Anesthesia Pitfalls and Considerations for Spine Surgery

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Surgery on the spine and spinal cord involves a wide variety of surgical procedures whose pathologies depend on the age of the patient. For children and teenagers the most common reason to need spine surgery is to either correct spinal deformities or oncologic disease. The pathologies that adult spine patients typically present with are trauma, infection, malignancy causing neurologic compromise, idiopathic spinal deformity, and degenerative disease. This can lead to a wide range of spinal surgeries including minimally invasive decompression procedures to major deformity correction involving osteotomies and major blood loss. These adult patients have a unique set of anesthetic challenges and the goal should be to provide an individualized anesthetic plan to optimize outcomes.

PREOPERATIVE

During the preoperative assessment, the anesthesiologist should consider the patient's airway and cardiac, respiratory and neurologic systems. All patients should undergo a standard airway exam to identify risk factors for difficult mask ventilation or intubation. Risk factors for difficult ventilation include the presence of a beard, the absence of teeth, abnormal mandibular protrusion, obesity and a history of snoring.[1] Small mouth opening, large tongue and short thyromental distance are predictors of difficult intubation. The presence of rheumatoid arthritis, ankylosing spondylitis, and cervical spine disease increase the likelihood of difficult intubation and these patients require special attention.[2]

The preoperative cardiac evaluation must consider the patient's individual probability of major adverse cardiac events (MACE), the patient's functional capacity, and the invasiveness and urgency of the surgery. An individual's risk for MACE can be calculated with the surgical risk calculator derived from data from the National Surgical Quality Improvement Program (NSQIP), published in the most recent 2014 ACC/AHA guidelines for preoperative management of patients undergoing elective non-cardiac surgery.[3] Assessment of functional capacity is often difficult in spine patients whose activity is limited by pain and deformity.

Most spine procedures are considered intermediate-risk procedures except for procedures at high risk for bleeding such as multilevel spine fusions. Lenoir et al found that age > 50, fusion of two or more levels, transpedicular osteotomy, and hemoglobin less than 12 mg/dL were risk factors predictive for the need for blood transfusion in adult elective thoracolumbar spine surgery.[4] Preoperative treatment of anemia with intravenous iron or erythropoietin may be helpful, however, erythropoietin was found to increase the risk for venous thromboembolism in cases where thromboprophylaxis was not used.[5,6]

Turning a patient into the prone position also affects the cardiac system. Increased intrathoracic pressure causes a decrease in left ventricular compliance leading to a decrease in cardiac output.[7-9] In addition, abdominal compression decreases venous return.[7] These changes may be particularly important for patients with preexisting cardiac disease.

Pathology of the spine may also directly influence the respiratory system. Patients with severe scoliosis may present with restrictive lung physiology causing reduced lung volumes, and in severe cases, pulmonary hypertension.[10,11] Despite the preservation of diaphragm innervation, patients with low cervical or high thoracic spinal injuries may also have decreased forced vital capacity due to decreased intercostal and abdominal muscle strength. This may lead to an inadequate cough for clearance of secretions.

Existing motor and sensory deficits should be recognized preoperatively so that they may be accurately monitored intraoperatively and postoperatively. Patients with chronic spinal cord injury or significant neuromuscular disorders should not receive the depolarizing muscle relaxant succinylcholine because of the potential for severe increase in serum potassium levels due to upregulation of acetylcholine receptors in denervated muscle. Patient with cervical myelopathy or spinal cord compression may warrant an arterial line to continuously monitor spinal cord perfusion.[12] Finally, any unstable neurologic deficits should be recognized so that extra care may be taken to avoid further damage during intubation or positioning.

AIRWAY MANAGEMENT

When evaluating the airway management of a patient with a cervical spine instability or compression the factors to consider include if the injury is acute vs chronic. For patients with chronic cervical spine disease the airway management is dictated by the severity of the disease. This is determined with imaging studies of the cervical spine, neurologic deficits at baseline and if the deficits worsen with cervical spine motion. For patients with adequate neck mobility and an otherwise reassuring airway exam the airway management can reasonably be expected to be routine. However, as the

neck mobility decreases or the patient becomes symptomatic with neck motion the airway management can become more challenging. When patients have disease involving the occipito-atlanto-axial spine this is more predictive of a difficult intubation compared to lower in the cervical spine. The incidence of a difficult intubation increased from 1-2% for patients without cervical disease to 8% for patient with cervical disease from level C3-

7. When the patients had cervical disease involving levels C1 or C2 the incidence of difficult intubation increased to 36%2. This is consistent with the radiographic study done by Horton that showed when the patient is placed in the classic intubation position “sniffing position” the majority of the neck extension occurs in occipito-atlanto-axial complex.[13]

