145BEvidence Tables for Chapter 35. Patient Safety Practices Targeted at Diagnostic Errors (NEW)

Table 1, Chapter 35. Evidence table

| **Author, Year** | **Diagnostic Error** | **Experimental Intervention** | **Patient or Related Outcome** | **Study Design: Result** | **Notes** |
| --- | --- | --- | --- | --- | --- |
| **Single Intervention Type** |
| **Additional Review Methods** |
| Galasko, 1971([51](#_ENREF_51)) | Diagnostic interpretation of radiographs | Review of x-ray films of outpatientsattending accident services by radiologist and other staff within a short turn around (24hrs) | Identification of a missed injury | Other: Retrospective review of radiographs 24 hrs after initial interpretation. In 0.6% of cases, review identified a missed injury. In 0.4% of cases, the radiologist failed to identify the injury while the senior houseman on duty did. In 0.6% of cases, review identified a missed injury, and in only 2 of 4,665 (0.04%) of cases, both review sessions missed the injury. | Missed diagnosis; misdiagnosis |
| Carew-McColl, 1983([49](#_ENREF_49)) | Diagnostic interpretation of radiographs | Review of x-rays in an accident and emergencydepartment | Number of patients allowed home with serious injuries which were radiologically apparent but which have been overlooked | Other: The majority (85%) of abnormalities were identified. Most overlooked abnormalities were not clinically significant. | Missed diagnosis; misdiagnosis; proof of concept |
| Robson, 1985([58](#_ENREF_58)) | Diagnostic interpretation of radiographs | Review of x-ray films by radiologist and other staff | Diagnostic accuracy of the interpretation of fractures impacting patient treatment and prognosis | Other: Diagnostic accuracy is correlated with seniority and experience (the casualty officer was more accurate than the students, second only to the radiologist). | Missed diagnosis; misdiagnosis |
| Ciatto, 1995([40](#_ENREF_40)) | Diagnostic errors during readings of mammograms | Independent double read of mammograms by experienced radiologists | Breast cancer detection rates and referral rates | Other: The mean increase in referral rate for double reading compared with single reading was 15.1%, and increased cancer detection by 4.6%. | Missed diagnosis |
| Lind, 1995([53](#_ENREF_53)) | Diagnostic errors in surgical pathology reports  | Review of surgical diagnostic pathology biopsies by a second pathologist prior to release of final reports | Major diagnostic errors in surgical pathology reports that could directly affect patient care | Other: 380 errors in 2,694 cases. 32 major errors with a potential for inappropriate patient care, 104 diagnostic discrepancies, 192 minor errors and 52 clerical errors. | Misdiagnosis; delayed diagnosis |
| Bruner, 1997([47](#_ENREF_47)) | Diagnostic discrepancies in brain and spinal biopsy reports | Review of brain or spinal cord biopsy results by a neuropathology consultation service | Substantial and serious neuropathology diagnostic errors  | Other: Disagreement between original and review diagnoses in 42.8% cases, with 8% serious errors in diagnosis. 96 cases (44%) less serious, but still clinically substantial. 31.9% disagreements occurred in patients referred directly compared to 51.0% of disagreements in review done solely based on pathology consultation. | Misdiagnosis |
| Dudley, 1997([29](#_ENREF_29)) | Serious errors of electrocardiograph (ECG) interpretation in an accident and emergency department | Provision of an (ECG) report by a cardiac technician at the time of recording, before senior house officers’ ECG interpretation | Serious errors of ECG interpretation | Other: Serious errors reduced by 59% when there was a prior technical report provided by an ECG technician. Many of these errors led to worse clinical outcomes. Independent review of ECG revealed moderate agreement between technicians and senior officers (kappa = 0.45) and between senior officers from different departments (kappa = 0.42). | Missed diagnosis |
| Thiesse, 1997([59](#_ENREF_59)) | Incorrect radiologic evaluation of overall response (to therapy) status in oncologic patients participating in multi-center trials  | Independent ascertainment of therapy response status of cancer patients by review of radiologic findings by an evaluation committee (EC) | Response status of cancer patients - major and minor disagreements between trial investigators and evaluation committee (that could impact patient management) | Other: Major disagreements occurred in 43% and minor in 8% of reviewed files. Number of tumor responses to therapy designated as significant was reduced by 23.2% after review by EC. | Diagnostic discrepancy: proof of concept |
| Lufkin, 1998([54](#_ENREF_54)) | Incorrect radiologic diagnoses by emergency department physicians | Radiologists’ review of radiographs interpreted by emergency room physicians  | Clinically significant discordant radiographic interpretations that alter patient’s treatment | Other: Emergency department physicians were confident in their interpretations in 9,599/16,410 cases (58%). Review of the 118 discordant interpretations in the confident group demonstrated 11 were significant. Discordant interpretations were higher in cases when emergency department physicians were not confident. | Misdiagnosis |
| Espinosa, 2000([50](#_ENREF_50)) | Radiograph interpretation errors in emergency department | Review of radiograph discrepancies at monthly meetings by radiologists; team redesigned the review process after intervention | Reduction of errors, including missed fractures or foreign bodies. | Pre/Post: Longitudinal study; after implementation, false negative error rate decreased from 3% to 1.2%. Review process revised; patient satisfaction improved, as did turnaround time for interpretations. | Missed diagnosis; misdiagnosis; delayed diagnosis |
| Nam, 2001([30](#_ENREF_30)) | Misdiagnosis due to inaccurate interpretation of colonic transit study in patients with chronic constipation | Repeat colonic transit study in patients with chronic constipation and suspected colonic inertia to confirm the diagnosis prior to colectomy  | Success rate post colectomy for chronic constipation | Experimental Design: The success rate of colectomy for colonic inertia was significantly higher in patients who underwent a repeat transit study confirming inertia than in patients who underwent colectomy based on a single study. | Misdiagnosis |
| Westra, 2002([60](#_ENREF_60)) | Missed diagnosis of head and neck cancers | A secondary review of histopathologic diagnoses  | Treatment modification based on changes in diagnoses | Other: Retrospective review; in 87% of diagnoses changes treatment was modified. | Missed diagnosis; misdiagnosis |
| Canon, 2003([48](#_ENREF_48)) | Detection of polyps and/or colorectal carcinomas | Secondary reading of barium enemas | Diagnostic accuracy of polyps and carcinomas | Other: Prospective study; double reading of barium enemas did not improve sensitivity and increased false positive rate. | Missed diagnosis; misdiagnosis |
