results	Outcome
Upperman (2005)[168] Design: Before-after N = Not reported ADE/1,000 doses Implementation: 00/2002 Study Start: 01/2002 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated EHR/EMR system	Acute care/tertiary, Pediatric stand alone hospital, Academic	rate of harmful ADEs	After implementation of CPOE the rate of harmful ADEs decreased (0.05/1,000 doses vs. 0.03/1,000 doses, p = 0.05).	+
Vartak (2009)[316] Design: Before-after N = 41,865 patients Implementation: 00/2005 Study Start: 10/2004 Study End: 07/2005	Prescribing	**CPOE/POE system, EHR and Emergency Room (ER) event tracking system** Integrated CPOE/POE system, EHR/EMR system, Hospital information system, Imaging systems, Laboratory system, Pharmacy	Emergency department, 193 Beds	Mean LOS*, number of patients treated in ED*	Although the system was designed to enhance efficiency, the mean (LOS) increased significantly from 116.8 minutes during the preimplementation period to 134.2 minutes during the postimplementation period (p <0.0001). The volume of patients treated in the ED however decreased significantly (p <0.0001) from preimplementation (n = 22,936) to postimplementation (n = 18,929).	-
Weingart (2008)[275] Design: Cohort study N = 267 patients Implementation: 09/2000 Study Start: 04/2001 Study End: 06/2002	Monitoring including patient adherence and compliance	**patient messaging via PHR** Integrated Billing/administration system, EHR/EMR system, Imaging systems, Laboratory system	Ambulatory care, Academic	ADE rate	Patients experienced 21 total ADEs; responders reported significantly more ADEs electronically (13%) than non-responders (3%) RRR-333%, p = 0.01.	+
Wrona (2007)[177] Design: Observational study N = 536 PCA patients Implementation: 00/2003 Study Start: 01/2003 Study End: 03/2004	Monitoring including patient adherence and compliance, Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Imaging systems, Laboratory system	Pediatric stand alone hospital	Occurrences of low respiratory rate, low oxygen saturation rate	Occurrences of low respiratory rate and low oxygen saturation were compared between ‘no order set’ and each of the two order sets groups (3.3% vs. 4.3% vs. 9.9%); the Acute Pain Service order set group had significantly higher rate of low respiratory rate (3.3% vs. 9.9%, -200%, p <0.05). No significant differences were found in the number of cases in which low oxygen saturation was recognized (13.4% vs. 20.9% vs. 14.6%).	+

Evidence Table 9. KQ1: primary clinical outcomes for all technologies assisting all medication phases (continued)

Article Information	**MM Phase(s)**	**HIT Studied** Integrated System	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Yu (2009)[317] Design: Case control N = 22,665 patients Implementation: 00/0000 Study Start: 10/2005 Study End: 09/2006	Prescribing	**CPOE/POE system** Integrated Imaging systems, Laboratory system, Pharmacy	Pediatric stand alone hospital	Reportable ADE, no CPOE vs. some CPOE*	Univariate conditional logistic regression analysis showed that the lack of CPOE in hospitals was associated with increased risk of ADE. Specifically, after controlling for co-morbidities, the odds of experiencing a reportable ADE were 42% higher for hospitals without CPOE compared with those with CPOE, after adjusting for the number of co-morbidities. OR of experiencing a reportable ADE, no CPOE vs. some CPOE 1.42 (95% CI 1.28 to 1.57)	+
Zanetti (2003)[180] Design: RCT N = 273 patients Implementation: 00/0000 Study Start: 03/2000 Study End: 06/ 2000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated Hospital information system	Acute care/tertiary, Academic	rate of infection	The rate of infection was similar in both groups (4% in alarm plus reminder group vs. 6% in the control, p = 0.4) and both were lower than before the study (p = 0.2)	-

Evidence Table 10. KQ1: primary qualitative outcomes for all technologies across phases

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Agostini (2007)[319] Design: Qualitative N = 36 house officers most of whom were PGY1 Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system EHR/EMR system	Acute care/tertiary, Academic	Benefits and barrier themes were identified. Benefits include awareness of patient safety risks (delirium, falls, and general patient safety risks), usefulness of computer technology, and value of educational content of the reminder (geriatrics pharmacology review and nonpharmacologic treatment options). Barriers were related to demands of reading the reminder, role of clinical experience, and information content of the reminder.	Both barriers and benefits of computer-based reminders were identified by house officers dealing with the elderly patients with insomnia.
Ahearn (2003)[320] Design: Qualitative N = 22 general practitioners Implementation: 00/0000 Study Start: 04/2002 Study End: 05/2002	Prescribing	**e-Rx**	Ambulatory care	7 main themes emerging from the focus groups; (1) reaction to prompts; (2) concerns and potential problems re: comprehensiveness and accuracy of alerts; (3) effects on prescribing behaviour; (4) need for training; (5) helpful CDSS features e.g. sensitivity settings, alerts in red, etc; (6) suggested improvements; and (7) attitudes to evidence-based guidelines.	GPs believed that important interactions may be missed because of desensitization from too many alerts (which also intrude on workflow); that interaction alerts need to be severity graded and only significant ones should appear; and that improved computer-user interface design could enhance the usefulness of the decision support systems.

The HIT system studied is in **bold**, followed by the systems that it was integrated with.
*indicates outcomes noted as being the primary outcome by the paper's authors
Abbreviations: ADE = Adverse Drug Event; AMDs = Automated Medication Dispensing Systems; BCMA = Bar Code Medication Administration ; CCDS = Computerized Clinical Decision Support; CDS = Clinical / Computerized Decision Support ; CDSS = Clinical Decision Support System; CIT = Clinical Information Technology; CPOE = Computerized Provider Order Entry; CR = computer reminder; ED = Emergency Department; EDI = Electronic Data Interchange ; EHR = Electronic Health Record; e-MAR = Electronic Medication Administration Record; EMR = Electronic Medical Records; EPA = Electronic Prescribing and Administration System; e-RX = Electronic Prescribing; e-TAR = Electronic Treatment Authorization Request; GPs = General Practitioners; HIT = Health Information Technology; ICT = Information and Communication Technology; MICU = Medical Intensive Care Unit; MM = Medication Management; N = sample size; OTC = Over the counter; PA = Physician Assistants; PGY1 = First Year Postgraduate; POE = Provider Order Entry

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Arar (2005)[321] Design: Observational study N = 50 clinical encounters with patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Education of patients and clinicians but not pre-professional education	**e-Rx** Integrated EHR/EMR system, Imaging systems, Laboratory system	Ambulatory care	Direct observation and content analysis showed that the EMR/e-Rx facilitated communication with respect to the process of care that included checking active and inactive prescriptions and new and refill prescriptions, names of medication, and other medication themes (mail-order issues, adherence, self regulation, alternate OTC issues).	The EMR improved communication between physicians and patients in relation to medication issues.
Ash (2004)[322] Ash (2003)[323] Sittig (2005)[324] Ash (1999)[325] Ash (2000)[326] Ash (2003)[327] Ash (2001)[328] Design: Qualitative N = 58 physicians, nurses, administrators, IT professionals Implementation: 1966 onwards Study Start: 00/1998 Study End: 00/2003	Prescribing	**CPOE/POE system**	Acute care/tertiary, General Hospital, Academic	[324] Negative emotional responses were more prevalent than positive or neutral.[323] Four high-level themes were identified: (1) organizational issues such as collaboration, pride, culture, power, politics, and control; (2) clinical and professional issues involving adaptation to local practices, preferences, and policies; (3) technical/ implementation issues, including usability, time, training and support; (4) issues related to the organization of information and knowledge, such as system rigidity and integration. Relevant differences between teaching and nonteaching hospitals include extent of collaboration, staff longevity, and organizational missions.[322] Themes included: language and misunderstandings, context matters and it affects the way of doing things, benefits and tradeoffs, 'contrasts, conflicts and contradictions', collaboration and trust, customization and organization of information, defining boundaries of CPOE, ongoing nature of implementation.[327] Explores the theme of leaders and bridgers-administrative; clinical;	[324] Designers need to recognize that CPOE features and implementation strategies can increase negative emotions and impact success of implementation. Positive feedback might alleviate some of the problems.[323] An organizational culture characterized by collaboration and trust and an ongoing process that includes active clinician engagement in adaptation of the technology were important elements in successful implementation of physician order entry at the institutions that we studied.[322] Publication of the results of these iterative inquiries served to promote a realization that implementation of CPOE is not easy and that the negatives must be weighed against the positives.[327] Understanding multiple perspectives should be undertaken, with insights used to form strategic implementation plans.[325] house officers felt that CPOE assists patient care but may undermine education; it works best when tailored to fit local and

