



Spinal Procedures in the Lateral Position

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Matthew T. Brown, Raul Cardenas,
and Julius Fernandez

Introduction

Lateral approaches to the thoracolumbar spine were initially described by Mayer and McAfee in 1997 and 1998. These approaches have become a more frequently used technique following the series published by Pimenta in 2006 and the implementation of minimally invasive techniques [1–3]. Most commonly touted as an alternative to the muscle-disruptive posterior approaches while avoiding the vascular and abdominal complications of anterior approaches, the lateral approach presents a unique set of risks to the patient while offering an alternative for decompression and stabilization of the thoracolumbar spine [4].

The two most common indications for utilization of the lateral approach include both trauma of the thoracolumbar junction and degenerative disease of the lumbar spine. Additionally, the

lateral position can be utilized when other lesions or pathology preclude safe prone positioning with compression of a large vessel or airway. Although a lateral approach can be utilized for thoracic disc disease, our institution feels a posterior approach provides both adequate exposure and a more familiar approach for these rare lesions when able.

Positioning for the Elective Spine

Once the patient has been identified for the procedure, the first critical step in positioning is the choice of operating tables. For the minimally invasive lateral, trans-psoas approach used by our group for lateral lumbar interbody fusion (MIS-LLIF) the Skytron operating bed is utilized. This bed allows for both an appropriate break, when necessary, as well as the option for the bed to be translated cranially or caudally. The translation allows for the primary operative site to be moved away from the base of the table, allowing for sufficient under-bed clearance for the C-arm fluoroscopy unit. Tables that are unable to translate will often limit C-arm positioning over the break, and/or the lumbar spine, significantly reducing the adequate visualization of the spine throughout the procedure; without a true AP and lateral image, the MIS-LLIF approach is much less safe, and not recommended [5].

M. T. Brown (✉)
Department of Neurosurgery, University of
Tennessee, Memphis, TN, USA
e-mail: mbrow135@uthsc.edu

R. Cardenas · J. Fernandez (deceased)
Department of Neurosurgery, University of
Tennessee, Memphis, TN, USA

Department of Neurosurgery, Semmes-Murphey
Clinic, University of Tennessee, Memphis, TN, USA
e-mail: rcardenas@semmes-murphey.com

Positioning the patient on the table is performed following intubation, induction of anesthesia, and placement of neuromonitoring electrodes. A bite block of rolled dressing sponges can be used to prevent tongue trauma if MEPs are to be used, though the use of monitoring, including MEPs, does not significantly change the positioning process for the elective patient. The patient is placed on the table in the lateral decubitus position; the upward facing side can be determined by the anatomy of the patient. If a scoliotic curve is present, the concavity is generally positioned upwards to both allow the maximum number of levels to be accessed with a single skin and fascial incision; this will also generally allow better access to the L4/5 disc space, when targeted. Some advocate for the convexity to be positioned upward for assistance in curve correction though this has not been routinely used in our adult practice of largely inflexible curves [6]. In degenerative cases, the more collapsed side of the disc space or the larger osteophyte is placed dependent in order to maximize the ease of disc space entry. If there is no curve or anatomic restriction, typically the right lateral decubitus position is preferred. Though the anatomic imaging study by Deukmedjian et al. does show a slight movement of the inferior vena cava (IVC) out of the operative field with left lateral decubitus positioning, this proved to have only millimeters of change and has not been felt to be practically advantageous in our experience. Instead, if a vascular injury were to occur, there is much greater ease in the repair of an arterial versus a venous structure [7]. We often use a shallow, inflatable beanbag beneath the patient that will not rise higher than midline upon deflation, as such practice would result in poor fluoroscopy projection. The beanbag is either covered with a flat sheet, or used without covering; no additional padding is present between the patient and the beanbag bolster. The patient is positioned on the table so that the iliac crest is overlying the break of the table. Historically, the table was angulated to a great extent to drop the iliac crest out of the operative field and increase visualization of the lower lumbar vertebrae. With institutional experience, and reports within literature of

