Positioning Injuries in Anesthesia: An Update

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SIGNIFICANCE AND INCIDENCE
Anesthesia professionals, operating room (OR) nurses, and surgeons worry about injury to skin and other organs when positioning the anesthetized patient. The true incidence of all perioperative position-related injury is subject to conjecture. An important type of position-related injury is peripheral nerve injury. The incidence varies with surgical procedure and positioning. For example, ulnar neuropathy has been found in as many as 26% of patients undergoing open-heart surgery [1], whereas lower extremity neuropathy occurred in 1.5% of patients in the lithotomy position [2]. The incidence of ulnar neuropathy is estimated at 0.46% after noncardiac surgery [3]. According to data from the American Society of Anesthesiologists (ASA) Closed Claims Database, peripheral nerve injuries represent the second largest class of adverse outcomes and account for 16% of all claims [4].

TYPES AND MECHANISMS OF POSITION-RELATED INJURY
To promote an optimal understanding of position-related injury and to lay a foundation for prevention thereof, it is useful to think in mechanistic terms. Knowing the mechanism of injury may allow practitioners to avoid certain positions and to use ancillary measures to counteract potentially injurious processes.

Broadly, position-related injury can result from tissue compression, blunt or sharp trauma, air embolism, and organ under perfusion. Temporary arterial occlusion and interruption of nerve blood supply result in reversible conduction block. Mild stretching of nerves may cause small areas of nerve ischemia from disruption of vasa nervorum. More severe stretching may tear intraneural connective tissue with resultant hemorrhage and necrosis [5]. This may further progress to intraneural edema and block axoplasmic transport, with nerve...
dysfunction lasting as long as several weeks [6]. With further prolongation and increased severity of injury, the nerve undergoes demyelination, followed by axonal loss and Wallerian degeneration [5]. Severe and prolonged tissue compression can result in sufficient ischemia and edema of surrounding tissues so as to compress capillary vessels and venous outflow routes, resulting in secondary perfusion failure. This is referred to as a compartment syndrome, a condition most commonly found in the extremities. Because some nerve injuries occur despite prudent positioning precautions, current knowledge does not permit the definitive assignment of injury mechanisms to certain conditions associated with positioning, such as certain peripheral nerve injury and optic deficits. Evidence exists that some patients are heavily predisposed to develop nerve injury despite adequate positioning technique. Peripheral vascular disease, diabetes, hereditary neuropathy, and anatomic variation (e.g., cervical rib), all predispose to perioperative nerve injury [7]. In a series of patients who developed ulnar neuropathy after cardiac surgery, all had evidence of nerve conduction abnormalities before surgery [1].

THE SUPINE POSITION

The supine position is by far the most commonly used position for surgical and diagnostic procedures requiring anesthesia. Even the supine position is associated with position injuries. Starting with the head, it is well known that prolonged contact of the back of the head may result in alopecia. Placing the patient’s head on a cutout foam ring and frequently repositioning the patient’s head may be helpful in preventing this cosmetically devastating complication.

More serious position-related injuries have been reported. Of all nerve injuries, ulnar neuropathy is the most common, constituting approximately one third. It occurs predominantly in men because of the greater degree of padding from subcutaneous fat in the female elbow; furthermore, the larger tubercle of the ulnar coronoid process in men may also compromise the resistance of the ulnar nerve to injury. Its incidence in noncardiac surgical patients is likely between 0.25% and 0.5% [3,8]. Occurrence of neuropathic symptoms may be delayed in as many as 57% of patients [9], with a median onset time of 3 days after surgery [4].

The mechanism of injury is incompletely understood and can only be identified in a small fraction (5%) of cases [10]. Nevertheless, stretching, compression, and double-crush injury (two separate injuries, one of which may be subclinical) have been mentioned. Studies in awake volunteers indicate that supination minimizes the pressure over the ulnar nerve at the elbow. A neutral (thumb up) forearm position results in intermediate pressure, whereas pronation generated the highest pressure on the ulnar nerve [11]. Ulnar nerve injury may occur despite the application of protective padding [12]. Neither does awake patient status protect against ulnar nerve injury. Half of all male volunteers failed to experience paresthesia with application of pressure to the ulnar nerve, despite severe reductions in evoked potential amplitude [11]. The following precautions should be taken when positioning the arms to minimize
ulnar nerve injury: arm abduction should be limited to 90°, pressure on the ulnar groove should be minimized, and padded armboards should be used that are positioned level with the patient’s torso. If the arms are tucked at the side, they should be kept in the neutral position (Fig. 1) [12].

Brachial plexus injury is the next most common; it is a particular risk if the arms are abducted more than 90° (Fig. 2) or dorsally extended because of inadequate horizontal support (Fig. 3). This arrangement allows the head of the humerus to act as a fulcrum around which nerves of the brachial plexus are stretched [5]. Brachial plexus injury has been reported in 12% to 38% of median sternotomies, but arm position seems to have little effect on its incidence [13].

Stretching of the brachial plexus by shoulder girdle depression, arm abduction to greater than 90°, and lateral head flexion away from the affected arm are associated with the development of neuropathy [14]. If the head is laterally flexed or rotated substantially, elevating the contralateral shoulder with a supportive pad may be beneficial (Fig. 4). A C5 brachial plexus neuropathy resulted from positioning the arms over the head for a 4-hour radiologic procedure under general anesthesia [15]. Other nerve injury can occur to the lumbosacral roots, the lateral femoral cutaneous nerve, the facial nerves, and the radial nerves. These injuries are not restricted to the supine position but can occur in any position in which the patient has been placed. The ASA practice advisory on prevention of perioperative peripheral neuropathies makes specific recommendations with respect to upper extremity positioning (Box 1).

Fig. 1. Patient positioned supine for microvascular decompression in the posterior fossa. Note padding of the elbows, knees, and ankles. The knees are slightly flexed, and the heels do not touch the surface.
Patients with preexisting deformities and nerve damage are at greatest risk. Patients with severe back pain who could not lie flat in the MRI scanner have been reported to awaken with new-onset paraplegia [16]. Care should be taken not to position such patients in a manner that they would not tolerate while

![Fig. 2](image1.png)

Fig. 2. (A) Stretching the brachial plexus by arm abduction greater than 90°. The nerve sheath is stretched around the head of the humerus. (B) Arm-down positioning prevents brachial plexus stretching. ([From Winfree CJ, Kline DG. Intraoperative positioning nerve injuries. Surg Neurol 2005;63(1):14; with permission.])