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
				bridgers/support staff; skills and training.[326] Physicians, admin and IT have different perspectives of the technical and organizational aspects of CPOE; the multiple perspectives model was used to offer structure to the results.[325] Themes relating to housestaff perceptions of CPOE included education; benefits; problems; feelings about; implementation strategies and the future of CPOE.	individual workflow; implementation strategies should include mechanisms for engaging housestaff in decision process.
Avery (2005)[329] Design: Survey N = 21 experts (Delphi panel members) Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance, Prescribing	**e-Rx**	Not specified	Key Themes: (1) importance of computerized alerts; (2) need to minimize spurious alerts; (3) making it difficult to override critically important alerts; (4) having audit trails of such overrides; (5) support for safe repeat prescribing; (6) effective computer–user interface; (7) importance of call and recall; (8) need to be able to run safety reports.	The high level of agreement among the expert panel members indicates clear themes and priorities that need to be addressed in any further improvement of safety features in primary care computing systems.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Banet (2004)[198] Design: Before-after N = 55 nurses Implementation: 05/2003 Study Start: 00/0000 Study End: 00/0000	Administering	**CPOE/POE system, e-MAR, e-Medication administration system (e-MAR, e-TAR)** Integrated Imaging systems, Laboratory system, Pharmacy	ED, Academic	For the open-ended question on ease of CPOE documentation, responses fell into the following themes: improvements in the clarity of orders, system helps organize and time their tasks, positive responses about efficiency and standardization of documentation provided by templates, general improvement in ED processes, decreased number of verbal orders and time searching for charts. For the open ended question for suggestions for improvements, themes included: additional terms and phrases for templates, process issues not affected by the ED application, complaints regarding technical problems with the system, suggestions for additional functionality, comments about the medication order icon on the tracking board.	The findings from this study indicate that users perceived no change in the total amount of time spent on documentation, a perception that was corroborated by the results of the time-motion studies. Nurses also perceived that certain processes, such as laboratory and radiology tests, were accomplished more efficiently after the implementation.
Bastholm Rahmner (2004)[330] Design: Qualitative N = 21 physicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**e-Rx** Integrated CDSS/CDS/CCDS/ reminders Pharmacy	General Hospital	4 categories for possibilities and obstacles. (1) possibilities related to access to patient drug history (which is not met by the new system), increased pharmacological knowledge from alerts etc., access to information more readily and time saved; (2) obstacles centered around technical problems given current problems with the EMR and too frequent alerts, computer shortages within the ED, altering routines and habits and the resulting diminishing patient contact since they need to leave the consulting room to enter the prescriptions;	Gaining access to patient drug history enables physicians to carry out work in a professional way. Alerts and producer-independent drug information are valuable in reducing workload. However, technical prerequisites form the base for a successful implementation. Time must be given to adapt to new ways of working.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Beuscart-Zephir, (2010)[331] Design: Qualitative N = Not Specified Nurse Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**CPOE/POE system** Integrated EHR/EMR system	Acute care/ tertiary, 3,000 Beds Academic	(3) standard ethnographic methods were used to support the analysis of the current work system and work situations, coupled with cognitive task analysis methods and documents review; (4) usability inspection (heuristic evaluation) and both in-lab (simulated tasks) and on-site (real tasks) usability tests were performed for the evaluation of the CPOE candidate. The study focused on the nurses' tasks of preparing and administering oral route drugs to the patients, with a particular attention to the nurses' needs in terms of information necessary to efficiently and safely support their tasks.	The analysis of the work situations identified different work organizations and procedures across the hospital's departments. The most important differences concerned the doctor–nurse communications and cooperation modes and the procedures for preparing and administering the medications. The assessment of the medication CPOE functions uncovered a number of usability problems, including severe ones which could be impossible to detect.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Boonstra (2004)[332] Design: Qualitative N = 36 GPs Implementation: 00/2001 Study Start: 00/2001 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders e-Rx** Integrated CDSS/CDS/CCDS/ reminders EHR/EMR system, Formulary, Insurance	Ambulatory care	Five factors related to the perceived advantages and disadvantages of the system. (1) system: usability issues and features of the system viewed as positive by some (user friendly, integrated) and negative by others (unfamiliar with the disease codes system, lack of flexibility, lack of computer resources); (2) finance: though the software was free, the government reaped the economic benefits of using it and the GPs were required to keep their EHR systems up to date; (3) system in consultation process: some felt it was more efficient during consultation and led to better quality; others felt it took longer and took away from patient focus; (4) cultural factors: users tended to have a culture of professional quality, non-users tended to focus on human relations; (5) policy environment: helps doctors become more cost conscious, but benefit only for insurers, and focused solely on costs.	Designing a system that met the diverse needs of users more satisfactorily, in being more compatible with their diverse cultures, may have encouraged wider and more creative use, and thus achieved more savings than the present arrangements have achieved.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Buhrer (2008)[333] Design: Qualitative N = 67 Nurses Implementation: 11/2007 Study Start: 10/2007 Study End: 12/2007	Administering	**BCMA**	Acute care/tertiary	Pre-BCMA: (1) scheduled medication passes take longer (35/35); (2) system is overwhelming (25/35); (3) the system would direct nurses' attention away from patients (23/35); (4) nurses expected system to improve patient safety (30/35). Post-BCMA: (1) liked working with the system (19/32); (2) BCMA improves safety (28/32); (3) overwhelmed at beginning of the implementation (12/32); (4) more focused on system than the patient and found this annoying (20/32); (5) would like to switch back to the previous, paper-based system. Negative attitude: (1) computer carts: too heavy and too big and some without storage drawer; (2) scanners: too few wireless scanners; (3) batteries: unreliable power indicators and weak batteries; (4) lost orders: sometimes disappeared from the medication schedule, causing confusion; (5) documentation: required launching a separate cumbersome application. Positive attitude: (1) organization: nurses found BCMA system's scheduling function helpful; (2) carts: some use cart as a "portable desk".	Implementation of BCMA into the active process of medication administration was a significant source of negative attitudes in nurses. Qualitative examination of users' attitudes (negative and positive) toward specific attributes can result in improved design of both technology and implementation strategies.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Campbell (2009)[334] Design: Qualitative N = 32 semi-structured interviews=43 hours; 400 hours of observation shadowing 95 clinical providers Implementation: 00/0000 Study Start: 08/2004 Study End: 04/2005	Prescribing	**CPOE/POE system** Integrated EHR/EMR system	Acute care/tertiary, General Hospital, 340 (Wishard); 893 (Mass.); 150 (Faulkner); 725 (Brigham); 238 (Alamance) Beds Academic	Themes: CPOE systems can affect clinical work by: (1) introducing or exposing human/computer interaction problems; (2) altering the pace, sequencing, and dynamics of clinical activities; (3) providing only partial support for the work activities of all types of clinical personnel; (4) reducing clinical situation awareness; (5) poorly reflecting organizational policy and procedure.	CPOE systems are tools intended to support and improve the delivery of care, and are not solutions for all problems related to clinical practice. Workflow issues resulting from CPOE can be mitigated by iteratively altering both clinical workflow and the CPOE system until a satisfactory fit is achieved.
Cross (2009)[335] Design: Qualitative N = 10 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders home automated tele-management** Integrated electronic messaging system, Personal health records systems	Ambulatory care, Home, Academic	Patients' perceptions: (1) constant communication: assist them in monitoring the symptoms of disease, both from a medical provider and a patient perspective; (2) use of computer was not difficult; (3) improved safety; (4) keep the patient and provider up to date on changes in symptoms. Analysis of the responses were sorted into three topic areas: (1) user attitudes about the interface; (2) user attitudes about the content of self-testing; (3) user attitudes about the self-testing process.	Pilot testing of a tele-management system customized for UC revealed a high level of acceptance and interest among patients. The results suggest that implementation of a tele-management system will be feasible on a long-term basis with only minor modifications.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Crosson (2007)[336] Design: Qualitative N = 47 clinicians Implementation: 10/2006 Study Start: 03/2006 Study End: 11/2006	Prescribing, Transmission, order communication	**e-Rx,** **e-Transmission of the prescription to/from doctor to pharmacy** **Handheld** Integrated, EHR/EMR system	Ambulatory care	Practices which successfully implemented the e-Rx system exhibited greater familiarity with the capabilities of the systems and had more realistic expectations of the benefits. Physicians in these practices tended to have positive attitudes about and previous experiences with e-Rx or EMR, participation in continuing education courses relating to e-Rx, and plans for the future use of other HIT. Physicians in the 3 practices where the programs were successfully installed but unevenly implemented had high expectations about the ease of implementation, but at the same time reported concerns about how e-Rx might affect their clinical independence or undermine their authority with patients. Prescribers and staff members in the 2 practices that successfully installed, but then discontinued use of the program exhibited very little advance knowledge of program functions or the potential effect on prescription workflow. Two practices failed to install e-Rx; physicians and support staff in these practices expected that e-Rx would lead to greater efficiency and safety but, at the same time, had little specific knowledge of program functionality.	Practice leaders should plan implementation carefully, ensuring that practice members prepare for the effective integration of e-Rx technology into clinical workflow.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Feldstein (2004)[337] Design: Qualitative N = 20 Clinicians Implementation: 00/1996 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated CDSS/CDS/CCDS/ reminders EHR/EMR system	Ambulatory care	The study found some common theme with respect to prescribers' frustrations with CPOE systems: (1) alerts that contained low-priority information; (2) intrusive alerts presented at the wrong time in the workflow; (3) difficult-to-interpret alerts; (4) delays caused by the alert; (5) redundant and repetitive alerts.	Although alerts may slow the work process, busy clinicians generally find them helpful. Safety alerts need to be concise and relevant, have clear action steps, and provide options for users with different experience levels and work styles. Health care decisionmakers should prioritize safety-related alerts and educational programs to facilitate the implementation of CDSS at CPOE.
Fernando (2009)[338] Design: Qualitative N = 9 ED specialists and registrars Implementation: 01/2006 Study Start: 05/2006 Study End: 12/2006	Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Imaging systems, Laboratory system	Acute care/tertiary, 66 ED beds	Three major issues emerged from the findings: (1) the implementation of the new system was accompanied by major shifts in ED work responsibilities and tasks; (2) the appearance of dysfunctional consequences related to the excess time it took to electronically order and the usability of some features of the new system; (3) doctors' concerns that their views and opinions about design and implementation of the new system had not been adequately addressed	The implementation of electronic ordering has important implications for ED functioning and the delivery of patient care. The complexity of the ED makes it vulnerable to disruption caused by inadequate system design and ineffective channels of communication across the hospital.
Fields (2007)[339] Design: Qualitative N = 17 Health care providers Implementation: 08/2006 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, Critical care units (CCU, ICU, NICU) 19 beds in the MICU Beds	Four themes were suggested: (1) ease of use; (2) speed; (3) trust; (4) hopefulness. Participants valued CPOE potential and were hopeful that future systems would be easy to use, decrease error potential, be more customizable for individual users, and contain concise physician order sets to foster medication order safety.	Participants valued CPOE potential although they commented on improvements and challenges.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	**MM Phase(s)**	**HIT studied** Integrated systems	**Settings**	**Results**	**Conclusions**
Franklin (2007)[50] Donyai (2008)[51] Barber (2007)[52] Franklin (2008)[53] Franklin (2007)[54] Design: Before-after N = 4,803 medication orders Implementation: 06/2003 Study Start: 00/0000 Study End: 00/0000	Administering, Prescribing	**Automated Dispensing Machine, e-Medication administration system (e-MAR, e-TAR) e-Rx** Integrated Pharmacy	Acute care/tertiary, 28 surgery bed ward of a teaching hospital Beds Inpatient hospital based, Academic	The system was successfully implemented on the ward, and remained in operation for over 2 years. Many of the technical components of the system initially showed problems, but evolved with increased functionality and improved performance. Attitudes to the system in the early stages were mixed. Over time, staff attitudes changed to become more balanced and the potential benefits of the system became clearer to most. The system structured the work of staff, sometimes unexpectedly.	This theory-led evaluation offers valuable insights into a critical contemporary policy area. Technical systems are never perfect, and they require time and effort to become embedded into any particular clinical context. The effectiveness of ICT changes and develops over time, have quite different effects in different settings. For this reason a sophisticated evaluation framework is necessary.
Georgiou (2009)[340] Design: Qualitative N = 50 hospital employees Implementation: 00/0000 Study Start: 01/2006 Study End: 03/2006	Prescribing, Transmission, order communication	**CPOE/POE system** Integrated EHR/EMR system, e-MAR	Acute care/tertiary, Not specified, Inpatient hospital based, Academic	The 20 recurring themes were grouped into 4 major constructs: Will it help?, Will it work?, Will it impair existing interaction?, and Will we cope?	The hospital employees had major concerns before implementation of a CPOE system. The elucidation and understanding of these concerns and worries can help to inform and strengthen implementation strategies.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	**MM Phase(s)**	**HIT studied** Integrated systems	**Settings**	**Results**	**Conclusions**
Graham (2008)[341] Design: Qualitative N = 7 physicians Implementation: 00/0000 Study Start: 00/2006 Study End: 00/2007	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system, Formulary	Emergency department, Academic	Coding categories for identifying usability problems from the analysis of video-based data included: (1) interface problems; (2) content problems; (3) slips and mistakes. From 56 recorded sessions, a total of 422 events were recorded. The events were further grouped into seven main categories: (1) negative comments; (2) positive comments; (3) neutral comments; (4) application events; (5) problems; (6) slips; (7) mistakes.	This study provides a framework for evaluating CDSS applications in a clinical environment and has identified specific areas for improvement in the applications utilized. A number of interface issues that could lead directly to adverse medical events that were identified raises concerns about the potential for similar undocumented problems in other clinical applications currently in use or being developed for implementation. Application of usability engineering principles can help identify interface problems that may lead to medical adverse events, and need to be incorporated early in the design phase to ensure that such problems can be corrected while there is still time and it is cost effective to do so.
Grossman (2007)[342] Design: Qualitative N = 26 organizations Implementation: 00/0000 Study Start: 11/2005 Study End: 03/2006	Prescribing, Transmission, order communication	**e-Rx, e-Transmission- of the prescription to/from doctor to pharmacy** Integrated Stand-Alone, EHR/EMR system	Ambulatory care	Qualitative data were narratively analyzed from 44 telephone interviews with 26 medical practices, 21 with e-Rx.	Barriers were reported related to maintaining complete lists of patients and their medications, use of CDSS, getting patient-specific formulary data, and EDI. Factors associated with these issues related to product limitations, external implementation challenges (e.g., communication with pharmacists and vendor support), and physician preferences on specific product features.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Holden (2010)[318] Design: Qualitative N = 20 attending Physicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system, EMR** Integrated EHR/EMR system	Acute care/tertiary, 400+ Beds	Behavioral beliefs: (1) performance outcomes; (2) productivity and efficiency outcomes; (3) patient outcomes; (4) financial, organizational, and other outcomes; (5) affective outcomes; External Normative beliefs; Control beliefs: controllability; self-efficacy.	EMR and CPOE were commonly believed to both improve and worsen the ease and quality of personal performance, productivity and efficiency, and patient outcomes. Physicians felt encouraged by employers and others to use the systems but also had personal role-related and moral concerns about doing so. Perceived facilitators and barriers were numerous and had their sources in all aspects of the work system.
Hurley (2007)[241] Design: Mixed methods N = 1,087 nurses Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated CPOE/POE system, EHR/EMR system, Pharmacy	Acute care/tertiary, Academic	Interview questions followed the same subscales as the satisfaction scale. Nurses found the new system more time consuming but acknowledged that the extra time was wisely spent to assure verification. They viewed saving time on handwritten, paper-based medication sheets transcribing as a positive change. They felt there was an increased sense of safety for the patients and the nurses and that the system helped with the 5 rights. In terms of access, they appreciated greater access to medications and information (policies, guidelines, drug resources, patient files, etc.), but felt there were still some delays in getting medications from pharmacy.	A medication administration system that nurses view as being effective, by promoting efficacy, safety, and easy access, will support their nursing practice. Results of this study can give confidence to nurse executives that nurses can be satisfied with technology to make medication administration safer and more efficient and provide easier access to system components.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Johansson (2010)[343] Design: Mixed methods N = 15 home-care nurses Implementation: 00/2007 Study Start: 12/2007 Study End: 3/2008	Administering	**BCMA, CDSS/CDS/CCDS/ reminders** Integrated Handheld, Drug reference software	Home, Academic	Medication profiles: Most of the nurses had access to the mobile information and the possibility to obtain a profile of the patients' medication regarding drug–drug interactions, therapeutic duplications and warnings for drugs unsuitable for elderly. Usability: The nurses discussed that it was a time consuming learning threshold, but once used to the LIFe-reader®s' functions, they were regarded as fast. The nurses experienced that the keyboard of the LIFe-reader® was too small and not suited to the Swedish language, and that the pen was not easy to use. Usefulness: The nurses believed that it would be different to use the PDA once they started to work as district nurses. Some nurses thought they would have used the LIFereader ® in a different way if they could have had it for a longer time or if they knew they could have kept it. The drug reference text in the LIFe-reader® had the highest priority but there was also a potential for more functions and features	We found that the LIFe-reader® has the potential to be a useful and user-friendly MDSS for nurses in home care when obtaining profiles of the patients' medication regarding drug–drug interactions, therapeutic duplications and warnings for drugs unsuitable for elderly patients.
Johnson (2010)[75] Design: RCT N = 3,285 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 08/2007	Prescribing, Transmission, order communication	**CDSS/CDS/CCDS/ reminders e-Rx** Integrated EHR/EMR system	Ambulatory care, Pharmacy, Not specified, Academic	Improving communication between prescribers and dispensers; Decreases callbacks in some cases; Pediatric dosing information helps check for potential errors; Increases callbacks in some cases; Need more information to be included in annotations; New SYW feature request	Comments suggested that SYW increased callbacks where necessary and decreased them in other situations, but did not contribute to unnecessary callbacks. These findings support the continued and potentially expanded use of SYW by e-Rx systems to enhance communication with pharmacists.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Kazemi (2008)[344] Design: Qualitative N = 19 physicians Implementation: 00/0000 Study Start: 12/2006 Study End: 01/2007	Prescribing	**CPOE/POE system** Integrated Hospital information system	General Hospital, 234 Beds Academic	3 themes emerged on current prescription process: (1) decision-making errors; (2) transcription errors; (3) over confidence errors. 3 themes were identified in the expected benefits category: (1) confidentiality issues; (2) reduction of medication errors; (3) educational benefits. 4 themes emerged in the perceived obstacles category: (1) high cost; (2) social and cultural barriers; (3) data entry time; (4) problems with technical support.	Prescription patterns in Iranian teaching hospitals are physician centered, top-down with possibility for medication errors. Although barriers exist towards implementation of CPOE, there is a general willingness among the physicians to use such a system if it provides significant benefit.
Koppel (2005)[345] Design: Mixed methods N = 291 health care providers Implementation: 00/1997 Study Start: 00/2002 Study End: 00/2003	Prescribing	**CPOE/POE system** **Integrated** nurses medication lists, Pharmacy	Acute care/tertiary, 750 Beds Academic	Identified 22 previously unexplored medication-error sources that users report to be facilitated by CPOE. We group these as: (1) information errors generated by fragmentation of data and failure to integrate the hospital's several computer and information systems; (2) human-machine interface flaws reflecting machine rules that do not correspond to work organization or usual behaviors.	A leading CPOE system often facilitated medication error risks, with many reported to occur frequently. As CPOE systems are implemented, clinicians and hospitals must attend to errors that these systems cause in addition to errors that they prevent.
Koppel (2008)[346] Design: Mixed methods N = 14,2203 medication administrations Implementation: 12/ 2001 Study Start: 00/2003 Study End: 00/2006	Administering	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated Hospital information system	Acute care/tertiary, 1,399 Beds Academic	15 workarounds falling into 3 categories were identified: omission of process steps (7 workarounds), steps performed out of sequence (1 workaround) and unauthorized process steps (7 workarounds). The probable causes and potential errors for each workaround were determined. Probable causes included technology, task, organizational, patient and environmental related causes.	BCMA systems are intended to advance medication safety, our data reveal that integrating BCMAs within real-world clinical workflows requires critical attention to ensure that technology safety features are used as intended and that systems are designed to support this use. Compliance with patient safety protocols is best achieved by configuring BCMAs for efficient as well as safe patient care. Repeated examinations and corrections of BCMA actual uses are needed to optimize their role in preventing medication errors.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	**MM Phase(s)**	**HIT studied** Integrated systems	**Settings**	**Results**	**Conclusions**
Krall (2002)[347] Design: Qualitative N = 16 clinicians (physicians, PAs and nurses) in 3 focus groups Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Monitoring including patient adherence and compliance, Prescribing	**Outpatient EMR** Integrated EHR/EMR system	Ambulatory care	5 themes were identified from the focus group data. (1) efficiency: alerts and reminders being efficient and not wasting time; (2) usefulness: alerts being useful and appropriate; (3) Information content: about timely, rich, and accessible information; (4) user interface: important for smooth and efficient work and provision of valuable information quickly and accurately; (5) workflow: issues related to the information being available when needed. Note that considerable emotion was associated with alerts and reminders (criticism, embarrassment, guilt, frustration, annoyance, and anger).	the clinicians provided considerable feedback on the usefulness and usability of alerts and reminders in EMRs.
Lai (2007)[348] Design: Mixed methods N = 15 pharmacists Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Dispensing, Transmission, order communication	**CPOE/POE system**	Unspecified Hospital, Pharmacy, Inpatient hospital based	1) patient safety: pharmacy leaders all believed CPOE would improve patient safety, allergy, dosing and interaction alerts. Some expressed concern that poor design/implementation could lead to increased errors; 2) pharmacy practice: most believed the system would lead to improved efficiencies facilitating more time spent with patients; 3) pharmacy profession: most felt CPOE would improve working relationships with physicians and nurses by facilitating new collaborations The scaling analysis found that pharmacy leaders of community, academia, and hospitals had different experience and/or opinions regarding the impact of CPOE.	Most pharmacy leaders held positive opinions regarding the impact of CPOE on the pharmacy practice and the profession, with varying concerns regarding its impact on practice and safety.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Lapane (2008)[90] Design: Mixed methods N = 276 primary care prescribers and their staff Implementation: 00/2003 Study Start: 04/2006 Study End: 08/2006	Prescribing	**e-Rx**	Ambulatory care	An open-ended approach was used to elicit information about the benefits and drawbacks of e-Rx. 15 different parent nodes were defined. Attention focused on 2 parent nodes, impact on clinical practice and software features. Physicians found the drug allergy alerts useful. For drug-drug interactions, they found these beneficial to patient safety. Many of the interaction alerts were however ignored and many were viewed as too trivial or unnecessary. Physicians suggested that alerts be provided for current medication only and for them to be less sensitive, more sensible, possibly having a personal setting for severity levels.	Prescribers believe that refinements to the drug alerting systems are necessary to reduce common overriding of alerts. In addition to honing the specificity of the alerts and permitting prescribers to set the severity threshold for alerts, prescribers recommend having the drug alert algorithms run against current medication regimens.
Li (2006)[247] Design: Qualitative N = 2 qualitative researchers (nurse and human factors psychology) Implementation: 02/2004 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated Hospital information system	Acute care/tertiary	The 2 researchers used heuristic methods and identified 5 major problem areas with the CPOE system. These problems centered on text presentation, too much information/too many decisions at one time, color scheme (monochromatic blue/grey with red used as accent and not to note caution or problems). Problems were given to the developers who addressed them in the next redesign of the system.	The 5 problem areas that were identified were given to the developers who addressed them in the next redesign of the system.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
McAlearney (2006)[349] Design: Qualitative N = 71 Healthcare providers (Physicians) Implementation: 00/0000 Study Start: 04/2002 Study End: 05/2005	Prescribing	**Computerized order sets & hand held computers, CPOE/POE system** Integrated EHR/EMR system	Pediatric stand alone hospital, Ambulatory care, Other, Academic	2 major themes emerged: (1) Can it work? Physicians expressed concerns about: (a) appropriateness of physician-directed CIT as a solution for medical errors; (b) current technical capabilities; (c) level of technical support for CIT solutions; (d) introduction of new errors. (2) At what cost to the medical profession? Physicians were concerned about the time efficiency and workload redistribution associated with the introduction of CIT.	The study concluded that health care organization attempting to promote physician use of CIT should consider physician's perspectives about technology adoption and use to address their concerns, reduce skepticism, and increase the likelihood of implementation success.
McCann (2008)[251] Design: Mixed methods N = 53 patients Implementation: 0 Study Start: 03/2006 Study End: 09/2006	Monitoring including patient adherence and compliance	**symptom management system** Integrated Handheld	Ambulatory care	1) training and familiarization of the handset: patients felt that the training was adequate and the handset was straightforward and easy to use; 2) length of data collection: patients felt that entering data twice a day for 14 days was acceptable; 3) daily routine: the system did not appear to impact on patients' daily routines as it was incorporated into their day in a variety of ways; 4) symptoms: patients often felt that the six symptoms that were recorded on the handset were adequate, although some patients did indicate that they would have liked the opportunity to report other symptoms; 5) the alerting facility: overall, patients were happy with the alerting facility of the system, and the real-time, quick response rate of the data collected.	The results of this study indicate that patients with breast, lung and colorectal cancer had positive perceptions and experiences of using ASyMS© to monitor and manage chemotherapy related toxicity.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Motulsky (2008)[350] Design: Qualitative N = 12 community pharmacists Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**e-Rx** Integrated Insurance, Personal health records systems	Pharmacy, Other	The model of the effects of e-Rx on professionalization of community pharmacists had 7 themes: (1) increased analytical capacity; (2) greater dissemination of knowledge; (3) better integration of process tasks; (4) increased process automation; (5) elimination of intermediaries; (6) increased tracking capability; (7) greater informational capability. The main effects of the e-Rx were analytical capacity of the pharmacists and physician and dissemination of knowledge, integration of process tasks, process automation, facilitates interpretation of prescriptions, improves relevance and meaningfulness of interaction and improves quality of information transmitted.	e-Rx has tremendous capacity to change and improve pharmacists professional work and interactions.
Nanji, (2009)[351] Design: Qualitative N = 10 pharmacy staff Implementation: 11/2003 Study Start: 00/0000 Study End: 00/0000	Dispensing	**Barcoding-dispensing** Integrated Barcoding system, Pharmacy	Acute care/tertiary, 750 Beds Pharmacy, Inpatient hospital based, Academic	3 barrier themes: (1) process (training requirements and process flow issues); (2) technology (hardware, software, and the role of vendors); (3) resistance (communication issues, changing roles, and negative perceptions about technology).	Bar code scanning system implementation is a difficult process with several barriers involving processes, technology and organizational resistance. Adequate training, continuous improvement, and adaptation of workflow to address one's own needs mitigated process barriers. Ongoing vendor involvement, acknowledgment of technology limitations, and attempts to address them were crucial in overcoming technology barriers. Staff resistance was addressed through clear communication, identifying champions, emphasizing new information provided by the system, and facilitating collaboration.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Novak (2008)[352] Design: Qualitative N = 50 hours of observations Implementation: 00/2007 Study Start: 00/0000 Study End: 00/0000	Administering	**BCMA, e-Medication administration system (e-MAR, e-TAR)** Integrated CPOE/POE system	Acute care/tertiary	For prior to BCMA implementation: Themes from the analytical coding were organized according to the nurses' practice goals-the familiar "Five Rights" of medication: Right Patient, Right Drugs, Right Dose, Right Time, and Right Way. For after BCMA implementation: In addition to the "Five Rights" of medication another theme emerged, namely, "New Articulation Work" and describes support and problem resolution strategies employed as nurses developed new coordination mechanisms.	The implementation of new information technology in the clinical setting can be disruptive to existing patterns of articulation work, or work that coordinates the activities of people across time and space. Implementation teams must familiarize themselves with articulation work and support users in developing new ways of coordinating with colleagues on other shifts and in remote physical spaces.
Novek (2000)[353] Design: Mixed methods N = 124 Health care providers (mostly nurses and pharmacists) Implementation: 05/1997 Study Start: 02/1998 Study End: 00/0000	Dispensing	**AMDs** Integrated Pharmacy	Long term care (nursing homes)	Distrust, resistance, miscommunication, unrealistic expectations, speed and scale of implementation, concurrent changes, inadequate support, and social factors.	Nurses were generally distrustful of the AMDs and skeptical that it reduced medication errors.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
O'Grady (2006)[354] Design: Qualitative N = 20 Patients Implementation: 06/2003 Study Start: 04/2003 Study End: 02/2004	Prescribing	**e-Medication administration system (e-MAR, e-TAR) e-Rx** Integrated Barcoding system, Ward-based automated dispensing system	Unspecified Hospital, 28 on the general surgery ward Beds	Themes (1) pre-EPA views: attitude about paper-based system was generally positive; (2) anticipated advantages of EPA before its introduction (save time, improve accuracy, and decrease mistakes); (3) the new system was expected to save time and be efficient (flexibility, comparisons with old system). (4) Concerns were shown over time, loss of personal touch, and not understanding the system; (5) advantage for staff when language is not English; (6) error reduction; (7) pre- EPA: inherent mistrust for computer systems; (8) post EPA: perceived disadvantages of the paper-based systems; (9) post EPA: perceived extra time needed if nursing staff had to check the drugs prescribed on the computer.	Patients generally had a good understanding of how paper-based system had worked and majority had safety concerns with it. Anticipated advantages were mostly about increased efficiency and reduced time. On balance, inpatients seemed neither for nor against EPA.
Patterson (2002)[355] Design: Qualitative N = 33 nurses--7 before BCMA and 26 after Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**BCMA** Integrated EHR/EMR system	Acute care/tertiary, Other specialty hospital (rehab, oncology) 784 in the 4 settings Beds Long term care (nursing homes)	6 unanticipated side effects were noted: (1) confusion by automated removal of medications by BCMA; (2) degraded coordination between nurses and physicians; (3) dropping activities to reduce workload during busy periods; (4) increased prioritization of monitored activities during goal conflicts; (5) decreased ability to deviate from routine sequences; (6) to reduce workload wristbands were not scanned and medication scanning was delayed.	Unanticipated adverse effects happen and nurses find solutions to cope with workloads.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Patterson (2004)[356] Design: Qualitative N = 46 clinicians working in 6 primary care clinics Implementation: 00/0000 Study Start: 10/2001 Study End: 10/2002	Monitoring including patient adherence and compliance, Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated Hospital information system, Laboratory system, Pharmacy	Ambulatory care	7 barriers were identified, some of which were not on the original list:1) workload; 2) time to document; 3) reminder did not apply; 4) inapplicability to the situation; 5) training lacks; 6) quality of provider-patient interaction; 7) use of paper forms.	Barriers exist. 17 recommendations were made to improve the situation: 9 related to design, 4 to the organization, and 1 each to team and role design, individual attitudes, patient and situation specific context, and interactions with other systems making issues redundant.
Pirnejad (2008)[256] Pirnejad (2009)[257] Design: Mixed methods N = 149 nurses Implementation: 09/2003 Study Start: 11/2003 Study End: 06/2007	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system, Hospital information system	Acute care/tertiary, 1237 Beds Academic	[256] The coding scheme included differentiation between those features that were considered supportive from features that were considered non-supportive to nurses' and physicians' medication work. Many of the paper-based system's non-supportive features were improved by the CPOE system. And, more useful features such as safety alerts and the possibility for physicians to prescribe electronically from everywhere in the hospital greatly benefited the prescription phase and improved the medication process. Nevertheless, nurses and physicians listed many non-supportive features of the CPOE system as well.[257] Workflow impediments from the perspective of physicians and nurses are described. The care providers devised compensatory work-arounds due to interoperabilities in the CPOE system.	[256] It is clear that moving from the paper based to the CPOE system had positive and negative impacts on nurses' and physicians' medication work. In our study, many of the CPOE system's non-supportive features were listed because the system damaged the synchronization and feedback mechanisms between nurses and physicians.[257] The interviews revealed that both nurses and physicians considered the system to be an improvement in their medication work compared to the old paper-based system. They complained about problems in coordination and collaboration. Problems forced them to develop informal rules and work methods to adapt the system in a way that it met their work requirements.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Ruiz (2010)[357] Design: Qualitative N = 19 primary care practitioners Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders** Integrated EHR/EMR system	Ambulatory care	Our data analysis elicited a number of themes, of which six are most relevant to the two areas of our inquiry. (1) pain as part of growing old; (2) concerns about using pain medications; (3) waiting times for pain clinic; (4) value of ancillary services; (5) poor training in pain management; (6) value of CPRS as a support tool.	The findings of this study clearly point to the need for a more systematic and solid understanding of the competencies of primary care practitioners in managing chronic nonmalignant pain in elderly veteran patients. While various types of support have been made available to primary care providers, competency-based training targeted on the elderly population must occur to facilitate the assessment and treatment of such pain. Particular attention must be given to the role of the EMR system as a source of clinical decision support complementary to and reinforcing competency-based training approaches.
Saleem (2005)[358] Design: Qualitative N = 90 Healthcare providers Implementation: 00/0000 Study Start: 01/2004 Study End: 06/2004	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated CPOE/POE system, EHR/EMR system, Laboratory system	Ambulatory care	Five barriers, four of which have related subcategories, and four facilitators, organized by three themes: (1) organizational; (2) workflow; (3) computer interface. Barriers: (a) Lack of coordination between nurses and providers; (b) Using the reminders while not with the patient, impairing data acquisition and/or implementation of recommended actions; (c) Workload; (d) Lack of CR flexibility; (e) Poor interface usability. Facilitators: (a) Limiting the number of reminders at a site; (b) Strategic location of the computer workstations; (c) Integration of reminders into workflow; (d) Ability to document system problems and receive prompt administrator feedback.	Barriers might explain some of the variability in the use of CRs. These barriers may be difficult to overcome but some strategies may increase user acceptance and therefore the effectiveness of the CRs. These include explicitly assigning responsibility for each CR to nurses or providers, improving visibility of positive results from CRs in the electronic medical record, creating a feedback mechanism about CR use, and limiting the overall number of CRs.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Schoville (2009)[359] Design: Qualitative N = 58 nurses Implementation: 09/2007 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CDSS/CDS/CCDS/ reminders CPOE/POE system** Integrated EHR/EMR system, Imaging systems, Laboratory system, Pharmacy	Acute care/tertiary, Pediatric stand alone hospital, Pedatric Hospital: 184 beds; Women's Hospital: 40 Beds Academic	There were 5 types of work-arounds and artifacts identified by both nursing leadership and staff nurses: (1) workflow timing of events; (2) communication changes; (3) system problems; (4) learning curve of the CPOE system; (5) patient safety	Although CPOE is considered a technical solution to prevent or reduce errors and enhance communication among caregivers, errors could result because of the redundancy in documentation between the paper record and the EMR, systems not interfacing with one another, and multiple screens needing to be viewed to find information about the patient. It was verified that multiple variables affect a successful transition to an electronic order entry system and that workarounds and artifacts were used.
Topps, (2005)[272] Design: Mixed methods N = 313 Healthcare provider Implementation: 11/2002 Study Start: 05/2002 Study End: 06/2003	Administering	**BCMA** Integrated Billing/administration system Hospital information system, Pharmacy	Pediatric stand alone hospital	Qualitative	Themes derived from the pre-survey indicated that medications would be given in a timely manner with less error, but may result in an increase in time with increase in safety along with more reported errors, but fewer errors in administering actual medications (near misses). The surveys collected post-implementation indicated that the staff felt there were fewer medication errors with a smoother administration of medication; however, it was perceived that more time was spent administering medications taking time away from patient care.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Varonen (2008)[360] Design: Qualitative N = 39 physicians Implementation: 00/0000 Study Start: 10/2005 Study End: 12/2005	Prescribing	**CDSS/CDS/CCDS/ reminders**	Ambulatory care, Academic	Facilitating factors: Flexibility of the system; (tailoring the selection of topics or patients for reminders and possibility to switch off the system); Reliability; Reliable knowledge base and trust in the developers of the system; Simplicity and ease of use; Concise reminders that facilitate and help work processes; Adequate budgeting; Concise and tailored education for the use of CDSS barriers. In all groups, repeatedly: experience of imperfect health care information systems; Threats to doctor–patient relationship: the computer should not have the leading role in the encounter; Obscured responsibilities; loss of own reasoning and clinical autonomy; Knowledge management: too much information or erroneous information; Resistance towards change; Issues of compatibility and updating, problems with several poorly interacting computer programs	Finnish physicians interviewed in this qualitative study had positive attitudes towards implementation of CDSS provided that they have some control over the system. They expected flexibility, individual tailoring and reliability of the CDSS. The high level of computerized practices and wide use of electronic guidelines have paved the way for the CDSS in Finland.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Vaziri (2009)[361] Design: Qualitative N = >30 informaticians, academic clinicians, pharmacists, clinicians with an IT (information technology) interest, human factor/user experience consultants and medical and non-medical commercial IT vendors, as well as members of the National Health Service (NHS) national programme for IT development team Implementation: 00/000 Study Start: 00/2008 Study End: 00/2008	Prescribing	**CDSS/CDS/CCDS/ reminders e-Rx** Integrated EHR/EMR system	Ambulatory care	End-users (principally GPs) at the workshop reported that prescribing alerts were more often a source of frustration more than of help. Delegates reported concerns about the current prescribing support prompts, primarily the low specificity of the pop-ups, which were too numerous, often unhelpful and therefore ignored. Information overload may have a negative impact on cognitive performance.	Prescribing errors remain a major source of unnecessary morbidity and mortality and current systems do not appear to have significantly reduced this problem; nor has the extensive literature about how to reduce unnecessary alerts been taken into account. We need a new and more rational basis for the selection and presentation of alerts that would help, not hinder, the clinician's performance.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Vogelsmeier (2008)[362] Design: Qualitative N = 88 nursing home staff Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**e-Medication administration system (e-MAR, e-TAR)** Integrated EHR/EMR system	Long term care (nursing homes)	Workarounds fell into 2 categories, relating to the technology itself and organizational processes. They occurred at new medication order entry, communication with the pharmacy and administration. The technology introduced intentional blocks (safety features such as excessive dose blocking, dual documentation and ADE monitoring) that lead to workarounds. Unintentional blocks leading to workarounds included wireless speed and printing each order on a separate page. Organization process blocks leading to workarounds included double checking of preparation and administration documents and limited resources such as fax machines.	As new technologies are introduced, continued monitoring to identify work flow is needed so appropriate changes can be made to address the underlying problems that create work flow blocks ultimately leading to potential workarounds. Additionally, as technology is implemented, organizational processes that will interface with the technology must be carefully re-engineered to reduce the unintended consequences of change.
Weingart (2009)[363] Design: Qualitative N = 25 health care providers Implementation: 00/0000 Study Start: 00/2007 Study End: 00/2007	Prescribing	**e-Rx** **Handheld** Integrated, CDSS/CDS/CCDS/ reminders Formulary, Pharmacy	Ambulatory care	problematic features: list management for patients; creating medication lists; poor recording of allergy information; awkward prescription writing leading to work-arounds; problematic alerts leading to alert fatigue	Front-line clinicians find many features of the e-Rx system burdensome. The value of e-Rx alerts is diminished by the quantity of irrelevant and inappropriate alerts. e-Rx triggers a variety of clinician behaviors (other than terminating or changing a prescription) that may improve patient safety.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Weir (1994)[364] Design: Qualitative N = 40 hospital staff (admin, physicians, support staff etc) Implementation: 03/1993 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated Pharmacy	Unspecified Hospital	A survey requesting a list of 6-10 factors facilitating and 6-10 most significant barriers from staff at 3 hospitals with successful implementation and 3 with unsuccessful implementations of CPOE was analyzed using a modified Delphi technique. Fourteen facilitating factors and 14 barriers were identified. Several categories differentiated the two hospital groups. Significantly more people from the successful hospital group reported supportive administration and supportive heads of medical sections; direct involvement of physicians, mandatory implementation, adequate training, and sufficient hardware facilitated success. In terms of barriers, only inadequate hardware and lack of ability to easily do patient transfer and advance admission orders (medical records package) differentiated the two groups and in both cases the item was mentioned more frequently by the successful hospitals.	These findings support the notion that the changes involved in instituting a physician order entry system are system wide and involve individual as well as organizational factors.
weir (2007)[365] Design: Qualitative N = 88 interviews Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated Hospital information system	Ambulatory care	Tasks were related to organization, assigning, determination, educating, scheduling, tracking, overview, correlating documenting, reminding, handing off, prioritizing, accepting, communicating, conforming, and informing. Task components were related to cueing, status, timing, communication, ownership, and linkage. Goals were associated with relevance screening, ensuring accuracy, minimizing memory load, and negotiating responsibility.	User creates strategies to learn how to effectively deal with new systems and processes, information overload must be carefully managed, and communication is vital and is often affected by new systems.

Evidence Table 10. KQ1: Primary qualitative outcomes for all technologies across phases (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results	Conclusions
Wentzer (2007)[366] Design: Qualitative N = 6 clinicians(2 physicians and 4 nurses) Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated EHR/EMR system	Acute care/tertiary	The study started with 3 relations (physician and patient interacting, physician and nurse coordination work, and the patients further route and medication path). Themes centered on transformation of the prescription and drug order during physician rounds, transformation of the drug order and dispensing with the CPOE system (user rights, inflexibilities and displacements with the use of CPOE, going back to the paper system, unified and inflexible CPOE medication model), transformation of continuing medication with the system (discharge, withdrawal or discontinuous patient routes, and new tasks and demands on the clinicians with the CPOE system).	CPOE system did not meet naive and early expectations. Some adverse effects of the CPOE system were noted.
Zhan (2006)[181] Design: Mixed methods N = 138,922 number of errors/100,000 doses Implementation: 00/0000 Study Start: 01/2003 Study End: 12/2003	Prescribing	**CPOE/POE system**	Unspecified Hospital	Some of the themes taken from the CPOE-related error descriptions included: faulty computer interface, CPOE design failures, especially lack of connection with other parallel systems, inadequacy of decision support and human errors occurring in interactions with the computer.	A national, voluntary medication error-reporting database cannot be used to determine the effectiveness of a CPOE system in reducing medication errors because of the variability in the level of underreporting from different institutions. However, it may provide valuable and useful information on the specific types of errors related to CPOE systems.

Evidence Table 11. KQ1: primary composite/population level outcomes for all technologies assisting education or other phase

Article Information	**MM Phase(s)**	**HIT studied** Integrated systems	**Settings**	**Outcomes Measured**	**Results**	**Outcome**
Holbrook (2009)[367] Design: RCT N = 511 patients Implementation: 00/0000 Study Start: 00/2002 Study End: 12/2003	Monitoring including patient adherence and compliance	**CDSS/CDS/CCDS/ reminders** Integrated Laboratory system	Ambulatory care, Home	Composite	A shared electronic decision-support system to support the primary care of diabetes improved the process of care and some clinical markers of the quality of diabetes care.	+
Yu (2009)[317] Design: Case control N = 22,665 patients Implementation: 00/0000 Study Start: 10/2005 Study End: 09/2006	Prescribing	**CPOE/POE system** Integrated Imaging systems, Laboratory system, Pharmacy	Pediatric stand alone hospital	Population Level	Using actual reportable ADEs from a relatively large number of pediatric hospitals, the study found significant beneficial associations between reportable ADE and CPOE implementation.	+

The HIT system studied is in **bold**; followed by the systems that it was integrated with. The outcome column indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: ADE = Adverse Drug Event; CCDS = Computerized Clinical Decision Support; CDS = Clinical / Computerized Decision Support; CDSS = Clinical Decision Support System; CPOE = Computerized Provider Order Entry; HIT = Health Information Technology; N = Sample Size; POE = Provider Order Entry; RCT = Randomized Controlled Trial

Evidence Table 12. KQ1: adverse effects measured for all technologies assisting all phases of medication management

Article Information	MM Phase(s)	**HIT studied** Integrated systems	Settings	Results
Ash (2007)[368] Design: Observational study N = 95 clinicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated CDSS/CDS/CCDS/reminders EHR/EMR system	Acute care/tertiary, General Hospital, Academic	47 examples of unintended consequences of CDS systems were observed. Thematic analysis showed 2 major patterns: generation by the content or presentation of the information. Issues related to content centered around elimination or shifting of human roles, currency of the CDS content or wrong or misleading CDS content. Issues related to the presentation centered around rigidity of the system, alert fatigue, sources of potential errors.
Ash (2007)[369] Design: Survey N = 176 hospitals Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system**	Acute care/tertiary	The preliminary qualitative study identified major types of UAC of CPOE.[370] The survey results verified the existence of eight UAC asked about at most of the 176 hospitals with CPOE. All types of UAC are widespread although two of them, power shifts and new kinds of errors, were not considered as important as the others (more/new work, workflow, system demands, communication, emotions, dependence on technology).
Ash (2007)[370] Design: Qualitative N = 4 outpatient clinics Implementation: 00/1997 Study Start: 04/2003 Study End: 10/2003	Prescribing,	**CPOE/POE system**	Ambulatory care, Not specified	Using the diffusion of innovations model, unintended sociotechnical consequences of CPOE were analyzed along 3 classifications: desirable vs. undesirable; direct vs. indirect; and anticipated vs. unanticipated for a total of 8 possible combinations. Examples of each combination were found in the narrative data. There were error and security concerns, and issues related to alerts, workflow, ergonomics, interpersonal relations, and reimplementation.

The HIT system studied is in **bold**, followed by the systems that it was integrated with.
*indicates outcomes noted as being the primary outcome by the paper's authors
Abbreviations: BCMA= Bar Code Medication Administration, CCDS= Computerized Clinical Decision Support, CDS= Clinical / Computerized Decision Support, CDSS= Clinical Decision Support System, CI=confidence Interval CPOE= Computerized Provider Order Entry, EHR= Electronic Health Record, e-MAR= Electronic Medication Administration Record, EMR= Electronic Medical Records, e-TAR= Electronic Treatment Authorization Request, HIT= Health Information Technology, HMO= Health Maintenance Organization, ICU= Intensive Care Unit, MM= Medication Management, MMC= Montefiore Medical Center, N= Sample Size, p = probability, POE= Provider Order Entry, RCT= Randomized Controlled Trial, RRR Relative Risk Reduction, UACs= Unintended Adverse Consequences, vs.= versus, WA= Workarounds

Evidence Table 12. KQ1: adverse effects measured for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results
Campbell (2006)[371] Campbell (2006)[372] Ash (2006)[373] Campbell (2009)[374] Design: Qualitative N = 95 clinicians (various) Implementation: 00/0000 Study Start: 09/2004 Study End: 04/2005	Prescribing	**CPOE/POE system**	Acute care/tertiary, General Hospital, Pharmacy, Inpatient hospital based, Academic	[371] UACs fell into nine major categories (in order of decreasing frequency): (1) more work for clinicians; (2) unfavorable workflow issues; (3) never ending system demands; (4) problems related to paper persistence; (5) untoward changes in communication patterns and practices; (6) negative emotions; (7) generation of new kinds of errors; (8) unexpected changes in the power structure; and (9) overdependence on the technology. Clinical decision support features introduced many of these unintended consequences.[374] CPOE systems can affect clinical work by: (1) introducing or exposing human/computer interaction problems; (2) altering the pace, sequencing, and dynamics of clinical activities; (3) providing only partial support for the work activities of all types of clinical personnel; (4) reducing clinical situation awareness; and (5) poorly reflecting organizational policy and procedure.[372] Careful analysis of overdependence on technology data revealed 3 themes: (1) system downtime can create chaos when there are insufficient backup systems in place; (2) users have false expectations regarding data accuracy and processing; and 3) some clinicians cannot work efficiently without computerized systems.[373] CPOE enables shifts in power related to work redistribution and safety initiatives and causes a perceived loss of control and autonomy by clinicians.
Campbell (2009)[334] Design: Qualitative N = 32 semi-structured interviews=43 hours; 400 hours of observation shadowing 95 clinical providers Implementation: 00/0000 Study Start: 08/2004 Study End: 04/2005	Prescribing	**CPOE/POE system** Integrated EHR/EMR system	Acute care/tertiary, General Hospital, 340 (Wishard); 893 (Massachusetts); 150 (Faulkner); 725 (Brigham); 238 (Alamance) Beds Academic	To identify and describe unintended adverse consequences related to clinical workflow when implementing or using computerized provider order entry (CPOE) systems we analyzed qualitative data from field observations and formal interviews gathered over a three-year period at five hospitals in three organizations. Five multidisciplinary researchers worked together to identify themes related to the impacts of CPOE systems on clinical workflow.