increased morbidity secondary to nerve strain, we have gradually decreased the degree of table break to the lowest amount that allows direct access to the operative level. An angle break of 40° has been shown to cause femoral nerve strain of 6–7%, which is typically considered sufficient to limit nerve perfusion and possibly result in neurapraxia [8]. Conventionally, postoperative hip flexor weakness has been attributed to dissection through the psoas muscle itself. A study by Molinares et al. in 2016 studied healthy individuals placed within the lateral decubitus position both with and without a table break of 25° for 1 h. The typical transient neurapraxia with hip flexor weakness and sensory disturbance was seen in all patients in the lateral jack-knife position, but not those in the lateral decubitus position. The L1, 2, and 3 nerve roots on the nondependent (would-be-operative) side experienced symptoms of neurapraxia with 10–60% decrease in hip flexion strength, and 38% still having diminished sensation even after 1 h of recovery following the positioning [9]. With this, lessening of the table break angle has decreased the postoperative neurapraxia seen in our patients. Additionally, hips and knees are both bent at 60° to relieve tension on the psoas and the lumbar plexus/femoral nerve.

Once lateral, several pressure points are identified and padded or supported accordingly. A pillow is generally used beneath the dependent knee to pad the peroneal nerve, two additional pillows are then placed between the knees to avoid an area of potential bony compression as well as to abduct the hip which further shortens the nondependent psoas muscle. The feet are similarly padded to avoid pressure along the medial and lateral malleoli. Peroneal nerve compression at the fibular head with resultant injury has been reported and can be identified early during the case by MEP monitoring that will show attenuation should nerve injury be ongoing [10, 11]. With proper padding, this has not been seen in our longstanding cohort of patients.

An axillary roll is also placed for decompression of the brachial plexus. Traditionally, this has included a rolled blanket or a wrapped liter bag of saline; with improvements in positioning aids,

we currently utilize an appropriately sized gel roll based upon the patient's body habitus. Use of gel padding has been shown to more effectively reduce pressure under the patient's shoulder and produce a lower chest wall pressure than a bag of IV fluid [12]. We position the axillary roll beneath the chest wall, allowing for elevation of the shoulder and decompression of the plexus. This allows for extension of the dependent arm and forearm perpendicular to the operating table with appropriate padding of the ulnar nerve and makes available line access to the anesthesia team. Rarely, a long thoracic nerve injury can be seen with the chest wall pressure from the axillary roll, but this has not been seen in our experience [13]. The nondependent arm and forearm are similarly extended perpendicular to the table and rest on a Mayo stand padded with pillows to prevent areas of pressure. It is important to adjust the Mayo stand appropriately with any subsequent repositioning or elevation change of the operative table as table changes during the case can change the angle and stress placed on the resting extremities. The elevation of the chest wall will cause an elevation of the shoulders and cervical spine. Without additional support beneath the patient's head, cervical angulation would cause stretch on the brachial plexus and possible compression of dependent vasculature with concern for interruption of cerebral blood flow or venous congestion [14]. A large foam head holder is utilized with additional bolstering material to ensure a neutral position of the head and cervical spine. Reusable, inflatable pillows are commercially available and can serve as both axillary rolls and head elevators with improvement in shoulder and chest wall pressures. Implementation of these has not been necessary given the rarity of brachial plexus or cervical injuries during lateral positioning with our aforementioned arrangement [12].