| Kwek, 2003([52](#_ENREF_52)) | Breast cancer detection | Double reading of mammograms in Singapore Breast Screening Project | Diagnostic accuracy of mammography screening results | Other: Retrospective review; double-reading mammography intervention led to cancer detection improvement. Double reading increased the number of patient recalls. Positive predictive value (PPV) decreased from 8.2% to 6.1%. | Missed diagnosis; misdiagnosis |
| Nordrum, 2004([44](#_ENREF_44)) | Incorrect histologic diagnoses | Use of still images sent via electronic network (from glass slides of paraffin-embedded histologic material) to obtain second pathologist’s opinion diagnosis | Discordant diagnoses expected to have clinical implications | Other: Agreement 67.8% of the time with still images, and 68.9% of the time with reviewing glass slides, when compared to an original second opinion diagnosis. The cause of error was interpretation for 15 (of 90 cases), both image selection and interpretation for 9 cases, image selection alone in 3 cases, and image quality, selection and interpretation in 2 cases. 37.9% of still image discrepancies are likely to have had significant clinical implications. | Misdiagnosis; delayed diagnosis |
| \*Howard, 2006([42](#_ENREF_42)) | Missed injuries in trauma patients in a Level II trauma center | Implementation of a trauma tertiary survey (reevaluation of laboratory studies) within 24 hours of admission | Missed injuries in trauma patients in a Level II trauma center | Other: 14% of patients had one or more injuries missed in primary and secondary examinations that were captured during tertiary examination.  | Missed diagnosis |
| Raab, 2006([45](#_ENREF_45)) | Diagnostic errors in interpretation of pulmonary cytology slides (based on correlation of cytology and surgical specimens histology results) | Pre sign-out double viewing of all pulmonary cytology slides | Incorrect diagnoses (that could impact patient management and outcome) | Pre/post: Double viewing did not lower the frequency of cytologic-histologic correlation false-negative errors. Double viewing detects errors in up to 1 of every 37 cases. While the double cytology slide viewing was helpful at some project sites in detecting pre-sign out error, the intervention did not significantly reduce error frequencies at any of three study sites. Agreement with subsequent surgical diagnosis was moderate when definitive diagnoses were made. | Missed diagnosis; misdiagnosis |
| Singh, 2006([46](#_ENREF_46)) | Diagnostic error for head and neck cancer | Urgent referral; timing-based referral to reduce delay in diagnosis and influence on diagnostic pathway | Presence of cancer diagnosis, and the time delay to reach diagnosis | Other: Retrospective review and audit; 86% of ‘urgent’ patients were seen within 2 weeks. 24% had oral squamous cell carcinoma. | Delayed diagnosis |
| Duijm, 2007([41](#_ENREF_41)) | Missed breast cancer diagnosis | Independent double reading of mammograms by two mammography technologists beyond the standard double reading by two radiologists  | Cancer detection rates and referral rates of women with positive screening results from any reader | Other: Additional reading by technologists increased the cancer detection rate by 0.36 cancers per 1,000 women and the referral rate by 0.13%. | Missed diagnosis |
| Manion, 2008([43](#_ENREF_43)) | Clinically significant diagnostic errors (varied clinical conditions) | Second opinion in pathology to expose clinically significant errors | Diagnostic accuracy – no major disagreement in pathology that would impact treatment or prognosis | Other: Retrospective chart review of major diagnostic disagreements (2.3% of reviewed cases). Second opinion for clinically significant error validated in 34 of 132 cases reviewed. | Missed diagnosis; misdiagnosis |
| Parameswaran, 2008([56](#_ENREF_56)) | Missed abnormal findings in histology specimens | Sampling the remaining tissue of colorectal biopsies originally diagnosed as normal- with additional step sections- to reveal pathologic abnormalities | Identification of pathologic abnormalities in remaining biopsy tissues (originally reported as normal) | Other: Review sampling showed pathologic abnormality in 3.9% cases. New diagnostic information identified in 1.7% of cases, but lost in 1.3% of cases (present in initial sections but not in remaining tissue). | Missed diagnosis; delayed diagnosis  |
| Raab, 2008([57](#_ENREF_57)) | Incorrect surgical pathology diagnoses  | Two diagnostic error detection processes: targeted review of a random 5% of surgical pathology specimens, and focused review by 3 subspecialty pathologists of cases with a perceived higher level of diagnostic uncertainty or lack of standardization in terminology | Although this was a retrospective review of surgical pathology specimens, the study evaluated: a) impact identified diagnostic errors could have had on patient outcomes, including management, and b) whether the patient experienced subsequent harm | Other: Targeted review process identified 195 errors, (2.6% of reviewed cases) and focused review process identified 50 errors (13.2%). The number of major errors detected was 27 (0.36%) and 12 (3.2%), respectively. In secondary review of major errors (follow-up range from 8 months to 5.5 years), subsequent harm to the patient was observed in 11 cases (41%) from the targeted review and 7 cases (58%) from the focused review. | Missed diagnosis |
| Murphy, 2010([55](#_ENREF_55)) | Missed colonic and extra-colonic lesions in minimal preparation Computer Tomography (CT) of colon | Double reporting by two radiologists of minimal preparation CT of colon (MPCTC) in elderly patients | Identification of clinically relevant colonic and extra-colonic lesions that could impact future patient management | Other: Double reporting of colonic identified one extra-colonic cancer, at the expense of 5 unnecessary endoscopies. The positive predictive value for colon cancer was 69% for single reporting and 54.5% for double reporting. | Missed diagnosis |
| Hamady, 2005([71](#_ENREF_71)) | Incorrect interpretation of pathology reports for thyroid cancer | Pathology reports that received discrepant interpretations from a referring and receiving clinician were reviewed by a third clinician blinded to the thyroid cancer diagnosis  | Malignancy status of tumor, indicated course of treatment and expected prognosis | Other prospective design: Of 66 patients with thyroid cancer referred from general hospitals to specialty clinics for a second opinion on diagnosis, 12 cases (18%) received disagreement between initial and second review of the pathology report, resulting in re-review by a third, blinded reviewer. Five cases involved strong disagreement leading to change in both prognosis and treatment strategy. All 12 cases involved a change in prognosis: worsened in 8 (67%) and improved in 4 (33%). There were two cases each where re-review resulted in a switch from benign to malignant and vice versa. | Misdiagnosis |
| **Educational Interventions** |
| McCarthy, 1990([86](#_ENREF_86)) | Incorrect diagnosis by parents of symptoms of serious illness  | Teach parents Acute Illness Observation Scale (AIOS) to detect child’s illness vs. 3-point global scoring system for evaluating chance of serious illness | Number of infants with serious illnesses | RCT: Judgments of the intervention group were more reliable than those of the control group (weight kappa = 0.50 vs. 0.26). Sensitivity, positive and negative predictive values not statistically different. | Misdiagnosis; proof of concept |