Evidence Table 12. KQ1: adverse effects measured for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT studied** Integrated systems	Settings	Results
Han (2005)[303] Design: Before-after N = 1,942 patients Implementation: 10/2002 Study Start: 10/2001 Study End: 03/2003	Dispensing, Transmission, order communication	**CDSS/CDS/CCDS/reminders** **CPOE/POE system** Integrated Hospital information system	Acute care/tertiary, Pediatric stand alone hospital, Academic	Mortality increased among patients transported in to the tertiary care pediatric center following the implementation of the CPOE system (2.8% vs. 6.6%, RRR -135%, p<0.001) as a result of delays in entering and processing orders and changes to workflow and communication among staff.
Keene (2007)[308] Design: Before-after N = 1,291 patients Implementation: 00/2001 Study Start: 09/2000 Study End: 02/2003	Prescribing	**CPOE/POE system** Integrated EHR/EMR system, Laboratory system, Pharmacy	Critical care units (CCU, ICU, NICU) Academic	The initiation of CPOE for the pediatric critically ill at MMC took place without the increase in mortality reported during a similar initiation period by Han and colleagues. Careful preparation, unit-by-unit tailoring, and extensive technical support may have improved the results at MMC.
Koppel (2005)[345] Design: Mixed methods N = 291 health care providers Implementation: 00/1997 Study Start: 00/2002 Study End: 00/2003	Prescribing	**CPOE/POE system** Integrated nurses medication lists, Pharmacy	Acute care/tertiary, 750 Beds Academic	a widely used CPOE system facilitated 22 types of medication error risks. Examples include fragmented CPOE displays that prevent a coherent view of patients' medications, pharmacy inventory displays mistaken for dosage guidelines, ignored antibiotic renewal notices placed on paper charts rather than in the CPOE system, separation of functions that facilitate double dosing and incompatible orders, and inflexible ordering formats generating wrong orders. Three quarters of the house staff reported observing each of these error risks, indicating that they occur weekly or more often. Use of multiple qualitative and survey methods identified and quantified error risks not previously considered, offering many opportunities for error reduction.
Lin (2008)[95] Design: Time series N = 1,123 high severity order checks Implementation: 00/1997 Study Start: 01/2001 Study End: 01/2006	Prescribing	**CDSS/CDS/CCDS/reminders** **CPOE/POE system** Integrated CPOE/POE system, EHR/EMR system	Acute care/tertiary, General Hospital, 444 Beds Ambulatory care, Long term care (nursing homes)	There were 215 high severity order checks in 2001 (0.5% of orders) and 908 in 2006 (2.5% of orders). Rate of overrides for drug-drug checks remained the same between 2001 and 2006 (88% vs. 87%, NS). Rate of overrides for drug-allergy order checks increased significantly from 2001 to 2006 (69% vs. 81%, RRR -17%, p<0.005). Override rates remain high and drug-allergy override rates increased.

Evidence Table 12. KQ1: adverse effects measured for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	HIT studied Integrated systems	Settings	Results
Patterson (2002)[355] Design: Qualitative N = 33 nurses--7 before BCMA and 26 after Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**Barcoding-medication administering** Integrated EHR/EMR system	Acute care/tertiary, Other specialty hospital (rehab, oncology) 784 in the 4 settings Beds Long term care (nursing homes)	6 unanticipated side effects were noted: confusion by automated removal of medications by BCMA, degraded coordination between nurses and physicians, dropping activities to reduce workload during busy periods. Increased prioritization of monitored activities during goal conflicts, decreased ability to deviate from routine sequences. To reduce workload, wristbands were not scanned and medication scanning was delayed.
Raebel (2007)[131] Design: RCT N = 11,100 women Implementation: 00/0000 Study Start: 01/2003 Study End: 04/2003	Prescribing	**CDSS/CDS/CCDS/reminders** Integrated Hospital information system, Pharmacy	Ambulatory care, HMO pharmacy	Although the study intervention was successful at decreasing the proportion of pregnant women with contraindicated drug dispensings, the study intervention was stopped after 4 of the planned 12 months. The 2 predominant factors contributing to the decision to end the intervention were the false-positive alerts resulting from misidentification of medications as contraindicated in pregnancy by the pharmacy information system and misidentification of pregnancy related to delayed transfer of diagnosis information.
Santell (2009)[375] Design: Observational study N = 90,876 potential errors Implementation: 00/1998 Study Start: 07/2001 Study End: 12/2005	Administering, Dispensing, Monitoring including patient adherence and compliance, Prescribing, Transmission, order communication	**CPOE/POE system, Medication-error reporting system**	Acute care/tertiary, Academic	The analysis of the national database focused on errors by non-prescribers resulting from CPOE. Errors generally occurred during dispensing (50.9%) and transcribing or documenting (42.5%). Errors tended to be improper dose or quantity (32.5%), omissions (22.2%), or unauthorized/wrong drug (14.35). Causes of errors included performance deficits (59.1%), inaccurate transcriptions (30.0%), procedure or protocol not followed (21.7%), documentation (19.5) and communication (18.3%). 62.2% of errors did not reach the patient. Fairly similar patterns were observed at University of Pittsburgh Medical Center.

Evidence Table 12. KQ1: adverse effects measured for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT studied** Integrated systems	Settings	Results
Shulman (2005)[150] Design: Time series N = 3,465 prescriptions over 4 time points Implementation: 04/2002 Study Start: 09/2001 Study End: 12/2002	Prescribing	**CPOE/POE system** Integrated Hospital information system	Critical care units (CCU, ICU, NICU) 22 (in the ICU) Beds Academic	Three intercepted errors with CPOE could have caused permanent harm or death if they had been administered as prescribed. These intercepted errors were not administered to the patient because either the pharmacist intercepted the prescription before administration or the nurse recognized the error.
Singh (2009)[376] Design: Cross-sectional N = 997 prescriptions Implementation: 00/1998 Study Start: 10/2007 Study End: 01/2008	Prescribing	**CPOE/POE system** Integrated CDSS/CDS/CCDS/reminders EHR/EMR system, Pharmacy	Acute care/tertiary, Pharmacy, Inpatient hospital based	Of 55,992 new prescriptions, 532 (0.95%) were reported to contain inconsistent communication (control prescriptions = 465), a rate comparable to that obtained from the unreported group. Drug dosage was the most common inconsistent element among both groups. Certain medications were more likely associated with errors, as was the inpatient setting (OR 3.30; 95% CI 2.18 to 5.00) and surgical subspecialty (OR 2.45; 95% CI 1.57 to 3.82). About 20% of errors could have resulted in moderate to severe harm, for which significant independent predictors were found. Despite standardization of data entry, inconsistent communication in CPOE poses a significant risk to safety.
Spencer (2005)[156] Design: Before-after N = 5,063 medication errors Implementation: 10/2002 Study Start: 01/2002 Study End: 05/2003	Prescribing	**CPOE/POE system** Integrated	Acute care/tertiary, 688 Beds Academic	A total of 23 reported errors were attributable to errors in computerized order entry after implementation of CPOE. Of these, 6 occurred during the calendar month when CPOE was implemented on the given unit and are therefore not accounted for in Table 3. All of these errors were classified as minor, with 14 (61%) constituting only potential errors. Twenty-one errors in computerized order entry (91%) were of severity category 1 or lower.

Evidence Table 12. KQ1: adverse effects measured for all technologies assisting all phases of medication management (continued)

Article Information	MM Phase(s)	**HIT studied** Integrated systems	Settings	Results
Vogelsmeier (2008)[362] Design: Qualitative N = 88 nursing home staff Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Administering	**e-Medication administration system (e-MAR, e-TAR)** Integrated EHR/EMR system	Long term care (nursing homes	WA presented in two distinct patterns: WA related to blocks introduced by technology and WA related to organizational processes that had not been reengineered to integrate effectively with the implementation of technology. WA resulted as nursing home staff attempted to individually problem solve how to overcome a work flow block rather than seeking to identify and understand the underlying cause of the work flow block. WA frequently circumvented the built in security features of the system.
Wentzer (2007)[366] Design: Qualitative N = 6 clinicians(2 physicians and 4 nurses) Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Prescribing	**CPOE/POE system** Integrated EHR/EMR system	Acute care/tertiary	The study started with 3 relations (physician and patient interacting, physician and nurse coordination work, and the patients further route and medication path). Themes centered on transformation of the prescription and drug order during physician rounds, transformation of the drug order and dispensing with the CPOE system (user rights, inflexibilities and displacements with the use of CPOE, going back to the paper system, unified and inflexible CPOE medication model), transformation of continuing medication with the system (discharge, withdrawal or discontinuous patient routes, and new tasks and demands on the clinicians with the CPOE system).
Zhan (2006)[181] Design: Mixed methods N = 138,922 number of errors/100000 doses Implementation: 00/0000 Study Start: 01/2003 Study End: 12/2003	Prescribing	**CPOE/POE system**	Unspecified Hospital	There were 7,029 CPOE related errors reported from May to December 2003. Most were potential errors, about 4.7 reached patients, 0.1% inflicted temporary harm. Error types, causes and contributing factors were further described.

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality

PICOM^	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
An RCT of hospitalized patients with coronary artery diseases. To asses whether a computerized alert identifying patients with elevated troponin I levels to pharmacists who mediated academic detailing was effective in increasing adherence to secondary prevention guidelines for coronary artery disease. 895 patients were considered eligible for the study and 216 discharge physicians were involved.	Bailey (2007)[7] Design: RCT N = 853 patients Implementation: 00/0000 Study Start: 02/2000 Study End: 05/2001	Acute care/ tertiary	Academic	16 months	3

^PICOM = description of patient, intervention, comparator, outcome and method

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: AMT = Antimicrobial Management Team; ATP III = Third Adult Treatment Panel; BMD = Bone Mineral Density; BP = Blood Pressure; CAD = Coronary Artery Disease; CCU = Critical Care Unit; CDS = Clinical / Computerized Decision Support; CDSS = Clinical Decision Support System; CIS = Clinical Information System; COPD = Chronic Obstructive Pulmonary Disease; CPOE = Computerized Provider Order Entry; CRS = Computer Reminder System; DCGP = Dutch College of General Practitioners; DHCP = Decentralized Hospital Computer System; DMA = Disease Management Application; DS = Decision Support; DSS = Decision Support System; DVT = Deep Vein Thrombosis; ED = Emergency Department; HER = Electronic Health Record; EMR = Electronic Medical Records; FEV1 = Forced Expiratory Volume in the first second; FU = Followup; GINA = Global Initiative for Asthma; GMC = General Medical Clinic; GPs = General Practitioners; HbA1c = Glycated hemoglobin; HCP = Health Care Provider; HF = Heart Failure; HIV = Human Immunodeficiency Virus; HMO = Health Maintenance Organization; ICU = Intensive Care Unit; IHD = Ischemic Heart Disease; JNC-7 = Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; LDL = Lowdensity Lipoprotein; MDI = Microbiologically Documented Infections; N = Sample Size; NAEP = National Asthma Education Program; NICU = Neonatal Intensive Care Unit; NSAID = Nonsteroidal anti-inflammatory drug; OA = Oral Anticoagulant; PCC = Pediatric Care Center; PE = Pulmonary Embolism; PEF = Peak Expiratory Flow; PICOM = description of patient, intervention, comparator, outcome and method; POC = Point of Care; PRISM = Prescription in Ischaemic Stroke Management; PWS = Physician Workstation; RAMQ = Régie de l'assurance maladie du Québec; RCT = Randomized Controlled Trial; RRR = Relative Risk Reduction; SADC = System of Clinical Decision Support; SGRQ = St. Georges Respiratory Questionnaire; SOC = Standards of Care; SYW = show your work; TIA = Transient Ischemic Attack; USFDA = United States Food and Drug Administration; VA = Veterans Affair; VTE = Venous thromboembolism

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A prospective cluster-randomized trial was conducted in 12 primary care sites within the Children's Hospital of Philadelphia over a 1-year period. Practices were stratified for analysis according to whether the site was urban or suburban. A clinical decision support (CDS) embedded in an electronic health record (EHR) to improve clinician adherence to the NAEPP guidelines for asthma management was assessed in the intervention group. Control group had passive access to the same asthma management tools. Proportion of children with persistent asthma with at least 1 prescription for a controller medication in each time period; with persistent asthma with an up-to-date asthma care plan filed in the previous year; with documentation of spirometry performed were measured and compared. To balance practices with previous asthma education or involvement in resident teaching and patient characteristics, the practices were stratified according to site (urban UP or suburban SP) in blocks of 2. Therefore, 4 clusters of practices were compared in the analysis: 2 control UPs, 2 intervention UPs, 4 control SPs, and 4 intervention SPs. 19,450 children with asthma were included in the analysis.	Bell (2010)[11] Design: RCT N = 19,450 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 04/2008	NA	Ambulatory care Academic	12 months	4
An RCT in a university-based resident clinic on 59 internal medicine residents using standardized patients to assess the impact of a PDA-based CDSS for safe prescribing of NSAIDs. Prescriptions were judged as safe or unsafe. The main outcome measure was the differential change in unsafe prescribing of NSAIDs for the intervention versus the control group. Both groups received PDAs with DS rule sets, the intervention group receiving the NSAID set following a 6 month baseline assessment period.	Berner (2006)[12] Design: RCT N = 59 internal medicine residents Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care Academic	8 months	5

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
29 practices received the Third Adult Treatment Panel (ATP III) intervention and 32 receiving an alternative intervention focused on the Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7). The ATP III providers received a personal digital assistant providing the Framingham risk scores and ATP III–recommended treatment. All practices received copies of each clinical practice guideline, an introductory lecture, 1 performance feedback report, and 4 visits for intervention specific academic detailing. Data were abstracted at 61 practices from random samples of medical records of patients treated from June 1 2001, through May 31 2003 (baseline), and from May 1 2004, through April 30 2006 (follow-up). Effect on screening of lipid levels and appropriate management of lipid level test results were compared for 8,878 patients.	Bertoni (2009)[14] Design: RCT N = 8,878 patients Implementation: 00/0000 Study Start: 06/2001 Study End: 04/2006	NA	Ambulatory care	24 months	5
This RCT was to determine the effectiveness of three different prompts, 92 providers from 5 intervention primary care clinics were randomized to receive one of the three prompts and compared to 6 control clinics. Prompts included letters sent to patients about lipid therapy prior to their scheduled visit, a progress note message within the computerized patient record system notifications area and a computerized reminder screen within the specific patient chart during the patient's visit.	Bloomfield (2005)[15] Design: RCT N = 9,105 patients Implementation: 04/2002 Study Start: 10/2001 Study End: 10/2003	NA	Ambulatory care	12 months	2
A RCT in a pediatric care clinic of a point of care (POC) evidenced based message system with real time evidence to providers based on their prescribing practice for otitis media. Compared change in prescribing behavior of the intervention and control providers before and after implementation of the message pop-up. Prescribing behavior change was measured as the change in the proportion of prescriptions of antibiotics for less than 10 days duration from baseline. The study included 38 providers and 1,339 visits for acute otitis media.	Christakis (2001)[23] Design: RCT N = 38 providers Implementation: 00/0000 Study Start: 03/0000 Study End: 05/0000	NA	Ambulatory care Academic	8 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
This study was conducted to assess the impact in effectiveness and direct costs of a CDSS to assist physicians in the implementation of an adapted version of the recommendations of the European Society of Cardiology and other societies for Hypercholesterolemia Management (ESCHM). 2,221 patients were included from 42 practices in the cluster-randomized controlled trial comparing lipid profile, cardiovascular risk, use of lipid lowering drugs and costs.	Cobos (2005)[25] Design: RCT N = 2,221 patients Implementation: 04/2000 Study Start: 04/2000 Study End: 05/2002	NA	Ambulatory care	12 months	5
This was a cluster randomized clinical trial of provider behavior change. Prescribing behavior was measured in both the intervention and control groups before and after the introduction in the intervention group of a pop-up DSS alert providing evidence at the time of electronic prescribing. The conditions included in the intervention were acute otitis media, allergic rhinitis, sinusitis, constipation, pharyngitis, croup, urticaria, and bronchiolitis. In this study the unit of intervention was the provider. This study was conducted at two clinical sites. One was the Pediatric Care Center (n = 36 Health Care Providers), an outpatient teaching clinic for pediatric residents and a clinical practice site staffed by full-time pediatric providers. The other site was Skagit Pediatrics (n = 8 HCP), a primary care pediatric clinic serving a rural and semi-urban patient mix.	Davis (2007)[30] Design: RCT N = 44 health care providers Implementation: 11/1999 Study Start: 11/1999 Study End: 12/2003	NA	Ambulatory care Academic	18 to 50 months	6
To examine whether a computerized reminder system operating in multiple Veterans Affairs (VA) ambulatory care clinics improves resident physician compliance with standards of ambulatory care an RCT was undertaken. A total of 275 resident physicians at 12 VA medical centers were randomly assigned in firms or half-day clinic blocks to either a reminder group (n=132) or a control group (n=143). During a 17-month study period (January 31 1995 to June 30 1996), the residents cared for 12,989 unique patients for whom at least 1 of the studied standards of care (SOC) was applicable. Compliance with 13 SOC, were compared, 5 relating to medication management. The reminders were presented to intervention residents in the electronic chart in the examination room and a paper copy was put into the patient paper chart with the standard health summaries printed at each clinic visit. Control residents continued to receive the health summaries.	Demakis (2000)[213] Design: RCT N = 12,989 patients Implementation: 00/0000 Study Start: 01/1995 Study End: 06/1996	NA	Ambulatory care Academic	17 months	2

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
An RCT of all hospitalized patients during an 18-month period, to determine the effects of computerized reminders vs. no reminders on the rates of compliance with 4 preventative therapies; national guidelines for the use of pneumococcal vaccination, influenza vaccination, prophylactic enteric-coated aspirin for cardiovascular disease and prophylactic subcutaneous heparin to reduce the risk of thromboembolic events. The reminder system identified 3,416 patients (53.6%) as eligible for preventive measures.	Dexter (2001)[33] Design: RCT N = 3,416 patients Implementation: 00/0000 Study Start: 05/1997 Study End: 10/1998	General Hospital	Academic	18 months	4
To determine the effects of computerized physician standing orders compared with physician reminders on inpatient vaccination rates. Randomized trial of 3,777 general medicine patients discharged from 1 of 6 study wards during a 14-month period (November 1, 1998, through December 31, 1999) composed of 2 overlapping influenza seasons at an urban public teaching hospital. The intervention was the use of the hospital CPOE to either, for patients with standing orders, automatically produce vaccine orders directed to nurses at the time of patient discharge or, for patients with reminders, provide reminders to physicians that included vaccine orders during routine order entry sessions. The main outcome measure was vaccine administration.	Dexter (2004)[34] Design: RCT N = 1,677 patients Implementation: 11/1998 Study Start: 11/1998 Study End: 12/1999	General Hospital	Academic	3 days	4
A two-stage, random-selection study to develop and evaluate appropriate empiric antibiotics in tertiary care Hospital in Salt Lake City. Antibiotics suggested by the antibiotic consultant with 482 associated antibiotic susceptibility results and the concurrent antibiotics ordered by physicians were compared. The antibiotics ordered by randomized physicians were then compared between crossover periods of antibiotic consultant use.	Evans (1994)[39] Design: RCT N = 482 cultures Implementation: 00/000 Study Start: 07/1990 Study End: 01/1991	Acute care/ tertiary		9 months	2

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
This study evaluated interventions to improve laboratory monitoring at initiation of medication therapy. This cluster-randomized trial compared 3 interventions to usual care for 10 medications in 15 primary care clinics in a health maintenance organization with an electronic medical record system. Eligible patients, identified from electronic databases, had not received recommended laboratory monitoring within 5 days after new dispensing of a study medication. Interventions were an electronic medical record reminder to the prescribing health care professional, an automated voice message to the patient, and a pharmacy team outreach to the patient. Primary outcome was completion of all recommended baseline laboratory monitoring. 961 patients were included. Direct HMO costs were calculated (repeat testing, extra visits, intervention costs) using trial data and external sources.	Feldstein (2006)[215] Smith (2009)[216] Design: RCT N = 961 patients Implementation: 09/2004 Study Start: 09/2003 Study End: 01/2005	NA	Ambulatory care	4.5 months	7
An interrupted time series RCT was performed at 15 primary care clinics including 239 primary care providers and 9,910 patients taking warfarin. EMR alerts and group academic detailing were implemented to reduce the co-prescribing of warfarin and 5 interacting medications. Physicians could continue with the prescription, change the medication or select from options presented. The academic detailing included group educational session. The unit of randomization was the primary care clinic; the unit of intervention was the primary care provider; and the unit of analysis was time (study month). The primary outcome was the "interacting prescription rate," defined as the number of co-prescriptions of warfarin-interacting medications per 10,000 warfarin users per month. The effect of the interventions was evaluated using an interrupted time series design, analyzed with segmented regression models that control for pre-intervention trends.	Feldstein (2006)[40] Design: RCT N = 9,910 patients with 239 care providers in 15 primary care clinics Implementation: 12/2002 Study Start: 01/2000 Study End: 08/2004	NA	Ambulatory care	12 months	6
A 3-arm RCT of women needing osteoporosis care after a fracture. Women were allocated to usual care, reminder letters and EMR notes alone or reminders plus patient education and related information. Outcomes were obtaining BMD measurement or starting medication or both by the end of the 6-month trial. Care recommendations were based on guidelines.	Feldstein (2006)[41] Design: RCT N = 311 women Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	6 months	5

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
Cluster RCT of 22 long stay units in long term care settings was done to determine if CPOE with CDSS improved prescribing for antidepressants in patients with renal insufficiency (94 alerts related to 62 drugs). Alerts centered on maximum daily doses or frequencies, medications to be avoided and missing values for creatinine clearance. Outcomes were the proportion of alerts that lead to appropriate drug orders and rates of inappropriate drugs avoided. 10 physicians and 833 patients (213,967 patient days) were studied.	Field (2009)[42] Design: RCT N = 833 patients (10 physicians and 213,967 patient days) Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Long term care	12 months	5
This study was conducted at the first 20 practices in the Children's Hospital of Philadelphia Pediatric Research Consortium that implemented the ambulatory EHR EpicCare. A prospective, 20-primary care site, cluster-randomized, decision-support trial between October 1, 2006, and March 31 2007 was conducted. At intervention sites, electronic health record-based clinical alerts for influenza vaccine appeared at all office visits for children between 5 and 19 years of age with asthma who were due for vaccine. For each site, captured opportunities for influenza vaccination and influenza vaccination rates were compared with those for the same period in the previous year.	Fiks (2009)[43] Design: RCT N = 22,586 patients Implementation: 00/0000 Study Start: 10/2006 Study End: 05/2007	NA	Ambulatory care Academic	6 months	3
A RCT among general practitioners (GPs) in Italy. An electronic reminder was put in a standard software system for patient data management to remind GPs to prescribe anti-platelet drugs in diabetic patients who were at high risk of developing cardiovascular disease. A letter summarizing the beneficial effects of anti-platelet drugs in such type of patients were given to both the intervention and the control group. Patients were classified into 3 risk groups. Data for patients receiving anti-platelet drug treatment in the control and the intervention group at the baseline and at the follow-up among the three risk groups were analyzed. 300 GPs and 15,343 high-risk diabetic patients were involved in the study.	Filippi (2003)[44] Design: RCT N = 15,343 patients Implementation: 00/0000 Study Start: 05/2001 Study End: 11/2001	NA	Ambulatory care	7 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A clustered RCT was conducted at general practices in Norway. the Winmed electronic medical record system was used by the practices. Computer based DS and reminders were implemented based on evidence based guidelines for urinary tract infection or sore throat. Changes in rates of ordering of antibiotics were compared between the intervention and the control group for sore throat and urinary tract infection.	Flottorp, (2002)[47] Design: RCT N = 26,826 Consultation Implementation: 00/0000 Study Start: 01/2000 Study End: 01/2001	NA	Ambulatory care	4.5 months	2
To evaluate the effectiveness of computerized prescribing alerts, with or without physician-led group educational sessions, compared to usual care, to reduce the prescribing of heavily marketed hypnotic medications. 14 internal medicine practice sites were randomly allocated to receive usual care, computerized prescribing alerts alone, or alerts plus group educational sessions. Proportion of heavily marketed hypnotics prescribed before and after the implementation of computerized alerts and educational sessions were compared. Usual care included an alert of the copayment tier of the medication; the computer alerts recommended generic brands; group education sessions were held at 4 sites and an educational information packet was sent to all internal medicine clinicians from those sites.	Fortuna (2009)[48] Design: RCT N = 257 clinicians Implementation: 00/1997 Study Start: 03/2006 Study End: 03/2008	NA	Ambulatory care Academic	12 months	6
An RCT was conducted to determine whether the combination of a computer- generated and written reminder system provided during patient visits could increase patient receipt of aspirin, beta-blockers, and cholesterol-lowering agents in patients with CAD. Physicians were randomly assigned to either a control group or an intervention group. The intervention group received computerized and written reminders for their patients with coronary artery disease, whereas those assigned to the control group were not contacted. Proportion of patients who had an active prescription for aspirin; the proportion of patients with myocardial infarction who had an active beta-blocker prescription; the proportion of patients receiving a cholesterol-lowering agent; and the proportion of patients with a level of low-density lipoprotein (LDL) cholesterol in the desired range (< 100 mg/dL) were evaluated and compared between the control and intervention group. 730 patients and 63 physicians were involved in the study. Sample size adjusted for clustering.	Frances (2001)[49] Design: RCT N = 63 physicians and 730 patients Implementation: 00/0000 Study Start: 03/1997 Study End: 06/1997	NA	Ambulatory care	12 months	3

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A quasi-randomized trial within a primary clinic with 10 physicians looking at the effectiveness of in consultation computer reminders about 12 outstanding preventive care activities. Patients were the unit of randomization; 5,118 in the intervention group and 5,389 in the control group. Reminders appeared on the medical record screen and pertained to 4 vaccine reminders and 8 non-medication related preventive care recommendations.	Frank (2004)[50] Design: RCT N = 10,507 patients Implementation: 00/0000 Study Start: 03/1998 Study End: 03/1999	NA	Ambulatory care	12 months	3
This cluster RCT is a complex set of multifaceted interventions to improve care and an economic evaluation (cost minimization and cost effectiveness analysis). The project sought to study passive vs. tailored interventions to improve management of cardiovascular risk factors according to guideline based care. The control group was usual care and the intervention group received an educational outreach visit by a pharmacist with audit and feedback, and computerized reminders linked to the EMR. The main outcomes were first time prescriptions for hypertension where thiazides were prescribed, patients assessed for cardiovascular risk before prescribing anti hypertensive or cholesterol-lowering agents, and patients treated for hypertension or high levels of cholesterol for 3 or more months who had achieved recommended treatment goals. Cost minimization framework was adopted, costs of intervention were set against reduced treatment costs. Net annual cost and cost per additional patient being started on thiazides.	Fretheim (2006)[56] Fretheim (2006)[57] Design: RCT N = 139 practices and 501 physicians Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	12 months	5