Once basic patient positioning is established, securing the patient to the table is performed in a regimented, step-wise fashion, shown in Fig. 12.1. Three-inch wide silk tape is utilized to secure the patient and make small corrections in the rotation of the patient to achieve a true AP and lateral view during the case. First, a line of

tape is run transversely across the iliac crest. This tape will wrap circumferentially around the patient and table. We ensure that the tape in contact with the patient is flat in order to reduce the risk of skin abrasions though direct skin contact is important to prevent motion of the patient intraoperatively [15]. This initial tape line will also initiate the process of orienting the patient perpendicular to the operating room floor. The second line of tape extends from the crest, at the site of the original tape line, caudally along the course of the thigh. This will extend distally from the knee to be secured to the table. This second tape is under subtle traction to bring the ipsilateral iliac crest down, enhancing visualization of the lower lumbar spine. A third tape line is then directed from the patient's knee distally along the leg, avoiding direct compression of the fibular head, again being secured to the table. A further line of tape is run circumferentially along the upper chest wall, care should be taken to avoid tape directly on the nipple or areola; this tape is placed with the assistance of fluoroscopy to align the vertebral bodies of the lumbar spine to further assist in obtaining a true AP and lateral view, with gentle rotation as necessary. The position of the C-arm fluoroscopy unit is then marked to allow for consistent angles with both lateral and under-table AP imaging throughout the case. The final line of tape retraces the first, making the last adjustment to the lower trunk rotation and to confirm appropriate visualization with C-arm fluoroscopy.

Once the patient is positioned and secured, the incision is planned using fluoroscopy. We utilize a cross-hair tool (Fig. 12.2) to assist in localizing the correct level. With lateral fluoroscopy, the crosshairs are aligned atop the center of the targeted disc space; an incision is then drawn along the diagonal overlying the disc space. In our experience, the most ergonomical and safest position is for the operating surgeon to stand on the dorsal aspect of the patient, with the C-arm base on the ventral side. This minimizes the distance to the operative field, particularly with obese patients. In our practice, this regimen of positioning for elective cases removes the need for caudal rib resection to enhance visualization.

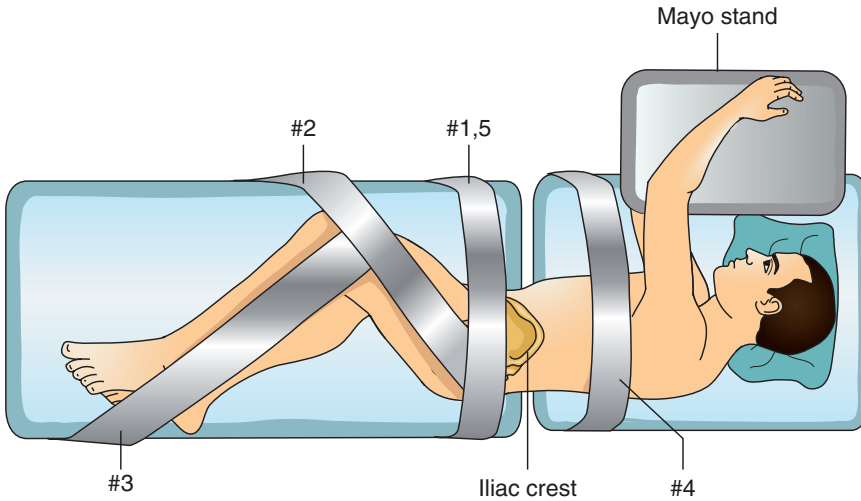


Fig. 12.1 The positioning and securing of the patient to the table with sequential placement of 3-in. silk tape bands



Fig. 12.2 The cross-hair tool to assist in incision planning over the localized, targeted disc space

Following typical preoperative preparation including local anesthetic and sterilization of the skin with appropriate draping, the procedure is carried out in accordance with the typical MIS-

LLIF routine. Care is taken with the superficial dissection to avoid injury of the transiting nerves. The nerves particularly at risk of injury during the exposure include the subcostal nerve, the iliohypogastric nerve, and the ilioinguinal nerve. These nerves exit the lumbar plexus and are often encountered traveling inferomedially atop the fascia of the transversalis muscle, deep to the internal obliques [16]. Early identification of the nerves proves the best way for avoidance of inadvertent injury during the initial stages of dissection. Injury of these nerves can lead to pain, numbness, or abdominal wall paresis [17–19].

