Chapter 12
Compartment Syndrome Due to Patient Positioning

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Background

- Proper patient positioning is mandatory to provide optimal surgical access.
- Incorrect positioning is a risk factor for potentially severe long-term complications.
- Patients cannot communicate pain or other symptoms during surgery under general anesthesia.
- The lithotomy position can cause increased intracompartmental pressure (ICP) especially in the calf.

Epidemiology

One of the first and critical steps for any surgery is proper patient positioning. Its importance is often underestimated or performed by less experienced personnel. It is important to ensure adequate surgical exposure and optimal surgical access. Careful positioning also minimizes the risk of perioperative complications. Optimal perioperative positioning depends on the procedure and the surgeons' preferred approach. In the United States, 16% of surgically treated patients claim neural injuries while under anesthesia. In medical malpractice cases, injuries to the ulnar nerve (28%) or brachial plexus (20%) were most commonly claimed. Nearly half (45%) of these patients received a median payment of USD 35,000 for their claims [1]. Of these malpractice claims, 21.5% reported pressure ulcers due to inadequate surgical positioning [2]. The less physiologically the patient is positioned, the higher the risks for position-related complications.

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An equally severe perioperative complication is compartment syndrome due to improper patient positioning. Its development is particularly dangerous because patients are unable to express pain and discomfort. Orthopedic and trauma surgeons are familiar with compartment syndrome treatment. However, other surgical specialties may only be confronted with compartment syndrome in the face of improper patient positioning of their own patients. Compartment syndrome develops most commonly in the calf. Prolonged positioning with intrusion of the forearm heightens the risk of development of a compartment syndrome. Further, one general risk factor that must always be considered is coagulopathy.

Positioning should maximize pressure distribution to avoid compression injuries to soft tissues or underlying neural structures. Every potential surgical position has advantages and pitfalls that medical personnel should be familiar with and consider when preparing for the procedure. This chapter serves to highlight specific risk factors in patient positioning for operative and nonoperative procedures in a variety of surgical subspecialties.

Compartment Syndrome

General Causes of Compartment Syndrome During Patient Positioning

In general, compartment syndrome is a result of decreased perfusion in a well-defined physiological space, associated with increased compartment pressure. Risk factors for the development of a compartment syndrome include the following:

- Prolonged direct pressure of the affected compartment. This scenario leads to edema, which increases compartmental pressure.
- Venous obstruction can elevate compartment pressures. Decreased venous drainage leads to extracellular fluid accumulation and edema.
- Insufficient perfusion. Diminished perfusion decreases tissue oxygen saturation leading to hypoxia, cellular edema, and ultimately cell death.
- Positioning of extremities alone can change intracompartmental pressures. For example, sustained dorsiflexion of the ankle physiologically increases intracompartmental pressure of the calf.
- Inappropriate fluid accumulation, for example, during misplaced/extravasal IV line.
- Increased bleeding due to coagulopathy.
- Duration of the procedure: After more than 5 hours of surgery, the risk of compartment syndrome rises significantly.

Surgeons must bear these considerations in mind during patient positioning for every individual procedure (Table 12.1).

Table 12.1 Summary of general risk factors in the development of a compartment syndrome during patient positioning or during surgical procedure

Prolonged surgery time (>5 hour) Lithotomy position Pressure on extremities Vascular obstruction Vascular procedures Inappropriate fluid accumulation
Prolonged pressure
Hypoperfusion Coagulopathy