![Fig. 3](image2.png)

Fig. 3. (A) Potential for stretch and compressive nerve injury from inadequate horizontal armboard support. (B) Armboard should allow positioning of the arm in the same horizontal plane as the body; note the added bolstering of the forearm to allow flexion at the elbow. ([From Winfree CJ, Kline DG. Intraoperative positioning nerve injuries. Surg Neurol 2005;63(1):14; with permission.])
awake. This is particularly an issue if the anesthesia time and scan time are lengthy. New-onset paraplegia has been reported with scan times of 90 to 110 minutes in high-risk patients [16].

When a neurologic injury is identified after surgery, immediate diagnostic workup should start to identify potentially reversible causes, such as compression by hematoma or fracture or dislocation. In the case of peripheral neuropathy, it is reasonable to request an electrodiagnostic evaluation within a few days after the injury to document neural functional status. For example, the

**Box 1: Recommendations from the American Society of Anesthesiologists Task Force on Prevention of Perioperative Upper Extremity Peripheral Nerve Injuries**

1. Padded armboards may decrease the risk for upper extremity neuropathy, as may padding at the elbow.

2. Limit arm abduction to 90° in supine patients.

3. Prone patients may comfortably tolerate greater arm abduction.

4. Position arms to decrease pressure on the postcondylar (ulnar) groove of the humerus.

5. When arms are tucked to the side, a neutral position is recommended.

6. When arms are on armboards, supination or a neutral position is acceptable.

7. Prolonged pressure on the radial nerve in the spiral groove of the humerus should be avoided.

8. Extension of the elbow beyond a comfortable (as assessed before surgery) range may stretch the median nerve.

9. The use of chest (‘axillary’) rolls in laterally positioned patients may decrease the risk for upper extremity neuropathy.

*Adapted from* Practice advisory for the prevention of perioperative peripheral neuropathies: a report by the American Society of Anesthesiologists Task Force on Prevention of Perioperative Peripheral Neuropathies. Anesthesiology 2000;92:1169; with permission.
presence of chronic neuropathy may be surmised with the recording of muscle fibrillations. A thorough history should be obtained, because a rather large number of diseases and drugs have been identified to predispose to neuropathies [5].

SUPINE POSITION IN PREGNANCY
Supine hypotension from aortocaval compression affects women during the later stages of pregnancy and parturients, and it is exacerbated during major conduction anesthesia. Some women are at greater risk for this complication than others and can be identified by a supine stress test in which maternal blood pressure, heart rate, and symptoms are observed in the supine and lateral positions. These patients are more likely to benefit from preprocedure colloid volume loading [17]. Left lateral pelvic tilt at 30° is commonly used to counteract caval compression by placing a wedge or blanket roll under the right hip and buttock. A rare complication of this positioning is sciatic neuropathy, suggesting that time in this position should be minimized [18].

THE LITHOTOMY POSITION
The lithotomy position is used extensively during surgical procedures of the perineum, such as for vulvovaginal and colorectal surgery. Several methods of leg support are available (Fig. 5). When the lithotomy position is combined with steep head-down posture, patient movement can result in a lower extremity compartment syndrome, which was reported to be prevented with the use of shoulder braces. Compartment syndrome, which occurred in 1.7% of patients undergoing lengthy cytoreduction surgery, may result from traction exerted on the popliteal vessels from movement of the torso in a cranial direction [19]. It should be remembered that shoulder braces in the steep Trendelenburg position by themselves can lead to brachial plexus injury if placed too medially and in procedures of long duration. Lower extremity neuropathies occur infrequently (1.5%) and are associated with surgical duration [2]. The common peroneal nerve is at risk for compression against vertical metal supports because of its superficial course just below the knee (Fig. 6). Compartment syndrome of the calves has been reported after prolonged (13-hour) head-down and lithotomy positions [20]. Knee extension is thought to predispose to sciatic nerve injury in the lithotomy position and should be avoided. Injury to wrist and fingers can occur as the foot piece of the OR table is flexed downward in preparation for surgical access to the perineum. All personnel need to be aware and ensure that the patient’s hands are clear of the mechanics of the operating table when this maneuver is begun (Fig. 7). A more recent adaptation of the lithotomy position has been used for minimally invasive anterolateral hip replacement surgery, which avoids dissection of muscles and tendons. The patient lies supine with the contralateral leg flexed to approximately 30° in a gynecologic footrest attached to the operating table [21]. ASA task force consensus recommendations regarding the prevention of lower extremity nerve injury and the lithotomy position appear in Box 2.
THE SITTING POSITION

The sitting position is used for surgery at the back of the head, such as posterior fossa craniotomy, and for cervical and upper thoracic spine surgery, such as cervical laminectomy.

Risks

The sitting position for cranial surgery is associated with a high incidence of air embolism (25%–45%). This situation occurs because noncollapsible venous channels, such as diploic and emissary veins, can be violated during craniotomy; this, in turn, leads to air entrainment in the sitting position because of the negative pressure gradient between the surgical site and the heart (Fig. 8). The sitting position can result in hypotension, especially if not attained gradually and not preceded by adequate hydration. Hypotension seemed to be particularly an issue in patients who are classified as ASA III or IV [22]. Cardiac output decreases because of a reduction in venous return and the inability for cardiovascular reflexes to compensate. Peripheral and pulmonary vascular
resistance increases but only incompletely compensates for the decrease in cardiac output, and cerebral perfusion pressure decreases [23]. In fact, orthostatic blood pressure decreases are common (76%) in the first 60 minutes after induction of anesthesia [24]. Hence, direct arterial pressure must be followed closely on attaining the sitting position, with the transducer leveled at the head.

Fig. 6. The common peroneal nerve (n.) is at risk for injury during lithotomy positioning.

Fig. 7. Hands are at risk for injury during lithotomy positioning.
Other reported complications include midcervical quadriplegia (thought to be attributable to a combination of preexisting cervical spine disease and low perfusion pressure); airway, tongue, and facial swelling (exacerbated by placement of oral airways for lengthy surgery); obstruction of the endotracheal tube (ETT; usually the result of overzealous flexion in the absence of a bite-block); brachial plexus stretch injuries (caused by inadequate arm support); and cardiovascular instability during tumor dissection. Airway obstructing supraglottic edema has also been reported after prolonged posterior fossa surgery.