After developing and entering the retroperitoneal space, the psoas muscle is identified and the lumbar plexus becomes at risk during the next portion of the procedure. Traditionally, lateral fluoroscopy is used to place a guidewire into the operative disc space with active monitoring during serial advancement of dilators, culminating with a self-retaining retractor system. The anterior half of the disc space, within the sagittal plane, is the target of choice to allow for adequate discectomy and graft position while decreasing the risk of injury to the lumbar plexus. The lumbar plexus moves ventrally within the psoas muscle the more caudal the spine level; this places the neural structures within the psoas at a higher risk with lower targeted levels. With this in mind, the entry point is moved slightly ventral,

up to the $2/3$ point of the radiographic disc space at the L4/5 level (Fig. 12.3). Prior to placing the guidewire, we recommend direct visualization of the psoas muscle to ensure the genitofemoral nerve (often found running atop the muscle within the surgical corridor) is avoided; a Wylie retractor is extremely helpful in this endeavor [5, 16, 18]. Active nerve monitoring during dilation of the muscle proves very useful, particularly when directional. Rotating a directional probe during dilation can prevent inadvertent nerve injury, as well as ensures that the retractor is opened ventral to the plexus. When docking the retractors, inadvertent placement dorsal to the plexus could result in ventral nerve retraction leading to root stretch and injury [19]. Once the psoas is dilated, the retractor is placed and anchored, centered on the disc space. The discectomy can be performed with the plexus remaining in safety, posterior to the retractors.

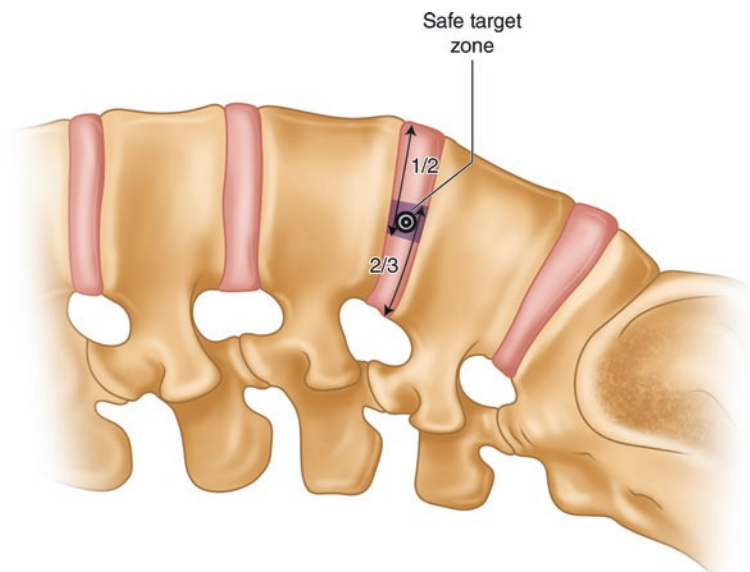
In addition to neural structures, the lateral approach to the thoracolumbar spine also places vascular structures at risk. During the discectomy, the anterior longitudinal ligament (ALL) is maintained intact to preserve a protective barrier between the instruments and the abdominal/pelvic vessels. The introduction of instruments is done in such a way to minimize exposure of the vessels to injury. Pituitary and Kerrison rongeurs

are advanced with the jaws directed dorsally to reduce inadvertent injury. The positioning of the patient places the structures at risk, but careful surgical technique can avoid pitfalls of iatrogenic injury.

Positioning for the Traumatic Spine

In addition to elective lumbar surgery, the lateral position is utilized within our practice for thoracolumbar trauma. Regional experience finds frequent thoracolumbar fractures from high-energy injuries that result in unstable burst fractures at the thoracolumbar junction. With neural canal compromise, or when posterior instrumentation does not fully stabilize the spine, a lateral approach to the fracture is indicated. This approach can successfully be utilized for pathology up to T10. In our experience, a combined procedure with general surgery exposure is ideal. An open exposure is preferred over minimally invasive due to the patient population and extent of the fractures encountered within our practice. For procedures on T12 and above, a dual-lumen endotracheal tube can be used to provide one-lung ventilation while deflating the ipsilateral lung. In the lateral position, one-lung ventilation can precipitate V/Q mismatch with pooling of

Fig. 12.3 The entry point should be placed within a “safe zone” within the disc between the midpoint and the ventral $1/3$ of the operative disc space to minimize injury to the lumbar plexus



blood within the dependent vasculature. Though this does not preclude the practice, it is a consideration to be accounted for in preoperative evaluation [20].