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A cluster RCT was conducted in a national network of primary care offices that use the Centricity EMR. The study examined the impact of an EMR-based intervention for lipid management incorporating nationally recognized guidelines (specifically the ATP-III guidelines) into the EMR. Prompts were generated at the point of care and included 3 pages: screening, assessment and management information. The 3 main outcome variables compared: proportion of patients tested adequately for hyperlipidemia, the proportion of patients whose most recent low-density lipoprotein cholesterol (LDL-C) was at goal (<100 for high-risk patients, <130 for moderate-risk patients, and <160 for low-risk patients), and the proportion of high-risk patients with an LDLC >=130 who were prescribed lipid-lowering medications. Univariate (McNemar) and multivariate analysis (accounting for clustering) were performed. Results were presented with patients stratified by risk groups. A total of 105 physicians from 25 practices and 64,150 patients were included in the study.	Gill (2009)[61] Design: RCT N = 64,150 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 10/2006	NA	ambulatory care	12 months	3
A cluster RCT was conducted in primary care clinics in Israel comparing the intervention with standard care. The pilot study was to evaluate the feasibility of a CDSS mainly on secondary prevention measure outcomes in patients with CAD and dyslipidemia followed by primary care physicians. In the intervention arm, a written reminder with patient tailored recommendations was mailed to the primary care physicians and nurses. The recommendations were based on the last 6 months data for new patients, and 4 months for patients in periodic follow-up. Rate of adequate monitoring, positive treatment trend, overall uptitration rate in patients with LDL = 110 mg/dl and LDL Levels were compared in between the control and intervention arms. 7,448 patients were included in the study. The intervention clinics included 204 general practitioners and 396 nurses.	Gilutz (2009)[62] Design: RCT N = 7,448 patients from 56 control and 56 intervention clinics Implementation: 00/0000 Study Start: 01/2000 Study End: 12/2003	NA	ambulatory care Academic	21 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A cluster randomized trail was conducted to assess the value of a discharge software application of CPOE in a 730-bed, tertiary care teaching hospital in central Illinois. The study compared the benefits of a CPOE with discharge software with usual handwritten discharge care for patients at high risk for repeat admission. Software features included required fields, pick lists, standard drug doses, alerts, reminders, and online reference information. The software prompted the discharging physician to enter pending tests and order tests after discharge. Hospital physicians used the software on the day of discharge and automatically generated 4 discharge documents. Proportion of patients readmitted at least once within 6 months of index hospitalization, emergency visits within 6 months and adverse events within 1 month were measured and compared. Perceptions about discharge from the perspective of patients, outpatient physicians and hospital physicians were examined by interview and survey. 631 patients, 70 hospital physicians and 496 outpatients physicians were involved in the study.	Graumlich (2009)[237] Graumlich (2009)[238] Design: RCT N = 631 patients Implementation: 00/0000 Study Start: 11/2004 Study End: 01/2007	Acute care/ tertiary	Academic	6 months	2
A cluster-randomized controlled trial involving 1,118 long-term care residents at 29 resident care units in 2 facilities. The resident care units, each with computerized provider order entry, were randomized to having a clinical DS system (intervention units) or not (control units). Alerts in the form of warning messages appeared in the CPOE of intervention units. The number of adverse drug events, severity of events, and whether the events were preventable were measured in this study.	Gurwitz (2008)[302] Design: RCT N = 29 units randomized containing 1,118 patients Implementation: 00/0000 Study Start: 00/2000 Study End: 00/2000	NA	Long term care	6.3 Months	5

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
RCT at general practice in Sør- and Nord-Trøndelag counties in Norway. The CDSS with clinical guidelines for treatment of hypertension was implemented as an external computer program, accessible from the main computerized record system. Health centers in intervention group had the CDSS. The CDSS guided the doctors in diagnostics, history and additional tests taking, physical examination, and treatments. Both doctors and assistants could use the CDSS, however, some parts of the CDSS where reserved for the doctors only. Doctors in control group followed their ordinary procedures for patients with hypertension. Group differences in level of systolic and diastolic BP, serum cholesterol, body mass index, and risk score for myocardial hypertension in general practice by use of a computer-based clinical infarction were calculated and compared. 53 doctors participated.	Hetlevik (1999)[304] Design: RCT N = 1,998 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	18 months	4
A cluster RCT of 2,027 racially diverse adults receiving hypertension care in 14 primary care practices. To examine the effectiveness of computerized DS (CDS) designed to improve hypertension care and outcomes. Intervention arm was 18 mo of the physicians receiving CDS for each hypertensive patient compared to usual care without computerized support (control). Assessed prescribing of guideline are commended drug therapy and levels of BP control for patients and examined if the effects of the intervention differed by patients' race/ethnicity using interaction terms.	Hicks (2007)[67] Design: RCT N = 1,422 patients Implementation: 00/0000 Study Start: 07/2003 Study End: 02/2005	NA	Ambulatory care Academic	18 months	4
Randomized trial of 511 adult patients with type 2 diabetes receiving either usual care or intervention involving shared access by patient and primary care provider to a Web-based diabetes tracker. The tracker interfaced with the providers EMR and a phone reminder system which sent monthly reminders for medications, labs or doctor visits. The primary outcome measure was a process composite score.	Holbrook (2009)[367] Design: RCT N = 511 patients Implementation: 00/0000 Study Start: 00/2002 Study End: 12/2003	NA	Ambulatory care Home	6 months	7

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
Cross-over randomized trial of 6 type 1 diabetic patients using a hand held insulin regimen optimizer. Patients had a 1 week run-in period using the tool as an electronic log book for their glucose measures. They then underwent 2 consecutive 3 week study periods, with and without the computerized insulin dose advice switched on. The clinical DS was suggesting optimum insulin dose based on patients entered data. Blood glucose was the primary outcome.	Holman (1996)[306] Design: RCT N = 6 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Home	1.2 months	3
An RCT was conducted to demonstrate the potential effect of deploying a sentinel system that scans administrative claims information and clinical data to detect and mitigate errors in care and deviations from best medical practices. The study was performed among the commercially insured population of a university-affiliated managed care plan. The system relayed all triggered recommendations to intervention physicians (those for control group were deferred until the end of the study). Compliance with recommendations, hospital admissions and attendant cost were measured and compared between control and intervention groups. A total of 39,462 subjects were initially enrolled in the study. Charges were also compared.	Javitt (2005)[218] Design: RCT N = 39,462 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	12 months	6
A randomized trial of the effect of a DS tool designed to detect and help physicians from one HMO correct "missteps". Study group had "Care consideration" alerts given to the physicians (n =19,716) and the control group did not (n = 19,792). The DS tool used data from billing, lab and pharmacy to detect care considerations that fell into 3 recommendation categories: stop a drug, do a test, start a drug along a gradient of severity from sever, moderate, least severe. Severe alerts were phoned in to the medical director who called the physician, moderate and least severe alerts were processed through HMO nursing staff and passed on at their discretion. Alert resolution rates and costs were assessed.	Javitt (2008)[75] Design: RCT N = 39.508 patients Implementation: 01/2001 Study Start: 01/2001 Study End: 12/2001	NA	Ambulatory care	12 months	6

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A randomized controlled double-blinded study was conducted at 3 pharmacies affiliated with an academic center to assess the impact of a system called Show Your Work (SYW) on pharmacy callbacks. The SYW system automatically annotates e-prescriptions by appending alerts and override comments to e-Prescriptions generated by an e-Prescribing system. This process adds notes below each medication order to describe any DS warnings that were displayed at the time of prescribing, any overrides to drug alerts provided by the prescriber during the session, and any dose calculations for pediatric prescriptions. Prescriptions were either printed or faxed to pharmacies throughout Tennessee. Pharmacy callback rates were measured and compared between those with “SYW off” and “SYW on” at 3 affiliated pharmacies; pharmacists’ perceptions of the system were also studied using a qualitative and quantitative survey.	Johnson (2010)[76] Design: RCT N = 3,285 patients Implementation: 00/0000 Study Start: 04/2007 Study End: 08/2007	NA	Pharmacies Academic	4 months	7
A randomized trial assessing whether off-line data analysis, instead of event monitoring, was a viable method for initiating a clinical quality alert. A cohort of patients eligible for an alert was identified by off-line data analysis and a flag was set in their ambulatory Electronic Medical Records. One hundred clinicians were randomly assigned either to a control group or to a group that received the alert when viewing the electronic medical record of eligible patients. A low dose aspirin therapy alert was selected to test the feasibility. Comparisons were made on the proportion of patients no longer eligible for alert at end of month.	Krall (2004)[89] Design: RCT N = 1,076 patients Implementation: 00/1994 Study Start: 01/2000 Study End: 02/2000	Acute care/ tertiary		1 month	3
An RCT at the Brigham and Women’s Hospital in Boston, MA. A computer program linked to the patient database identified consecutive hospitalized patients at increased risk of VTE using 8 common risk factors identified from the EHR. Physicians in the intervention group were alerted of a patient’s risk of VTE - they were required to acknowledge the alert and then withhold or order prophylaxis. Number of patients with DVT or PE and death were compared between at 90 days. Of the 2,506 patients studied, 2,361 were followed up beyond the index hospitalization.	Kucher (2005)[90] Design: RCT N = 2,506 patients Implementation: 00/0000 Study Start: 09/2000 Study End: 01/2004	Acute care/ tertiary	Academic	3 months	6

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
Cluster RCT of 32 Dutch General Practices. All had EMRs and half were given Asthma Critic which suggested actions for patients with asthma. Reminders were based on the Dutch College of General Practitioners asthma and COPD treatment guidelines. Outcomes were 3 patient (contact frequency, peak-flow, FEV1) and 5 prescribing (cromoglycate, deptropine, antihistamines, and oral bronchodilators).	Kuilboer (2006)[219] Design: RCT N = 32 primary care practices (78,926 patients of whom 9,798 had asthma or related symptoms) Implementation: 07/1998 Study Start: 07/1998 Study End: 05/1999	NA	Ambulatory care	5 months	4
This RCT recruited physicians within an academic primary care practice who used EHR for majority of visits, then randomized adults (without their consent) identified by EHR review as having CAD or CAD risks and high levels of LDL cholesterol. Physicians received 1 email per intervention patient facilitating statin prescription and monitoring. Outcomes were changes in statin prescription, and cholesterol levels across times during the 1-year trial.	Lester (2005)[95] Design: RCT N = 235 patients and 14 clinicians Implementation: 07/2003 Study Start: 07/2003 Study End: 07/2004	NA	Ambulatory care Academic	12 months	6
A cluster RCT was conducted at 27 primary care clinics (matched pairs by size for all but 1 practice) associated with Partners HealthCare that uses internally developed full featured EHR called LMR. ARI Smart Form is an LMR module that is launched from the notes page of the EHR only when a physician triggers the module. Among many features, it provides DS in antibiotic prescribing, and antibiotic choices generation of diagnostic appropriate order set. Rate of antibiotic prescribing to patients with ARI (acute respiratory infection)were compared between the control and intervention groups. 111,820 patients and 443 clinicians were involved in the study. Analysis was adjusted for clustering.	Linder (2009)[97] Design: RCT N = 111,820 patients Implementation: 00/0000 Study Start: 11/2005 Study End: 05/2006	NA	Ambulatory care	6 months	4
A randomized, controlled trial of 22 primary care clinics using either the existing system of no lab monitoring alerts or noninterruptive, on-screen recommendations for baseline laboratory tests when prescribing new medications. Prescribers did not need to respond to the alert. Differences in the proportion of visits resulting in lab testing within 14 days were analyzed. The clinics included 366 physicians, 2,765 patients and 3,673 events requiring lab monitoring test orders.	Lo (2009)[220] Design: RCT N = 3,673 potential alert trigger events (prescriptions) Implementation: 00/2000 Study Start: 07/2003 Study End: 01/2004	NA	Ambulatory care Academic	0.5 months	3

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
Cluster-RCT with an incomplete block design in the south of the Netherlands to assess the effect on drug-prescribing behavior of implementing prescribing guidelines by means of a reactive computer reminder system (CRS). 25 GPs (7 GP practices) received reminders about antibiotics and asthma/COPD prescriptions, 28 GPs (7 GP practices) received reminders about cholesterol prescriptions. Prescription guidelines were integrated into the computerized GP information system. Both performance indicators and prescription volumes were calculated as the main outcome measures.	Martens (2007)[101] Design: RCT N = 77 physicians (GPs) Implementation: 04/2004 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	12 months	4
An RCT trial of electronic clinical reminders for primary care physicians to improve lab monitoring for maintenance therapy of potassium, creatinine, liver function, thyroid function and therapeutic drug levels. Reminders were generated if patients were on a target medication for at least 365 days with no record of a relevant lab test within the previous 365 days. Compliance rates were compared with usual care.	Matheny (2008)[221] Design: RCT N = 2,507 outpatient visits in 1,922 geriatric patients and 303 primary care physicians Implementation: 00/0000 Study Start: 01/2004 Study End: 06/2004	NA	Ambulatory care	6 months	3
Prospective randomized study of diabetic patients at an adult diabetes clinic at Wishard Memorial Hospital to assess the impact of computer reminders to clinicians about a) out-of-date test results and b) specific changes in therapeutics. Each patient visit (n = 794 visits by 257 patients) was regarded as an independent event during the 8 month trial. Computer reminders consisted of paper reports printed for each patient encounter.	McDonald (1976)[222] Design: RCT N = 601 patient visits by 226 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care Academic	8 months	1
An RCT in Maryland design to test if AMTs improve hospitalized patient care with respect to costs, mortality, length of stay, or time spent managing antimicrobial utilization. Patients were randomized to DS (DS) for the AMT or usual care in all wards according to their chart number (odd/even). The reminder system was within the pharmacy information system. No EMR or CPOE were available.	McGregor (2006)[105] Design: RCT N = 4,507 patients Implementation: 00/000 Study Start: 05/2004 Study End: 08/2004	Acute care/ tertiary	Academic	3 months	3

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
This study was intended to test effects of a web-based DS tool, the diabetes Disease Management Application (DMA), developed to improve evidence-based management of type 2 diabetes. A group RCT of 12 intervention and 14 control staff providers and 307 intervention and 291 control patients with type 2 diabetes was conducted in a hospital-based internal medicine clinic. Providers were randomly assigned from May 1998 through April 1999 to have access to the DMA (intervention) or not to have access (control). The web-based DMA is not an involuntary reminder system, but needs to be actively opened; it displays interactive patient-specific clinical data, treatment advice, and links to other web-based care resources. We compared patients in the intervention and control groups for changes in processes and outcomes of care from the year preceding the study through the year of the study by intention-to-treat analysis. Power analysis performed for change in HbA1c levels which is abstracted as the primary outcome.	Meigs (2003)[309] Design: RCT N = 598 patients Implementation: 05/1998 Study Start: 05/1997 Study End: 04/1999	NA	Ambulatory care	12 months	4
Cluster RCT of 27 general practices in Avon, U.K. which included 614 patients between 60 and 79 years with high BP. The trial was to investigate the effect of a computer based clinical DS system and a risk chart on absolute cardiovascular risk, BP, and prescribing of cardiovascular drugs in hypertensive patients. Interventions: Patients got CDSS system plus cardiovascular risk chart, cardiovascular risk chart alone, or usual care.	Montgomery (2000)[108] Design: RCT N = 552 patients Implementation: 00/0000 Study Start: 09/1996 Study End: 09/1998	NA	Ambulatory care	12 months	5

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
Randomized controlled trial with a 2 x 2 factorial design of physician and pharmacist CDSS alert interventions was conducted at a large, inner city, academic, internal medicine practice. The primary venues for this study were the general medicine practice and the Wishard Memorial Hospital outpatient pharmacy. The study assessed the effects of evidence-based treatment suggestions for hypertension made to physicians and pharmacists using a comprehensive electronic medical record system. Using data from patients' electronic medical records from Regenstrief medical records system, (RMRS) and data entered by physicians after patient visit. The computer-based ordering system generated care suggestions for both intervention and control groups; All hypertension care suggestions for intervention patients were displayed as "suggested orders" on physicians' workstations when they wrote orders after patient visits. For this study pharmacist intervention included the same care suggestions as generated for physicians and were displayed on the PIRS. There were 4 groups: control, physician intervention, pharmacy intervention and both interventions. QoL was the primary endpoint. 712 patients were included in the study.	Murray (2004)[310] Design: RCT N = 712 patients Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	NA	Ambulatory care Academic	12 months	5
To determine if computer reminders increase the provision of inpatient preventive care for 22 preventive care actions, 8 of which related to medication issues. Randomized, controlled trial on the general medicine inpatient service of an urban, university-affiliated public hospital. Study subjects were 78 house staff rotating on the 6 general medicine services. The intervention was reminders to physicians printed on daily rounds reports about preventive care for which their patients were eligible, and suggested orders for preventive care provided through the physicians' workstations. The preventive care guidelines were derived from the US Preventive Care Task Force recommendations. Compliance with preventive care guidelines and house staff attitudes toward providing preventive care to hospitalized patients were the main outcome measures. Reminders were generated for a total of 4,649 preventive care measures.	Overhage (1996)[117] Design: RCT N = 24 practice teams Implementation: 10/1991 Study Start: 10/1992 Study End: 03/1993	General Hospital	Academic	6 months	6

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A RCT to assess if automated, guideline-based reminders to physicians, provided on-screen as they wrote orders, could impact compliance rates with 87 corollary (associated monitoring) orders. During the 6-month trial, reminders about corollary orders were presented to 48 intervention physicians and withheld from 41 control physicians in a general medicine public teaching hospital. All physicians had access to the guidelines, intervention physicians received the onscreen reminders that they could easily accept, reject or modify; for control physicians the computer tracked the number of time corollary orders would have been triggered. Compliance rates were compared immediately (at the time of the trigger order), at 24 hours post trigger order and within hospital stay compliance rates. In all there were 7,394 trigger orders and 11,404 suggestions for corollary orders.	Overhage (1997)[118] Design: RCT N = 86 physicians on 6 services (services randomized) Implementation: 00/0000 Study Start: 10/1992 Study End: 04/1994	General Hospital	Academic	6 months	3
An RCT of 207 HMO primary care physicians who either received or did not receive drug laboratory monitoring alerts form within the CPOE system. The intervention group used the same CPOE and had the same electronic medication list as controls with additional information recommending specific lab monitoring for 25 select medications provided as nonintrusive reminders on the ordering screen. Compliance with guidelines for lab monitoring was compared between the groups, rates among the different drugs were also compared.	Palen (2006)[121] Design: RCT N = 26,586 (index dispensing) patients Implementation: 00/0000 Study Start: 11/2002 Study End: 10/2003	NA	Ambulatory care	12 months	3
Cohort study comparing TREAT's advice, CDSS to physician's treatment followed by a cluster RCT comparing wards using TREAT (intervention) versus antibiotic monitoring without TREAT (control). Patients had suspected harboring bacterial infections in 3 hospitals (Israel, Germany and Italy) 2,326 patients. The primary outcome, appropriate antibiotic treatment, was assessed among patients with MDI. Length of hospital stay, adverse events, mortality and antibiotic costs, including costs related to future antibiotic resistance, were compared for all patients.	Paul (2006)[124] Design: RCT N = 3,529 patients in the RCT and 1,203 in the cohort study Implementation: 00/0000 Study Start: 05/2004 Study End: 11/2004	Acute care/ tertiary	Academic	6 months	7

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
In a cluster-randomized design, 19 physicians caring for 334 eligible patients at least 40 years of age were randomized. All clinicians received computerized reminders through their EMR at office visits. Intervention physicians also received e-mails asking whether aspirin was indicated for each patient. If so, patients received a mailing and nurse telephone call addressing aspirin. The primary outcome was self reported regular aspirin use in 242 patients.	Persell (2008)[205] Design: RCT N = 242 Patients Implementation: 00/0000 Study Start: 10/2004 Study End: 03/2005	NA	Ambulatory care Academic	6 months	4
A randomized trial to determine physicians' response rates of guided dosing for hospitalized patients 65 and older. Designed to assess if a guided dosing system delivering advice to physicians about appropriate initial dosing for a minority of drug orders as well as discouraged prescription of contraindicated drugs affects their compliance with guidelines. Dosing is to reduce falls in the elderly. 9,111 study-related orders by 778 providers were entered for 2,981 patients.	Peterson (2007)[126] Design: RCT N = 9,111 medication orders Implementation: 00/0000 Study Start: 12/2005 Study End: 08/2006	Acute care/ tertiary, Critical care units, Emergency department	Academic	9 months	3
Multicenter, prospective, pragmatic, with randomization of groups (clusters) designed to determine the cost-effectiveness of a intervention to promote the recommendations of the Global Initiative for Asthma (GINA). Group of 10 pulmonologists and 10 primary care physicians (who recruited 98 and 100 patients with persistent asthma respectively) were randomized to intervention and control. The intervention consisted of providing physicians with a hand-held clinical decision support system (SADC) that offered recommendations based on the GINA PLUS nurse trainers to assist patients. Doctors in the control group had handheld but did not have the SADC or nurses. Effectiveness was determined by measuring the quality of life through the St. Georges Respiratory Questionnaire (SGRQ). Costs were calculated from the consumption of resources registration for 12 months and determined the cost effectiveness of intervention by an incremental analysis.	Plaza (2005)[280] Design: RCT N = 20 physicians+B44 Implementation: 03/2000 Study Start: 10/1999 Study End: 02/2001	NA	Ambulatory care	12.3 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A clustered RCT by Prescription in Ischaemic Stroke Management (PRISM) Study Group. Hospitals were randomized CDSS or control. Baseline clinical data were entered via an automated telephone data entry system as soon as possible after the hospital admission (inpatients) or clinic appointment (outpatients) of a study patient. The CDSS estimated individual acute stroke or TIA annual risks of recurrent ischaemic stroke, haemorrhagic stroke, myocardial infarction, other ischaemic vascular events and other haemorrhagic complications associated with each possible antiplatelet or anticoagulant therapy. Relative risk reduction (RRR) in ischaemic and haemorrhagic vascular events was compared. The information provided by the CDSS enabled informed prescribing decisions.	Prescription in Ischaemic Stroke Management (PRISM) Study Group (2003)[127] Design: RCT N = 1,640 Patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Unspecified Hospital		6 months	4
A non-blinded pilot RCT was conducted in Maryland to assess the impact on A1c of a cell phone based diabetes management software system used with web data analytics and therapy optimization tools. Study patients received a Bluetooth enable blood glucose meter, a cell phone and WellDoc's proprietary diabetes management software, Diabetes Manager. Blood glucose reading are automatically sent to the cell phone and the phone-based software CDSS is initiated providing real time feedback. Patient is then prompted to enter insulin dosage and on hitting "OK" data is sent to the WellDoc server. Patient data were analysed by automated algorithms and by the research team. Average decrease of A1c and physicians change of medication were measured and compared between the groups. 30 patients were enrolled in the study.	Quinn (2008)[128] Design: RCT N = 30 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	3 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
An RCT was conducted on 400,000 HMO members 18 years and older who were assigned to the intervention group (alerts) or usual care group. The objective of the study was to determine whether computerized alerts were effective at increasing the percentage of ambulatory patients with laboratory monitoring at initiation of drug therapy. The primary outcome measure was the percentage of drug dispensing with baseline laboratory monitoring. Alerts were triggered by a dispensing of one of 15 target drug or drug classes. The alert was sent electronically to the Clinical Pharmacy Call Center daily if lab tests were not completed. This team of pharmacists contacted patients by phone to remind them their test was due or to order the tests if the physician did not do so. The intervention therefore had 2 stages; the alerting of the pharmacist by the computer and the phone follow-up by the pharmacist. 10,169 dispensing were included; the primary outcome was the percentage of drug dispensing with baseline lab monitoring.	Raebel (2005)[130] Design: RCT N = 9,565 patients, 10,169 dispensing Implementation: 00/0000 Study Start: 09/2002 Study End: 12/2003	NA	Ambulatory care	15 months	6
Randomized trial of HMO patients 65 and over prescribed one of a newly targeted group of 11 potentially inappropriate medications. To determine if a computerized pharmacy alert system plus collaboration between health care professionals can affect the rate of potentially inappropriate medication dispensed in elderly patients. During this 1-year study, 1,187 patients (2.0% of 59,680 included) were newly dispensed one or more of the 11 medications. An alert generated in the pharmacy system prevented printing of the label until a pharmacist intervened by contacting prescribing clinicians by phone.	Raebel (2007)[131] Design: RCT N = 59,680 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	NA	Ambulatory care	12 months	5
Randomized trial of a computerized alert for pharmacists when pregnant patients were prescribed USFDA category D or X medications (evidence for fetal risk) compared to usual care. Measured by the proportion of pregnant women dispensed a category D or X medication and the total number of first dispensing of targeted medications. Alerts were sent to pharmacists who had to review prescription and contact prescriber before the prescription label would print. The alerts were generated from the integration of administrative and EHR data with the pharmacy system. Patients included 11,100 potentially pregnant women, HMO members, between 18 to 50 years randomized to intervention or usual care.	Raebel (2007)[132] Design: RCT N = 11,100 women Implementation: 00/0000 Study Start: 01/2003 Study End: 04/2003	NA	Ambulatory care	4 months	7