| Fridriksson, 2001([87](#_ENREF_87)) | Misdiagnoses of sudden onset headache (an early sign of ruptured aneurysm) | A community teaching program on educating local physicians about sudden onset of headache in subarachnoid hemorrhage (SAH); continuous interaction between neurosurgeons and local physicians including seminars on SAH, individual follow-up of all referred patients | Early misdiagnoses of ruptured aneurysms; aneurysm surgery rates, surgery outcomes and morbidity and mortality outcomes at 6 months post SAH | Other: An initial misdiagnosis was identified in 12% of patients, and diagnostic error decreased by 77% with intervention. | Missed diagnosis |
| Thaler, 2010([88](#_ENREF_88)) | Errors in ECG readings due to switched electrode cables  | A 45 min teaching session for ICU nurses and physicians about correct ECG recording and errors resulting from improper electrode placements  | Reduction of cable reversal rates (which could lead to incorrect ECG diagnoses and unnecessary subsequent tests and hospitalizations) | Pre/post: Frequency of electrode cable misplacements was 4.8% pre-intervention and 1.2% post-intervention. This translates to a 75% reduction in ECG errors due to electrode cable reversals. | Missed diagnosis; misdiagnosis |
| **Personnel Changes** |
| De Lacey, 1980([84](#_ENREF_84)) | Incorrect diagnoses of radiographs in accident and emergency departments | Comparison of diagnostic accuracy between casualty officers and radiologists | Diagnostic accuracy of radiograph interpretation | Other: Prospective study to compare radiograph interpretation between casualty officers and radiologists. Uncertain or incorrect interpretation led to 6.8% of all patients receiving unnecessary procedures (e.g., casting an unbroken limb), 1.7% unnecessary return to X-ray, and 0.6% unnecessary outpatient referral. | Missed diagnosis; misdiagnosis |
| Sakr, 1999([37](#_ENREF_37)) | Clinically important errors, including errors in the diagnosis pathway (i.e., history, physical examination, and radiographic interpretation errors) | Use of junior doctor or nurse practitioner (NP) in providing care in the Emergency Department | Clinically important errors in history, examination, radiograph interpretation, treatment and/or advice and/or follow-up | RCT: There was no difference between the clinically important radiographic diagnostic errors made by NPs and by junior doctors (e.g., 89.8% of patients seen by junior doctors reported improvement in condition, while 91.1% of patients seen by NPs reported improvement). 15% of patients seen by junior doctors required follow-up visits within 28 days while 9.7% of patients seen by NPs required follow-up visits within 28 days. | Missed diagnosis; misdiagnosis |
| **Structured Process Changes** |
| Enderson, 1990([91](#_ENREF_91)) | Missed injuries associated with trauma | Tertiary Survey to capture missed trauma injuries  | Diagnostic accuracy; improvement of patient outcomes (mortality and morbidity) by identifying missed injuries | Pre/Post: 41 missed injuries were identified in 37 patients (N = 399) with Tertiary survey. | Missed diagnosis |
| Klassen, 1993([92](#_ENREF_92)) | Missed positive radiographic findings (fracture, dislocation or effusion) after trauma  | Brand protocol (protocol for ordering radiographs of injured extremities in patients >15 years old) applied by triage nurses to determine the need for a radiograph in the pediatric emergency department | Number of positive radiographic findings; number of missed positive radiographic findings and long-term clinical importance thereof, in pediatric trauma patients | RCT: Brand group ordered 81.9% radiographs; control 87.1%. Positive radiograph percentage was 40.8% vs. 42.6%, respectively. 3.2% were missed in Brand compared to 0% in control. | Missed diagnosis |
| Schriger, 2001([39](#_ENREF_39)) | Occult mental illness | Implementation of computerized psychiatric interview (PRIME-MD) | Detection of occult mental illness (upon admission to emergency department) | RCT: PRIME-MD survey, completed by emergency department patients, provided to emergency physician did not improve the frequency of diagnosing psychiatric conditions. 42% of patients within the study were identified as high risk for occult psychiatric illness according to PRIME-MD. Physicians reached psychiatric diagnosis 5% and offered psychiatric consultations to 3%. | Missed diagnosis |
| Biffl, 2003([93](#_ENREF_93)) | Missed injuries in Level I trauma center | Routine trauma survey (TS) in trauma intensive care unit patients | Missed injuries in level I trauma center | Pre/post: Missed injuries decreased from 2.4% to 1.5% overall, and from 5.7% to 3.4% in Trauma ICU patients after TS implementation. Missed injuries occurred more often in older patients, those that were admitted and those with high injury severity scores. | Missed diagnosis; delayed diagnosis |
| Soundappan, 2004([94](#_ENREF_94)) | Missed injuries associated with trauma (pediatric) | Extended tertiary survey in pediatric trauma patients | Incidence of missed diagnosis | Other: Prospective study; 13 missed injuries identified in 12 of 76 pediatric trauma patients. Fractures were the most common missed injury. Children involved in motor vehicle incidents were most likely to have missed injuries. | Missed diagnosis |
| \*Perno, 2005([25](#_ENREF_25)) | Delayed diagnosis of injury in a Pediatric Trauma Center | Implementation of a Pediatric Trauma Response team and trauma service for severely injured children in Pediatric Trauma Centers | Delayed diagnoses of injury (DDI) in admitted pediatric trauma patients | Other: DDI occurred in 15 (0.46%) of trauma patients. Previous study by same group revealed 4.3% DDI, an almost 10-fold decrease between the two studies. Among the 15 DDI cases in the latter study, 13 diagnoses were identified by tertiary examination, and 2 patients were discharged without diagnosis and returned to the hospital after worsening symptoms. | Missed diagnosis; delayed diagnosis |
| Ursprung, 2005([95](#_ENREF_95)) | Diagnostic errors related to laboratory tests or radiologic studies; delays in patient care or information transfer/ communication (additional errors probed) | Real time patient safety auditing during routine clinical work in the ICU (36-item patient safety checklist focused on several errors including diagnostic errors) | Impact of errors (i.e., delays in patient services or errors in information transfer) on patient clinical management and on adverse outcomes | Other: 338 errors detected; 27 of 36 items on checklist detected >1 error. Significant safety errors were detected promptly and rapid changes in policy and practice ensued. | Missed diagnosis; misdiagnosis;delayed diagnosis |