For patients with acute cervical spine instability or compression they experience the same challenges as the patients with chronic disease. In addition, these patients will also typically have some form of neck immobilization that invariably increases the difficulty of successfully intubating the patient. Significant energy is devoted to protecting the cervical spine in these patients as it should, but it is important to remember that there have been few documented cases in the literature of secondary neurologic injury from intubation. While formulating the plan to safely intubate the patient and protect the cervical spine as much as possible, it is essential to remember the ABCs. Ensuring that the patient is ventilating adequately takes precedence over protecting the cervical spine. Unfortunately, the patients with high cervical trauma are both the most at risk during intubation and also the most likely to develop respiratory failure from the injury. To develop an intubation plan it is important to take into account the extent of the neurologic injury, the patient’s mental status, the airway exam, adequacy of ventilation and the urgency of the surgery. There are a variety of techniques available to intubate the patient but no one technique is ideal for every situation. In formulating the plan, it is essential to weigh the pros and cons of each technique and also understand how each technique leads to movement of the cervical spine.

FIBEROPTIC INTUBATION

An awake fiberoptic intubation is considered by some to be the gold standard for the management of an acute spine injury. The advantages include the ability to do a post intubation neurologic exam and minimal pressure is placed on the cervical spine by the fiberoptic scope. The challenges in performing an awake fiberoptic intubation include the time necessary to topicalize the airway with local anesthetic and to perform the intubation. Typically it will take 20-30 minutes to do an awake fiberoptic intubation. A second challenge is despite adequate topicalization of the airway, it is not uncommon for the patient to cough or move during the intubation of the airway. This movement can be violent at times and can potentially put the

spinal cord at significant risk. In addition it is necessary to have a patient who is alert and able to cooperate with the intubation.

An alternative to an awake fiberoptic intubation is doing the fiberoptic intubation after the patient is under general anesthesia. If this is done the patient can receive a short acting paralytic medication to ensure that there is no movement or coughing during the intubation. For this to occur safely, the anesthesiologist must feel confident that the patient can be mask ventilated to ensure adequate ventilation prior to the intubation. The advantage of doing the intubation under general anesthesia is it is typically much quicker and a cooperative patient is not necessary. The disadvantages include the inability to do a neuro exam after the intubation has occurred. While the fiberoptic scope leads to minimal movement of the spinal cord the act of mask ventilating the patient does lead to movement in the spine. In a cadaver study the performance of a jaw thrust to allow mask ventilation lead to 5mm of movement of the cervical spine at the site of injury.[14] This issue is also present with all of the following techniques listed below.

DIRECT LARYNGOSCOPY AND VIDEO LARYNGOSCOPY (GLIDESCOPE)

An alternative to performing a fiberoptic intubation is doing direct laryngoscopy. To minimize movement of the cervical spine during the intubation it is common practice to maintain “manual in-line immobilization” (MILI). However while this prevents gross extension of the cervical spine, subluxation still occurs.[15] Maintaining the cervical spine in a neutral position instead of the classic “sniffing position” worsens the view of the vocal cords in 45% of patients. In addition the vocal cords were not visible in 22% of patients whose spine was maintained in the neutral position. When the patients were placed in the “sniffing position” the vocal cords were not visible in 1% of patients.[16]

Due to the expected difficulty in intubating the patient with MILI it has become common practice to use a video laryngoscope in the place of direct laryngoscopy. This has been shown to significantly improve the ease of intubation.[17] However the movement in the cervical spine during intubation is similar with 3-4 mm widening of disc space.[18] Compared to fiberoptic intubation the use of direct laryngoscopy or video laryngoscope is significantly quicker. Since the patient is anesthetized under general anesthesia the patient does not have to be awake or cooperative. Direct laryngoscopy or video laryngoscopy is also technically simpler than fiberoptic intubation especially in patients with blood in the pharynx from trauma.

LARYNGEAL MASK AIRWAY (LMA)

The LMA potentially has several advantages compared to direct laryngoscopy. In normal patients it is placed blindly into the oro-pharynx with

a high rate of success. It then allows the ability to provide positive pressure ventilation. The patient can be intubated with an endotracheal tube either blindly through the LMA or with the assistance of a fiberoptic scope.

However when MILI is applied with cricoid pressure the successful placement of the LMA became significantly more challenging. In addition when they attempted to perform a fiberoptic intubation with the LMA in place the vocal cords were identified in significantly fewer patients maintained in MILI vs the sniffing position (38% vs 83%).[19] The insertion of an LMA into the oropharynx has been shown to place pressure which leads to posterior displacement of the upper cervical vertebrae. In a randomized controlled cadaver study with an injury to the C3 segment, the motion of the cervical spine was similar between mask ventilating a patient and the placement of an LMA.[20]

AIRWAY RECOMMENDATIONS

For the airway management of patients with cervical spine disease currently there is no recommendations for the optimum method to manage the airway. The literature does not contain any outcome studies that support one technique over another.[21] The ultimate decision will depend on the expertise of the provider managing the airway, how quickly the airway needs to secured, and the ability for the patient to cooperate with the intubation. In addition, it is important to understand the extent of the cervical injury and how the different airway management techniques will affect the cervical spine.