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
This 3 arm cluster RCT randomized 200 US primary care physicians to 3 groups. Patients were in groups according to their physician: 78 patient's physicians received active reminders on treatment advice for patients with depression, 77 patient's physicians were told of the patient's depression, and 71 patient's physicians received usual notes. Notes were produced from an EMR (reminder system CDS). CDS based on AHCPR guidelines on depression.	Rollman (2002)[137] Design: RCT N = 200 Patients with documented major depression Implementation: 00/0000 Study Start: 04/1997 Study End: 12/1998	NA	Ambulatory care	6 months	3
A randomized, controlled trial with an off-on-off design whereby a glucose regulation guideline was implemented in an intensive care unit in paper form during the first study period. During the second period, the guideline was randomly applied in either paper or computerized form. In the third period, the guideline was available only in paper form. Periods were 6, 10 and 4 weeks respectively. For the computer intervention each noncompliant event triggered a pop-up window to appear on top of the active CIS screen, alerting clinical staff members. This window appeared on bedside workstations and at any workstation where the patient's record was activated. 484 patients from an 18-bed ICU were included, 120 during the intervention period, attended by 11 intensivists and 93 nurses. The two guideline-related outcome measures consisted of compliance with: (a) glucose measurement timing recommendations and (b) insulin dose advice.	Rood (2005)[138] Design: RCT N = 484 patients Implementation: 04/2001 Study Start: 00/0000 Study End: 00/0000	Critical care units	Academic	5 months	6
To evaluate whether displaying context sensitive links to infrequently accessed educational materials and patient information via the user interface of an inpatient computerized care provider order entry (CPOE) system would affect access rates to the materials. The CPOE of Vanderbilt University Hospital included ''baseline'' clinical DS advice for safety and quality. Authors augmented this with 7 new, primarily educational DS features. A prospective, RCT compared clinicians' utilization rates for the new materials via two interfaces. Control subjects could access study-related DS from a menu in the standard CPOE interface. Intervention subjects received active notification when study-related DS was available through context sensitive, visibly highlighted, selectable hyperlinks. Rates of opportunities to access and utilization of study-related DS materials from April 1999 through March 2000.	Rosenbloom (2005)[262] Design: RCT N = 418,739 opportunities to access an information item Implementation: 00/1995 Study Start: 04/1999 Study End: 03/2000	Acute care/ tertiary	Academic	12 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
An RCT at 6 teaching practices of the Ottawa Civic Hospital Family Medicine. With the use of a standard randomization computer program these patients were assigned to the control group, the physician reminder group, the telephone reminder group or the letter reminder group. For patients in the physician reminder group a computer-generated reminder to ask the patient about tetanus vaccination was included on the routinely printed encounter form used for billing purposes. Proportion of patients who received tetanus toxoid during the study year or who had a claim of vaccination in the previous 10 years. 8,069 patients participated in the study. Costs were also assessed.	Rosser (1992)[2] Design: RCT N = 8,069 patients Implementation: 00/0000 Study Start: 04/1985 Study End: 03/1986	NA	Ambulatory care Academic	12 months	4
A randomized controlled trail was conducted at General Medical Clinic (GMC) at the Veterans Affairs (VA) Palo Alto Health Care System. The study chose two-period parallel design with the study subjects randomly divided into two groups the Physician Workstation (PWS) group and the Decentralized Hospital Computer Program (DHCP), group. The PWS system contained features designed to reduce prescription-drug costs and to reduce the number of adverse drug interactions. The PWS system provided alerts about potential adverse drug interactions. User Satisfaction rating was measured and compared. 34 physicians were involved in the study.	Rotman (1996)[264] Design: RCT N = 34 Physicians Implementation: 00/0000 Study Start: 07/1994 Study End: 06/1995	NA	Ambulatory care	12 months	2
Cluster randomized, controlled trial to improve Blood pressure within 2 hospital-based and 8 community-based clinics in the Veterans Affairs Tennessee Valley Healthcare System. There were 1,341 veterans with essential hypertension cared for by 182 providers compared across 3 study arms for 6 months. Providers were randomly assigned to receive an e-mail with a Web-based link to the 7th Report of the Joint National Committee on the Prevention, Detection, Evaluation and Treatment of High Blood Pressure guidelines (provider education); provider education and a patient-specific hypertension computerized alert (provider education and alert); or provider education, hypertension alert, and patient education, in which patients were sent a letter advocating drug adherence, lifestyle modification, and conversations with providers (patient education).	Roumie (2006)[226] Roumie (2007)[227] Design: RCT N = 871 patients Implementation: 00/0000 Study Start: 06/2004 Study End: 12/2004	NA	Ambulatory care	6 months	6

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A controlled clinical trial (cluster randomization) among physicians and nurse practitioners caring for 349 patients (191 I and 158 C) infected with the human immuno-deficiency virus (HIV). Intervention was a very poorly described 'knowledge-based medical record ' which was an integration of the on-line patient record, rule-based DS, and full-text information retrieval into a clinical workstation. Main outcome was time to implementation of clinical alerts with secondary review of and improved quality of care. In the 18 month trial, 191 patients were treated by 70 physicians and nurse practitioners assigned to the intervention group, and 158 patients were treated by 66 physicians and nurse practitioners assigned to the control group.	Safran (1995)[141] Safran (1993)[142] Design: RCT - cluster N = 126 physicians, 10 nurse practitioners Implementation: 00/0000 Study Start: 05/1992 Study End: 09/1993	NA	Ambulatory care Academic	18 months	4
A RCT at Partners HealthCare System which is an integrated health care network consisting of outpatient clinics, community hospitals, and 2 academic teaching hospitals (Brigham and Women's Hospital and Massachusetts General Hospital) in Boston. Internally developed ambulatory EMR system integrated with patient specific electronic clinical reminder (recommendation for diabetes care and coronary artery disease[CAD]) allowed physicians to maintain patient problem, medication, and allergy lists and view laboratory results. Physicians also used the system to enter patient notes and medication prescriptions. Each time a clinician opened a patient chart within the system, the algorithm for all reminders determined whether the patient had received care in accordance with the recommended practice guidelines. Diabetes and CAD reminders resulting in recommended action were compared. 194 primary care physicians and 6,243 patients.	Sequist (2005)[228] Design: RCT N = 6,243 Patients Implementation: 07/2000 Study Start: 10/2002 Study End: 04/2003	NA	Ambulatory care Academic	6 months	3
RCT comparing the prescribing of vancomycin by hospital physicians receiving real time computerized guidelines during the physician order entry process vs. no computerized guidelines during physician order entry. Measures of vancomycin prescribing were the number of orders, duration of the therapy and number of days per course of treatment. 396 physicians and 1,798 patients in a tertiary-care teaching hospital were studied.	Shojania (1998)[148] Design: RCT N = 396 physicians Implementation: 00/0000 Study Start: 06/1996 Study End: 03/1997	Acute care/ tertiary	Academic	9 months	5

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
A cluster RCT in Quebec to test whether CDS in primary care EMR would reduce inappropriate prescribing. Physicians in the CDS group obtained information on each patient by downloading updates of dispensed prescriptions from the Régie de l'assurance maladie du Québec (RAMQ) drug-insurance program. All retail pharmacies had a data link to the RAMQ for online prescription adjudication, which provided a daily update of all prescriptions dispensed for each patient. These data were integrated into the patient's HR and categorized as having been prescribed by the study physician or by another physician. Alerts identified 159 clinically relevant prescribing problems in the elderly, a list established previously by expert consensus. The alerts appeared when the electronic chart was opened, when prescription-record updates were downloaded from the RAMQ, and when current health problems and prescriptions were recorded by the physician in the chart. Each alert identified the nature of the problem and possible consequences and suggested alternative therapy in accordance with the expert consensus. The primary outcomes were initiation and discontinuation rates of the 159 prescription-related problems. 107 physicians participated.	Tamblyn (2003)[159] Design: RCT N = 12,560 Patients Implementation: 00/0000 Study Start: 01/1997 Study End: 02/1998	NA	Ambulatory care	13 months	2
An RCT to determine if a cardiovascular medication tracking and nonadherence alert system, incorporated into a computerized health record system, would increase drug profile review by primary care physicians, increase the likelihood of therapy change, and improve adherence with antihypertensive and lipid-lowering drugs. There were 2,293 primary care patients prescribed lipid-lowering or antihypertensive drugs by 59 physicians who were randomized to the adherence tracking and alert system or active medication list alone to determine if the intervention increased drug profile review, changes in cardiovascular drug treatment, and refill adherence in the first 6 months.	Tamblyn (2010)[160] Design: RCT N = 2,293 patients Implementation: 00/0000 Study Start: 04/2006 Study End: 00/0000	NA	ambulatory care	6 months	7

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
An RCT at the Wishard Memorial Hospital is a tax-supported, 450-bed, university-affiliated, urban, public hospital located on the Indiana University Medical Center campus. Physicians were randomized. The intervention was CDSS designed to reduce prescribing of potentially inappropriate medications for older adults. CDSS was provided only when a physician in the intervention group prescribed a targeted inappropriate medication for a patient aged 65 and older who was being discharged from the Emergency department (ED). Proportion of ED visits by seniors with an inappropriate medication was measured. 5,162 patients and 63 physicians were involved in the study.	Terrell (2009)[164] Design: RCT N = 5,162 Patients Implementation: 00/0000 Study Start: 01/2005 Study End: 07/2007	Acute care/ tertiary	Academic	30 months	7
An RCT was conducted at the Wishard Memorial Hospital, a tax-supported, 450-bed, university-affiliated, urban, public hospital. DS advised against use of nine potentially inappropriate medications and recommended safer substitute therapies. DS was provided only when a physician in the intervention group attempted to prescribe a targeted inappropriate medication for a patient aged 65 and older who was being discharged from the ED. The primary outcome measured was the proportion of ED visits by older adults that resulted in one or more prescriptions for a targeted inappropriate medication. The secondary outcome of interest examined was the proportion of all prescribed medications that were potentially inappropriate. 5,162 patients and 63 physicians were involved in the study.	Terrell (2009)[165] Design: RCT N = 63 physicians had 5,162 patient visits Implementation: 00/0000 Study Start: 01/2005 Study End: 07/2007	Acute care/ tertiary	Academic	30 months	8
An RCT at an Inner-city academic general internal medicine practice to assess the effects of guideline-based care suggestions for asthma and CPOD delivered to physicians when writing orders on computer workstations. 246 physicians general internists, and 20 outpatient pharmacists were randomized to Care suggestions concerning drugs and monitoring. This 2 X 2 factorial randomization of practice sessions and pharmacists resulted in four groups of patients: physician intervention, pharmacist intervention, both interventions, and controls. Enrolled 706 of their primary care patients with HF or IHD. Outcomes were adherence to preventive care guidelines. 4 groups studied: control, pharmacist, physician or both health professionals. CPOE and CDSS intervention for physicians, pharmacist prompts were to provide education on several computer identified issues.	Tierney (2003)[166] Design: RCT N = 706 patients, 20 pharmacists, 94 physicians and 1 nurse practitioner Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	NA	Ambulatory care Academic	12 months	4

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
An RCT at an Inner-city, academic, general internal medicine practice to assess the effects of guideline-based care (NAEP Expert Panel Report and Canadian Thoracic Society) suggestions for asthma and CPOE delivered to physicians when writing orders on computer workstations. 246 physicians general internists, and 20 outpatient pharmacists were randomized to Care suggestions concerning drugs and monitoring. This 2 X 2 factorial randomization of practice sessions and pharmacists resulted in four groups of patients: physician intervention, pharmacist intervention, both interventions, and controls. Enrolled 706 of their primary care patients with asthma or COPD. Outcomes were adherence to preventive care guidelines. 4 groups studied: control, pharmacist, physician or both health professionals. CPOE and CDSS intervention for physicians, pharmacist prompts were to provide education on several computer identified issues.	Tierney (2005)[167] Design: RCT N = 706 patients Implementation: 00/0000 Study Start: 01/1994 Study End: 05/1996	NA	Ambulatory care Academic	12 months	4
A cluster RCT in practices using ELIAS EHR system inthe Netherlands were invited to participate in the study. Anon-commercial home grown CDSS for lipid managementbased on recommendations from the guideline of DutchCollege of General Practitioner (DCGP) was developedand integrated with the EHR system. Practices wererandomly assigned to 3 arms of the study: control arm,and 2 intervention arms (an on-demand arm and an alerting arm). Each practice was subsequently assigned bysimple random allocation to CDSS alerting, CDSS on demand,or control groups for the complete study period.The CDSS analyzed and interpret the patient data in theEHR, generating patient-specific guidelinerecommendations for preventative activities. Data onpatients requiring treatment and patient treated based onthe two intervention arms were measured and compared.87,866 patients participated in the study. 77 physicianscompleted the study.	Van Wyk (2007)[171] Design: RCT N = 87,860 Patients Implementation: 00/0000 Study Start: 05/2004 Study End: 00/0000	NA	Ambulatory care	12 months	3
A randomized trial was undertaken at LDS Hospital to assess the effects of digoxin alert reports generated by nightly review of the patient database, lab data and electrocardiographic findings. Reports were printed in the nursing division and placed in patient charts. 396 patients were randomly assigned to alert and non-alert groups over 3 months. Rate of physician actions were compared.	White (1984)[229] Design: RCT N = 396 patients Implementation: 00/0000 Study Start: 00/0000 Study End: 00/0000	Acute care/ tertiary	Academic	3 months	7

Evidence Table 13. KQ7: integrated CDSS study characteristics: setting and quality (continued)

PICOM	Article Information	Type of Hospital	Other Settings	Length of Follow-up (mean months)	Summary Methods Score
RCT to assess the impact of an automated intraoperative alert to redose prophylactic antibiotics in prolonged cardiac operations. All patients were randomization to an audible and visual reminder on the operating room computer console at 225 minutes after the administration of preoperative antibiotics (reminder group, n =137) or control (n =136).	Zanetti (2003)[180] Design: RCT N = 273 patients having cardiac surgery Implementation: 00/0000 Study Start: 03/2000 Study End: 06/ 2000	Acute care/ tertiary	Academic	1 week	6

Evidence Table 14. KQ7: integrated CDSS study characteristics: participants and interventions

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Field (2009)[42]	Meds, Prescrip, Orders	NA	NA	renal Insufficiency	anti-depressants	alerts related to medication prescribing for residents with renal insufficiency were displayed to prescribers in the intervention units and hidden but tracked in control units.	monitoring, prescribing	Comm
Holbrook (2009)[367]	Patients	NA	UnDiff	diabetes	No	usual care of vascular risk patients	monitoring	NR
Lo (2009)[220]	Patients	NA	NR	No	No	usual care	monitoring	NR
Gurwitz (2008)[302]	Patients	NA	65+	No	No	usual care - units already had CPOE	prescribing	HG

*indicates outcomes noted as being the primary outcome by the paper's authors

Abbreviations: ACE = Angiotensin Converting Enzyme; AD = Academic Detailing; Adol = Adolescents; AMTs = Antimicrobial Management Teams; APAP = acetaminophen; ARB = Angiotensin Receptor Blocker; ARI = acute respiratory infection; CAD = Coronary Artery Disease; CDS = Clinical / Computerized Decision Support; Comm = Commercial; COPD = Chronic Obstructive Pulmonary Disease; CPOE = Computerized Provider Order Entry; CVD = Cardiovascular Disease; DMA = Disease Management Application; ED = Emergency Department; ESCHM = European Society of Cardiology and other societies for Hypercholesterolemia Management;GI = Gastrointestinal; GINA = Global Initiative for Asthma; GP = General Practitioner; HG = Homegrown; HIT = Health Information Technology; HMG Co-A = 3-hydroxy-3-methylglutaryl-coenzyme A; Meds = medications; MI = Myocardial Infarction; MM = Medication Management; NA = Not Applicable; NR = not reported; NSAIDs = Nonsteroidal anti-inflammatory drugs; Prescrip = prescriptions; PRISM = Prescription in Ischemic Stroke Management; UnDiff = undifferentiated, SYW = show your work; UTI = Urinary Tract Infection

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Matheny (2008)[221]	Outpatient visits	Primary Care	65+	multiple	Metformin; Potassium Supplement; Potassium Sparing Diuretic, Thiazide Diuretic; Angiotensin Converting Enzyme Inhibitor; HMG Co-A Reductase Inhibitor; Thyroxine; Carbamazapine; Cyclosporine, Phenobarbital, Phenytoin, Proc-NAPA, Valproate	usual care - clinics were randomized so that physicians received either usual care or electronic reminders at the time of office visits focused on potassium, creatinine, liver function, thyroid function, and therapeutic drug levels.	monitoring	NR
Javitt (2008)[75]	Patients	Physicians UnDiff	ages 13 to 44	no	no	usual care- no care consideration with decision support tool	prescribing	Comm
Hicks (2007)[67]	Patients	NA	19 to 64, and 65+	hypertension	antihypertensive drugs	usual care without decision support	monitoring	NR
Martens (2007)[101]	Health Care Providers	Primary Care GP	NA	asthma	antibiotics and cholesterol-lowering drugs	reminder about 2 different types of prescriptions. All GPs were blind to the fact that they only received a specific subset of all available prescribing reminders and that they were analysed on certain prescribing behavior as controls	prescribing	NR
Peterson (2007)[126]	Meds, Prescrip, Orders	Hospitalists	NA	No	No	recommended drugs	prescribing	HG

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Raebel (2007)[132]	Patients	NA	19 to 64 years	pregnancy	21 drugs that were pregnancy risk category D (contraindicated with fetal risk although some therapeutic benefit) and X (evidence of fetal risk and no therapeutic benefit)	usual care	prescribing	Comm HG
Bailey (2007)[7]	Patients	NA	UnDiff	heart disease	ACE inhibitors, statins, aspirin and B-blockers	Usual care- Acute MI Patients in the control group received standard care	prescribing	NR
Paul (2006)[124]	Patients	NA	19- 64 years	No	antibiotics	Control group antibiotic monitoring without CDS	prescribing	HG
Fretheim (2006)[56] Fretheim (2006)[57]	Patients	Primary Care GP	45-64 and 65+	hypertension or hypercholes-terolemia	thiazides	Usual care	Prescribing	NR
Feldstein (2006)[215] Smith (2009)[216]	Patients	NA	19-64 and 65+	No	10 study medications or medication classes; ACE/ARB, Allopurinol, Carbamazepine, Diuretic, Metformin, Phenytoin, Pioglitazone, Potassium	Usual care	monitoring	NR
Kuilboer (2006)[219]	Patients	NA	UnDiff	asthma	cromoglycate, deptropine, antihistamines, and oral bronchodilators	Usual care	Monitoring, Prescribing	NR
Roumie (2006)[226] Roumie (2007)[227]	Patients	NA	19-64 and 65+	hypertension	antihypertensive medications	Not clear - it was a Multiple Intervention comparison	prescribing	Comm

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
McGregor (2006)[105]	Patients	NA	19- 64 and 65+	No	23 restricted antimicrobials	Control was without the system in the control arm - antimicrobial management teams	prescribing	Comm
Palen (2006)[121]	Meds, Prescrip, Orders	NA	NA	No	25 specific drugs requiring lab monitoring according to guidelines, within the following classes: ACE inhibitors (2), Angiotension II receptor blocker (1), antiarrythmic (1), antiinfective agents (2), antigout (2), cholesterol-lowering (5), diuretics (5), hyperglycemics (2), metabolic (2), neurological (3)	Control group - Did NOT receive drug laboratory monitoring alerts within the CPOE system.	Monitoring, Prescribing	Comm
Feldstein (2006)[40]	Meds, Prescrip, Orders	NA	NA	No	Warfarin	Control - All 15 clinics received electronic medical record alerts for the coprescription of warfarin and 5 interacting medications.	prescribing	NR
Feldstein (2006)[41]	Patients	NA	45-64 and 65+	probably osteoporosis	No	Usual care- Control was no provider reminder or patient education, just usual care.	prescribing	NR
Berner (2006)[12]	Health Care Providers	Primary Care GP and Other Physicians	NA	No	NSAIDS	Control group did not receive the rule for GI risk assessment.	prescribing	Comm HG

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Lester (2005)[95]	Patients	NA	19-64 and 65+	high cholesterol levels	statins	Control - Physicians did NOT receive a visit-independent disease management tool which was initiated by an email with CDS and facilitated “one-click” order writing.	Monitoring, Prescribing	HG
Raebel (2005)[130]	Meds, Prescrip, Orders	NA	NA	No	15 drugs/drug classes requiring lab monitoring	Pharmacists were alerted to missing laboratory test information only for intervention patients. Pharmacists were not provided information about laboratory monitoring for patients in the usual-care group.	Monitoring, Prescribing	HG
Bloomfield (2005)[15]	Patients	NA	NR	heart disease	lipid modifying therapy: fibrates (such as gemfibrozil), statins, bile acid binding resins, or niacin	6 control clinic did NOT received prompts.	prescribing	NR
Rosenbloom (2005)[262]	Health Care Providers	Hospitalists	NA	No	No	Control subjects could access study-related decision support from a menu in the standard CPOE interface but they DID NOT receive active notification when study-related decision support was available through context sensitive, visibly highlighted, selectable hyperlinks	Prescribing	Comm
Tierney (2005)[167]	Patients	Hospitalists	19-64 and 65+	asthma and COPD	No	4 comparison groups 1 was control - usual care	prescribing	HG

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Kucher (2005)[90]	Patients	NA	19-64 and 65+	venous thromboembolism	No	Control group - no alert given	Prescribing	HG
Tierney (2003)[166]	Patients	NA	19-64 and 65+	heart disease	No	control - No Evidence-based cardiac care suggestions	Prescribing	HG
Rollman (2002)[137]	Health Care Providers	Primary Care GP	18- 64 years	depression	antidepressants	Usual pt care for depression	Monitoring, Prescribing	Comm
Krall (2004)[89]	Patients	NA	UnDiff	No	aspirin	Control - no alert for aspirin	prescribing	Comm
Filippi (2003)[44]	Patients	NA	19-64 and 65+	diabetes	antiplatelet drugs	Control - No electronic reminder only a letter summarizing the beneficial effects of antiplatelet drugs	prescribing	NR
Zanetti (2003)[180]	Patients	NA	19- 64 and 65+	heart disease	antibiotics - Cefazolin	Control - No audible and visual reminder on the operating room computer console at 225 minutes in surgery	prescribing	HG
Flottorp, (2002)[47]	Consults	NA	NA	sore throat UTI	antibiotics	72 practices received interventions to implement guidelines for urinary tract infection and 70 practices received interventions to implement guidelines for sore throat, serving as controls for each other.	prescribing	NR
Dexter (2001)[33]	Patients	NA	NR	No	pneumococcal vaccination, influenza vaccination, prophylactic enteric coated aspirin and prophylactic subcutaneous heparin	Control - no preventive care reminders	prescribing	NR

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Christakis (2001)[23]	Health Care Providers	Primary Care GP, Hospitalists, Other Physicians	NA	acute otitis media	antibiotics for otitis media	Control - Providers did not receive real time evidence-based prompts on their prescribing practice for otitis media.	prescribing	HG
Montgomery (2000)[108]	Patients	NA	60-79 years	hypertension	No	Usual care for patients with Hypertension	monitoring	Comm HG
Shojania (1998)[148]	Health Care Providers	Hospitalists	NA	No	vancomycin	Control physicians encountered no guidelines screens only the usual computer prompt to renew or discontinue the order after 72 hours of therapy	prescribing	HG
Overhage (1997)[118]	Health Care Providers	Hospitalists, Other Physicians	19-64 and 65+ years	No	No	Control - reminders about corollary orders were withheld	monitoring	HG
Holman (1996)[306]	Patients	NA	19- 64 years	diabetes	insulin	Control - patients were their own control - had device but dose support turned off (could still enter glucoses)	Administering, Monitoring	HG
Safran (1995)[141] Safran (1993)[142]	Patients	Physicians, Nurse Practitioners	NR	HIV	No	Control - alerts were not visible to control group	Monitoring, Prescribing	HG
Evans (1994)[39]	antibiotic cultures	NA	NA	No	antibiotics	Control -No computerized antibiotic consultant. Two-stage random-selection study. antibiotics ordered compared between crossover periods.	Prescribing	HG
Cobos (2005)[25]	Patients	NA	19-64 and 65+	Hypercholes-terolemia	No	Usual Care	Prescribing	NR

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Davis (2007)[30]	Health Care Providers	Primary Care GPs	NA	acute otitis media, allergic rhinitis, sinusitis, constipation, pharyngitis, croup, urticaria, and bronchiolitis	No	Control Group Provider - Did NOT have point-of-care evidence-based prescription writer and decision support system.	Prescribing	HG
Dexter (2004)[34]	Patients	NA	NR	No	influenza and pneumococcal vaccines	Comparison of computerized physician standing orders compared with physician reminders for inpatient vaccinations.	prescribing	NR
Fiks (2009)[43]	Patients	NA	2 to 18 years	asthma	Influenza vaccine	Control sites had no electronic health record-based clinical alerts for influenza vaccine	prescribing	Comm
Hetlevik (1999)[304]	Patients	NA	45-64 and 65+	hypertension	No	Control - No CDS, doctors in control group were supposed to follow their ordinary procedures in the treatment of patients with hypertension.	Prescribing	NR
Rood (2005)[138]	Patients	NA	UnDiff	No	No	Control was glucose regulation guideline in an intensive care unit in paper form. Paper form was implemented in the first and third period of the study.	Monitoring, Prescribing	Comm
Rosser (1992)[2]	Patients	NA	19-64 and 65+	No	Tetanus Toxoid	Control – no reminder	Prescribing	NR

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Sequist (2005)[228]	Patients	NA	45-64 and 65+	diabetes CAD	No	Control was usual care for diabetics and CAD pts, no guideline recommendations.	monitoring	HG
Van Wyk (2007)[171]	Patients	NA	19-64 and 65+	high cholesterol	No	Usual care	prescribing	HG
Persell (2008)[205]	Patients	NA	19-64 and 65+	diabetes	aspirin	Control group received electronic Reminder only for aspirin	Administering	NR
Terrell (2009)[164]	Patients	NA	65+	No	No	Control - No Decision support that advised against use of potentially inappropriate medications in ED visit	prescribing	NR
Prescription in Ischemic Stroke Management (PRISM) Study Group (2003)[127]	Patients	NA	45-64 and 65+	ischemic stroke	antiplatelets anticoagulants	Usual care	prescribing	NR
Tamblyn (2003)[159]	Patients	NA	65+	No	No	Control no CDS	prescribing	NR
Rotman (1996)[264]	Health Care Providers	Physicians UnDiff	NA	No	No	Control - not using Physician Workstation	Prescribing	HG
Bertoni (2009)[14]	Health Care Providers	Primary Care GPs	NA	No	lipid lowering therapy	Control - Alternative Intervention for High BP treatment	Monitoring, Prescribing	NR
Demakis (2000)[213]	Health Care Providers	Other Physicians	NA	No	No	Control - No reminder on standards of ambulatory care.	monitoring	NR

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Fortuna (2009)[48]	Health Care Providers	Primary care GPs, Specialist, Nurses, Mid level practitioners	NA	No	hypnotics: Ambien CR® (zolpidem tartrate extended release), Lunesta® (eszopiclone), Sonata® (zaleplon), and Rozerem® (ramelteon)	Control usual care - received an alert stating only the copayment tier of the medication. NO computerized alerts or educational sessions for hypnotic prescribing.	prescribing	Comm HG
Frank (2004)[50]	Patients	NA	UnDiff	No	No	Control - usual care, no reminders of the 12 preselected preventive care activities.	prescribing	NR
Meigs (2003)[309]	Patients	NA	NR	diabetes	No	Control providers continued their usual care practices during the intervention and did not have access to the CDS DMA.	Monitoring,	NR
Overhage (1996)[117]	Health Care Providers	Physicians UnDiff	NA	No	No	Control - no electronic preventative care guideline reminders	prescribing	HG
White (1984)[229]	Patients	NA	UnDiff	No	digoxin	Control - no alert for digoxin intoxication	monitoring	HG
McDonald (1976)[222]	Patients	NA	UnDiff	diabetes	No	Control - without computer reminders/ suggestions	monitoring	HG
Plaza (2005)[280]	Patients	Primary Care GPs, Respirolo-gist	14 years +	asthma	No	Access to handheld but no nurse trainers of Global Initiative for Asthma guideline advice.	Monitoring, Prescribing	Comm (likely)

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Raebel (2007)[131]	Patients	NA	Geriatric (65 plus)	No	Drugs innaproriate for the elderly - amitriptyline, chlordiazepoxide, chlorpropamide, diazepam, doxepin, flurazepam, aspirin in combination with hydrocodone or oxycodone,ketorolac, oral meperidine, and piroxicam	Usual Care – Pharmacists did not receive the medication alerts generated by the pharmacy information management system for elderly patients newly prescribed a potentially inappropriate medication.	Dispensing, Prescribing	HG
Murray (2004)[310]	Patients	NA	Geriatric (65 plus) Middle age (45 to 64)	hypertension	antihypertensive agents were angiotensin-converting enzyme (ACE) inhibitors, b-blockers, calcium channel blockers, oral clonidine and topical patch, diuretics, and other less commonly prescribed drugs such as methyldopa and reserpine	Control - Neither physician nor pharmacist received hypertension care suggestions for patients	Prescribing	HG
Frances (2001)[49]	Patients	NA	Geriatric (65 plus)	heart diseases	aspirin, Beta-blockers, and cholesterol-lowering agents	Usual care	Prescribing	NR
Javitt (2005)[218]	Patients	NA	Adol (13 to 18) Adults (19 to 44), Middle age (45 to 64)	No	No	Control Group - The system relayed all triggered recommendations to intervention physicians - those for control group were deferred until the end of the study	Monitoring and Prescribing	HG