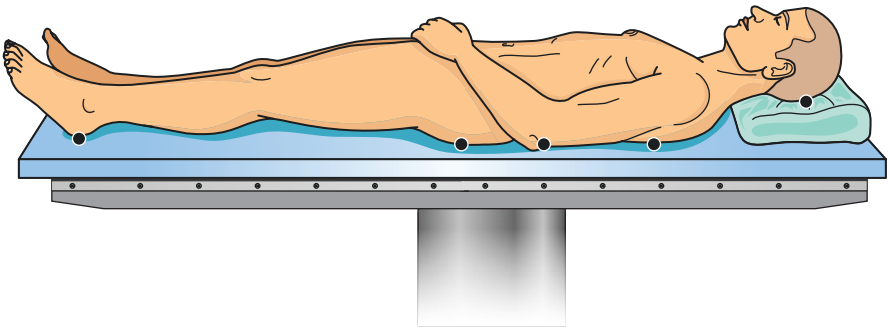

Fig. 12.1 Supine position with typical pressure points

Specific Surgical Positions Associated with Compartment Syndrome

Supine Position

Supine positioning is the most common surgical position and is the most physiologic position of an anesthetized patient (Fig. 12.1). Its advantages include ease of access to the abdomen, thorax, and extremities as well as the ease and speed of patient positioning. However, the supine position is subject to common complications including injury to superficial peripheral nerves and pressure ulcers. Injuries to the brachial plexus or venous obstruction in the neck due to lateral rotation of the head have also been reported. Acute compartment syndrome of the extremities rarely develops in the supine position. However, in prolonged surgeries or modified supine positioning, compartment syndrome has been reported. Positioning the limbs away from the body (such as 90° abduction of the upper extremity onto arm table) and subsequently fixating the positioned extremities pose the following risk factors:

- Pressure on the extremity due to fixation or a surgeon leaning against an extremity

- Extremities elevated above the level of the heart such as in angulated supine positioning
- Venous obstruction such as thoracic outlet syndrome

Lateral Decubitus Position

General complications of lateral decubitus positioning are similar to those found with the supine position (Fig. 12.2). The lateral decubitus position allows lateral approaches to the hip and the lower extremities. Moreover, it is used for certain spine procedures, some shoulder surgeries, and fibular bone grafting harvesting. In this position, the patient lies on the side with flexed hips and knees. The head should maintain a neutral position, and osseous prominences need sufficient padding. Prolonged discomfort raises the risks for subsequent complications. Similar to the lithotomy position, the lateral decubitus position is associated with the following risk factors for compartment syndrome:

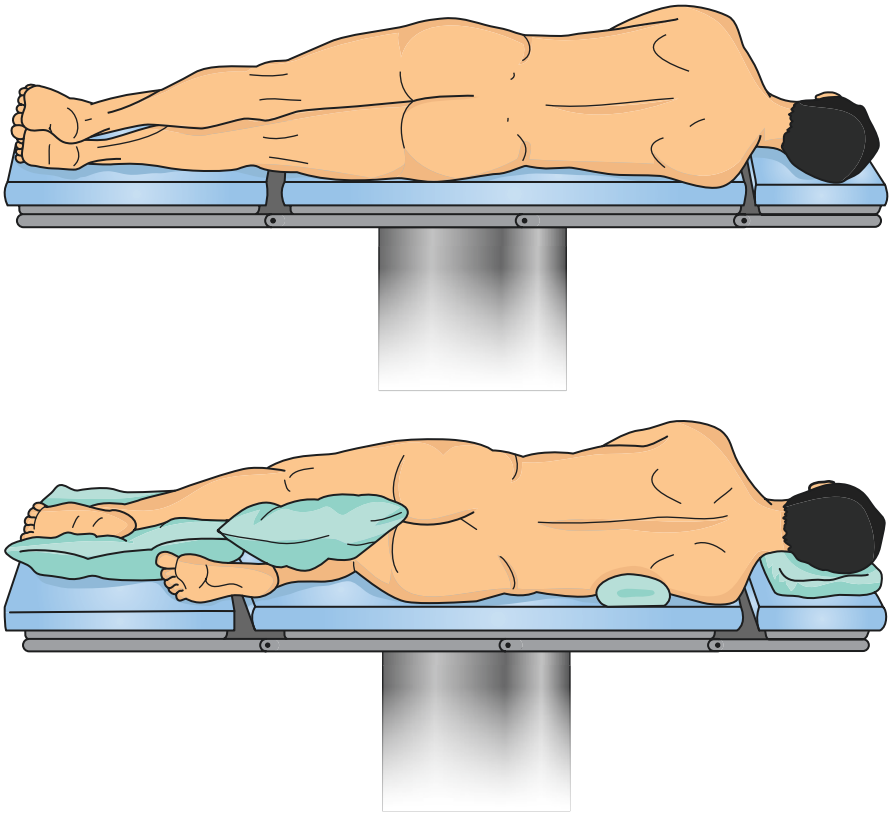

Fig. 12.2 Example of lateral decubitus position

- Pressure on the contralateral lower extremity
- Venous obstruction in the inguinal region due to hip flexion