POSITIONING

In spine surgery the common positions include supine, prone and occasionally lateral. For these three positions the most challenging position is typically prone, which will be the focus of this section but the overall principles can be applied to the other positions. In positioning the patient the primary objections include

· Providing optimum surgical exposure

· Protecting sensitive structures from injury due to pressure

· Minimize pressure on the abdomen to decrease compression of vena cava

· Minimize pressure on the thorax to allow for adequate ventilation

· Normal positioning of the extremities to decrease the risk of stretch injuries to nerves

NERVE INJURIES

In a review of the American Society of Anesthesiologists closed claim database, nerve injuries were found to represent 15-16% of claims.[22] Common causes of nerve injuries include stretch or compression of the nerve, ischemia and direct injury to the nerve. The most common nerve injuries include ulnar (33%), brachial plexus 23% and lumbosacral roots (16%).[23]

When the patient is positioned prone the following nerves are susceptible to injury

· Brachial Plexus – Typically occurs due to a stretch injury. Susceptible to occur when the neck is extended and rotated laterally or if the arm is abducted greater than 90 degrees.[24]

· Ulnar Nerve – More likely to occur due to pressure on the cubital tunnel at the elbow or due to over flexion of the elbow. Injuries have also occurred due to malpositioned blood pressure cuffs or the arm falling off the arm board during surgery.

· Lateral femoral cutaneous nerve – Occurs due to direct compression of the nerve by the pelvic bolsters close to the anterior superior iliac spine.[25]

EYE INJURY

The most common eye injury is a corneal abrasion. It can occur due to direct trauma to the cornea, but the most common cause is inadequate closure of the eyelid which leads to drying of the cornea.[26] To decrease the risk of corneal abrasions the eyelids are typically taped closed

and various ointments may be added to prevent drying of the cornea. Postoperative visual loss (POVL) is a feared complication from spine surgery in the prone position with an incidence of 0.2%.[27] It can occur due to a variety of mechanisms in the eye, optic nerve or brain. Risk factors for post-operative visual loss have been proposed but few have been definitively shown to increase the risk. A Practice Advisory has proposed the following.[28]

· Deliberate hypotension has not been associated with POVL

· Intravascular volume monitoring is important in high risk surgeries and the use of colloids with crystalloids is advised

· Direct pressure on the eye will lead to increased ocular pressure and this may increase the risk of central retinal artery occlusion and therefore should be avoided

· For high risk patients it is advisable to position the head at or above the level of the heart and the neck should be maintained in a neutral position to improve venous drainage

· Since the majority of patients with ischemic optic neuropathy had significant blood loss (>1 L) and surgery lasting >6 hours, it is advised to consider staging lengthy procedures

INADVERTENT EXTUBATION

With the prone position the risk of inadvertent extubation of the endotracheal tube is significantly higher than other positions. This can occur during turning the patient from supine to prone. Once the patient is prone the endotracheal tube is exposed to saliva, blood and other secretions. This can make it challenging to secure the endotracheal tube with the standard adhesive tapes that are commonly used. The secretions will weaken the adhesive qualities of the tape and decrease the security of the endotracheal tube. In addition, spine surgery typically

has a fluoroscopy machine moving around near the head of the bed. Multiple reports in the literature have described cases where the patient was inadvertently extubated by the fluoroscopy machine pulling on the airway circuit.[29] The endotracheal tube is also challenging to access in the prone position to verify that it is secure, so the first sign of trouble is frequently the patient becoming extubated. This can be disastrous because replacing the endotracheal tube in the prone position can be challenging to impossible. It could necessitate moving the patient supine with the incision open and the spine potentially unstable.

To prevent this complication a variety of techniques have been developed to secure the endotracheal tube. Adhesive tape despite its limitations is still the most common method for securing the endotracheal tube. If used the adhesive tape is typically reinforced with multiple layers of tape or non-occlusive dressings to minimize the secretions contact with the tape. A different option is the use of cloth non-adhesive tape that is then tied to the endotracheal tube and the patient. An alternative is to suture the endotracheal tube to the patient. Multiple commercial devices (Haider Tube Guard[30] and Thomas Endotracheal Tube Holder[31]) have been developed to try and improve on the limitations of the other methods. These devices have been shown to be successful in decreasing movement of the endotracheal tube and therefor potentially minimizing inadvertent extubation.