| Raab, 2006([98](#_ENREF_98)) | Incorrect interpretation of frozen sections of pathology specimens | Continuous monitoring over time of data correlation between frozen sections and permanent sections via the Q-Tracks Quality Improvement Program | Number of frozen–permanent section discordant results and deferred diagnoses (that could impact patient management and outcome) | Other: Mean frozen-permanent section discordant frequencies 1.36%. Longer participation in Q-Tracks significantly associated with lower discordant frequencies; 4- or 5-year participation showed decrease in discordant frequency of 0.99%; 1-year was 0.84%. Median discordant rates increased with increased bed size of institution. Government-owned institutions exhibited lower deferred diagnoses than non-government institutions. | Missed diagnosis; misdiagnosis |
| Raab, 2006([96](#_ENREF_96)) | Improved diagnostic accuracy from Pap test | Toyota production system redesign to improve workflow by 1-by-1 continuous flow process | Decrease in additional Pap test or surgical procedure, increase in diagnostic accuracy | Experimental Design; Pre/Post: 8-month non-concurrent cohort study; the number of correlating Pap tests and surgical pathology specimens increased from 42 in pre-intervention to 51 in the intervention group. Slight, but not significant, decrease in diagnostic discrepancies between pre-intervention/post-intervention. | Missed diagnosis |
| Raab, 2006([97](#_ENREF_97)) | Thyroid gland fine needle aspiration (FNA) diagnostic error  | Standardized terminology scheme (Toyota Production System Process Redesign) for reporting of cytologic results from thyroid fine needle aspirations (FNA) | Diagnostic accuracy of the FNA interpretation; surgery rates and repeated FNA rates | Pre-post: Separate cohorts/interventions analyzed; post intervention significantly fewer patients had surgery, received non-interpretable results, or repeated FNA. False-negative diagnosis rate decrease from 41.8% to 19.1% (p = .006), FNA sensitivity increased from 70.2% to 90.6% (p < .001), and atypical diagnoses rate decreased from 8.2% to 3.7% (p < .001). The false positive rate increased slightly and FNA specificity decreased but neither difference was significant. | Missed diagnosis |
| Raab, 2008([99](#_ENREF_99)) | Incorrect Pap test cytologic diagnoses | Continuous monitoring of the correlation of Pap test cytologic-histologic data - via the Q-Tracks Quality Improvement Program | Pap test diagnostic accuracy and detection of pre-neoplastic lesions (that could impact patient management and outcome) | Other: Longer participation in program by an institution associated with higher Pap test sensitivity and higher proportion of positive histologic diagnoses for a Pap test of atypical squamous cells (ASC). Longer participation also associated with higher proportion of women with follow-up positive histologic diagnoses for ASC. Compared to government-owned institutions, non-government institutions exhibited slightly higher predictive value of positive tests. Larger institutions had significantly lower sensitivity, but time of participation in the quality improvement program remained a significant factor in all analyses. | Missed diagnosis; misdiagnosis |
| Mueller, 2010([100](#_ENREF_100)) | Geriatric health problems previously unknown to a general practitioner (GP) and overlooked treatment needs | Standardized Assessment for Elderly Patients in a Primary Care Setting (a 44-item STEP instrument based on self-reporting and standardized patient interview), to explore conditions new to GPs | Further management interventions planned by GPs for previously overlooked geriatric health problems and treatment needs (that could affect patient outcome) | Other: STEP intervention helped GPs identify missing or unknown immunizations, anxiety in patients, chest pain, depression, urinary incontinence, breathlessness, smoking habits as well as claudication, abnormal clock drawing test, and thyroid dysfunction. Patients had a median of 11 health problems identified by STEP, of which 2 were new to the GP. | Missed diagnosis; delayed diagnosis |
| De Vries, 2011([101](#_ENREF_101)) | Surgical diagnosis accuracy | Surgical checklist, SURgical PAtient Safety System (SURPASS); review of claims records to see if checklist could have prevented claims | Morbidity, mortality, level of patient disability and need for additional operations; malpractice claims | Other: Retrospective review; cognitive, system, technical or unknown categorization of errors determined postoperatively. | Missed diagnosis; misdiagnosis; delayed diagnosis; proof of concept |
| **Technique** |
| Attard, 1992([72](#_ENREF_72)) | Incorrect diagnosis in patients presenting with abdominal pain | Pain relief with paraveretum for acute abdominal pain | Incorrect management decision (to operate or not) and incorrect discharge diagnoses | RCT: Reduction in pain after paraveretum, without reducing diagnostic accuracy. Subsequent decision to operate or observe was considered incorrect in fewer cases treated with paraveretum vs. the saline group (2/50 vs. 9/50; p=0-051, Fisher’s exact test).  | Misdiagnosis |
| Resnick, 1996([73](#_ENREF_73)) | Incorrect diagnosis of urinary incontinence in nursing home women | Stress test combined with cystometry to diagnose urinary incontinence  | Misdiagnoses of urinary stress incontinence  | Other: Combining cystometry with stress test improved diagnostic accuracy drastically. Of the 77% of women in whom the results of both tests were congruent, all were correctly classified (vs. video-urodynamic evaluation). No woman with stress incontinence was missed by the two-test strategy, nor was anyone with DH misclassified. Neither test was more accurate in cases where the test results diverged. | Missed diagnosis; misdiagnosis |
| Borgstein, 1997([74](#_ENREF_74)) | Incorrect appendicitis diagnosis | Diagnostic laparoscopy for female patients of child-bearing age with clinical signs of acute appendicitis, prior to appendectomy | Correct diagnoses post laparoscopy (and post-appendectomy when surgery was performed) | Other: The negative appendectomy rate after laparoscopy was 5%. In the group of fertile females without laparoscopy the negative appendicectomy rate was 38%. | Misdiagnosis; delayed diagnosis |
| Vermeulen, 1999([75](#_ENREF_75)) | Incorrect appendicitis diagnosis | The influence of pain medication administration on diagnosis of appendicitis | Diagnostic accuracy; whether surgery was deemed necessary or not | Experimental Design: Emergency department patients presenting with pain in lower right abdominal quadrant were randomized to receive morphine or placebo. The morphine cohort had a higher positive predictive value, and lower negative predictive value; differences between morphine and placebo group were not statistically significant. | Misdiagnosis |
| Prieto, 2003([76](#_ENREF_76)) | Incorrect indication of surgical margins of melanocytic lesions in en face frozen compared to permanent paraffin-embedded sections | Use of en face frozen sections (i.e., sections cut parallel to the surgical margin) for evaluation of surgical margins of melanocytic lesions | Although no direct patient outcomes studied,evaluation of the diagnostic accuracy of a rapid method to identify the surgical margins of melanocytic lesions could have had impact on patient management and outcome | Other: Poor overall agreement by frozen v. permanent analysis (kappa = .03).Better agreement between frozen and permanent section diagnoses for the non-melanocytic lesions (NML) than for the malignant melanomas (MM) cases. Within-physician agreement ranged from poor to moderate (kappa range from -.1 to .4). | Misdiagnosis; proof of concept |