This condition can lead to limb complications including ischemia, transient paresthesias, and rhabdomyolysis with the subsequent potential for renal failure. In one study, transient neurologic symptoms occurred after 5 hours and 45 minutes, with persistent neurologic deficits occurring after 8 hours. Another study that measured compartment pressures in healthy volunteers found that anterior tibial compartmental pressures in the bottom positioned contralateral leg could reach 240 mm Hg [3]. Compartment pressures of the anterior compartment of the bottom leg during compression by the upper leg showed elevated maximum average pressures of 57 mm Hg when padded on a soft surface and rises to an average 64 mm Hg on hard surfaces. The bottom upper extremity, compressed by the torso, showed maximum average compartment pressures of 100 mm Hg in the anterior flexor compartments. When the risk factors of pressure and vascular obstruction are combined, the risk of compartment syndrome rises significantly, especially in the bottom lower limb.

Prone Position

The prone position (Fig. 12.3) is one of the more complex surgical positions because it requires a high number of assistants to position the patient. Further, it requires increased anesthesiologic attention to ventilation and airway management, such as affirming proper endotracheal tube positioning by using mirrors. Prone spinal surgery may lead to bilateral superior iliac pressure ulcers. With respect to compartment syndrome, the following risk factors need to be considered when positioning the patient in prone position:

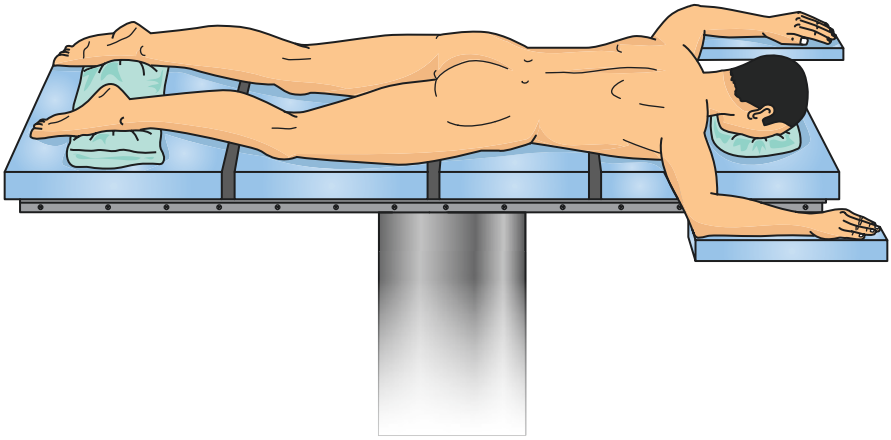

Fig. 12.3 Prone position: This position is more complex because it requires more personnel and higher anesthesiologic attention prior and during positioning

- Vascular obstruction in the inguinal region due to the patients' weight
- Pressure on the thighs
- Intra-orbital edema due to increased pressure in the fascial region

Fortunately, no wide-spread reports of compartment syndrome are available. One case [4], however, reported a compartment syndrome of the anterior compartment of the thigh after a procedure on the lumbosacral spine in prone position. Vascular obstruction in the inguinal region was postulated as the most likely cause of this complication. The combination of diminished inguinal blood flow and increased local pressure on the thigh in overweight patients raises the risk of developing compartment syndrome. Visual loss is also a known complication associated with prone positioning. Should a patient's head be positioned improperly on a soft headrest device, particularly if direct pressure on the eye is observed, the risk of orbital edema and subsequent compartment syndrome rises. While this complication is very rare, cases of ischemic orbital compartment syndrome have been reported in the literature [5].