**Box 2: Recommendations from the American Society of Anesthesiologists Task Force on Prevention of Perioperative Peripheral Nerve Injuries in the Lithotomy and Head-Down Positions**

1. Padding at the fibular head may decrease the risk for lower extremity neuropathy.
2. Prolonged pressure on the peroneal nerve at the fibular head should be avoided.
3. Neither hip flexion nor hip extension increases the risk for femoral neuropathy.
4. Lithotomy positions that stretch the hamstring muscle group beyond a comfortable (as assessed before surgery) range may stretch the sciatic nerve.
5. Shoulder braces in steep head-down positions may increase the risk for brachial plexus neuropathy.

Adapted from Practice advisory for the prevention of perioperative peripheral neuropathies: a report by the American Society of Anesthesiologists Task Force on Prevention of Perioperative Peripheral Neuropathies. Anesthesiology 2000;92:1169; with permission.

**Fig. 8.** The level of right atrial (or central venous) pressure primarily determines at which height above the heart a noncollapsible blood vessel entrains air. RAP, right atrial pressure.
conducted with the head in forced flexion [25]. Although 100% of patients undergoing sitting craniotomies develop pneumocephalus, the contributory role of nitrous oxide (N₂O) is in doubt. Its elimination from the anesthetic regimen at the time of dural closure has not been found to be efficacious [26]. To date, experts are aware of at least 20 cases of paraplegia after acoustic neuroma resection in the sitting position [16].

Despite its potential problems, the sitting position was not associated with increased morbidity in large series. In fact, sitting patients were less likely to bleed and had fewer cranial nerve deficits than nonsitting cases [27]. Surgical preference for the sitting position is grounded in familiarity with it, the advantages of a clear field (blood readily drains away) and better exposure requiring less aggressive retraction. Dural venous pressure is indeed 5 to 10 cm lower in the sitting versus the supine position [28]. Cerebral blood flow may not decrease on achieving the sitting position in anesthetized neurosurgical patients [29]. Other advantages of the sitting position include improved ventilation (less chest wall compression compared with the prone position), as well as improved access to the face (eg, for cranial nerve monitoring, ETT check) and extremities (eg, for monitoring neuromuscular blockade, checking vascular access).

Contraindications to the sitting position include cardiovascular instability, known intracardiac or other right-to-left shunts, orthodeoxia (evidence of intrapulmonary vascular malformation), severe cervical spine disease, and, for some, advanced age.

Procedure for attaining the sitting position
The goal should be to achieve a semirecumbent position with legs elevated to near the level of the heart rather than a “bolt-upright” seated position. This position assists in keeping central venous pressure (CVP) positive, which, in turn, reduces the atmospheric pressure gradient favoring venous air embolism (VAE). Before upright positioning, the transesophageal echocardiography (TEE) probe and head-pin holder are placed. A colloid fluid bolus of approximately 10 mL/kg is administered to compensate for venous pooling. This maneuver has been shown to increase CVP and improve systemic blood pressure [30]. The anesthetic associated with the least hypotension on assumption of the sitting position is an opioid–N₂O technique [31]. Appropriate positioning technique for the sitting position ensures support of arms and shoulders through the use of special armboards that are placed so that the arms are not pulling the shoulders downward. Excessive neck flexion is avoided, and a distance of two fingerbreadths is maintained between the chin and the sternum (Fig. 9). In addition, the inspired pressure is checked, such that kinking of the ETT can be detected at an early stage. Some advocate the routine use of armored tubes, but proper positioning technique allows the use of conventional ETTs in the author’s experience. When attaining the sitting position, the lower extremities are elevated with the “kidney rest” adjustment of the operating table, to which pillows and folded blankets are added. Venous return from the lower extremities is further enhanced by compression stockings. To
avoid abdominal compression and sciatic nerve stretch injury [32], the buttocks
should be padded and excessive hip flexion avoided.

The seated position should not be achieved at the expense of the ability to
lower the head rapidly with respect to the heart (ie, the ability to put the table
in the Trendelenburg position). With the overall plane of the OR table in
a slight Trendelenburg position, the back is elevated to achieve a 60° to 90°
head-up posture. Once the final position has been achieved, the head is fixed
to the frame, the arterial pressure transducer is zeroed at the level of the fora-
men magnum to assess cerebral perfusion pressure better, and the precordial
Doppler instrumentation is positioned and tested for VAE detection. A visual
checklist of steps designed to ensure proper management of the sitting position
appears in Fig. 10.

Prevention and detection of venous air embolism
Nitrous oxide expands venous air bubbles, but its use has not been shown to
result in greater morbidity [33]. Monitoring and early detection are key to pre-
venting the serious consequences of VAE. Monitors of venous air differ in their
sensitivity for detection. TEE is the most sensitive monitor, detecting microliter
bubbles. The incidence of microbubble detection is 100%, and the incidence of
VAE is 76% with intraoperative TEE monitoring [34]. TEE is also the only
monitoring modality that can diagnose paradoxical embolization. It is feasible

Fig. 9. Head in a neurosurgical headholder with pins in place. (1) Eyes are taped occlusively
to prevent irritation from irrigating and antiseptic fluids. (2) ETT cuff is taped for better access.
(3) Adequate chin-to-sternum distance (two fingerbreadths) is maintained. (4) Breathing circuit
tubing is padded to avoid impression and excoriation into the skin. (5) Depth of ETT insertion is
checked by ascertaining the presence of bilateral breath sounds and by palpating the ETT cuff
in the sternal notch. (6) Before neurosurgical pin insertion, additional anesthetic is adminis-
tered to prevent sudden hypertension. Also note that pin sites may provide a portal of entry
for VAE.
to screen patients for the presence of a patent foramen ovale with TEE before achieving the sitting position. Using contrast echography, Kwapisz and colleagues [35] examined 35 neurosurgical patients with contrast TEE and found 3 with a patent foramen ovale, who were consequently operated on in the supine position. TEE (Fig. 11) is increasingly becoming the preferred modality for VAE monitoring in high-risk situations, such as the sitting position [36].