INTRAOPERATIVE

When forming an anesthetic plan, the anesthesiologist must consider the neurologic structures at risk, the likelihood for blood loss, and the patient

positioning. This will determine the plan for neuromonitoring, anesthetic maintenance, need for hemodynamic monitoring, and intravenous access.

The use of neuromonitoring often dictates the choice of anesthetic maintenance. Inhalational anesthetics cause a dose-dependent increase in latency and decrease in amplitude of the evoked potentials, and should be used with caution, if at all, when neuromonitoring is ongoing.[32,33] An intravenous technique using propofol and an opioid infusion such as remifentanil or sufentanil is typically recommended. It is important to maintain a consistent anesthetic depth to facilitate the reliable interpretation of evoked potential responses.

Motor evoked potentials and electromyography (EMG) are affected by neuromuscular blockade. When the intermediate-acting non-depolarizing muscle relaxants such as rocuronium, vecuronium or cisatracurium are used during intubation or to facilitate surgical exposure, their effects may need to be quickly reversed to facilitate neuromonitoring. The onset and duration of action depends on the dose, but for intubating doses, onset is typically 3-5 minutes and duration of action is typically 30-45 minutes.[34] Until recently the only choice for reversal of muscle relaxation was the anti-cholinesterase neostigmine, which requires partial recovery of neuromuscular function. Sugammadex is a relatively new drug that works by selective binding the muscle relaxant drug, and it can facilitate the reversal of moderate to deep muscle relaxation.[35] It should be noted that sugammadex is contraindicated in renal failure patients and can only reverse the aminosteroid muscle relaxants rocuronium and vecuronium.

Significant blood loss can occur during spine surgery, and various blood conservation techniques are used to decrease blood loss and transfusion. Positioning patients in the prone position with the abdomen hanging freely decreases venous pressure which is thought to decrease bleeding.[36,37] The antifibrinolytics tranexamic acid and epison-aminocaproic acid have

been used in orthopedic surgical patients for many years, and there is evidence to support the use of antifibrinolytics in spine surgery specifically.[38-40] We do not recommend the use of antifibrinolytics in patients with hypercoagulable disorders. For procedures with a high predicted blood loss, intraoperative cell salvage is also useful to decrease allogeneic blood transfusion.[41]

Although controlled hypotension was historically used with the goal of decreasing intraoperative blood loss, it should be used extremely cautiously.[40,42] The mechanism of this technique was thought to be due to decreased local wound blood flow caused by a decreased mean arterial pressure. Various authors, however, have suggested that bleeding during spine surgery from bone is dependent upon venous rather than arterial

pressure.[43] Induced hypotension also increases the risk for ischemia of brain, heart, kidney. Recent retrospective cohort data from 33,000 noncardiac surgeries has shown that intraoperative hypotension to MAP less than 65 is independently associated with acute kidney injury and myocardial infarction.[44,45] Cerebral autoregulation is responsible for maintaining a constant cerebral blood flow by changing the résistance of cerebral vasculature in the face of decreased mean arterial pressure, but this is only effective at the lower limit of autoregulation of about 70 mm Hg,[46] and adult patients with chronic hypertension may require even higher mean arterial blood pressures. In a study of deliberate hypotension in scoliosis patients, somatosensory evoked potentials were affected in some patients and reversed when the blood pressure was corrected.[47] In addition, although hypotension has not been found to cause postoperative visual loss (POVL), it also may be prudent to avoid hypotension in patients at risk for POVL.[48] Therefore, we suggest that induced hypotension be used very cautiously, and that it never be

used in patients with spinal cord compression, and patients with a neurologic deficit may benefit from higher blood pressures to optimize spinal cord perfusion.

ANALGESIA

A multimodal pain management program has been advocated for spine surgery patients. There are several agents that may be added to standard intravenous opioid regimens. For patients on chronic opioids, intraoperative sub anesthetic doses of ketamine may be useful for its opioid sparing effect, and was found to decrease opioid consumption.[49-51] Oral or intravenous acetaminophen has also been shown to decrease opioid consumption after major surgery.[52] Finally, gabapentin 600 mg preoperatively was studied in lumbar discectomy patients and found to reduce visual analog pain scores and opioid consumption, however these benefits must be weighed against the side effects of dizziness and sedation.[53]

CONCLUSION

In caring for patients with spinal cord disease these patients can represent a wide spectrum of pathologies. In formulating the anesthetic plan the patient’s concurrent medical conditions, the severity of the neurologic deficits and the complexity of the surgery are all considered. The anesthetic plan primarily focuses on the preoperative workup, the airway management, positioning challenges and maintenance of the anesthesia. A thorough understanding of these issues can help both the anesthesiologist but also surgeons care for these patients.

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