Lithotomy Position

The lithotomy position is a supine surgical position that is most commonly associated with compartment syndrome. Surgeons use this position for optimal access to the pelvic and perineal organs (Fig. 12.4). The patient is placed supine while hips

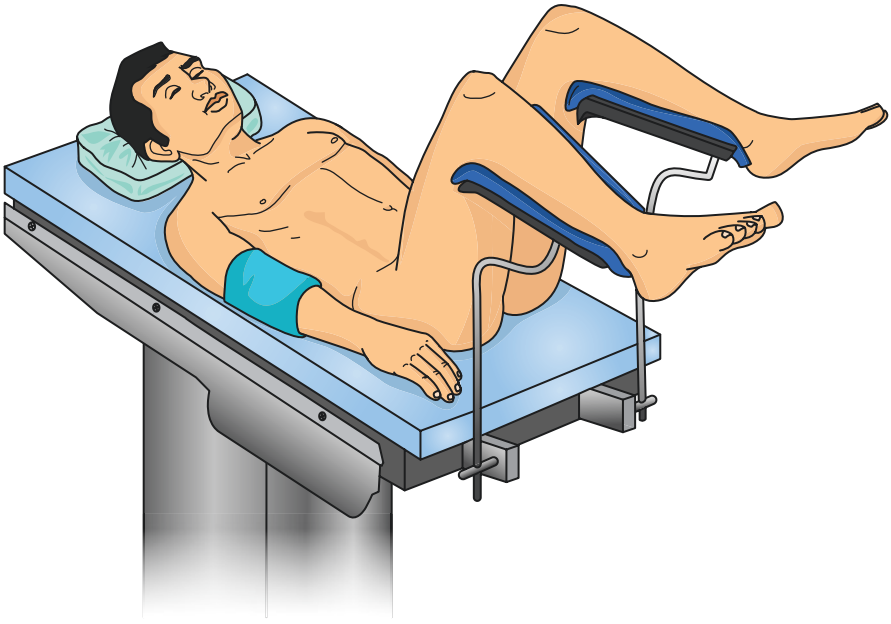

Fig. 12.4 Lithotomy position: During procedure, the surgeon gains good access to the perineal region. The elevated legs and the flexion in the hip are next to the pressure on the lower extremities considered as risk factors in the development of compart syndrome most commonly in the calf region

and knees are flexed as both legs are elevated. The legs are abducted, flexed, and elevated for adequate access to the lower abdomen and pelvic region. The most common complication associated with this position is neuropraxia of the common peroneal nerve (15.8%) [6] followed by compartment syndrome of the lower extremity.

The following characteristics of the lithotomy position are risk factors for the development of compartment syndrome:

- Pressure on the lower legs due to fixation of the legs on a support
- Legs elevated above the level of the heart
- Venous obstruction in the inguinal region due to hip flexion

The fixation of the legs produces increased external pressure, which subsequently causes intracompartmental edema, thereby raising intracompartmental pressure which may ultimately lead to compartment syndrome. Elevation of the legs above the level of the heart lowers local tissue perfusion, inducing hypoxia and producing edema or even tissue necrosis. In extreme cases, rhabdomyolysis and compartment syndrome result. Oftentimes, the lithotomy position requires hip flexion of at least 90°. Venous obstruction in the inguinal region may result, thereby lowering venous return, which allows interstitial fluid to accumulate, causing edema and increased compartment pressure.

Beach Chair Position

The beach chair position is characterized by Trendelenburg tilt of 10°–15°, 45°–60° of hip flexion, and 30° of knee flexion. Complications associated with this position include hypotensive bradycardic events, venous air embolism, hypoglossal nerve palsy, and neuropraxia of cutaneous nerves of the cervical plexus [7, 8]. Compartment syndrome risk factors include the following:

- Inguinal venous obstruction
- Pressure on the extremity due to fixation
- Elevation of the lower extremities due to Trendelenburg in modified beach chair positioning

In a case report of a laparoscopic robot-assisted cystoprostatectomy in modified beach chair position with Trendelenburg for 6 hours and total surgery time of 11 hours, Galyon et al. [9] reported compartment syndrome of limbs requiring fasciotomy. The etiology was postulated to be a combination of long duration of surgery, high BMI (33.9 Kg/m^2), obstruction of venous outflow in the lower extremity, hypoperfusion, and pressure due to fixation.