| Thomas, 2003([26](#_ENREF_26)) | Diagnostic errors based on altered physical examination findings | Morphine sulfate (MS) administered for pain during diagnostic process | Patient disposition and ultimate diagnosis (including presence and severity of physical findings) | RCT: No differences between control and MS group with respect to disposition from the emergency department, ultimate need for operation, ultimate diagnosis (according to medical records and patient’s follow up) and need for repeat physician visit within a week for abdominal pain. | Missed diagnosis; misdiagnosis |
| Kokki, 2005([77](#_ENREF_77)) | Delay in diagnosis or decrease in diagnostic accuracy of physical examination findings for appendicitis | Oxycodone for pain relief in children presenting to the emergency department with moderate to severe abdominal pain | Pain relief and diagnostic accuracy of physical examination findings and clinical outcomes | RCT: Prospective, double-blind, and placebo-controlled clinical trial; there was significantly greater reduction in pain reported on a visual analog scale among patients that received oxycodone than those administered saline placebo. From before drug or placebo administration to after administration, diagnostic accuracy increased from 72% to 88% in those treated with oxycodone and remained at 84% in the placebo group. The rate of negative exploratory laparotomy was similar in both groups. | Missed diagnosis; misdiagnosis; delayed diagnosis |
| Hewett, 2010([78](#_ENREF_78)) | Missed colorectal adenoma diagnosis in colonoscopy | Cap-fitted colonoscopy, which allows for flattening of haustral folds and/or improves mucosal exposure | Missed colorectal adenoma diagnosis in colonoscopy | Experimental Design: Patients undergoing cap-fitted colonoscopy had significantly lower miss rate for all adenomas compared with regular colonoscopy (21% vs. 33%), but there was no difference when analyzed at the patient level rather than number of adenomas. | Missed diagnosis |
| **Technology-based Systems Interventions** |
| Wexler, 1975([103](#_ENREF_103)) | Time to correct diagnosis | Computer-assisted system of diagnosis (MEDITEL)  | Diagnostic accuracy; time to reach diagnosis | Experimental Design: In control group, MEDITEL identified correct diagnosis in 85% of cases; physicians reached the correct diagnosis in 65% of cases. In the experimental group, MEDITEL reached correct diagnosis in 58% of cases, and physicians in 83%. Time to diagnosis reduced in the experimental group, but did not reach statistical significance. | Missed diagnosis; misdiagnosis; delayed diagnosis |
| Wellwood, 1992([104](#_ENREF_104)) | Appendicitis diagnosis accuracy | Computer-aided diagnostic (CAD) tool; abdominal pain interpretation | Discharge diagnosis accuracy | RCT: Randomized trials with prospective data collection; predictive accuracy of CAD was 48% initially, but rose to 69% with decision aids, computers and performance feedback.  | Missed diagnosis; misdiagnosis |
| Selker, 1998([105](#_ENREF_105)) | Missed diagnosis of acute cardiac ischemia | Implementation of a computerized acute cardiac ischemia time-insensitive predictive instrument (ACI-TIPI) | Diagnostic accuracy (proxy – CCU or telemetry unit admission) | Experimental Design: controlled clinical trial. Appropriate admission to CCU or telemetry unit did not change for patients with acute MI or unstable angina when ACI-TIPI implemented. Use of ACI-TIPI reduced CCU admissions from 14% to 10%, telemetry unit admissions from 39% to 31% and increased discharges to home from 45% to 65% for non- AMI patients. Among patients with stable angina, use of ACI-TIPI reduced CCU admissions from 26% to 13% and increased discharges from 20 to 22%. Telemetry unit admissions decreased from 68% to 59%. | Missed diagnosis or delayed diagnosis (presumed from “appropriate admissions”) |
| Pozen, 1984([117](#_ENREF_117)) | Missed diagnosis of acute cardiac ischemia | Implementation of an acute cardiac ischemia predictive instrument, similar to acute cardiac ischemia time-insensitive predictive instrument (ACI-TIPI), calculated and delivered in hardcopy to clinicians | Diagnostic accuracy and proxy of CCU admission | Experimental Design: interrupted time series. Of the 2,320 patients seen across six emergency departments, diagnostic accuracy (83.4% vs. 79.6%, p = .002) and specificity (78.1% vs. 73.2%, p = .002), but not sensitivity (94.5% vs. 95.3%), were significantly improved by providing physicians with predictive instrument results. False-positive rate among patients with a low probability of ischemia dropped significantly (47% vs. 60%, p = .002), and admissions to CCU significantly decreased from 44% to 33% (p = .001) among patients without ischemia when physicians had access to predictive instrument results. | Missed diagnosis, misdiagnosis |
| Kuperman, 1999([28](#_ENREF_28)) | Time interval between laboratory results and clinical action | Computer system to detect critical conditions and notify the physician | Interval from when a critical result was available for review until appropriate treatment administered | RCT: Prospective, randomized controlled trial; intervention group had a 38% shorter median time interval between receipt of critical laboratory result and action with patient. However, the time until alerting condition was resolved did not reach clinical significance. | Delayed diagnosis |
| Bogusevicius, 2002([27](#_ENREF_27)) | Acute mechanical small bowel obstruction | Computer-aided diagnosis (CAD) and contrast radiography for diagnosis of acute mechanical small bowel obstruction | Time to diagnosis; morbidity, mortality, sensitivity, specificity and positive/negative predictive values | RCT: Prospective, randomized clinical trial; CAD had no significant advantage over contrast radiography in terms of diagnostic accuracy, but reduced time to diagnosis. Mean time to diagnosis was 1 hour for CAD and 16 hours for contrast radiography. | Missed diagnosis; misdiagnosis; delayed diagnosis |
| Major, 2002([32](#_ENREF_32)) | Diagnostic errors from omission of laboratory alerts and physiologic condition alerts | Computer system coupled to an alert engine to reduce errors of omission for critical care units. Patients randomly assigned to (1) alerts group, or (2) no alerts group. | Mortality | Experimental Design /Other: Prospective data collection; patients in alerts group had a higher mortality rate in both SICU and ward compared to no alerts. Critical alerts for ICU patients increased morbidity and mortality. |  |
| \*Poon, 2002([106](#_ENREF_106)) | Inadequate communication to physicians of patients’ laboratory test results  | “Result Notification via Alphanumeric pagers” (ReNAP) feature in clinical information system for real-time laboratory notification of physicians via pagers | Although no patient outcomes studied (only usage patterns and users’ satisfaction studied) related to unnecessary delays in patient care | Pre/post: Improved ReNAP usage patterns and satisfaction. | Delayed diagnosis |