In general, the patient is positioned in a similar manner to elective lumbar procedures. If MEPs are to be used, a baseline is obtained both before, and immediately after, positioning to ensure no loss of function in the setting of an unstable fracture or potentially compressive fragment. With unstable fractures, attention is also given to maintaining neutral alignment during the transition from the stretcher to the operative table. A slide board, log-rolling, and multiple assistants are often indicated to ensure safe alignment during positioning.

A standard flat-top bed is utilized with a beanbag with vacuum seal positioned beneath the patient and form-fit to maintain stability of the torso throughout the procedure. The lateral margin of the beanbag should remain below the level of the spine, so as to not obstruct AP fluoroscopy. The table can be left either flat, or with a slight break should a Skytron bed be utilized; the iliac crest is not an anatomic barrier for this level, and the break, if used, is generally for surgeon ergonomics. A right lateral decubitus position is preferred to avoid the obstruction of the liver at the surgical level, as well as to encounter arterial, rather than venous, anatomy on the surface of the spine. An axillary roll is appropriately positioned, and the patient is secured with traditional straps as well as tape. Without the crest as an anatomic obstruction, the full, regimented taping protocol of the elective thoracolumbar access is not required. Foam and pillow padding is placed over pressure points with attention to the ulnar nerves, the dependent peroneal nerve, between the patient's knees, and the malleoli of both ankles in a similar manner as during elective cases. The upper extremities are positioned out from the torso in a similar manner to elective cases. This, again, offers decompression of the plexus, peripheral nerves, and pressure points, while allowing access to lines by the anesthesia team.

With the patient secured, intraoperative fluoroscopy is utilized to identify the surgical level and to assist in planning of the surgical incision.

In our practice, an experienced general or trauma surgeon is relied upon for the retroperitoneal access, with or without reflection of the diaphragmatic attachments; this also is of use in the event the vascular anatomy is obstructing direct access to the vertebral body [21]. A lateral transverse incision is used for initial skin opening. The access surgeon will perform the exposure in a retro- or transperitoneal approach as required by the patient condition, additional injuries, and nature of the procedure. The Bookwalter retractor system is generally preferred and remains in place following the exposure, but it is important to utilize radiolucent retractor blades to enable radiographic visualization during the spinal portion of the case.

Once the spine is properly exposed and the abdominal contents are out of the surgical field, the spinal portion of the procedure can begin. The lateral approach will expose the radicular arteries that travel circumferentially from the aorta, around the midportion of the vertebral body, before entering the spinal canal via the neuroforamina. As these vessels contribute to the vascular supply of the spinal cord, and the artery of Adamkiewicz can be found in the region, care must be taken when exposing the levels and performing vertebrectomies. If the vessel must be taken, it should be ligated and transected sharply. It is preferable to limit the arterial sacrifice, when possible, to unilateral and to no more than three segments to minimize the chances of cord ischemia and infarction [22–24].

With a large exposure, a traumatic injury of the spine can be repaired with appropriate bony and disc removal, graft or strut placement, and lateral instrumentation as necessary. The lateral position lends itself to harvesting iliac crest graft, if desired. Wide prep and draping during the initial positioning should take this into account to ensure adequate exposure to allow the harvest. It is not uncommon in our practice to supplement a lateral corpectomy for trauma with posterior instrumentation. The neural element decompression and anterior/middle column stabilization is best performed from the lateral approach, but with the forces often involved in these injuries, a cage and lateral plate is often insufficient to

restore stability. For this, an additional posterior instrumentation, open, or often minimally invasive, is utilized to further regain structural stability and increase the chances of a solid fusion across the injury. Our current practice is to reposition for prone, posterior pedicle fixation, though other posterior instrumentation techniques from a lateral position have been described [25].