Gluteal Compartment Syndrome

While gluteal compartment syndrome has only rarely been reported in the literature, anatomic studies show that the gluteal musculature is compartmentalized. A systematic review of the literature found 28 cases of gluteal compartment syndrome

Table 12.2 Position-specific pathophysiologic response in the development of compartment syndrome

Lithotomy position	Elevation of the legs
	Pressure on legs due to fixation
	Vascular obstruction in the inguinal region
Lateral decubitus position	Pressure on the lower extremities on the nonoperated site
	Obstruction of vascular structures in the inguinal region
Supine position	Pressure on extremities
	Vascular obstruction in the neck
	Elevation of extremities in angulated supine positioning
Prone position	Vascular obstruction in the groin
	Pressure on the thigh
	Increased pressure in the facial region
Beach chair position	Inguinal vascular obstruction
	Pressure on extremities due to fixation
	Elevation of the extremity

reported in the literature with the most common cause being prolonged immobilization, accounting for 50% of cases [10]. Other major causes included trauma in 21% of cases and joint arthroplasty in the setting of epidural analgesia also in 21% of cases. Prolonged pressure on the gluteal area leads to hypoperfusion with subsequent tissue necrosis. Subsequent edema combined with venous obstruction raises intracompartmental pressure and increases the risk of developing gluteal compartment syndrome. Overall, risk factors include the following:

- Prolonged immobilization
- Epidural analgesia in the setting of joint arthroplasty
- Infection
- Trauma
- Vascular surgery
- Intramuscular drug abuse
- Altered level of consciousness (alcohol or drug overdose)

The position-specific risk factors are summarized in Table 12.2.

Intraoperative Diagnosis of Compartment Syndrome

Diagnosing compartment syndrome intraoperatively is challenging. The surgeon must be aware of major risk factors associated with the development of compartment syndrome including the following:

- Prolonged time of surgery (>5 hours)
- Lithotomy position
- Pressure on the extremities
- Inguinal vascular obstruction

If a compartment syndrome is suspected intraoperatively, the authors recommend measuring intracompartmental pressures with an ICP device while the patient is under general anesthesia. Normal physiologic supine intracompartmental pressure of an extremity at heart level is 5 mm Hg. Compartment syndrome is defined as an intracompartmental pressure 30 mm Hg greater than the diastolic blood pressure and serves as the threshold for surgical decompression of the compartment [11].

Therapeutic Recommendations

Therapy bases exclusively on decompression of all compartments of the affected extremity. The most effective and commonly used method is complete dermatofasciotomy (Fig. 12.5). We recommend protecting the fasciotomy with negative-pressure wound therapy (VAC), although a polyurethane synthetic skin substitute such as Epigard® may also be used. Secondary closure often follows about 5 days postoperatively depending on soft tissues.

Limitations and Pitfalls

The diagnosis of compartment syndrome is challenging, especially intraoperatively during general anesthesia, because patients are not able to express their symptoms. The lithotomy position is most commonly associated with the development of positional compartment syndrome. This position is mainly used for urologic and gynecologic procedures. Oftentimes, urologists and gynecologists are not routinely involved in treating compartment syndrome, as treatment is usually managed by general, orthopedic, or trauma surgeons. Physicians that are experienced in the

Fig. 12.5 Intraoperative documentation of an early compartment syndrome depicts immediately below the fasciotomy and swelling of the calf muscle as a sign of early compartment syndrome

diagnosis and treatment of compartment syndrome should be promptly consulted if a compartment syndrome is suspected intra- or postoperatively.

While technical and digital advances in surgery provide huge potential for minimally invasive surgery with less surgical complications and morbidity, it is also associated with new complications. This case is especially true in robotic surgery (e.g., DaVinci) as the surgeon is not directly next to the patient. While focus on the procedure is high, the overview of the patient as a whole decreases, which potentially risks missing perioperative complications around the operating field.

Future Directions

Compartment syndrome due to surgical positioning is an uncommon complication, but can be associated with severe impacts on patient quality of life. The development of noninvasive devices for monitoring intracompartmental pressure intraoperatively and postoperatively represents a useful direction for future research and development.

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