| Gur, 2004([107](#_ENREF_107)) | Recall and breast cancer detection rates | Introduction of computer-aided detection (CAD) and mammography diagnosis system | Diagnostic accuracy of breast cancer | Other: Retrospective review; recall rates were 11.39% and 11.40% for without CAD and with CAD, respectively. Cancer detection rates were 3.49% and 3.55% without CAD and with CAD, respectively. | Missed diagnosis; misdiagnosis |
| Kakeda, 2004([108](#_ENREF_108)) | Lung cancer detection | Computer-aided diagnosis (CAD) system to detect nodules from lung cancers | Diagnostic accuracy of lung cancer | Other: Retrospective review; CAD system improved the detection of lung nodules by improving area under ROC curve from 0.924 to 0.986. | Missed diagnosis; misdiagnosis |
| Cupples, 2005([109](#_ENREF_109)) | Breast cancer detection rates (from mammography screening program) | Implementation of computer-aided detection (CAD) program | Screening results (diagnostic accuracy) of breast cancer detection rates | Other: Prospective study; cancer detection increased 16.3%, with invasive cancer detection increasing 164% while in situ cancer detection declined 6.7%. | Missed diagnosis |
| Ramnarayan, 2006([110](#_ENREF_110)) | Unsafe workups | Implementation of computer-aided detection (CAD) program | Diagnostic accuracy | Pre/Post: Prospective study; CAD reduced the number of ‘unsafe’ workups from 45.2% to 32.7%. | Missed diagnosis; misdiagnosis |
| Fenton, 2007([111](#_ENREF_111)) | Breast cancer detection rates | Implementation of computer-aided detection (CAD) technology to assist in the interpretation of mammography | Diagnostic accuracy | Other: Comparative study; cancer detection rate did not improve with use of CAD in mammography screening. Specificity decreased from 90.2% to 87.2%. | Missed diagnosis; misdiagnosis |
| Park, 2008([112](#_ENREF_112)) | Interval between results and clinical action | Starting in 2005, SMS text message notifications with patient critical values sent to clinician. From 2001-, a callback system had been in place to send patient critical values to clinicians | Time delay between receipt of clinically significant information and appropriate course of patient treatment | Pre/post / Other: Comparative study; time to action for critical hyperkalemia in ICUs and general wards in 2001 was 213 minutes and 476 minutes, respectively. In 2005, with SMS, times dropped to 74.5 minutes and 241 minutes, respectively. Clinical response to callback alerts was 73.3%, and was 79.3% for SMS texts. | Delayed diagnosis |
| \*Piva, 2009([113](#_ENREF_113)) | Failure to adequately communicate a critical laboratory value  | Computerized notification system for reporting critical values | Although no patient outcomes studied, timely physician notification could have had impact on patient events | Other: The computerized system improved communications within 1 hour timeframes as compared to the traditional phone process for all hospital services except medical specialties. | Delayed diagnosis |
| \*Singh, 2009([114](#_ENREF_114)) | Inadequate communication of abnormal cancer-screening test results in electronic health records | Electronic medical record alert for positive fecal occult blood (FOBT) cancer screening test results | Timely follow-up of abnormal cancer screening test results (FOBT) to reduce missed or delayed diagnoses of colorectal cancer | Pre/post: Lack of timely follow-up decreased immediately from 29.9% to 5.4% and was sustained at month 4 after implementing the intervention. | Missed diagnosis; delayed diagnosis |
| David, 2011([115](#_ENREF_115)) | Misdiagnosis of non-infectious conditions as cellulitis  | Visually-based computerized diagnostic decision support system (VCDDSS, also named VisualDx) to generate an improved differential diagnosis  | Number of patients admitted to the hospital with an incorrect cellulitis diagnosis | Other: In 18/28 of misdiagnoses, VCDDSS included the correct diagnosis, while in only 4/28 cases did the physician identify the correct diagnosis. | Misdiagnosis |
| Etchells, 2011([33](#_ENREF_33)) | Diagnostic errors due to lack of timely information of physicians for critical laboratory abnormalities | Real-time clinical alerting systems for critically abnormal laboratory values via text messages sent to physicians using alphanumeric pagers or smart phones (decision support also provided via smart phones or hospital intranet) | Clinical actions completed in response to the alerts (that could affect patient outcome) and patients’ adverse events | Experimental Design: Based on laboratory values, 50% of potential clinical actions occurred when the alert system was on as well as 50% while off. Adverse events within 48h were actually higher in cases while alert system was on (42%) than while off (33%) but this difference only approached significance (p = .06). | Delayed diagnosis |
| Fitzgerald, 2011([34](#_ENREF_34)) | Errors during reception and resuscitation of severely injured adult trauma patients (including errors in the diagnosis pathway) | Real time computer-prompted evidence-based decision support system (with decision and action algorithms) during reception and resuscitation of severely injured adults in Level I adult trauma center | Patient morbidity and mortality; including length of hospital stay | RCT: Error free resuscitation in 16% of baseline controls and 21.8% intervention. Predicted mortality rate 11%, but actual of 5.2%, meant insufficient power for analyzing a true mortality difference statistically. No significant reduction in sepsis or adult respiratory distress syndrome, but aspiration pneumonia was reduced from 5.3% (control group) to 2.5% (intervention). | Misdiagnosis; delayed diagnosis |
| Olsson, 2006([116](#_ENREF_116)) | Missed or delayed diagnosis of acute cardiac ischemia | Neural network-based decision making tool added to ECG results to recommend statistical likelihood that results indicated thrombolytic agents and revascularization | Diagnostic accuracy (proxy for indicated treatment for ST-segment elevation myocardial infarction)  | Other prospective design: Compared to cardiology attending, interns regularly treating chest pain patients in the emergency department classified 68% ECGs indicating ischemia and 92% of normal ECGs correctly without the decision aid. After switching to the decision aid two weeks following baseline, the interns’ rates changed to 93% and 87%, respectively, with significant increases in sensitivity and decreases in specificity. | Missed diagnosis, misdiagnosis |
| **Multiple Intervention Types** |
| **Additional Review Methods and Educational Interventions** |
| Seltzer, 1981([61](#_ENREF_61)) | Interpretation of radiographs | Film review process and education sessions with medical students | Diagnostic accuracy | Other: Retrospective review; seniority positively correlated to diagnostic accuracy. 80% of abnormalities were thought to be of clinical importance. First year residents had an omission rate of 6.1% while second and third year residents had 4.8%. | Missed diagnosis; misdiagnosis; proof of concept |