Physiologic Considerations

Lateral positioning changes several physiologic parameters that should be considered when planning for the anesthetic portion of the case. For respiratory considerations, the lateral position has been shown to decrease both vital capacity and tidal volume by 10% in awake subjects. This decrease is mitigated by the placement of an axillary roll in that a mildly suspended chest wall has improved compliance and decreases peak inflation pressures, possibly improving cardiac output and oxygenation that would be otherwise affected by positioning. The angulation of the table across the break has also been shown to decrease forced vital capacity when compared to flat lateral positioning due to decreased pulmonary compliance. Additionally, the lateral position can create a V/Q mismatch due to the vertical fluid static pressure gradient within the pulmonary vasculature. This becomes more important when single-lung ventilation is utilized in the thoracic spine [20].

In addition to pulmonary consideration, the vascular system is also affected by the lateral positioning. Significant venous pooling can occur within the dependent extremities which can create a type of “third-spacing” of the intravascular volume of up to 1 unit of blood. This can become more significant in patients with additional thoracic or abdominal pathology that can cause venous caval compression that can lead to hemodynamic instability. Further, the vertical gradient across the patient’s body can also lead to changes in blood pressure readings in the dependent extremities. Due to fluid static pressure, the systemic blood pressure reading can change by 2 mmHg per in. of height difference across the

body. With this in mind, it has been recommended that the blood pressure cuff be placed on the nondependent arm; this practice not only avoids incorrect measurements due to additional body weight compression, but also will read lower, so as to avoid any inadvertent hypotension that could potentially exacerbate a compromised cord vascular supply [20].

Complication Avoidance

The lateral position provides a direct surgical corridor to the thoracolumbar junction and thoracic spine, but does still present risk to the patient from the positioning itself. Many key positioning maneuvers have been developed from attempts at complication avoidance and assisting in surgical exposure. In addition to those listed previously, there are several positioning-related complications that can be avoided with careful attention to the patient prior to the skin incision.

Any prolonged surgical procedure can place the patient at risk for dependent decubitus ulcers. The lateral position, in particular, exposes several bony prominences to direct contact with the surgical table and support equipment. The lateral aspect of the ankle, knee, greater trochanter, iliac crest, chest wall, humeral head, and the parietal boss are all in line with the surgical table, and the upper extremities, when flexed at the shoulder, will also likely rest on solid support surfaces. Studies indicate that ulcers can develop following the first 1–4 h of positioning over bony prominences [26, 27]. For this, each bony prominence that is contact with a solid surface must be carefully checked and either padded or repositioned. A full-table load dispersing gel-pad is used as the base layer for our surgical beds, but additional foam or pillow padding is added for each pressure point on the patient. The axillary roll placed along the chest wall decompresses the plexus as well as the shoulder though it can increase the pressure measured at the chest wall [12]. For this, our institution has moved from use of a wrapped, liter bag of saline to gel rolls for reduction in local pressure; reusable, inflatable pillows have also

been advocated for this purpose to further reduce chest wall pressure [12, 28, 29]. Attention at this stage of the procedure can prevent serious morbidity to the patient and should be a priority, regardless of the expected length of the procedure given the rapid nature of onset of ulcer formation.