Precordial Doppler, end-tidal nitrogen, end-tidal carbon dioxide, transcutaneous oxygen, CVP, and esophageal stethoscope are other monitors, listed in order of decreasing sensitivity. Doppler ultrasound monitoring for VAE is performed with a precordial Doppler probe that is placed between the third and sixth interspaces parasternally. To confirm proper Doppler probe position, intravenous fluid (10 mL) can be injected rapidly into the central or peripheral venous catheter. The presence of a distinctive high-pitched swishing sound when microbubbles of air enter the heart confirms adequate placement of the precordial Doppler probe.
Treatment of venous air embolism

For prevention and treatment of air embolism, placement of an appropriately positioned central vein catheter (tip at atrial-superior vena cava (SVC) junction; confirmed by ventricular pullback, chest radiograph, or intra-atrial electrocardiography) is needed. When a VAE is suspected on the basis of Doppler or end-tidal carbon dioxide (ETCO₂) changes, the surgeon is notified immediately so that air entry can be stopped by applying bone wax and flooding the surgical field. The anesthesia team discontinues N₂O (if applicable), lowers the head, compresses neck veins, and aspirates the central catheter. Plans for supporting the circulation and resuscitation should be made. If refractory hypotension occurs, the right heart should be supported with volume loading and inotropy [37].

Sitting spine surgery

Some surgeons prefer to operate on the posterior cervical spine with the patient in the seated position. The risk for VAE in the sitting position is somewhat lower for spinal surgery than it is for craniotomy. In this position, the spinal cord, especially when compromised by vascular disease compression syndromes, is particularly at risk for ischemia. Blood pressure may decrease from venous pooling, and perfusion pressure is determined by the driving pressure at the site of surgery, which may be considerably higher than at the site at which systemic blood pressure is measured, resulting in unintentional underperfusion. Monitoring requirements for sitting spine surgery include direct arterial blood pressure, a multiorifice central venous catheter positioned at the atrial-SVC junction for optimal air aspiration, and precordial monitoring. Direct arterial blood pressure monitoring allows for better appreciation of the cardiovascular effects incident to seated positioning in addition to the adverse hemodynamic effects of potential VAE.
The beach chair position
This position is frequently used for shoulder arthroscopic surgery. Patients are positioned 30° to 60° head-up. This technique has recently been associated with hypotensive episodes and consequent severe neurologic dysfunction, including brain stem infarction from cerebral hypoperfusion [38] and visual loss [39]. The incidence of hypotensive or bradycardic events has been reported to be 5.7% under propofol target-controlled anesthesia [40] and up to 28% with an interscalene brachial plexus block [40–42]. Prophylactically administered metoprolol (up to 10 mg) but not glycopyrrolate decreases the incidence of hypotensive or bradycardic events [42].

In rare cases, what is thought to be an activation of the Bezold-Jarisch reflex has resulted in full cardiac arrest [43]. Cerebral perfusion pressure should be maintained at a level of 70 to 80 mm Hg. It is important to realize that the blood pressure cuff or arterial catheter is situated substantially below the level of the head and that cerebral perfusion pressure calculations need to be adjusted for the blood pressure readings obtained from these devices. For example, if mean arterial pressure (MAP) by cuff is 70 mm Hg and the cuff is positioned 12.5 cm below the foramen magnum, cerebral perfusion pressure is only 60 mm Hg, because there is a decrease in 1 mm Hg for each 1.25-cm gradient in height between the cuff and head.

As is true for other sitting position variants, arm support is important to avert stretch injury to the brachial plexus. An elevated contralateral arm position was associated with fewer episodes of venous thrombophlebitis from intravenous catheter placement for arthroscopic surgery [44].

Other head-up positions
Laparoscopic surgeons use the head-up position routinely to improve pneumoperitoneal exposure during procedures of the upper abdomen, such as cholecystectomy and fundoplication. In the awake state, head-up posture results in a decrease in cardiac index and filling pressure, compensated for by an elevation in systemic vascular tone. Under isoflurane-fentanyl anesthesia, head-up positioning by 15° to 20° resulted in significantly decreased pulmonary capillary wedge pressure and stroke index. Systemic vascular resistance increased slightly, whereas CVP and mean pulmonary artery pressure decreased mildly [45]. Although fit patients tolerate the required head-up posture without difficulty, those with impaired cardiovascular reserve should receive special attention to cardiac performance through advanced monitoring based on the severity of the cardiac condition [46]. Intraoperative echocardiographic observations in patients who have aortic stenosis suggest that patients who have this condition tolerate head-up posture and pneumoperitoneum less well than patients who have ischemic cardiac disease or normal controls [47].

Head-down (Trendelenburg) positioning
Head-down tilt is frequently used during gynecologic or colorectal pelvic surgery to improve surgical exposure. Adverse events referable to this position include VAE (the site of potential surgical entry into pelvic veins is above the
level of the heart), brachial plexus injury from shoulder stops used to keep the patient from sliding off the operating table during steep head-down positioning [48], and right mainstem intubation attributable to cephalad shift of the pulmonary hila. Robotic-assisted pelvic surgical procedures, such as radical prostatectomy, can require a steep Trendelenburg position for prolonged periods. Respiratory compromise from laryngeal edema and brachial plexus injuries from shoulder braces have been described [49]. The head-down position worsens oxygenation, particularly in the obese, with a widening of the alveolar-to-arterial oxygen gradient, an effect partially counteracted by the induction of a surgical pneumoperitoneum [50]. The cardiovascular changes associated with steep Trendelenburg positioning are minimal in normal subjects [51]. A prolonged steep head-down position does not affect the cerebral circulation as assessed by transcranial Doppler monitoring [52].

**THE PRONE POSITION**

The prone position is used to gain access to the back of the head, the spine, the back of the lower extremities, and for certain retroperitoneal interventions. Positioning efforts should be guided by the desire to avoid position-related injury and to minimize the physiologic abnormalities induced by bearing weight on the ventral aspect of the body. The anesthesiologist can be primarily liable for position injury even if the position is prescribed by the surgeon.

**Injury risks**

Important position injuries in the prone position include eye injury (eg, corneal abrasion, retinal ischemia); brachial plexus stretch injuries; and pressure injury to the face, elbows, knees, breasts, and male genitalia. Brachial plexus injury can occur when the head is severely rotated toward the contralateral side or extended, stretching nerve roots; excessive pressure on the clavicle can compress the neurovascular bundle against the first rib; and the head of the humerus can likewise press into the brachial plexus when the arms are hyperabducted and the shoulder is not sufficiently mobile and relaxed. The arms should be abducted no more than 90°. Pressure on the femoral nerve or lateral femoral cutaneous nerve may be experienced, especially with post-type positioning devices (eg, the Relton-Hall or Jackson frame) (Figs. 12 and 13). In addition, ulnar nerve damage may occur from pressure against hard OR table edges or leaning by the surgical team.