| Thomas, 1992([64](#_ENREF_64)) | Interpretation of radiographs | Red star report reminds or indicates something possibly missed or incorrectly interpreted. Educational conference held to discuss results of reports | Diagnostic accuracy | Other: Internal audit system; Red star reports issued in 2.8% of cases. 0.7% of patients needed to return for follow-up due to incorrect interpretations. Less than 50% required an alteration to treatment. |  Missed diagnosis; misdiagnosis |
| **Additional Review Methods, Educational Interventions, and Structured Process Changes** |
| Kundel, 1990([62](#_ENREF_62),[63](#_ENREF_63)) | Diagnostic accuracy of pulmonary nodule interpretation | Visual (gaze-duration threshold algorithm) feedback to radiologists based upon eye-position recordings. Re-review of radiographs | Proper interpretation of chest radiographs | Other: The more time spent looking at a certain section of a radiograph, the higher the chance for error. Feedback cohort outperformed the control group. Feedback led to more confident true-positive diagnoses. 42% of nodules missed initially were identified after feedback. | Missed diagnosis; misdiagnosis; proof of concept |
| **Additional Review Methods, Educational and Technology-based Systems Interventions** |
| McPhee, 1989([62](#_ENREF_62)) | Missed cancer diagnosis | Cancer screening reminders, audit with feedback or control (no intervention). Half the cohort was also provided with educational course; 6 intervention cohorts with medical residents randomly assigned. | Cancer screening test performance | RCT: 20% of patients had active colorectal symptoms, 37% had one or more colorectal cancer risk factors, and 48% had one or more cervical cancer risk factors. Cancer screening reminders increased performance the most, followed by audit with feedback. | Missed diagnosis; misdiagnosis; delayed diagnosis |
| **Additional Review Methods and Personnel Changes** |
| Trotter, 2003([67](#_ENREF_67)) | Diagnostic errors from interpretation of skin biopsies by general pathologists (vs. dermatopathologists) | Interpretation of skin biopsies by general pathologists (vs. dermatopathologists) | Clinical importance of discrepant skin biopsy results between general pathologists and dermatopathologists | Other: Agreement in 93.5% of cases; blinded review of skin biopsies by dermatopathologists had a sensitivity of 100% in review of general pathologist identification of lesions. 1.4% of biopsies had discrepancies that were of potential clinical significance. | Missed diagnosis; misdiagnosis |
| **Additional Review Methods, Personnel Changes, and Structured Process Changes** |
| Tsai, 2005([69](#_ENREF_69)) | Incorrect diagnosis of acute renal failure (ARF) based on urine analysis interpretation | Interpretation of urine analysis by a nephrologist for patients with kidney disease; Urinalysis conducted and report written by a nephrologist rather than clinical laboratory | Correct diagnosis of acute renal failure based on urine analysis interpretation (that can impact patient management and outcome) | Other: The first nephrologist (“A”) provided correct cause of ARF in 24 of 26 cases (92.3%) when performing urinalysis directly. However, diagnosis was correct by nephrologist A in only 23.1% and by a second nephrologist (“B”) in 19.2% when analyzing clinical laboratory-generated urinalysis reports. Diagnosing from nephrologist A’s direct urinalysis report, nephrologist B increased diagnostic accuracy to 69.3%. Nephrologists were more likely to recognize presence of RTE cells, granular casts, and dysmorphic RBCs in urine. | Missed diagnosis |
| **Additional Review Methods and Structured Process Changes** |
| Ross, 1996([65](#_ENREF_65)) | Incorrect vertebral fracture diagnoses | Blinding of X-ray readings to film sequence and patient identity for the detection of vertebral fractures | Incorrect vertebral fracture diagnoses (that can impact patient management and outcome) | Other: Blinding x-rays to sequence offers no advantages, increases frequency of errors and may inflate incidence rates. “Incidents” in this study are when there was no fracture at index x-ray but fracture was present at follow-up x-ray (average = 3.6 yrs follow-up). | Missed diagnosis; misdiagnosis  |
| Goodyear, 2008([70](#_ENREF_70)) | Laboratory error | Daily supervisory review of culture reports in microbiology laboratory | Proper treatment; if microorganism susceptibility is mistaken, incorrect antibiotic prescribed | Other: Prospective assessment; review of culture results and antibiotic susceptibility were found to correct errors in 0.8% of cases, and in 0.3% of cases the corrections were clinically significant. Most clinical significance was related to the susceptibility issues concerning culture results. 302 positive cultures / 101,703 were considered potentially clinically significant. | Missed diagnosis; misdiagnosis |
| **Additional Review Methods and Technique** |
| Beigi, 2007([31](#_ENREF_31)) | Incorrect diagnosis of lacrimal duct obstruction/stenosis/functional block  | Re-examination of patients scheduled for dacryocystorhinostomy based on lacrimal duct syringing with four tests  | Epiphora status at 12 months follow-up; and surgery rates | Other: Re-examination resulted in 18% not requiring previously scheduled major surgical intervention. | Misdiagnosis |
| **Additional Review Methods and Technology-based Systems Interventions** |
| Jiang, 2001([66](#_ENREF_66)) | Breast cancer detection | Computer-aided diagnosis (CAD) program | Diagnostic accuracy, as measured by interobserver variability, of breast cancer via mammogram interpretation | Other, Pre/Post: Prospective review; access to the tool improved radiologist agreement and reduced the occurrence of substantial disagreements. Among attending radiologists, and residents, the reductions were statistically significant at 63% and 28%, respectively. | Missed diagnosis; misdiagnosis; proof of concept |
| Peldschus, 2005([68](#_ENREF_68)) | Lung lesions/cancer detection | Reevaluation of chest CT studies for focal lung lesions with the computer-aided detection (CAD) system as a second reader | Diagnostic accuracy of lung lesions | Other: Retrospective review; CAD detected significant lung lesions in an additional 33% of patients. | Missed diagnosis; misdiagnosis |
| Moore, 2009([9](#_ENREF_9)) | Delayed sepsis detection in surgical intensive care | For early identification of sepsis, utilized routine bedside nursing measurements taken every 12 hours to determine whether a patient met threshold for escalating further assessment by nurse practitioner or resident physician. If one of these providers identified a source of infection, an intensivist was then included to determine whether treatment for sepsis was initiated.  | Mortality as a proxy of delayed diagnosis of sepsis | Other Prospective Design, Pre/Post: Of 4,991 sepsis screens with 920 patients across 927 admissions to the surgical ICU, the sepsis early identification tool and protocol yielded a sensitivity of 96.5%, specificity of 96.7%, positive predictive value of 80.2%, and negative predictive value of 99.5%. Compared to the year before implementing the sepsis tool, mortality from severe sepsis and septic shock decreased from 35.1% to 24.2%. The authors reported that mortality in the medical and cardiovascular ICUs did not decrease notably at the same location during the study period. | Delayed diagnosis |