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Quinn (2008)[128]	Patients	NA	Adol (13 to 18) Adults (19 to 44) Middle age (45 to 64)	diabetes	No	Usual out patient care - Controls received one touch ultra BG meters, Testing strips and lancets. Faxed or called in results. Intervention pts -bluetooth enable blood glucose meter, a cell phone and WellDoc's proprietary diabetes management software, Diabetes Manager, automatically sent to the cell phone and the phone-based software CDSS is initiated providing real time feedback.	Monitoring, Prescribing, Education	Comm
Linder (2009)[97]	Patients	NA	Middle age (45 to 64)	ARI	antibiotics	Usual care	Prescribing	HG
Bell (2010)[11]	Patients	NA	Adol (13 to 18) Children (2 to 12)	asthma	No	Control group had passive access to the same asthma management tools.	Prescribing	Comm
Graumlich (2009)[237] Graumlich (2009)[238]	Patients	NA	Adol (13 to 18) Adults (19 to 44) Geriatric (65 plus) Middle age (45 to 64)	No	No	Usual Care - usual handwritten discharge care for patients at high risk for repeat admission.	Prescribing	NR

Evidence Table 14. KQ7: integrated CDSS Study Characteristics: participants and interventions (continued)

Author (year)	Primary unit of study analysis	Health Care Provider type	Patient type	Disease Specify	Drug specify	Control Group Type	MM PHASE(S) Target	Nature of HIT
Terrell (2009)[165]	Patients	NA	Geriatric (65 plus)	No	Promethazine DiphenhydramineDiazepam Propoxyphene with APAP Hydroxyzine Amitriptyline Cyclobenzaprine Clonidine Indomethacin	Usual care no DS - . Physicians in the control group did not receive the decision support, but the computer system tracked their prescribing.	Prescribing	NR
Johnson (2010)[76]	Meds, Prescrip, Orders	NA	NA	No	No	Control - Each day, SYW output across the enterprise was turned ''on" or ''off" randomly for all e-prescriptions. Three pharmacies, blinded to SYW status, submitted callback logs each day.	Prescribing, Transmission, order communication	NR
Gilutz (2009)[62]	Patients	NA	Adults (19 to 44) Geriatric (65 plus) Middle age (45 to 64)	CAD dyslipidemia	No	Usual Care	Monitoring, Prescribing	NR
Tamblyn (2010)[160]	Patients	NA	Geriatric (65 plus) Middle age (45 to 64)	CVD	anti hypertensive lipid lowering therapy	Usual care received medication list alone	Monitoring, Prescribing	NR
Gill (2009)[61]	Patients	NA	Adults (19 to 44) Geriatric (65 plus) Middle age (45 to 64)	hyper-lipidemia	No	Usual Care did not have the disease management tool.	Monitoring, Prescribing	Comm

Evidence Table 15. KQ7: integrated CDSS study characteristics: results

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Bailey (2007)[7]	CDSS/ CDS/ CCDS/ reminder	Hospital information system	853 patients	compliance rates - pts discharged on a full-complement regimen of secondary prevention medications*, compliance rates- ACE inhibitor*, compliance rates- statins*, compliance rates-aspirin, compliance rates- beta-blockers	When individual drug class exclusions were considered, compliance rates increased for pts discharged on a full-complement regimen of secondary prevention medications (70.3% vs. 83.6%, RRR -19% , p<.001). Compliance rates for ACE inhibitor (83.6 vs. 89.9, RRR -8%, p = 0.01) and statin use (89.3 vs. 94.2%, RRR 5%, p = 0.02) were significantly higher, while rates for aspirin (96.5% vs. 96.4%, RRR 0%, p = 0.95) and beta-blockers (91.8% vs. 95.9%, RRR -5%, p = 0.08) remained the same.	+	No	NA	NA

The outcome columns (+/-) indicates whether at least 50% of the relevant outcomes abstracted were positively impacted by the MMIT (+) or not (-).
*indicates outcomes noted as being the primary outcome by the paper's authors
A1c = hemoglobin A1c; ACE= Angiotensin Converting Enzyme; ADE= Adverse Drug Event; AHR= Airway Hyperresponsiveness; AQLQ= Asthma Quality of Life Questionnaire; BMD= Bone Mineral Density; BMI= Body Mass Index; BP = Blood Pressure; CCDS= Computerized Clinical Decision Support; CCs= Care Considerations; CDS= Clinical / Computerized Decision Support ; CDSS= Clinical Decision Support System; CI= CI; COPD= Chronic Obstructive Pulmonary Disease; CPOE= Computerized Provider Order Entry; DBp = Diastolic Blood Pressure; DHCp = Decentralized Hospital Computer Program; DVT= Deep Vein Thrombosis; ED= Emergency Department; EHR= Electronic Health Record; EMR= Electronic Medical Records; e-RX= Electronic Prescribing; FEV1= Forced Expiratory Volume in the first second.; GPs= General Practitioners; HbA1c= Glycated hemoglobin; HMG Co-A= 3-hydroxy-3-methylglutaryl-coenzyme A; INR= International Normalized Ratio; LDL= Lowdensity Lipoprotein; MCID= Minimal Clinically Important Difference; MM= Medication Management; mmHg= millimeter of mercury; mmol/l= millimoles per litre; MMR= Measles, Mumps and Rubella; NPs= Nurse Practitioners; NS= Not specified; NSAID= Nonsteroidal anti-inflammatory drug; OR= OR; p = Probability; PDA= Personal Digital Assistants ; POE= Provider Order Entry; QoL= Quality of Life; RCT= Randomized Controlled Trial; RR= Relative Risk; RRR Relative Risk Reduction; SBP = Systolic Blood Pressure; SD= Standard Deviation; SF-36= Short Form 36; UTI= Urinary Tract Infection; vs.= Versus; yr= Year

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Bell (2010)[11]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	19,450 patients	proportion of children with asthma having at least 1 prescription for controller medication*, proportion of children with asthma having an up-to-date asthma care plan*, proportion of children with asthma having spirometry performed*	Increases in the number of prescriptions for controller medications, over time, was 6% greater (p = 0.006) and 3% greater for spirometry (p = 0.04) in the intervention urban practices. Filing an up-to-date asthma care plan improved 14% (p = 0.03) and spirometry improved 6% (p = 0.003) in the suburban practices with the intervention	+	No	NA	NA
Berner (2006)[12]	CDSS/ CDS/ CCDS/ reminder	Handheld	59 internal medicine residents	proportion of unsafe NSAID prescribing per physician at follow-up	The proportion of cases per physician with unsafe NSAID prescriptions were similar at baseline for control (0.29) and intervention residents (0.27). At follow-up, the rates were statistically different, with lower proportions for intervention residents after adjustment for baseline rates (0.45 control vs. 0.23 intervention, p<0.05). Control group prescribing degraded over time while the intervention group was stable.	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Bertoni (2009)[14]	CDSS/ CDS/ CCDS/ reminder	Handheld	8,878 patients	adherence to guideline-screening*, adherence to guideline-appropriate lipid management*	There was no difference in screening rates between the CDSS-PDA group and the control. The control group had a 10.8% drop in appropriate management from baseline, while the PDA group had a 1.1% drop, p<0.01. Stable adherence was observed in the PDA intervention group, whereas a decline in guideline adherence was observed in the control group.	-	No	NA	NA
Bloomfield (2005)[15]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	9,105 patients	rate of prescription - lipid therapy (before-after), rate of prescription -lipid therapy among prompt groups	Rate of lipid therapy prescriptions after implementation of the prompts: intervention clinics (8.3%) control (39.1%), RRR -371, p<0.0001 Prescription rates: 40.7% for progress notes, 36.9% for patient letters, 39.4% for reminders (p = 0.60, NS). Alternative logistic regression analysis: significant interaction between group and site, indicating that the efficacy of prompts differed by site.	+	No	NA	NA
Christakis (2001)[23]	CDSS/ CDS/ CCDS/ reminder	online prescription writer	38 providers	change in the frequency of antibiotic prescription*	Providers in the intervention arm had a 44% change in the frequency with which they prescribed antibiotics for <10 days, whereas providers in the control arm had a 10% change. Change in behavior was significantly related to the intervention, although both groups improved (p<0.01).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Cobos (2005)[25]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	2,221 patients	proportion of patients prescribed lipid lowering drugs (secondary)	The proportion of patients prescribed lipid lowering drugs was significantly lower in the CDSS guideline intervention group (59.1% vs. 40.8%, RRR 31%, p<0.0001).	+	Proportion of patients achieving successful lipoprotein-cholesterol goals or cardiovascular risk reassesssment*	The proportion of patients achieving success in the ITT analysis was similar between usual care and intervention groups (50.5% vs. 54%, NS).	-
Davis (2007)[30]	e-prescribe CDSS	CPOE/POE system EHR/EMR system	44 health care providers	changed physician behavior in accordance with the intervention message screens*	Prescribing behavior in accordance with the evidence improved only marginally, by 1% in control group and 4% in the intervention group (absolute difference 3%, 95% CI 1% to 15%).	+	No	NA	NA
Demakis (2000)[213]	CDSS/ CDS/ CCDS/ reminder	Hospital information system	12,989 patients 275 physicians	adherence rates for 5 medication management standards of care*	Adherence rates for medication management standards of care were NS different for monitoring warfarin treatment; treatment of atrial fibrillation with warfarin, aspirin or ticlopidine; treatment of myocardial infarction with beta-blockers or switching NSAID therapy for gastrointestinal bleeds. There was a large effect for pneumococcal vaccination (12.7% vs. 4.3%; OR, 3.26; 95% CI, 2.09 to 5.09). Overall, for 13 standards including non-medicinal preventive care actions, adherence was significantly improved (53.5% vs. 58.8%, OR 12.4; 95% CI 1.08 to 1.42, p = 0.002).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Dexter (2001)[33]	CDSS/ CDS/ CCDS/ reminder	Imaging systems, Pharmacy	3,416 patients	proportion compliance - pneumococcal vaccination* , proportion compliance - influenza vaccination *, proportion compliance - subcutaneous heparin , proportion compliance -aspirin at discharge	The use of the reminders led to a higher ordering rate all 4 preventive therapies for eligible patients; pneumococcal vaccination (0.8% vs. 35.8%, RRR -4375%, p<0.001) Influenza vaccination (1.0% vs. 51.4%, RRR -5040%, p<0.001) subcutaneous heparin (18.9% vs. 32.2%, RRR -70%, p<0.001) aspirin at discharge (27.6% vs. 36.4%, RRR -32%, p<0.001).	+	No	NA	NA
Dexter (2004)[34]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system	1,677 patients	rate of receipt of vaccination - influenza*, rate of receipt of vaccination - pneumococcal*	Pts in the standing order group received both vaccinations more often than patients in the pop-up reminder group; for the influenza vaccine 30% reminder vs. 42% standing order, p < 0.001; for the pneumococcal vaccine 51% vs. 31%, p < 0.001.	+	Length of stay	The median length of stay for the first hospitalization were identical between the 2 study groups.	NA
Evans (1994)[39]	CDSS/ CDS/ CCDS/ reminder, CPOE/ POE system	EHR/EMR system, Laboratory system	482 cultures from 451 patients	rate of prescribing antibiotics to which all of the isolated pathogens were susceptible	The computer group had a higher rate of prescribing antibiotics to which all of the isolated pathogens were susceptible (77% vs. 94%, RRR 22%, p< 0.001).	+	No	NA	NA
Feldstein (2006)[215] Smith (2009)[216]	CDSS/ CDS/ CCDS/ reminder	Billing/ administration system, EHR/EMR system, Pharmacy	961 patients	rates of completing lab monitoring*	Pts in the EMR group were 2.5 times more likely than patients in the Usual Care group to complete laboratory monitoring (p< 0.001), patients in the Automated telephone Voice Message group were 4.1 times more likely (p< 0.001), and patients in the pharmacy team outreach group were 6.7 times more likely (p< 0.001).	+	Chronic Disease score, also number of patients with abnormal lab results, so needed some actual lab results though not reported.	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Feldstein (2006)[40]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, Laboratory system	9,910 patients with 239 care providers in 15 primary care clinics	interacting prescription rate (/10,000 warfarin users/month) slope for interacting prescription rate	Overall interacting prescription rate decreased immediately after the alerts were implemented, with an estimated reduction of 329.7 interacting prescriptions per 10,000 warfarin users in the first month (p = 0.002). The alerts also significantly changed the trend in the interacting prescription rate, with a preintervention increasing rate of 1.1 and a postintervention decreasing rate of 21.3 (slope change, -22.4; p = 0.01). Academic detailing did not have an effect on interacting prescription rates.	+	No	NA	NA
Feldstein (2006)[41]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, Laboratory system	311 women	rate of completion of BMD or medication for osteoporosis	The control group had fewer women who had BMD completer or medication for osteoporosis compared with the reminder and reminder plus education groups (5.9% control, 51.5% reminders, and 33% reminders and education, p< 0.01 for both comparisons with control RRR for reminders alone 690% and RRR for reminders and education 460%). The same pattern was evidence for medication only (5.0% for control, 27.7% for reminders and 20.2% for reminders plus education; p< 0.01 for comparisons with control.	+	Yes - BMD, Charlson Comorbidity Index, patients weight and a satisfaction questionnaire at baseline and 6 months	BMD test and Charlson Comorbidity Index and actual weight - results not reported. Satisfaction questionnaire showed no significant differences.	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Field (2009)[42]	CDSS/ CDS/ CCDS/ reminder, CPOE/ POE system	EHR/EMR system	833 patients 10 physicians 213,967 patient days	proportion of appropriate orders*, proportion of inappropriate drugs avoided	The proportion of appropriate antidepressant order rates for patients with renal insufficiency was higher in the CDSS group (52% vs. 63%, OR 1.2, 95% CI 1.0 to 1.4). More inappropriate drugs were avoided (15% vs. 46%, OR 2.6, CI 1.4 to 5.0). Improvements were seen in frequency and missing information but not for doses in the CDSS group.	+	No	NA	NA
Fiks (2009)[43]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system EHR/EMR system	22,586 patients	rates of up-to-date influenza vaccination*, rates of captured opportunities for vaccination*	Rates of up-to-date influenza vaccination increased from 44.2% to 48.2% at control sites and from 45.0% to 53.0% at intervention sites, a 4.0% (95% CI -1.3% to 9.1%) NS. Overall rates of captured opportunities for vaccination increased 3.8%, from 12.3% to 16.1%, at control sites and 4.8%, from 14.4% to 19.2%, at intervention sites, a difference of 1% (95% CI -2.4% to 4.9%).	-	No	NA	NA
Filippi (2003)[44]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system EHR/EMR system	15,343 patients	antiplatelet drug treatment	Number of treated patients was significantly increased in the intervention group (OR 1.99, 95% CI 1.79 to 2.22)	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Flottorp, (2002)[47]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	26,826 Consults Actual- 18,106 patients, 113 practices completed.	use of antibiotics for sore throat, use of antibiotics for UTI	Pts in the sore throat group were 3% less likely to receive antibiotics after the intervention (49.5% vs. 43.8%, p = 0.032). Those for UTI were 43.4% vs. 46.3%, p = 0.639. Women with symptoms of UTI in the intervention group were 5.1% less likely to have a laboratory test ordered (55% vs. 49.8%, p = 0.046). For the sore throat, the numbers were 39.7% vs. 42.0%, p = 0.638. The absolute increase in the proportion of telephone consults for sore throat was 1.2% greater in the control group than in the intervention group (14.1% vs. 12.9%, p = 0.128). The proportion decreased for UTI (18.9% vs. 19.8%, p = 0.874).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Fortuna (2009)[48]	CDSS/ CDS/ CCDS/ reminder	eRx	257 clinicians	relative risk of prescribing heavily marketed medications*	The relative risk of prescribing heavily marketed medications in the alert-group during the intervention period was less than in the usual-care group (RRR 0.74; 95% CI 0.57 to 0.96; p = 0.02). The RR of prescribing heavily marketed hypnotics in the alert-plus-education group was less than in the usual-care group (RRR 0.74; 95% CI 0.58 to 0.97, p = 0.03). The prescribing of heavily marketed medications was similar in the alert-only group and the alert-plus-education group (RRR 1.02; 95% CI 0.80 to 1.29; p = 0.90).	+	No	NA	NA
Frances (2001)[49]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system Pharmacy	63 physicians and 730 patients	receiving aspirin*, History of MI and receiving beta-blocker*, Receiving cholesterol-lowering agent*	1. the proportion of patients who had an active prescription for aspirin 37.9% vs. 35.1%, RRR 7%, p = 0.440, NS; 2. the proportion of patients with MI who had an active beta-blocker prescription 22.2% vs. 33.3%, RRR -50%, p = 0.465, NS; 3. the proportion of patients receiving a cholesterol-lowering agent 73.2 % vs. 71.0%, RRR -15% p = 0.512.	-	LDL level <100 mg/dL*	The proportion of patients with a level of LDL cholesterol in the desired range (< 100 mg/dL) Did not improve cholesterol management in patients (73.2 % vs. 71.0%, p = 0.512) with CAD.	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Frank (2004)[50]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	10,507 patients 10 physicians	proportion of opportunities taken for preventive activity*	Reminders did not improve adherence to MMR and flu vaccinations, but there was a significant increase in tetanus immunization (1.5% vs. 2.8%, RR 1.89, 95% CI 1.59 to 2.25). and pneumococcal immunization rates (1.6% vs. 2.8%, RR 1.70, 95% CI 1.10 to 2.62). Two of 8 non-medication related preventive care recommendations were significantly improved as well.	+	No	NA	NA
Fretheim (2006)[56] Fretheim (2006)[57]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	139 practices 501 physicians	thiazides prescription rates*, rates of cardiovascular risk assessment , proportion of patients achieving treatment goal at 3 months	Prescribing of thiazides increased in the reminders + group (11% vs. 15%, RRR 54%, p < 0.001, RR 1.94 95% CI 1.49 to 2.49). The groups did not differ for cardiovascular risk assessment (RR 1.04, 95% CI 0.60 to 1.71) or proportion that achieved treatment goal at 3 months (RR 0.98, 95% CI 0.93 to 1.02).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Gill (2009)[61]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	64,150 patients	up-to-date lipid test*, Lipid medication if not at goal (high risk patients only)*	Outcomes improved for most measures from before to 1 year after the intervention (univariate analysis). However, after controlling for confounding variables and for clustering in multilevel modeling, only up-to-date lipid testing for high-risk patients was statistically better in the intervention group as compared to the control group (ARR 15.0, p<0.05). Intervention status was NS for any other analysis.	-	Lipids at goal*	After controlling for confounding variables and for clustering in multilevel modeling, the proportion of patients with lipids at goal was NS between control and intervention groups.	-
Gilutz (2009)[62]	CDSS/ CDS/ CCDS/ reminder	Hospital information system, Laboratory system, Pharmacy	7,448 patients from 56 control and 56 intervention clinics	rate of adequate monitoring, positive treatment trend, overall up titration rate in patients with LDL = 110 mg/dl	A higher rate of adequate monitoring was documented in the intervention arm (54.8% vs. 48.7%, p<0.001). Medication initiation or up-titration was recommended for patients with LDL levels above 110 mg/dl. The results showed that overall positive trends were minimally more prominent in the intervention arm (59.1% vs. 53.7%, p< 0.003). This difference constitutes a higher rate of drug initiation (2.5%), up-titration (1.8%)and avoiding drug cessation (1.1%). However, overall up titration in patients with LDL = 110 mg/dl was poor, both in the intervention arm and in the control arm (8.6% vs. 7.4%, NS).	+	LDL level reduction*	In the group of patients with initial LDL levels above 120 mg/dl a significant decrease in LDL levels was observed in the two groups, which was minimally more pronounced in the intervention arm (from 145.5 ±22.3 mg/dl to 121.9 ± 34.2, mg/dl, 16.2% reduction) than in the control arm (from 145.8 ± 22.9 to 124.3 ± 34.6, 14.8% reduction; p< 0.02).	+

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Graumlich (2009)[237] Graumlich (2009)[238]	CDSS/ CDS/ CCDS/ reminder CPOE/ POE system	CPOE/POE system	631 patients	patient mean score for discharge preparedness*, patient score for satisfaction with medication information, outpatient physicians perception of discharge software	When comparing patients assigned to discharge software vs. usual care, patient mean (standard deviation [SD]) scores for discharge preparedness were higher (17.7 [4.1] vs. 17.2 [4.0]; p = 0.042), patient score for satisfaction with medication information were unchanged (12.3 [4.8] vs. 12.1 [4.6]; p = 0.567). and their outpatient physicians scored higher quality discharge (17.2 [3.8] vs. 16.5 [3.9]; p = 0.027). Hospital physicians found mean effort to use discharge software was more difficult than the usual care (6.5 [1.9] vs. 7.9 [2.1]; p = 0.011) and discharge software users had mean (SD) satisfaction 7.4 (1.4) vs. 7.9 (1.4) for usual care physicians; p = 0.129.	-	Readmitted within 6 months*, emergency department visit within 6 months, adverse events within 1 month.	When comparing patients assigned to discharge software vs. usual care, there was no difference in hospital readmission within 6 months (37.0% vs. 37.8%; coefficient 0.005 95% CI - 0.074 to 0.065 p = 0.894), emergency department visit within 6 months (35.4% vs. 40.6%; coefficient 0.052, 95% CI -0.115 to 0.011; p = 0.108), or adverse events within 1 month (7.3% vs. 7.3%; coefficient 0.003, 95% CI -0.037 to 0.043, p = 0.884).	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Gurwitz (2008)[302]	CDSS/ CDS/ CCDS/ reminder	Integrated CPOE/ POE system, Laboratory system	1,118 residents/ patients	No	NA	NA	ADE rates per 100 resident months*	similar for control and intervention units (10.4 vs. 10.8, NS). The same was found for the rate of preventable ADEs per 100 resident months (3.9 vs. 4.0, NS). Hospitalization measured.	-
Hetlevik (1999)[304]	CDSS/ CDS/ CCDS/ reminder CPOE/ POE system	EHR/EMR system	1,998 patients	NA	NA	NA	*SBP mmHg (SD), DBP mmHg (SD), Serum Cholesterol mmol/1 (SD), BMI kg/m2 (SD)	The groups did not differ for BP, cholesterol levels or BMI: SBP was 155.6 vs. 156.8 mmHG (95 % CI -0.6 to 3.0) between the control and the intervention group. DBP was 89.8 vs. 88.8 mmHg (95% CI -1.9 to -0.2). Serum cholesterol was 6.57 mmol/l vs. 6.64 mmol/l (95% CI -0.1 to 0.2) between the two groups. BMI was 27.7 kg/m2 vs. 27.8 kg/m2 (95% CI -0.4 to 0.07).	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Hicks (2007)[67]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	1,422 patients	BP controlled, receiving a recommended drug class medication within 1 week of the clinic visit adjusted	This study had 4 groups: usual care, CDS, NPs, and NPs+CDS. No difference was seen across all 4 groups for BP readings: Usual care vs. CDS: 45% controlled vs. 48% controlled, OR 0.96 (95% CI 0.78 to 1.19). Pts in the CDS group were more likely to have received a recommended drug class medication within 1 week of the clinic visit than patients in the usual care group: adjusted OR 1.32 (95% CI 1.09 to 1.61).	-	Study endpoints included BP control and mean SBP or DBP at the outcome visit.	Adjusting for patients' demographic and clinical variables, the number of prior visits, and levels of baseline BP control, there were no differences between intervention groups in the odds of outcome BP control.	NA
Holbrook (2009)[367]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, Laboratory system, Personal health records systems	511 patients	1) Composite* 2) Adequacy of monitoring A1c, BP, lipids, foot, eye	1) A shared electronic decision-support system to support the primary care of diabetes improved the process of care and some clinical markers of the quality of diabetes care; 2) Improvement in monitoring was seen significantly more in the intervention group than in the control group. Number of visits to the primary care provider (as recommended) increased significantly more in the intervention group than in the control group (difference of 0.66, 95% CI 0.37 to 1.02, p<0.001). 3) Satisfaction, ease of use, usefulness, preference for paper vs. computer.	+	A1c, BP, cholesterol, urine albumin, foot, eye	no significant change reported	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Holman (1996)[306]	CDSS/ CDS/ CCDS/ reminder	Handheld, Stand-Alone	5 patients	NA	NA	NA	Glycemic control NR, therefore includes Pre-prandial blood glucose levels, A1c and fructosamine*	Pre-prandial blood glucose levels* were significantly less during the 'advice on' period compared to the 'advice off' period (7.5 vs. 8.9 mmol/l, p = 0.015) but A1c and fructosamine not changed	-
Javitt (2005)[218]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	39,462 patients	compliance with recommendations to add-a-drug*	Physicians complied with 24% of these "add-a-drug" recommendations in the intervention group. In the control group, physicians spontaneously instituted the treatment that would have been recommended in 17% of instances in which the recommendation was triggered but not issued. This 42% relative difference in compliance was statistically significant (P = .007).	-	Admissions per 1,000 persons*	Among those in both groups who triggered recommendation s, there were 19% fewer hospital admissions in the intervention group compared with the control group (213.8 ± 5.7 vs. 264.6 ± 5.7, p< .001).	+

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Javitt (2008)[75]	CDSS/ CDS/ CCDS/ reminder	Pharmacy, Laboratory system, billing	39,508 patients	resolution rate-add a drug alert*, resolution rate-stop a drug*, resolution rate -do a test*	Resolution rate for “add a drug” CCs was 8.6 % higher in the study group than the control group (p <0.05). There was, however, no significant difference in the resolution rates for “stop a drug” CCs (change -6%, NS). Resolution rates for “do a test” CCs were 5.8% higher in the study group, p <0.05.	+	No	NA	NA
Johnson (2010)[76]	CDSS/ CDS/ CCDS/ reminder e-prescribe	EHR/EMR system	3,285 patients	rate of call backs generated* perceptions*	There was no significant difference in the call back rates between the “SYW off” and the “SYW on “ periods (0.4% vs. 0.45%; p = 0.47) Other Outcomes: perceptions* of Show your work were mostly positive trends, in the questionnaire.	-	No	NA	NA
Krall (2004)[89]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	1,076 patients	proportion of patients no longer eligible for alerts at the end of the month*	Following implementation of the alert, more patients were ‘no longer eligible for alerts at the end of the month’ (25.8% pre vs. 54.3% post, RRR -103%, p <0.001).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Kucher (2005)[90]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, CPOE/POE system	2,506 patients	No	NA	NA	*DVT, PE, bleeding	Clinically diagnosed DVT at 90 days Control: 103 (8.2%) Intervention: 61 patients (4.9%) (RRR 40%, p = 0.001); Clinically diagnosed PE at 90 days Control: 35 (2.8%) Intervention: 14 (1.1%) (RRR 61%, p = 0.004). The groups did not differ for proximal- or distal DVT, DVT of the arms, death, or hemorrhage.	+