**Postoperative visual loss**

Faulty positioning only accounts for a small fraction of postoperative visual loss (POVL) [53]. An example is the occurrence of central retinal artery occlusion (CRAO), which is known to be a consequence of direct or indirect pressure on the globe. There is periorbital and scleral edema; funduscopic examination reveals the hallmark “cherry red spot” of CRAO. An orbital compartment syndrome has also been reported in which increased orbital venous pressure and external compression from the silicone headrest were implicated as potential causes [54]. Intraocular pressure increases progressively with time in the
prone position [55], although a causal relation between this phenomenon and postoperative blindness has not been established. Such anatomic features as exophthalmos and a small nasal bridge may predispose to excess pressure on the eyes during prone positioning [56].

Still, most POVL (89% in the ASA POVL registry) is diagnosed as ischemic optic neuropathy (ION), which, to date, remains an enigmatic idiopathic disease. ION is associated with the prone position, Mayfield pin headholder use, anesthetic duration greater than 6 hours, or high blood loss greater than 1000 mL [53]. Association with other conditions, such as diabetes, hypertension, smoking, atherosclerosis, anemia, ulcerative colitis, and preexisting retinal disease, has been reported [56]. It is not thought to be the result of optic globe compression or specific prone position-related factors. ION occurred in patients who were positioned on the Wilson frame (Fig. 14), the Jackson table (see Fig. 13), or chest rolls (Fig. 15); Mayfield head pinning was not protective,
and ION occurred in patients positioned on foam or gel pads whether or not regular eye checks were documented during the case [53].

Rational strategies to promote prevention of ocular injury during prone surgery include (1) staging of the surgical procedure to avoid surgical duration longer than 6 hours, (2) careful positioning and frequent position rechecks, (3) 10° to 15° head-up positioning to reduce periorbital edema, (4) maintenance of blood pressure within 20% of preoperative baseline (some suggest MAP ≥70 mm Hg) and (5) maintenance of hematocrit greater than 25.

Achieving the prone position for craniotomy
Before achieving the prone position, the patient should be well anesthetized and relaxed. If the head is to be fixed in a neurosurgical head-pin holder, this is done before turning prone. If chest rolls are planned, they are placed longitudinally so as to make use of the iliac crests and the shoulder girdle to absorb pressure. Care is taken that the ETT is secured well to the face, because it can become dislodged during the turn or later as operative fluids and secretions loosen tape attachments. All monitoring catheters are inserted and securely taped. In patients who are not expected to tolerate the turn into the prone position without hypotension (ie, the elderly, patients who have cardiac or autonomic dysfunction), the author prefers to administer a pressor agent prophylactically (ephrine, 5 mg, or phenylephrine, 50–100 μg, administered
intravenously). In this situation, it is also useful to maintain intra-arterial blood pressure monitoring throughout the turn.

The patient should be log-rolled into the prone position by a team of at least five individuals, with the surgeon in control of the head for cranial or cervical cases. The anesthesiologist monitors vital signs and ensures that the ETT and monitors remain intact, while at least two individuals effect the turn from the stretcher to the OR bed and the fifth ensures that the lower extremities are secure. For a craniotomy, the patient’s clavicle should be aligned with the cephalad edge of the OR table before the turn so that ample space is preserved for the neck and face. If this is not done, the face is often pushed into the cephalad edge of the table on turning, which requires repositioning to avert injury.

Before the head frame is fixed to the OR table attachment, the anesthesiologist should inspect the neck and ensure a space of at least two fingerbreadths between the chin and the chest. Positioning the head in forced flexion, especially in patients who have micrognathia, has been associated with postoperative airway obstruction because of supraglottic edema [25]. In addition, a bite-block should be placed between the teeth to prevent biting on the tongue and ETT. The author prefers a bite-block between the molar teeth over an oral airway, because the latter has been associated with macroglossia. Immediately after the turn, the position of the ETT should be reverified and blood pressure, heart rate, and oxygenation checked. Then, a general survey to check the patient’s positioning is made, concentrating on the padding of bony prominences and decompression of soft tissue areas. Any cables or intravenous tubing or other equipment that may have come to lie under the patient is removed. Obese patients may have their torso sag in a cephalad direction, further flexing the angle of the neck on the body [57]. This position is prevented by tilting the OR table up by $10^\circ$ to $15^\circ$ and by taping the shoulders and posterior torso to the OR table. A modification of the prone position is the “flying swan” or “sea lion” position, which uses elevation of the upper torso and mild hyperextension at the hip joint to accomplish head-elevated surgical exposure for cervical spine and suboccipital work, with improved venous return from the extremities.

The three-quarter prone “park-bench” position
This position is used to get the nondependent shoulder away from the operating field and is primarily utilized for lateral approaches to the posterior fossa. The position is initially achieved in a manner similar to the full lateral position. The body is turned forward slightly (“three-quarters prone”), however, and the nondependent arm is positioned on a pillow or stack of blankets and taped to the OR table. An axillary roll is positioned just caudal to the dependent axilla. The dependent shoulder is positioned beyond the cephalad edge of the OR table. The dependent arm must be padded (wrapped in a folded blanket) and suspended in a partially flexed position near one of the cephalad corners of the OR table (Figs. 16 and 17). Brachial plexus injury may result
from inadequate positioning of the axillary roll or the dependent arm, or from excessive traction on the nondependent arm.

The prone position for spine surgery

For spine procedures involving extensive bony dissection, a risk for VAE also exists, because the surgical site is located above the level of the heart in the
prone position [58]. The incidence of VAE in prone spine cases has been estimated at 5% [59]. In these procedures, the anesthesiologist’s index of suspicion should be roused if clinical signs of VAE occur, including circulatory collapse. A central venous catheter might be helpful in the diagnosis of VAE, although its therapeutic efficacy for air removal is in question [60] when used in the prone position.

Turning the patient who has spinal surgery

Before turning the patient prone, the esophageal stethoscope should have been inserted and the eyes protected with bland ointment and covered with plastic adhesive eye shields. The ETT should be taped after the skin has been prepared with a skin protectant so as to minimize facial skin abrasions from tape removal. An orogastric tube should be inserted when necessary to decompress the stomach; gastric decompression can assist with abdominal relaxation and optimal positioning in some cases. In procedures that are expected to last more than 2 hours or if substantial fluid resuscitation is expected, the bladder is catheterized to prevent distention and hypertension.