| **Educational Interventions and Structured Process Changes** |
| Gleadhill, 1987([89](#_ENREF_89)) | Diagnostic error in radiograph interpretation | Casualty officer’s interpretation reviewed by radiologist, who was considered to have the correct report. Clinical guidelines introduced to standardize patients selected for referral | Reduction in clinically significant errors; late error detection | Experimental Design, Pre/Post: Number of referrals to Radiology dropped significantly from 59% to 48%, while rate of late error detection was unchanged. | Missed diagnosis; delayed diagnosis |
| Chern, 2005([35](#_ENREF_35)) | Diagnostic errors in high-risk patients discharged from the emergency room | Feedback to physicians of outcomes for high-risk patients discharged from the emergency department according to telephone follow-up and review of 3-day return emergency department visits; residents educated about uncertain presentations of serious diseases | Return visits to the emergency department and clinically significant adverse events (including return visits with serious misdiagnoses) | Pre/post: Intervention reduced adverse events (diagnostic and other) from 4.1% to 1.5%, and return emergency department visits from 10.1% to 4.9%. Of the 54 patients across both study periods that experienced adverse events, 40 had misdiagnoses. | Misdiagnosis; delayed diagnosis |
| **Educational and Technology-based Systems Interventions** |
| Linver, 1992([90](#_ENREF_90)) | Breast cancer detection | Dedicated mammography computer system. Educational mammography courses dedicated to radiologists. | Diagnostic accuracy | Pre/Post: Breast cancer diagnoses increased 50% pre-training and post-training, sensitivity increased from 80 to 86%. Positive predictive value remained 32%. Surgical consultations increased significantly. | Missed diagnosis; misdiagnosis |
| **Personnel Changes and Technology-based Systems Interventions** |
| Jacobs, 2002([85](#_ENREF_85)) | Facial fractures | Telemedicine system compared to plain radiography and diagnosis by oral and maxillofacial surgeons (OMFS) and accident and emergency department doctors | Diagnostic accuracy of facial fractures | Other: Comparative study; sensitivity and specificity of diagnosis by OMFS and A&E higher while viewing plain radiography than telemedicine system. | Missed diagnosis; misdiagnosis; Proof of concept; |
| **Personnel Changes and Structured Process Changes** |
| Vernon, 1999([36](#_ENREF_36)) | Interval between emergency department arrival and critical tests | Development of a formal trauma response team | Mortality, time to receiving necessary medical attention (CT scan, etc.) | Experimental: prospective, case-control study; patients treated by trauma response team had shorter wait times for computerized tomography scanning, operation room and overall time within the emergency department. Mortality rate was similar for both groups, but better for severely injured children treated by response team in comparison to reference population. | Missed diagnosis; misdiagnosis; delayed diagnosis |
| **Structured Process Changes and Technology-based Systems Interventions** |
| Lewis, 1996([102](#_ENREF_102)) | Mental illness; referral to mental health specialist | Three cohort intervention: (1) no additional information, (2) results of 12-item General Health Questionnaire (GHQ), and (3) results of self-administered computerized assessment (PROQSY) of common mental disorders | Clinical outcome; referral to mental health specialist | Other: GPs given varying levels of information to accurately diagnose mental disorders. Those given computerized assessment results saw modest clinical improvements in patients. No increase in referral rates to mental health professionals in computerized results group. | Missed diagnosis; misdiagnosis |
| Rollman, 2002([38](#_ENREF_38)) | Depression screening and diagnosis | PRIME-MD survey with 3 levels of electronic medical record feedback: (1) active care, (2) passive care, and (3) usual care | Diagnosis; treatment plan | RCT: Patient depression score on Hamilton Rating Scale for Depression decreased similarly regardless of physicians’ level of feedback. Screening for major depression, assisted diagnostic tools, and exposure to evidence-based treatment guidelines did not influence treatment plan. | Missed diagnosis; misdiagnosis |
| **Structured Process Changes and Technique** |
| Brossner, 2000([79](#_ENREF_79)) | Prostate biopsies and cancer detection | Ultrasound-guided prostate biopsy technique; comparative study of two techniques to ascertain which is more accurate at identifying prostate cancer | Cancer detection rate; morbidity differences between techniques | Other: Comparative study; diagnostic accuracy did not differ between approaches; morbidity and duration of pain increased with 12-core biopsy procedure. | Missed diagnosis |
| Naughton, 2000([80](#_ENREF_80)) | Prostate biopsies and cancer detection | 12 vs. 6 biopsy cores taken via transrectal ultrasound | Diagnostic accuracy of prostate cancer | Other: Comparative study; no difference in overall prostate cancer detection rate or in pain assessment. | Missed diagnosis; misdiagnosis |
| Presti, 2000([81](#_ENREF_81)) | Prostate biopsies and cancer detection | Adding additional biopsies to the diagnostic process | Diagnostic accuracy of prostate cancer | Other: Trends did not achieve statistical significance between 8- and 10-biopsy regimens. Routine sextant biopsies detected 82% of cancers, and 77% of missed cancers were detected by lateral peripheral zone biopsies. Performing 10 biopsies of peripheral zone increased cancer detection rates by 14%. | Missed diagnosis |
| Ravery, 2000([82](#_ENREF_82)) | Prostate cancer detection | Extensive biopsy protocol implemented | Diagnostic accuracy of prostate cancer | Other: Prospective study; protocol had a 6.6% improvement in prostate cancer detection rate. DRE significantly influenced detection rate of each protocol. | Missed diagnosis |
| **Technique and Technology-based Systems Interventions** |
| \*Weatherburn, 2000([83](#_ENREF_83)) | Overall rate of misdiagnoses and rate of serious misdiagnoses leading to patient recall and treatment change | Picture Archiving and Communications System (PACS) in the accident and emergency department  | Overall rate of misdiagnoses and rate of serious misdiagnoses leading to patient recall and treatment change | Experimental Design / Pre/post: Significant reduction in misdiagnosis when PACS was used (1.5% for film vs. 0.7% for PACS), but the rate of serious misdiagnoses involving patient recall did not change significantly. PACS reduced false negative interpretations but not rate of serious misdiagnosis. | Missed diagnosis |
| \* The evaluations of interventions (n=6) with evaluations that were identified in the Singh 2012 systematic review([23](#_ENREF_23)). |