Though the lateral position is typically utilized for thoracolumbar pathology, the upper extremities are of key importance during the positioning, and many nerves of the upper extremities are placed at risk, including the brachial plexus itself. The dependent shoulder is addressed with an axillary roll to reduce pressure on the joint and the bony prominence, but alleviating the pressure on the shoulder also reduces the risk of compression of the plexus by the humeral head. The placement of the axillary roll is crucial in that it can reduce the tension on the plexus by rotation of the arm out from beneath the chest, but the roll can also injure the plexus with direct compression if placed within the true axilla rather than along the superior chest wall. Compression of the long thoracic nerve from placement of an axillary roll has been reported though this is uncommon [13]. Attention to placement of the roll out of the axilla and, as suggested by Ameri et al., 10 cm distal to the axillary folds can avoid this rare complication. Overflexion of the shoulder should be avoided; we typically limit this to approximately 90°. Full supination and elbow extension can also stretch the descending nerves and should be avoided. As previously shown, peripheral nerve injury can occur with nerve stretch greater than 5–15% of baseline length [30]. In addition to the dependent arm and plexus, the nondependent upper extremity also faces positioning risk. Similar to the dependent arm, shoulder flexion greater than 90° and full elbow extension should be avoided to prevent nerve stretch. Over pronation also exposes the ulnar nerve to a greater chance of compression at the elbow. Cervical traction caused by lateral neck flexion can place stress on the nondependent plexus and should be mitigated by placement of a pillow to support the head [29].

Typically, the prone position raises the greatest concern for postoperative vision loss (POVL),

but it has been reported in the lateral position. Posterior ischemic optic neuropathy (PION) is the most common cause of POVL, and most cases are associated with prolonged cases within the prone position [27, 30]. In reported cases performed in the lateral decubitus position, it is often felt that hypotension and anemia are causative factors. While in the lateral position, maintaining a stable blood pressure, avoiding overhydration with crystalloid, treating preoperative and intraoperative anemia, and minimizing operative time can reduce the risk of PION [31]. Further, the dependent eye can also be subject increased intraocular pressures; this can be mitigated by ensuring a neutral position of the neck with head support/pillow and maintaining the head at, or above, the level of the patient's heart during the procedure [27]. Direct compression of the dependent eye in the lateral position is less likely than while prone with use of a horseshoe head holder, but vigilance to ensure no globe compression can reduce the risk of causing a drop in ocular perfusion pressure. When PION does occur, asymmetric bilateral visual loss is seen, with more involvement of the dependent eye [31]. Additionally, postoperative visual disturbances and ocular pain can be seen secondary to corneal abrasion, most commonly in the dependent eye; in our experience, abrasions can be successfully avoided with tegaderm coverage overlying closed eyes and avoidance of any direct compression of the globe.

Another rare, but reported, complication of spine surgery while in the lateral decubitus position is unilateral parotid enlargement, otherwise known as anesthesia mumps. The complication is seen following surgeries in the prone or lateral decubitus position. Though the exact etiology is unknown, it is seen following prolonged cases and is often thought to be associated with intubation/extubation trauma to the parotid duct, external compression on the lateral face, or secondary to the use of certain anesthetic medications that predispose to stimulation of the salivary glands. Presenting with unilateral fullness and firmness of the parotid gland with painful sensations and lack of parotid secretions, the symptoms can last several minutes to several days. The condition is

self-limiting and the treatment is supportive in nature, with NSAIDs, rehydration, and reassurance. To avoid this complication during spine surgeries in the lateral position, a soft, foam head-pillow is utilized to support the patient's face while avoiding extrinsic compression, and rotation of the neck is avoided to maintain good venous drainage. Premedication with anticholinergic drugs can also be considered to reduce secretions [32, 33].

Conclusion

Placing a patient in the lateral position for a spinal surgery provides many benefits. Some of these include access to the anterior columns of the spine with reduced approach morbidity, direct visualization of the vertebral body and disc space, and morbidity avoidance from muscle damage incurred during posterior exposures. With the benefits gained, the approach also places the patient at new risks from the unique positioning demands. The majority of these risks include proximity to abdominal and vascular structures during the procedure as well as the risk of nerve damage from stretch or direct injury. These risks can be successfully mitigated with careful attention to the positioning of the patient on the table and the joints and extremities with respect to the body. By correctly positioning, padding, and minimizing extremes, the lateral position can provide spine surgeons with an alternative and safe approach to treat various thoracic and lumbar spine pathologies.

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