An arterial catheter should be placed when ischemic spinal cord pathologic findings (myelopathy) preexist or may develop during the procedure. The purpose is to be able to monitor and control spinal cord perfusion pressure closely. When the patient’s arms are tucked at the side, and thus relatively inaccessible, it is prudent to err on the side of additional intravenous access and invasive monitoring, because placement of additional lines is extremely challenging in this position.

During the turn, the ETT should be disconnected temporarily, in addition to most monitoring devices to avoid tangling and dislodgment. A bite-block should be placed between the back molar teeth to prevent biting of tongue. Patients with few remaining teeth may injure the opposing gum surface when flexion of the neck causes the mouth to close. Care should be taken to insert gauze padding to avoid this. It is preferable to place vascular catheters in the extremity closest to the axis of the turn into the prone position. This arrangement minimizes the potential for tangling and displacing lines during the turn. If multiple catheters are present, it is wise to disconnect and cap them temporarily during the turn so as to prevent dislodgement, disconnection, and potential air entry. Patients should be turned prone with their arms straight at their side to avoid shoulder dislocation [61]. For lumbar procedures, the arms are available for access, whereas in cervical and thoracic cases, they are tucked to the patient’s side. If blood pressure is measured noninvasively, the automatic blood pressure cuff should be backed up with a manual cuff on the other extremity, especially when both arms are tucked at the side. An esophageal stethoscope is essential, because breath and heart sounds are difficult to hear through the posterior chest.

The integrity of all intravascular cannulae should be confirmed after the turn and before the cannulation sites become inaccessible as a result of further positioning and draping. During long cases, intravenous infiltration can be
missed, especially if the arms are hidden from view. A high index of suspicion and periodic checks of the extremities may help to prevent serious extremity swelling from extravasation of intravenous fluids.

Positioning the head in the prone position must be accomplished without hyperextension or excessive rotation. To this end, the chest should be elevated sufficiently with chest rolls, bolsters, or an appropriately designed frame (see Figs. 13–15; Fig. 18). Once the patient is turned, it is necessary to have a small pillow or folded towels on which to position the patient’s forehead, unless the horseshoe headrest or skeletal fixation is used. It is absolutely essential to eliminate pressure on the globe when supporting the head after the patient is turned. Similarly, pressure on the nose, ears, and branches of the facial nerve should be avoided. These sites should be checked in the beginning, rechecked, and documented at regular intervals during the case, because head position can change as a result of surgical manipulation and slippage of support devices. For lumbar spine surgery, the arms are positioned on sideboards with the wrists slightly flexed to avoid stretching peripheral nerves. Similarly, extension of the shoulders should be avoided by positioning the forearms below chest level (Fig. 19). For cervical and thoracic posterior spine cases, the arms are tucked to

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**Fig. 18.** (A) Eye patches and lubricant prevent corneal injury. (B) Foam cushion or intravenous bag elevates head to prevent pressure on the globe; head position is frequently rechecked during the case. (C) Extended breathing circuit supports the patient, who is positioned toward the bottom end of the table; the ETT is secured with tape after application of skin protectant. (D) Padding protects ulnar nerves and knees. (E) Chest pads support the shoulder and chest. (F) Electrocardiogram pads are placed on the side of the chest and back of arms to avoid pressure injury on anterior chest. (G) Abdomen hangs free. (H) Support and padding are provided for buttocks.
the side and protected with padded hard plastic “sleds.” Patients who are not expected to tolerate head rotation may require a special foam head holder (Fig. 20), which allows face down positioning and convenient lateral routing of the ETT.

A preconceived plan to deal with circulatory collapse and with accidental extubation in the prone position should always have been agreed on by the perioperative team. Accidental extubation may be managed with a laryngeal mask airway if the ETT cannot be replaced. Successful insertion of laryngeal mask airways in 25 prone patients has recently been reported [62]. Sudden hypotension may be the result of brisk surgical bleeding, accidental puncture of the inferior vena cava or aorta, allergic reaction, drug overdose, or pulmonary embolism (including VAE, because the operative field is higher than the heart). Cardiac arrest dictates turning the patient into the supine position as
soon as possible (a stretcher or bed should always be close at hand during the case), in addition to turning off the anesthetic and initiating appropriate standard resuscitation protocols.

Prone positioning techniques
Positioning techniques vary with surgeon and institution. Common prone positioning approaches for spine surgery include the use of the laminectomy or Wilson frame, the Relton-Hall frame, longitudinal chest rolls, and the kneeling and sitting-prone positions (see Figs. 12–15).

The Relton-Hall frame and Jackson table
The Relton-Hall frame supports the prone patient through pads on the chest and hips (see Fig. 12). In a modification of the Relton-Hall concept, the Jackson table allows prone positioning by means of support through chest, hip, and upper thigh pads. Two adjustable pads support the chest, whereas four such pads are positioned over the iliac crests and upper thighs (Fig. 13). This table also allows cervical traction and head-pin holder attachment, in addition to 180° turns for patients with an unstable spine. Abdominal venous pressure with Relton-Hall positioning is significantly lower compared with a conventional pad [63] and, by inference, compared with chest rolls and the Wilson frame.

The Wilson laminectomy frame
The Wilson frame consists of two interconnected padded arches, whose curvature can be adjusted (see Fig. 14). The patient’s chest and abdomen are supported on the curvature of the arch. Patients positioned on the Wilson frame have less severe hypotension and bradycardia than those positioned in the kneeling position, suggesting that the latter position is less conducive to promoting cardiovascular adaptation to venous pooling [64]. Patients with diminished cardiovascular reserve thus may be preferentially positioned on the Wilson frame.

Chest rolls
In a prospective study of problems related to prone surgical positioning, Smith and colleagues [65] found transverse chest rolls and rolls under the sternum to be associated with pressure pain after surgery. Furthermore, longitudinal chest rolls were uncomfortable for female patients. Accordingly, transverse chest rolls should be avoided and breast tissue pushed medially when using longitudinal chest support devices.

The kneeling position
For kneeling positions (see Fig. 18), a breathing circuit extender is needed because the patient’s head is positioned at a greater distance from the anesthesia machine than in the normal position. One should be prepared to move the patient’s head and torso to the foot of the OR table. To improve space and reduce distance to the anesthesia machine, the head of the OR table should be folded down. The kneeling position should not be used for patients who have knee
joint pathologic conditions (e.g., severe arthritis, artificial joints). The main advantage of this position is the superior decompression of the abdomen when compared with chest rolls or the Wilson frame.