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Kuilboer (2006)[219]	CDSS/ CDS/ CCDS/ reminder CPOE/ POE system	EHR/EMR system	32 primary care practices (78,926 patients of whom 9,798 had asthma or related symptoms) Actual: 156,772 patients and 40 GPs	rate of prescribing for cromoglycate	Prescribing for cromoglycate was reduced in the 12 to 39 year and 40 to 59 year groups (12 to 39: 9.9/1,000 patients vs. 4.1, p = 0.03) and (40 to 59: 9.0/1,000 patients vs. 4.2, p = 0.05). Other prescribing (3 drugs or drug classes and 4 age groups) did not differ across groups.	-	Peak flow measurements	Of 20 potential changes, 8 were observed: The AsthmaCritic group had more contacts for the 12 to 39 year group (p = 0.03), more measurement of peak flow total for the 0 to 11 year group (p = 0.02), more FEV1 total peak flow ratio measurement in the 12-59 year groups (p = 0.04 and 0.009), and more measurement of FEV1 rates in the 3, 12 and older groups (p = 0.01, 0.01, and 0.016).	-
Lester (2005)[95]	CDSS/ CDS/ CCDS/ reminder, email message of high levels of LDL	EHR/EMR system	235 patients 14 clinicians	proportion of patients with changes in statin prescriptions at 1 and 12 months*	At 1 month more patients in the email group had received statins than control patients (15.3%, vs. 2%, p = 0.001). At 1 year the difference in receipt of statins had disappeared (24.6% vs. 17.1%, p = 0.14).	-	LDL cholesterol also process	LDL cholesterol did not differ between group	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Linder (2009)[97]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	111,820 patients, 443 physicians within 27 practices	rate of antibiotic prescribing to patients with ARI *	In the intent-to-intervene analysis, clinicians prescribed antibiotics to 43% of patients with ARI diagnoses in control clinic compared to 39% in the intervention clinic (OR. 0.8; 95% CI, 0.6 to 1.2, p = 0.30). The ARI Smart Form did not significantly reduce overall antibiotic prescribing. The smart form was used by 33% of intervention clinicians (86/262) at least once. For the as-used analysis, appropriate antibiotic prescribing rate was 88% (n = 990 visits)	-	No	NA	NA
Lo (2009)[220]	CDSS/ CDS/ CCDS/ reminder	Imaging systems	3,673 potential alert trigger events Actual: 2,765 patient 366 providers	clinic, doctors office, etc.	3,673 total events where baseline lab tests would have been advised: 1,988 events in the control group and 1,685 in the intervention group. control group: baseline labs requested for 771 (39%) of the medications. intervention group: baseline labs ordered by clinicians for 689 (41%) of the cases. No significant association existed between the intervention and the rate of ordering appropriate baseline laboratory tests (RRR 5%, p = 0.782, NS).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Martens (2007)[101]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	77 physicians (GPs)	quinolone prescriptions , inhaled corticosteroids for newly diagnosed COPD in patients > 40 yr , first choice drugs for sore throats	GPs got reminders to either stop prescribing drugs or to prescribe a specific first-line drug. No differences were seen for either group to prescribe a drug. No differences were found for those in the cholesterol reminder group. GPs in the antibiotics, asthma and COPD group showed changes in 3 of 8 drug categories. Outcome measures were for sum scores for drug volume: lower scores were improvements in prescribing. Reminder physicians prescribed fewer quinolones (4.6 (95% CI 2.8 to 8.1)) vs. (1.5 (95% CI 0.8 to 2.2)); fewer inhaled corticosteroids for COPD in newly diagnosed patients >40 yrs (0.5 (95% CI 0.3 to 0.9)) vs. (0.0 (95% CI 0 to 0.1), p = 0.00); and better first choice drugs for sore throats (0.8 (95% CI 0.3 to 2.4) vs. (0.2 (95% CI 0.0 to 9.4), p = 0.03).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Matheny (2008)[221]	CDSS/ CDS/ CCDS/ reminder	Laboratory system	2,507 outpatient visits in 1,922 geriatric patients 303 primary care physicians	rate of receiving appropriate laboratory testing within 14 days of the clinical encounter/ 10 medication lab reminder categories.	Reminders for appropriate laboratory monitoring had no impact on rates of receiving appropriate testing for creatinine, potassium, liver function, renal function, or therapeutic drug level monitoring for patients overdue for lab monitoring NSAIDs; Angiotensin Receptor Blockers; Metformin; Potassium Supplements; Potassium Sparing Diuretics, Thiazide Diuretics; Angiotensin Converting Enzyme Inhibitors; HMG Co-A Reductase Inhibitors; Thyroxine; (or the following therapeutic drugs combined: Carbamazapine; Cyclosporine, Phenobarbital, Phenytoin, Proc-NAPA, Valproate).	-	No	NA	NA
McDonald (1976)[222]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	601 patient visits by 226 patients	compliance with drug monitoring test alerts*, compliance with recommendations to change therapeutic regimens*	Alerts to patients overdue for drug monitoring tests resulted in an increased number of tests ordered (11% vs. 36%, RRR -227%, $p < 0.0001$). Recommendations for changes to therapeutic regimens were followed in 28% of study events compared to 13% of control events ($p < 0.026$).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
McGregor (2006)[105]	CDSS/ CDS/ CCDS/ reminder	Pharmacy	4,507 patients	mean time spent on antimicrobial management:	Team members spent 3.2 hours per day on management of antimicrobials with the decision support system compared with 4 hours per day without. Not statistical testing was done.	-	Yes - mortality, Length of stay	Mortality: NS All patients 3.0% vs. 3.3%, p = 0.6 or for those patients who got alerts 8.2% vs. 7.8%, p = 0.5. Length of stay: All patients: 4.0 days vs. 3.8, p = 0.04 and 5 vs. 4 days for patients with alerts, p = 0.6 (NS)	-
Meigs (2003)[309]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, Laboratory system	598 patients 26 staff providers	NA	NA	NA	HbA1c levels*	The intervention had a modest benefit on glycemic control; HbA1c levels tended to improve in the intervention group (change -0.23) and worsen in the control group (change +0.14) NS	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Montgomery (2000)[108]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	552 patients	probability of patients taking 2 drugs , probability of patients taking 3 drugs	Adjusted data showed that compare with those in the risk chart group alone, those with computer support had a lower probability of patients taking 2 drugs (OR 0.5, 95% CI 0.2 to 0.9) p< 0.05) or 3 drugs (OR 0.3, 95% CI 0.1 to 0.6, p< 0.05).	-	*a five year cardiovascular risk >10%, SBP, DBP	no difference between groups with cardiovascular risk reduced below 10%. SBP and DBP were not reduced in the CDSS group (SBP 153 vs. 153 mmHg) (DBP 85 vs. 85 mmHg)	-
Murray (2004)[310]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system Pharmacy	712 patients	NA	NA	NA	SF-36 QoL*	No intergroup differences were found for the primary endpoint the SF-36 QoL* scale (Table 3). No analysis presented.	-
Overhage (1996)[117]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system EHR/EMR system, Hospital information system, Laboratory system, Pharmacy	24 practice teams - 78 house staff	rates of compliance with preventive care recommendations*	Overall, control teams complied with 24% of the reminders compared with 23% for intervention teams (P = 0.78). When preventive care measures were analyzed individually, 2 significant differences were seen in compliance (24-hour urine protein and angiotensin-converting enzyme [ACE] inhibitor) between control and intervention teams. These were assumed to be due to chance with multiple testing and because they were in the opposite directions.	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Overhage (1997)[118]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system EHR/EMR system Laboratory system	86 physicians on 6 services	immediate compliance with corollary ordering*, 24 hour compliance*, hospital-stay compliance*	Intervention physicians ordered the corollary orders required by the guidelines twice as often as control physicians did when measured by immediate compliance (46.3% vs. 21.9%, RRR -111%, p < 0.0001). Significant differences between study and control physicians also appear in 24 hour compliance (50.4% vs. 29.0%, RRR -74%, p < 0.0001) and hospital-stay compliance (55.9% vs. 37.1%, RRR 51%, p < 0.0001).	+	Length of stay	Length of stay was not different for intervention patients compared with control patients (8.12 days vs. 7.62 days, a difference of -0.5 days, 95% CI 0.17 to 1.19; p = 0.94).	-
Palen (2006)[121]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system, Pharmacy	26,586 patients	compliance rate	No significant differences between group physicians in the overall rate of compliance with ordering recommended lab monitoring for patients prescribed study meds. Lab monitoring Intervention: 56.6% Control: 57.1% (p = .31). Improved compliance: Gemfibrozil 71.2% vs. 62.3% (p = .003); Statins 75.7% vs. 73.9% (p = .05), Colchicine 52.8% vs. 46% (p = 0.05); Methotrexate 42.9% vs. 0% (p = 0.03).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Paul (2006)[124]	CDSS/ CDS/ CCDS/ reminder	Hospital information system	3,529 patients in the RCT and 1,203 in the cohort study	appropriate antibiotic prescribing increased	Appropriate antibiotic prescribing increased for both intention to treat analyzes (64.5% vs. 72.7%, RRR 13%, p< 0,05) and for per protocol analyzes (64.5% vs. 85.1%, RRR 32%, p< 0.05). The cohort study showed similar increases in improved prescribing (57% vs. 70%, p< 0.001)	+	Yes -(secondary outcomes) - duration of stay, duration of fever, or 30-day mortality, adverse events, costs.	Mortality not affected	NA
Persell (2008)[205]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	242 patients	self-reported aspirin use*	the control rate (reminders only) of self-reported aspirin use was NS different than the intervention (reminders plus clinician emails and patient phone calls) group (39% vs. 46%, p = 0.20)	-	NA	NA	NA
Peterson (2007)[126]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system, EHR/EMR system	9,111 medication orders Actual : 778 providers 2,981 patients	ratio between prescribed and recommended doses	Ratio between the prescribed dose and recommended dose showed that compared to controls the intervention group (reminders) received lower doses (3.0 vs. 2.5, p< 0.001).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Plaza (2005)[280]	CDSS/ CDS/ CCDS/ reminder	Handheld	198 patients	NA	NA	NA	QoL-St George's Respiratory Questionnaire*	Scores on the St George's Respiratory Questionnaire were significantly lower for intervention patients (34.1 vs. 27.3, p = 0.002, difference 6.8 (95% CI 2.5 to 11.1). % patients reaching MCID of decrease by 4 points was 65.3% I vs. 41.0% C	+
Prescription in Ischemic Stroke Manage-ment (PRISM) Study Group (2003)[127]	CDSS/ CDS/ CCDS/ reminder	Hospital information system	1,640 Pts	relative risk reduction (RRR) in ischemic and hemorrhagic vascular events*	For each patient, the CDSS was used to calculate the relative risk reduction (RRR) in ischemic and hemorrhagic vascular events which was achieved by the actual therapy prescribed vs. the option of 'no antiplatelet or anticoagulant therapy'. Estimated RRR(%) for the control and intervention in the first phase was 16.7 (13.2–23.7) vs. 16.3 (15.2–21.2) (NS different). For the second phase it was 16.3 (13.1–23.8) vs. 16.7 (13.5–22.9) (NS different).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Quinn (2008)[128]	CDSS/ CDS/ CCDS/ reminder	Glucose Meter	30 patients	changes in medication (medication intensified)	Process Monitoring - Pts using WDS were more likely to have physicians intensify diabetes medications (84.6% vs. 23.08%, p = 0.002).	+	Average decrease in AIc values *	Average decrease in A1c for intervention patients was 2.03% compared to .68% for control patients (p<.04)	+
Raebel (2005)[130]	CDSS/ CDS/ CCDS/ reminder	Laboratory system, Pharmacy	9,565 patients with 10,169 dispensings	percentage of dispensings with baseline monitoring*	Recommended laboratory monitoring was completed in 74.7% (n= 7,598) of dispensings at initiation of therapy. Compared to the usual care group, monitoring was higher in the intervention group (70% vs. 79%, RRR - 13%, p<0.001).	+	Lab tests - alanine aminotransferase /aspartate aminotransferase ; CBC; TSH	no results given in this paper, reported directly to care provider only	NA
Raebel (2007)[131]	CDSS/ CDS/ CCDS/ reminder pharma info system	EHR/EMR system	59,680 patients	new dispensing of targeted medications*	In the analysis of all dispensing of targeted medications, there was a significant reduction of new dispensing of at least one targeted medication (2.2% vs. 1.8%, RRR 16%, p<0.002). For dispensing of targeted medications considered inappropriate, there was also a significant reduction with the use of the alerting system (1.5% vs. 1.1%, RRR 27%, p<0.001).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Raebel (2007)[132]	CDSS/ CDS/ CCDS/ reminder	Hospital information system, Pharmacy	11,100 women	proportion of pregnant women dispensed a category D or X medication*, total number of first dispensings of targeted medications	The alerts resulted in a significant 47% reduction in the proportion of pregnant patients receiving category D or X drugs (p<0.001). Intervention patients received 238 dispensings of unique targeted medications and usual care patients received 361 dispensings (p = 0.03). The study was stopped primarily due to 2 false-positive alert types: Misidentification of medications as contraindicated in pregnancy by the pharmacy information system and misidentification of pregnancy related to delayed transfer of diagnosis information.	+	No	NA	NA
Rollman (2002)[137]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	200 Pts with documented major depression	antidepressant prescribing rate (secondary)	Prescribing of antidepressants (continuous use of change in prescriptions) did not differ across the 3 groups at 3 or 6 months.	-	Mean depression scores*	All groups improved their mean depression scores at 3 and 6 months. However the groups did not differ from each other in mean scores at 3 or 6 months.	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Rood (2005)[138]	CDSS/ CDS/ CCDS/ reminder	Hospital information system	484 patients	adherence to glucose measurement timing recommendations*, adherence to insulin dose advice*	Rate of compliance with glucose measurement timing recommendations control-intervention-control (29% vs. 38% vs. 41% with period 2 and 3 greater than period 1, p = 0.05). During the intervention period the rate for computerized group was higher than the control (36% vs. 40%, p = 0.05) Rate of compliance with insulin dose advice was higher in period 2 than 1, and then decreased significantly in period 3 (56% vs. 70% vs. 42%, p = 0.05). During the intervention period the rate for computerized group was higher than the control (64% vs. 77%, p = 0.05)	+	Glucose measurements	Glucose measurement actual levels NR. Measured the number of times the levels fell within normal range.	NA
Rosen-bloom (2005)[262]	CDSS/ CDS/ CCDS/ reminder CPOE/ POE system	CPOE/POE system EHR/EMR system	418,739 opportunities to access an information item 147 house staff	access rate for educational opportunities	Study physicians accessed educational opportunities for 278 of 240,504 (0.12%) vs. 18 of 178,35 opportunities (0.01%), RRR 1100, p< 0.05.	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Rosser (1992)[2]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	8,069 patients	rate of tetanus toxoid vaccination*	The rates of tetanus toxin given were 3.2% in control, 22.8% in physician reminder, 24% in telephone reminder, and 30.6% in the letter reminder. The differences in the recorded vaccination rate between the randomized control group and the three reminder groups are as follows: 19.6% in the physician reminder group (95% CI 17.1 to 22.2, p < 0.00001), 20.8% in the telephone reminder group (95% CI 18.3 to 23.5, p < 0.00001) and 27.4% in the letter group (95% CI 24.8 to 30.2, p< 0.00001).	+	No	NA	NA
Rotman (1996)[264]	CDSS/ CDS/ CCDS/ reminder e-prescribe	Hospital information system, Laboratory system	34 Physicians	user Satisfaction Rating*	After the physicians used the PWS, their user-satisfaction, score decreased by 0.34 Likert-scale units (approximately one half of one standard deviation of the mean score, p = 0.008). In contrast, the mean satisfaction in the control group (DHCP) increased by 0.49 Likert-scale units (p <0.0001). Overall, the two groups diverged with a difference of 0.83 Likert-scale units between the two groups (p < 0.0001).	-	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Roumie (2006)[226] Roumie (2007)[227]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	871 patients	prescribing changes*	No differences were seen comparing the groups who had provider education alone vs. those who had provider education and computer alerts for prescribing of any medication, changing doses, or adding medications (all data adjusted for multiple variables).	-	Yes -proportion of patients with controlled hypertension*	Pts of providers randomly assigned to the patient education group had better BP control (138/75 mm Hg) than those in the provider education (146/76 mm Hg) and alert or provider education alone (145/78 mm Hg). The patient education group had a SBP of 140 mm Hg or less compared with those in the provider education or provider education and alert groups ARR 1.31 (95% CI, 1.06 to 1.62; p = 0.012).	-

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Safran (1995)[141] Safran (1993)[142]	CDSS/ CDS/ CCDS/ reminder, CPOE/ POE system	EHR/EMR system	349 patients with HIV	mean response time to alerts*	Physicians who got alerts responded more quickly to them (mean 52 vs. 11 days, p< 0.0001). Physicians who got reminders responded more quickly to them (mean 500 vs. 114 days, p = 0.0001).	+	Rate of emergency visits, rate of non-primary care visits, hospitalizations, deaths	Pts in the control group had a higher rate of hospitalizations than those in the intervention group (44% vs. 35%, RRR 20%, p = 0.04) but other outcomes negative. Mortality not affected.	-
Sequist (2005)[228]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, Imaging systems, Laboratory system	6,243 Pts	compliance rate with Diabetes reminders*, compliance rate with Coronary Artery Disease reminders*	Diabetes reminders resulted in the recommended action in 19% of patients in the intervention group vs. 14% of patients in the control group. After adjusting for baseline patient and physician characteristics, patients in the intervention group were more likely than control patients to receive recommended diabetes care based on the composite outcome (OR] 1.30, 95% CI 1.01 to 1.67). CAD reminders resulted in the recommended action for overdue items: Intervention 22% Control: 17% Pts in the intervention group received recommended CAD care more often than those in the control group (OR 1.25, 95% CI 1.01 to 1.55) after adjusting for baseline differences.	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Shojania (1998)[148]	CDSS/ CDS/ CCDS/ reminder	Imaging systems Pharmacy	396 physicians	number of vancomycin orders/ prescriber*, mean duration of treatment prescribed per physician*, mean number of days of vancomycin per course of treatment*	The total number of orders for vancomycin for physicians in the control group was higher than in the intervention group (16.7 vs. 11.3 orders per physician, p = 0.04). Physicians in the intervention group prescribed vancomycin for 36% fewer days than physicians in the control group (26.5 vs. 41.2, p = 0.05). The number of days of vancomycin per course of treatment was also lower for the physicians in the intervention group, mean of 1.8 d vs. 2.0 for the control group (p = 0.05).	+	Length of stay	There was no significant differences between the groups with respect to the average length of stay.	
Tamblyn (2003)[159]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	12,560 Pts 107 physicians	rate of initiation of inappropriate drugs per 1,000 visits, Rate of discontinuation of inappropriate drugs per 1,000	During the study the number of new potentially inappropriate prescriptions per 1000 visits was lower (52.2 v 43.8) in the CDS group than in the control group (RR 0.82, 95% CI, 0.69 to 0.98). The rate of discontinuation of inappropriate drugs per 1,000 was not different: 67.4 vs. 71.4, RR (95% CI 1.06, 0.089 to 1.26)	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Tamblyn (2010)[160]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, Insurance databases	2,293 patients	rate of drug profile review, Changes in therapy	Process Monitoring - Significant increase in drug profile review in the intervention compared to the control group (44.5% vs. 35.5%;p<0.001). There was NS difference between the intervention and control group in the proportion of patients who had increases in therapy (28.5% vs. 29.1%; OR, 0.98; p = 0.86).	+	No	NA	NA
Terrell (2009)[164]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system	5,162 Pts 63 physicians	proportion of ED visits by seniors with an inappropriate medication*, proportion of medications that were potentially inappropriate was also reduced	The decision support reduced the proportion of ED discharges that resulted in potentially inappropriate prescriptions (3.9% vs. 2.6%; p = 0.02; OR = 0.55, 95% CI 0.34 to 0.89). The proportion of medications that were potentially inappropriate was also reduced, from 5.4% to 3.4% (p = 0.006; OR 0.59, 95% CI 0.41 to 0.85).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Terrell (2009)[165]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system, CPOE/POE system	63 physicians had 5,162 patient visits	visits with an inappropriate medication prescription* , prescriptions that were inappropriate	Primary Outcome: Decision support significantly reduced the proportion of ED discharges that resulted in a potentially inappropriate prescription (3.9% vs. 2.6%; p = 5.02; OR 50.55, 95% CI 50.34 to 0.89). This difference represents an ARR of 1.3% (95% CI 50.4 to 2.3%). Secondary Outcome: When analyzed as a percentage of all medications prescribed by physician subjects, the proportion of medications that were potentially inappropriate was significantly reduced, from 5.4% to 3.4% (p = 5.006; OR 50.59, 95% CI 50.41 to 0.85), with an ARR 2.0% (95% CI 50.7 to 3.3%).	+	No	NA	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Tierney (2003)[166]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	706 patients, 20 pharm-acists, 94 physicians, 1 nurse practitioner	NA	NA	NA	Quality of Life - SF-36*, heart failure exacerbations*	Across the 4 groups (physician intervention, pharmacist intervention, both interventions, and controls) no differences were seen for the SF-36 (8 subscales), or for Heart Failure exacerbations (4 subscales) and emergency department visits or hospitalizations (all or related to HF).	-
Tierney (2005)[167]	CDSS/ CDS/ CCDS/ reminder	CPOE/POE system EHR/EMR system, Pharmacy	706 patients	adherence to the care suggestions*	There were no differences between the four study groups in either adherence to the care suggestions, combined or individually (32% control, 32% physician intervention, 32% pharmacist intervention, 37% both interventions, NS).	-	Qualtiy of Life - SF-36, Chronic Respiratory Disease Questionnaire, hospitalizations	Change in Quality of life measures (NS). Hospitalization was measured and not affected.	NA

Evidence Table 15. KQ7: integrated CDSS study characteristics: results (continued)

Author (year)	MM System studied	Systems CDSS Integrated with	Number Analyzed	Process			Clinical		
				Outcomes Measured	Results	+/-	Outcomes measured	results	+/-
Van Wyk (2007)[171]	CDSS/ CDS/ CCDS/ reminder	EHR/EMR system	87,860 Pts 77 physicians	percentage of patient treated	Of the patients requiring treatment, 66% were treated in alerting arm, 40% in on-demand arm, and 36% in control arm. After adjustment for differences between arms, likelihood of being treated was 40% higher in alerting arm (adjusted RR 1.40; 95% CI 1.15 to 1.70) and 19% higher (NS) in on-demand arm in comparison to the control arm (adjusted RR 1.19; 95% CI 0.94 to 1.50). A similar pattern was shown for the need for screening within the 3 groups.	+	No	NA	NA
White (1984)[229]	CDSS/ CDS/ CCDS/ reminder	Imaging systems	396 patients	physician actions*	Physicians were 1.22 times as likely to take action in the alert group as compared to the non-alert group (p < 0.003). Actions included medication and lab monitoring changes.	+	No	NA	NA
Zanetti (2003)[180]	CDSS/ CDS/ CCDS/ reminder	Hospital information system	273 patients having cardiac surgery	more patients in the alarm plus reminder group received appropriate redosing of antibiotics after > 240 minutes in surgery.	More patients in the alarm plus reminder group received appropriate redosing of antibiotics after > 240 minutes in surgery (adjusted OR 3.31, 95% CI 1.97 to 5.56, p< 0.0001).	+	Rate of infection	Rate of infection Intervention: 4% Control: 6% (p = 0.4) lower than before the study (p = 0.2)	-

Evidence Table 16. Article references for studies across the phases of medication management (and education and reconciliation) by research design

Design	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Cohort	87,106,121,124,138,169,268,281, 292,293,297,300,317	188,190	188,190	203	267,275,287,292,296, 301		233
Observational	16,26,27,29,44,59,81,91,93,97, 113,128,135,144,146,153,155, 158,162,176,235,244,253,278,375 -377 1,3,50,67,73,77,78,85,99,140, 151,172-174,177,242,277, 280,295,305,368,369 17,19,34,58,72,80,82,108,110, 115,119,150,152,154,157,168, 236,266,269,286,294,329 2,4,6,11,14,15,18,20,25,33,43,46, 57,65,69,70,83,84,105,109,111, 156,163,274,276,315 22,35,36,63,64,71,95,98,112,122, 133,145,147,161,175,179,246, 260,261,270,284,288,298,316 7,30,62,76,79,86,92,101- 103,114,134,143,149,170,178, 250,259,271,290,291,307,308	65,99,172,182-187,189,191- 194,243,265,303,375	65,99,191,195,197,234, 265,278,303,375	46,50,99,186,187,197- 202,204,206- 210,234,240,253- 255,278,280,305,375	1,19,57,84,105,113, 177,214,223,225,283, 285,286,295,299,315, 329,375 36,133,143,147,211, 212,224,261,298,311, 314	249,341	230-232,245

Evidence Table 16. Article references for studies across the phases of medication management (and education and reconciliation) by research design (continued)

Design	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Qualitative	90,181,248,256,273,319,320,322, 330,336,337,339,340,342,344, 347,349,350,356,360,363,364, 366,370,371 247,318,332,334,338,341,345, 354,357,359,361,365	258,336,340,342,348	348,351,353	239,241,272,331,333,343, 346,352,355,362	251,335,347,356,358		
RCT	5,10,13,24,38-40,55,66,74,89,94,100,104,120, 123,125,129-132,166,167,262,302 8,21,23,28,31,32,37,42,45,48,88, 107,117,136,148,180,306,310 9,12,41,47,49,60,61,75,96,116, 118,126,127,137,139,141,159, 160,164,165,171,237,252,264, 289,304	75	130,196	205,306	23,40,66,89,94,104, 107,117,120,129,132, 136,166,167,215,217, 219-221,226,263,306,312, 367 12,60,61,127,137, 141,213,218,222,228, 229,279,309	127	313

Evidence Table 17. Article references for studies across settings for the phases of medication management (and reconciliation and education)

Setting	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Ambulatory care	10,13,29,38,39,55,67,73,74,82,90,94, 100,113,120,129-132,136,140,154,157,162,166,167, 172,236,242,244,266,269,273,281, 336,337,342,349,360,370 15,20,21,23,28,41,42,45,48,83,87,95, 107,118,139,147,161,171,260,270, 276,298,304,310,320,347,356,363 9,12,30,47,49,60-62,75,92,96,106,127,141,143,145, 159,160,259,264,291,307,332,357, 361,365	75,172,185,191,336,342	130,191	205	23,94,107,113,120,129, 132,136,166,167,215, 217,219-221,226,263,275,301, 312,347,367 12,60,61,127,141,143, 147,213,218,228,251, 267,279,298,309,335, 356,358	127,321	
Community (school, community centre etc)					228		
Home	113,306			306,343	113,217,306,335,367		

Evidence Table 17. Article references for studies across settings for the phases of medication management (and reconciliation and education) (continued)

Setting	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Hospital	16,26,27,59,73,78,81,85,91,93,97, 121,125,128,135,144,146,151,153, 155,158,174,176,177,235,253,256, 277,278,293,305,319,339,340,344, 349,366,368,375,376 1,3,5,17,19,24,34,50,58,72,77,80,82, 99,104,108,115,119,123,150,152,173, 181,248,262,268,280,286,294,295, 369,371 2,4,6,8,11,14,18,25,31,33,35,43,46, 57,63,69,70,84,88,89,105,109,110, 117,122,124,148,156,163,168,180, 274,276,288,292,315,322,330 7,22,32,36,37,64,71,95,98,112,116, 126,133,137,149,164,169,175,179, 246,247,250,252,261,271,284,289, 308,316,345,354,364 6,79,86,101-103,114,134,165,170,178,237,259, 290,297,300,317,318,334,338,341, 359	99,186-189,192-194,303,340,348,375	99,188,195,197,278,303, 348,351,375	46,50,99,186,198-200,202,204,208-210,241,253,255,278,280,305,346,355,375 187,197,201,203,206, 207,239,240,254,272, 331,333,352	1,19,57,84,89,104,105, 117,177,214,217,223, 225,263,283,285-287,292,295,299,301, 315,375 36,133,137,211,212, 222,224,228,229,261, 311,314	249	230-233,245,313
Long term care (nursing homes)	40,95,302,377		234,353	234,355,362	40		
Pharmacy	65,75,99,105,111,167,173,310,350, 371,376	65,75,99,182-184,188,190,191,243,258,265, 348	65,99,188,190,191,195, 196,265,348,351	99,202	105,167,287,296		233

Evidence Table 18. Article references for outcomes studies evaluating clinicians across the medication management for phases, education, and reconciliation