**Unstable cervical spine**

Patients with an unstable cervical spine can be turned prone while anesthetized as long as their neck is externally stabilized and the positioning is supervised by the surgeon. With unstable fractures of the thoracic and lumbar spine, external stabilization is impractical. Patients are turned anesthetized in a Stryker frame or are positioned awake in a log-roll fashion after awake sedated intubation. Log-rolling the patient minimizes destabilizing spine motion. The active muscle tone of the awake patient further helps to splint an unstable spine. Positioning the patient awake in the prone position is used for severe upper cervical spine pathologic conditions; its feasibility in documenting new positioning-related versus surgically related neurologic findings was recently reported [66].

**Physiologic changes related to the prone position**

The prone position, especially for lumbar surgery, implies that the head is lower than the heart, and venous drainage from the brain, face, and neck (including the airway) may be significantly impaired. It is not uncommon to see facial edema in patients after long prone procedures. When combined with vigorous crystalloid fluid resuscitation, such facial edema can be severe. If this is the case, the patient should remain intubated after surgery until the edema begins to resolve. In addition, with the ETT cuff deflated, an air leak should be present before extubation. Patients who have intracranial lesions, such as tumors, edema, and trauma, should not be positioned head-down for prolonged periods and require alternative positioning.

Blood flow in the vertebral and carotid arteries can be reduced in the prone position if excessive head rotation is used. Rotation by 60° or more begins to reduce vertebral flow, and flow may cease at 80° of rotation [67]. Patients with known vertebral or carotid flow restrictions or the suspicion thereof should be positioned in such a manner as to minimize rotation (face down). The spinal cord settles ventrally in the prone patient [68], thus enlarging the dorsal epidural space. This has been interpreted as being advantageous for epidural catheter placement.

The epidural plexus of veins [69] can become an alternate conduit for venous return when normal venous return by way of the inferior vena cava (IVC) is restricted by abdominal compression in the prone position. High intra-abdominal and thoracic pressure can therefore result in shunting of blood through the epidural space and augment venous surgical bleeding substantially. Prone positions, which allow the abdomen to hang freely (especially the kneeling position with the Andrews frame, the sitting prone position, the Hastings frame, and the Relton-Hall frame), allow IVC pressure to remain optimally low. By contrast, positioning with chest rolls, the Wilson frame, or in the Georgia prone position causes substantial increases in abdominal venous pressure [70].
The work of breathing is increased in the prone position, making spontaneous ventilation an ineffective mode of ventilation. Assuming appropriate positioning, the distribution of pulmonary blood flow and the magnitude of pulmonary shunting are not different from the supine position [71]. Prone functional residual capacity (FRC) is diminished to a lesser extent than supine or lateral FRC. In fact, when patients with respiratory failure were positioned prone, their oxygenation improved [72,73]. Recently, it was shown that preschool-aged children’s FRC did not change with assumption of the prone position, and it improved by 20% when the prone position was “augmented” with gel pad support to the pelvis and upper thorax [74]. Nevertheless, severe hypoxemia can occur after anesthetized patients are turned prone. Causes to be evaluated immediately include accidental extubation, turn-induced right mainstem intubation, as well as hypoventilation and abdominal compression attributable to malpositioning. Higher ventilatory pressures are uniformly seen and may predispose to barotrauma, decreased venous return from the abdomen and cranium, and a resultant reduction in cardiac output. High inflation pressures may also transmit to venous pressure in the operative field, enhancing surgical blood loss. Airway rescue after extubation in the prone position can be a challenge. Laryngeal mask placement has recently been shown to be feasible in the prone position [62] and should be considered seriously as a rescue technique.

The cardiovascular consequences of the prone position include increased pulmonary and systemic vascular resistance and a decrease in venous return [75]. Stroke volume and cardiac index decrease, whereas arterial blood pressure, CVP, and pulmonary artery occlusion pressure remain unchanged when compared with the supine position. Venous return may be particularly impaired when the lower extremities are positioned much below the rest of the body (especially seen in the “kneeling” positions and its variants). Preventive measures include venous compression stockings and wrapping of the legs before positioning, but circulating volume frequently has to be augmented by appropriate fluid therapy. Crystalloid infusion of 1 to 2 L may be needed to compensate for pooling of blood in the lower extremities.

THE LATERAL DECUBITUS POSITION
The lateral decubitus position (Fig. 21) is used for access to the thorax, flank, and hip areas. Surgeons use the lateral position for operative interventions, such as thoracotomy, thoracoscopy, pyelolithotomy, total hip arthroplasty, and nephrectomy. The orthopedic fracture table is adapted for the lateral position for repair of femoral shaft fractures.

To avoid compression of nerve structures in the axilla, a chest or axillary roll is placed under the thorax just caudad to the axilla. The axillary roll should not be pushed into the axilla because its beneficial effect accrues from lifting the thorax slightly, thus decompressing the ipsilateral axilla (Fig. 22). In the lateral position, arms are frequently placed on a “double armboard,” a metal double-decker airplane-like device that is secured onto the operating table after turning
the patient. Nerve injury can occur if arms are not appropriately padded or if there is undue pressure on the arm from the edges of the armboards or the metal rods connecting the two stacked boards. Radial nerve injury has been reported because of settling of the patient’s body and concomitant compression of the radial nerve by the edge of the armboard (see Fig. 23) [76]. In the author’s experience, the use of a deflatable shape-holding “bean bag” to stabilize patients in the lateral position requires special caution so as to avoid pressure of hard edges against lower extremity soft tissue, where prolonged contact may result in compartment syndrome, and against upper extremities, where neuropathy

Fig. 21. Laterally positioned patient. Note arms at 90°, padding between legs and chest roll positioning.
may result. On the fracture table, patients are at risk for pudendal nerve injury from the perineal post and for lower extremity compartment syndrome [77]. Optimal surgical positioning for nephrectomy requires the operating table to be flexed and the kidney rest raised (Fig. 24). Special care is needed to position the patient securely on the table, to decompress the axilla with an appropriately placed axillary roll, and to position the kidney rest so that respiratory embarrassment is avoided.

**BENEFICIAL ASPECTS OF POSITIONING**

Nonstandard patient positioning is used to exploit a distinct advantage for placement of regional anesthetics, to reduce bleeding, and to improve surgical exposure. To equip clinicians with the wherewithal to make the best judgment calls about the relative risk and benefit of a particular position, position-related injuries cannot be discussed without mentioning position-related advantages.