Provider	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Primary care physicians	10,12,21,28,47,55,65,67,100,118,140,161, 236,242,244,260,269,273,320,332,337,356, 357,360,361,363	65,258	65		12,356,358	321	
Specialists	47,147,169,236,246,248,252,268,273,338, 360				147		
Hospitalists	21,58,64,117,125,148,152,167,235,246,262, 277,319,330,338,345,349,368				117,167		
Other Physicians	7,10,21,117,235,271,349				117,213		
Physicians undifferentiated	58,90,116,138,143,149,248,256,259-261,264,266,274,276,318,322,334,338-341,344,345,347,364	340		355	143,261,347		245
Nurses	47,50,67,235,246,253,256,259,260,274,322, 334,339,340,345,347,359,364,366,371	340		50,198,206,239-241,253,254,272,331,333, 343,346,352,355,362	347,358		245
Mid level practitioners (PA, NP, MW)	47,67,236,337,347,357				347,358		
Pharmacists	167,276,277,322,334,339,340,345,350,361, 370,371,377	188,243,258,265,340,348	188,196,265,348,351	272,355	167		245
Other health professionals	90,152,260,270,271,276,334,339,361,371		351,353	272,346,352,362	358		
Hospital administrators	322,334,340,364	340		346			

Evidence Table 19. Article references for patients studied by phase of medication management and education and reconciliation

Patient	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Infants (0 to 2 years)	25,62,70,79,176,294	303	303	203	219		
Children (2 to 12)	9,19,41,62,70,176,177,250,294,305,308	303	303	305	19,177,219		
Adolescents (13 to 18)	9,19,41,70,74,86,102,127,132,176,177, 237,250,294,295				19,127,132,177,211,218, 219,295,335	127	245
Adults (19 to 44)	8,16,17,23,42,58,66,70,74,83,85,89,94, 104,108,119,123,131-133,135,167,177,180,293,295 60,61,86,102,103,106,114,127,139,170, 171,237,250,307				23,60,61,66,89,94,104, 127,132,133,167,177,211, 215,218,219,226,263,275, 295,296,311,335	127,249	245
Middle age (45 to 64)	8,16,17,26,35,39,42,55,58,66,70,74,83,85 ,89,91,94,104,107,108,119,123,131,132,1 35,136,166,167,180,292,293,295,310,315 23,60,61,86,92,96,102,106,112,114,126,1 27,133,139,145,160,170,171,237,300,306 ,307	189		306	66,89,94,104,107,132,136, 166,167,214,215,217,219, 225,226,263,275,287,292, 295,296,301,306,315 23,60,61,127,133,211,212, 218,228,251,267,311,314, 335	127,249,321	245
Geriatric (65 plus)	3,8,16,17,26,39,42,48,55,65,66,70,83,85, 89,91,94,104,107,108,115,117,119,123, 130,135,166,167,180,242,292,293,295, 302,310,315 23,60,61,64,92,102,106,112,114,126,133, 139,159-161,164,165,170,171,175,237,297,300, 304	65,189	65,130	205	23,66,89,94,104,107,117, 166,167,215,217,219,221, 225,226,275,287,292,295, 296,312,315 60,61,133,211,212,228, 267,311,314,335	249,321	232,245,313
Undifferentiated	5,22,33,36,49,88,137,289,298				36,137,222,229,279,285, 298,367		

Evidence Table 20. Main health IT studied by medication management phase and education and reconciliation

MMIT System	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
CDSS/ reminders	3,5,16,26,29,40,59,66,74,78,81,85,91,93,97, 99,100,113,121,125,128,130,131,135,144, 146,155,162,176,256,277,293,295,302,319, 360,377 1,10,11,13,17,20,38,39,55,58,69,72,82,88,89, 94,104,108,115,119,120,123,124,129,132, 136,140,152,154,157,166,167,173,236,248, 262,269,281,294,337 2,6,14,15,18,21,31,33,35-37,42,43,45,48,57,63,65,83,84,87,105,107, 109,117,122,148,163,180,260,284,288,292, 306,310,315 9,12,22,23,28,32,41,47,49,64,79,95,96,98, 102,103,112,114,116,126,127,133,137,139, 141,145,147,159,161,164,169,171,175,261, 264,297,298,300,304,332,356,361 30,60-62,75,76,86,92,101,106,134,143,160,165, 170,178,237,290,307,341,357,359	65,75,99,183,185,192,243,303	65,99,130,303	99,205,210,306,343	1,36,40,57,66,84,89, 94,104,105,107,113, 117,120,129,132,136, 166,167,214,215,219-221,223,225,226,283, 285,287,292,295,296, 301,306,315,367 12,23,60,61,127,133, 137,141,143,147,211-213,218,222,224,228, 229,261,279,298,309, 311,335,356,358	127	230
Barcoding-dispensing			351				
BCMA	278		234,278	200-204,206,207,234,239-241,254,255,272,278, 333,343,346,352,355			

Evidence Table 20. Main health IT studied by medication management phase and education and reconciliation (continued)

MMIT System	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
CPOE/POE system	1,19,24,27,34,40,77,80,99,128,153,155,158, 172-174,177,235,248,253,256,278,286,295,305, 339,340,344,349,366,368-371,375,376 2,4,8,17,18,20,25,70,71,95,98,109,115,118, 119,133,150,156,168,181,236,246,270,274, 276,304,322,337,356,364 7,30,79,141,149,170,175,179,237,247,250, 252,259,271,289,308,316-318,334,338,345,359,365	99,172,183,186,189,192-194,303,340,348,375	99,278,303,348,375	99,186,198,209,253,278, 305,331,375	1,19,40,133,141,177, 286,295,314,356,375		
e-Rx	44,50,67,73,75,90,111,138,151,242,244,264, 266,268,270,273,280,281,288,291,295,320, 329,330,332,336,342,350,354,361,363	75,182,184,187,190,191, 258,265,336,342	190,191,265	50,187,199,280	295,329	321	233
e-Transmission of the prescription to/from doctor to pharmacy	336,342	182,336,342					
Pharmacy information system	99,130	99,188,243	99,130,188,196	99		249	233
e-Medication administration system (e-MAR, e-TAR)	50,354	186,187	197,234	50,186,187,197-199,203,204,207,234, 241,346,352,362			
Other	36,46,50,110,127,242,250,277,316,318,347, 349,375	258,375	195,353,375	46,50,198,199,208,210, 375	36,127,212,217,251, 263,267,275,283,299, 312,335,347,375	127	230-232,245,313

Evidence Table 21. Article references for articles where the primary technology being studies was integrated with the various health IT systems

Integrated System	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
EHR/EMR system	26,29,40,66,67,73,85,93,97,99,100, 125,130,135,144,151,162,176,177, 242,253,256,277,295,305,319,336, 340,342,349,366,368,376,377 1,2,13-15,19,20,34,38,39,42,45,48,55,69, 80,87,88,94,105,107,108,115,119, 120,124,136,154,157,166-168,288,292,294,310,337,347 9,23,35,37,41,47,49,71,95,96,114, 116,117,141,145,148,159,161,171, 175,260,271,289,300,304,308,316, 332 30,60,62,75,86,92,103,106,143,160, 165,259,290,318,334,338,341,357, 359,361	75,99,185,186,188,189,191, 193,336,340,342	99,130,188,191,234	99,186,201,205,207,210, 234,239,241,253,255, 305,331,355,362	1,19,40,66,94,105, 107,117,120,136,166, 167,177,215,217,219, 225,226,275,283,287, 292,295,301,312,347 23,60,141,143,212, 222,224,228,229,267, 311,314,358	321	230,231,245
Formulary	1,3,8,44,77,138,259,280,332,341, 363	187	197	187,197,280	1,211,225		
Pharmacy	1,25,31,36,48,50,65,71,73,74,77, 104,105,111,120,128,129,131,146, 148,151,162,166,167,173,248,274, 276,280,305,310,330,356,364,376 61,112,116,170,178,250,259,270, 290,308,316,317,345,359,363	65,184,185,187,190,191,194 ,243,265	65,190,191,195,234, 265,351,353	50,187,198,201,203,204, 207-209,234,241,254,272, 280,305	1,36,61,104,105,120, 129,166,167,212,214, 215,225,283,287,299, 314,356		231,233

Evidence Table 21. Article references for articles where the primary technology being studies was integrated with the various health IT systems (continued)

Integrated System	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
CPOE/POE system	3,11,14,24,33,38,42,43,57,58,69,78, 81,82,84,89,97,108,117,119-121,124,125,135,148,154,155,157, 162,167,262,292,293,302,315,319, 377 28,32,41,64,76,95,101-103,116,118,134,164,165,178,261, 297,300,307,316		195	201,239-241,254,255,352	57,84,89,117,120, 167,223,261,287,292, 315,358		230,313
Hospital information system	1,5,6,8,16,18,22,24,33,46,59,70,72, 77,83,84,89,99,109,110,115,122, 131,150,163,180,236,253,256,268, 269,276,284,286,294,339,344 7,61,76,79,98,116,126,133,134,137, 149,247,264,300,316,356,365	99,183,193,303	99,197,303	46,99,197,202,204,253,254,272,346	1,61,84,89,133,137, 213,224,225,283,286, 314,356	249	232
Laboratory system	1,2,5,19,24,34,39,57,74,84,93,104, 105,110,113,115,129,146,152,157, 162,163,176,177,276,294,302,377 35-37,61,96,112,116,117,148,175,250, 264,274,289,290,308,316,317,338, 356,359	186,188,189	188	186,198,254	1,19,36,57,61,84,104, 105,113,117,129,177, 212,217,221,225,228, 229,275,283,285,299, 309,314,356,358,367	321	
Imaging systems	1,2,18,25,35,70,77,96,112,118,148, 163,175,177,248,274,276,294,316, 317,338,359	186,188	188	186,198,254	1,177,217,220,228, 229,275	321	
CDSS/reminders	1,14,27,38,57,71,119,120,128,154, 172,174,246,250,266,270,289,291, 330,332,337,363,368,376	172		239	1,57,120,220,221,312		
Billing/administration system	6,8,19,24,74,112,118,276			272	19,215,217,275		
Insurance	44,160,242,332,350				218		
Personal health records systems	350				312,335		
Patient decision support system					217		
Barcoding system	170,354		351				

Evidence Table 21. Article references for articles where the primary technology being studies was integrated with the various health IT systems (continued)

Integrated System	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
Not specified	4,10,12,17,63,90,123,139,140,147, 153,156,158,179,181,235,237,244, 252,273,278,281,298,306,320,322, 329,360,369-371,375	182,258,348,375	196,278,348,375	199,206,278,306,333, 375	12,147,251,279,298, 306,329,375		
Other	14,21,47,73,91,115,127,132,160, 169,178,259,340,345,354	186,192,340		186,200,201,209,343	127,132,223,263,296, 335	127	232

Evidence Table 22. Study designs used in studies measuring intermediate outcomes across the phases for medication management

Design	Prescribing	Order Communication	Dispensing	Administering	Monitoring	Education	Reconciliation/ Other
RCT	75,237,252,262,264	75			263		
Cohort	268				267,275		
Observational	235,236,242,244,246,250,253,259-251,266,269-271,274,276,277	243,265	234,265	234,240,253-255	261	249	245
Qualitative Mixed Methods	247,248,256,273	258		239,241,272	251		

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Appendix D. Technical Expert Panel and Peer Reviewers

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Appendix E. Excluded Studies

Organized security. To address compliance and IT security, Piedmont Healthcare chose to establish baseline metrics for it security risk. Health Manag Technol 1918;30(12):14-6, 18. OVID EMBASE.
Exclude - Not a Primary Study

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Exclude - Not a Primary Study

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Exclude - Not a Primary Study

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Exclude - Not a Primary Study

Bars and stripes forever? ... Well, maybe .. Hosp Purch Manage 1985;10(Dec):3-8. Database: IPA.
Exclude - Not MMIT

Pharmacy microcomputer software exchange. Hosp Pharm 1986;21(Apr):384-5. Database: IPA.
Exclude - Not MMIT

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Exclude - No Outcomes of Interest

Medical informatics needs assessment. 1993. http://healthit.ahrq.gov/portal/server.pt/gateway/PTARGS_0_1248_846504_0_0_18/medinds3.doc Grey Lit.
Exclude - Not a Primary Study

Technology in pharmacy: Friend or foe? Computertalk for the Pharmacist 1993;14(Nov-Dec):16-23. Database: IPA.
Exclude - Not a Primary Study

Automated decentralized pharmacy dispensing systems. Health Devices 1996;25(12):452-73. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

Ciba-Geigy program warns doctors. Pharmaceutical Journal 1996;236(Feb 1):134 Database: IPA.
Exclude - No Outcomes of Interest

Computer scripts favoured--survey. Pharmaceutical Journal 1996;236(Mar 8):300 Database: IPA.
Exclude - No Outcomes of Interest

Equipment management guide. Improving the drug distribution process--do you need an automated decentralized pharmacy dispensing system? Health Devices 1996;25(12):441-51. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

Top-priority actions for preventing adverse drug events in hospitals: Recommendations of an expert panel. Am J Health Syst Pharm 1996;53(Apr 1):747-51. Database: IPA.
Exclude - Not MMIT

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Exclude - Not a Primary Study

Physician order entry system cuts error rate, improves path compliance, tracks data. Health Care Cost Reengineering Rep 1997;2(10):152-7. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

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Exclude - Not a Primary Study

Proceedings of the 1997 9th Annual Quest for Quality and Productivity in Health Services. In St.Louis, MO, USA: IIE; 1997. 1998023929188
Database: Compendex.
Exclude - Not MMIT

State of the chains: Special report. Computertalk for the Pharmacist 1997;17(Nov-Dec):19-27. Database: IPA.
Exclude - Not a Primary Study

Even in best-run centers, preventable medication errors lengthen LOS, increase costs. Health Care Cost Reengineering Rep 1998;3(10):149-51. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

Electronic point-of-care prescribing: Selling the benefits, identifying initial steps for success. Formulary 1999;34(1): Database: Embase Sept 22-09.
Exclude - Not a Primary Study

Antibiotic-related ADEs plummet and pharmacy costs shrink with computer-aided decision support. Clinical Resource Management 2000;1(10):151-3. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

Can an automatic alert system eliminate medication errors? Hospital system gives it a go. Clinical Resource Management 2000;1(10):154-6. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

Chains speak out on technology. Computertalk for the Pharmacist 2000;20(Jul-Aug):14-25. Database: IPA.
Exclude - Not a Primary Study

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Exclude - Not a Primary Study

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Exclude - Not a Primary Study

Patient safety/medication safety: the impact of computerized physician order entry on medication error prevention in hospitalized patients (project). The Netherlands Organisation for Health Research and Development (ZonMw) 2000; http://www.zonmw.nl/ Grey Lit saved abstract -describves a research study not yet complete.
Exclude - Not a Primary Study

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Exclude - Not a Primary Study

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Exclude - Not a Primary Study

Can e-prescribing reduce drug costs under capitation? Capitation Manag Rep 2002;9(4):58-62. Database: Ovid MEDLINE(R).
Exclude - Not a Primary Study

Computers. Good medicine: e-prescribing. Fam Pract Manag 2002;9(9):63-4. Database: CINAHL.
Exclude - Not MMIT

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Appendix F. Glossary of Terms

Adverse drug event (ADE). Harm caused by the use of a drug. ADEs also include adverse drug reactions, which is harm directly cause by a drug at the normal doses. ADEs can also be classified as preventable or not.
Source: Nebeker JR, Barach P, Samore MH. Clarifying adverse drug events: A clinician's guide to terminology, documentation, and Reporting. Annals of Internal Medicine. 2004;140:795-801.

Adverse event. An adverse event is a specific undesirable medical occurrence. It can be either a new undesirable medical problem or worsening of an existing health or medical problem.
Source: http://www.gsk-clinicalstudyregister.com/glossary.jsp.

Bar Code Medication Administration (BCMA). BCMA is a barcode system consisting of a barcode reader, a portable computer with wireless connection, a computer server, and software. Patients and medications are barcoded and both barcodes must match before the medication is administered. Often BCMA systems also record medication events and timing.
Source: http://en.wikipedia.org/wiki/Bar_Code_Medication_Administration

Clinical Decision-Support System (CDSS). Computer tools or applications to assist in clinical decisions by providing evidence-based knowledge in the context of patient specific data. CDSSs for this report must be capable of integrating patient specific information from an existing system and external evidence to provide an alert or reminder to the clinician about actions to be or not be taken.
Source: Health IT.hhs.gov glossary

Clinical Outcomes. For this report we defined clinical outcomes liberally as any clinical morbidity, mortality, adverse event or clinical surrogate such as improved LDL cholesterol, asthma symptoms or quality of life, as the primary outcome of the study. They are also defined in this report as those things that happen to, and are important to patients in the study or real life situations.

Computerized Provider Order Entry (CPOE). A computer application that allows a provider's orders for diagnostic and treatment services (such as medications, laboratory, and other tests) to be entered and transferred electronically. During ordering or monitoring the CPOE system can compare the order against standards for dosing, checks for allergies or interactions with other medications and warns the physician about potential problems including duplication. Most CPOE systems are integrated into other existing health IT.
Source: Health IT.hhs.gov glossary

Cost-Benefit Analysis. Cost-Benefit Analysis (CBA) requires programme consequences to be valued in monetary units, thus enabling the analyst to make a direct comparison of the programme's incremental cost with its incremental consequences in commensurate units of measurements. CBA compares discounted future streams of incremental programme benefits with incremental programme costs; the difference between these two streams being the net

social benefits of the programme. In simple terms, the goal of analysis is to identify whether a programme's benefits exceed its costs a positive net social benefit indicating that programme is worthwhile.
Source: Drummond MF, Methods for the Economic Evaluation of Health Care Programmes, Ch-7, 3rd Edition, 2005, Oxford University Press

Cost-Effectiveness Analysis. Cost-Effective Analysis (CEA) is one form of full economic evaluation where both the costs and consequences of health programmes or treatments are examined. In CEA, the incremental cost of a programme from a particular viewpoint is compared to the incremental health effects of the programme, where the health effects are measured in natural units related to the objective of the programme. The results are usually expressed as a cost per unit of effect.
Source: Drummond MF, Methods for the Economic Evaluation of Health Care Programmes, Ch-5, 6, 3rd Edition, 2005, Oxford University Press.

Cost study. The cost study designation is a broad umbrella term used for all studies that include costs. More formal costs studies include cost-benefit, cost-utility, cost effectiveness analyses.

Cost-Utility Analysis. Cost-Utility Analysis (CUA) is one form of evaluation where both that focuses particular attention on the quality of the health outcome produced or forgone by health programmes or treatments. In CUA, the incremental cost of a programme from a particular viewpoint is compared to the incremental health improvement attributable to the programme, where health improvement is measured in quality-adjusted life-years (QALYs) gained, or possibly some variant, like disability adjusted life-years (DALYs) gained. The results are expressed per QALY gained.
Source: Drummond MF, Methods for the Economic Evaluation of Health Care Programmes, Ch-6, 3rd Edition, 2005, Oxford University Press.

e-Prescribing. A type of computer technology that clinicians use handheld or personal computer devices to review drug and formulary coverage and to transmit prescriptions to a printer or to a local pharmacy and often store this information. e-Prescribing software can be integrated into existing clinical information systems to allow physician access to patient specific information to screen for drug interactions and allergies. e-Prescribing systems are less complex than CPOE systems that allow ordering of drugs. For this report we use author-derived designations to differentiate between e-Prescribing and CPOE systems that are used to order medications.
Source: Health IT.hhs.gov glossary.

Electronic Data Interchange (EDI). Refers to the exchange of routine business transactions from one computer to another in a standard format, using standard communications protocols. This report concentrates on EDI in the communication between clinicians and pharmacists to perfect the order or prescription.
Source: Centre for Medicare and Medicaid Services, HHS

Electronic Health Record (EHR). An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be created, managed, and consulted by authorized clinicians and staff across more than one health care organization. An EHR system is usually broader than an EMR system. EMRs have traditionally been hospital based. For this report we use whatever designation the authors provide in their studies.
Source: Health IT.hhs.gov report page 15

Electronic Medical Record (EMR). An electronic record of health-related information on an individual that can be created, gathered, managed, and consulted by authorized clinicians and staff within one health care organization. These EMR systems are often hospital based and often not connected with information on the patient available outside the hospital system.
Source: Health IT.hhs.gov report page 15

Electronic Medication Administration Record (eMAR). Electronic medication administration record systems are hospital based, point-of-care systems that usually incorporate BCMA capabilities to make the administration of medications safer for patients by reducing error rates and allowing nurses to more efficiently manage medication tasks. eMAR systems record all medication administrative events including time of administration and integrate with pharmacy information systems.
Source: fgraham blog post

Health Information Technology (health IT). Health IT is the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of health care information, data, and knowledge for communication and decision making.
Source: Health IT.hhs.gov glossary

Intermediate Outcomes. For this evidence report intermediate outcomes were defined as satisfaction with system, usability, knowledge, skills, and attitude, and other related issues.

Major Endpoint. Also known as the primary outcome. The major endpoint is the main outcome that researchers determine to be the most important of any of the measures taken during planning and implementation of a study. Most studies have one to two major endpoints and multiple endpoints. Study size calculations are based on the major endpoint.

Medication Errors. Any error that occurs during the medication management process (prescribing, order communication, dispensing, administering, and monitoring). These can be potential errors--ones that are identified and addressed before the patient receives the medication or actual errors. The actual errors are ones that occur when the patient receives the wrong medication, the wrong dose or form, or at the wrong time. Medication errors can also be preventable and non-preventable. We used author identified statements of our classification of medication errors in this report.
Source: Ferner RE, Aronson JK. Clarification of terms used in medication errors: Definitions and classifications. Drug Safety. 2006 Nov;(11):1011-22.

Medication Management. Medication management is a continuum that covers all aspects of prescription medication. Medication management includes the five phases of the medication process (prescribing and ordering, order communication, dispensing, administering, and monitoring).Bell and colleagues in their seminal work on describing and modeling medication management outline the phases as being prescribe, transmit, dispense, administer and monitor[1] For this report, based on input from our TEP, to have greater clarity of what is occurring in the transmit phase, especially the active involvement by the pharmacist, we refer to the transmission of the order or prescription and the bi-directional communication between prescriber and pharmacy staff as "order communication".

Medication management can also include procurement, storage, reconciliation, and reporting involved in the assessment of patients for the need for drugs through to optimal care and monitoring after the drugs are prescribed. For this report we also included issues related to education or training in the use of health IT in medication management.

Medication Management through Health Information Technology (MMIT). MMIT systems are electronic systems that (1) collect, process, or exchange health information about patients and formal caregivers, (2) are integrated with existing health IT such as EHR or EMR systems, and (3) provide advice or suggestions to either the health care provider or the patients and their families on issues related to medication management.
Source: http://www.ahrq.gov/clinic/tp/medmgttp.htm.

Medication Monitoring. The process of assessing a patient's response to a medication and documenting its outcomes based on physical findings, history, laboratory testing, or a combination of any of these.
Source: Handler SM, Nace DA, Studenski SA, et al. Medication error reporting in long term care. Am J Geriatr Pharmacother 2004;2(3):190-6.

Medication Monitoring Errors. Errors due to inadequate laboratory evaluation of drug therapies or a delayed or failed response to signs or symptoms of drug toxicity or laboratory evidence of toxicity.
Source: Fillit H, Rockwood K, Woodhouse L. Brocklehurst's Textbook of Geriatric Medicine and Gerontology. 7th.Churchill Livingstone; 2010. Geriatric Pharmacotherapy and Polypharmacy.

Medication Reconciliation. A formal process of identifying the most complete and accurate list of medications a patient is taking and using that list to provide correct medications for the patient anywhere within the health care system.
Source: http://www.wicheckpoint.org/DefinitionOfTerms.aspx

Patient Safety. Freedom from accidental injuries during the course of receiving medical care.
Source: http://www.bvs.org.ar/pdf/seguridadpaciente.pdf

Personal Health Record (PHR). An electronic record of health-related information on an individual that is maintained by the person themselves. The PHR can conform to nationally

recognized interoperability standards. Data may be stand alone and entered only by patients and their caregivers or be fully integrated with EHRs and other health IT systems.
Source: Health IT.hhs.gov

Pharmacy Information System. An application that provides complete support for the pharmacy (hospital, community based or other pharmacies) from an operational, clinical and management perspective, helping to optimize patient safety, streamline workflow and reduce operational costs.
Source: http://www.himssanalytics.org/docs/Definitions-By-Term.pdf

Pragmatic Trial. Pragmatic trials are designed to find out about how effective a treatment actually is in routine, everyday practice. Pragmatic trials answer questions about the overall effectiveness of an intervention, and cannot study the contributions of its different components. Pragmatic trials are used to test an overall 'package' of care, including the contribution of the therapeutic relationship, patients' expectations, and any specific therapy that is used. Generally a pragmatic trial would compare the effect of this package of care with another treatment, not with a placebo. Pragmatic trials are used with the aim of providing the evidence that will help policy makers, practitioners or patients make choices between two interventions. They help define the best use of limited resources.
Source: http://www.frtcm.org/Pragmatic%20trials%20CTM%202004%2012%20136-40.pdf

Primary Outcome: *See Major Endpoint.*

Process Changes: Also known as Process Outcomes. These are study outcomes related to how the care process happens. For example, time to perform tasks, workflow changes, improved efficiencies, modifications of prescriptions, and errors in prescriptions are considered to be process changes or outcomes for studies of MMIT.

Qualitative Research. Qualitative research seeks out the 'why', not the 'how' of its topic through the analysis of unstructured information—things like interview transcripts, open ended survey responses, emails, notes, feedback forms, photos and videos. It doesn't just rely on statistics or numbers, which are the domain of quantitative researchers. Qualitative research is used to gain insight into people's attitudes, behaviors, value systems, concerns, motivations, aspirations, culture or lifestyles. It's used to inform business decisions, policy formation, communication and research. Focus groups, in-depth interviews, content analysis, ethnography, evaluation and semiotics are among the many formal approaches that are used, but qualitative research also involves the analysis of any unstructured material, including customer feedback forms, reports or media clips.
Source: http://www.qsrinternational.com/what-is-qualitative-research.aspx.

Signs. Evidence of disease ascertained by the clinician using direct observation or tools such as a stethoscope or blood pressure monitor. These signs are used to diagnosis a disease or disorder or monitor the progress of a healthcare issue.

Sustainability. The ability of a health service to provide ongoing access to appropriate quality care in a cost-effective and health-effective manner.

Source: Humphreys JS, Wakerman J, Wells R. What do we mean by sustainable rual health services? Implications for rural health research. Aust J Rural Health 2006;14(1):33-5.

Symptoms. Symptoms are patient reported issues (e.g., pain, fatigue, or depression) that the clinician considers along with signs to ascertain a disease or disorder or monitor disease progression.

Tall Man letters. Use of capital letters in look-alike drug names to help guarantee differentiation, For example, Novo**LOG** and Novo**LIN**, and Huma**LOG** and Humu**LIN**, helped differentiate these products.

Usability. Usability is a measure of how learnable, efficient, memorable, error free, and satisfactory a computer system or program is. Standard methods are available that measure the usability of a system and provide strategies to improve its usability aspects. A system that has high usability will be used and used efficiently.
Source: Neilsen J. Usability Engineering. Academic Press. San Diego, CA. 1993

Use. A simple measure or count of how often a system or application is used.
Source: Neilsen J. Usability Engineering. Academic Press. San Diego, CA. 1993

Usefulness. Usefulness is a soft measure of whether the system or application meets its stated goals.
Source: Neilsen J. Usability Engineering. Academic Press. San Diego, CA. 1993

Value proposition. Broadly speaking, 'value proposition' refers to the benefits one receives by adopting a particular product, approach, or technology, as compared to what you currently have, or what some other competitive offering would provide. In monetary terms, the value proposition is what the customer gets for his/her money/time. It can also be regarded as differences in performance and/or cost between two different alternatives, such as response speed, product or service quality, and the relative performance in terms of satisfaction or preference. Search terms: 'return on investment,' 'cost benefit,' 'relative value,' 'relative performance,' etc.
Source: Dr. Norm Archer, McMaster University, July 2009.

Value of health IT. Clinical, organizational, financial or other benefits derived from the adoption, utilization, and diffusion of health IT less the costs of achieving these benefits (http://grants.nih.gov/grants/guide/rfa-files/RFA-HS-04-012.html).