It is well known that position during spinal anesthetic placement influences the spread of denervation. What is less often understood is the fact that positioning also may influence hemodynamic stability after neuraxial block placement. The lateral position was associated with greater cephalad spread of
a hyperbaric bupivacaine spinal anesthetic and a delayed onset of hypotension that required smaller vasopressor doses [78]. Similarly, elderly patients with a low ejection fraction undergoing hip surgery had less hypotension when kept in the lateral position for 15 minutes after spinal anesthetic placement, compared with returning them to the supine position immediately after placement [79]. The incidence of hypotension does not differ whether patients have their hyperbaric spinal anesthetic placed in the sitting or lateral position, provided they are returned to the supine position immediately after placement [80]. Conversely, higher sensory block resulted for parturients who were sitting during the administration of hypobaric 0.25% bupivacaine with fentanyl when compared with the lateral position [81]. The use of a 10° head-up position during hyperbaric spinal block in the lateral position reduced the incidence of hypotension and the extent of the sensory block in patients undergoing cesarean section [82]. For epidural anesthesia, the lateral recumbent head-down position may be used to advantage in the placement of epidural catheters. Compared with the sitting and horizontal lateral positions, the lateral head-down position was associated with the least incidence of epidural vessel cannulation in obese parturients [83]. Moreover, maintaining a full lateral position, compared with a supine position with a left lateral tilt, reduced the incidence of hypotension.
in mothers anesthetized with a combined spinal epidural and made it easier to treat [84].

Head-up positions can result in demonstrated benefits for patients and surgeons. The sitting position has been associated with lower blood loss, better surgical exposure, and fewer cranial nerve injuries during posterior fossa craniotomy. A head-up tilt of 20° during thyroidectomy resulted in less postoperative nausea or vomiting and lower severity of nausea [85]. A head-up posture of 30° during bariatric surgery was associated with lower airway pressure and improved gas exchange [86], while also providing the longest safe apnea period during induction [87].

Placing critical care patients in the prone position, especially those afflicted with acute lung injury, has long been used to improve oxygenation, while positioning-related complications were minimal [88]. Similarly, the lateral position has been associated with benefits. Particularly in patients with widespread unilateral pulmonary infiltrates, placing the injured (bad) lung in the nondependent (up) position resulted in substantial improvement in oxygenation [89].

Fig. 24. Flexed lateral decubitus (kidney) position. (C) The kidney rest is correctly positioned directly under the iliac crest. If the kidney rest is placed more cephalad, ventilation may be compromised from diaphragmatic restriction and thoracic compression (A, B).
PREVENTION AND MANAGEMENT OF POSITION INJURIES

It goes without saying that surgeons, nurses, and anesthesiologists alike would prefer to prevent patient injuries from positioning. Prevention is the realization of differential risk, for example, that a steroid-dependent patient is at substantial risk for bone fracture and skin tearing, and the use of proper technique, such as the use of a correctly positioned axillary roll for the lateral position. Preventive approaches include proper surgical planning, such as the avoidance of the sitting position in patients with known intracardiac defects or the performance of a complex spine procedure in two stages so as to reduce operative time, which is associated with blindness from optic ischemic neuropathy. Anesthesiologists can contribute by stimulating discussion regarding such strategies and by pointing out available evidence.

Diagnosis of position-related injuries requires vigilant awareness during and after surgery. Anesthesia personnel perform position checks routinely and at regular intervals during the progress of surgery. The author considers such checks to be reasonable every 30 minutes. This allows the timely identification of malpositioning. Nerve injuries may not manifest themselves immediately on awakening, and patient complaints voiced even days later must be taken seriously and investigated in light of recent surgery.

Once a position-related injury is suspected, it is prudent to perform a thorough physical examination and document the appearance and functional extent of the injury in the medical record. Motor and sensory function should be assessed, and painful conditions should be documented. Further documentation of nerve injuries and possible recommendations for intervention should be sought through neurologic or ophthalmologic consultations. The most pressing need is to exclude other serious problems, such as epidural hematoma or cervical spine compression, and to determine if immediate intervention, such as surgical decompression, is indicated. Electromyography (EMG) is useful to identify and pinpoint the lesion. For example, positioning injuries frequently affect only a single nerve, whereas brachial plexitis, a rare inflammatory condition associated with surgery, affects several nerves [90]. This technique can discriminate between acute and chronic conditions affecting the nerve, and thus potentially identify preexisting neuropathy. Therefore, it may be helpful to conduct an immediate EMG study and then to wait 3 to 4 weeks to document denervational changes.

Interactions with patients and their families should be empathic and supportive. Because the cause of many position injuries, especially nerve injury, is unknown, caution is advised in categorically accepting responsibility for their occurrence, except in entirely clear-cut circumstances.

Subacute and chronic treatment of nerve injuries is best accomplished in close collaboration with a neurologist and physiatrist. It may include analgesics, medications effective in the treatment of neuropathic pain, splinting, and physical therapy. Chronic pain syndromes, including sympathetically mediated pain syndromes, may result. In certain situations, sympathetic blockade, surgical neurolysis, and nerve grafting may be necessary.
RECENTLY GAINED INSIGHTS THAT MAY MODIFY OUR PRACTICE

1. Elevating extremities with intravenous catheters may decrease the incidence of venous thrombophlebitis. Elevated contralateral arm position was associated with fewer episodes of venous thrombophlebitis from intravenous catheter placement for arthroscopic surgery [44].

2. The beach chair position is associated with the risk for cerebral underperfusion. Blood pressure must be maintained at a level that guarantees a perfusion pressure of 60 to 70 mm Hg measured at the level of the foramen magnum.

3. Peripheral nerve injury occurs despite adequate positioning precautions because patients may have preexisting subclinical nerve impairment. Early postoperative examination, including EMG studies, may help to establish the diagnosis.

4. The prone position is associated with postoperative blindness, primarily idiopathic ION. Because this condition is associated with a surgical duration of longer than 6 hours, staging of surgical procedures to reduce operative duration may be a worthwhile consideration.

SUMMARY

Positioning injuries persist in the modern practice of anesthesia and account for a substantive fraction of claims. Injury may accrue from nerve compression and stretching, cardiovascular changes, VAE, and respiratory decompensation. Newer surgical techniques not only do not obviate but frequently require the use of nonstandard positioning. Insidious morbidity, such as blindness and stroke, require a reappraisal of positioning strategy. More knowledge of pathophysiologic mechanisms and genetic predisposition is needed. Only through such further advanced investigation is it possible to further identify and alleviate patient risk from surgical positioning.

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