19 Postoperative Positioning in the Neurointensive Care Unit

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Introduction

Positioning of patients in the operating room (OR) is extremely important to the success of neurosurgical procedures. Patient outcomes are also influenced by positioning outside of the OR including during transport and while in the intensive care unit. Neurosurgeons and critical care providers need to be well versed in the proper positioning in each of their respective settings in order to optimize patient outcomes. Positioning varies based on comorbidities, type of pathology, timing of injury, and type of surgical intervention. The fundamentals of proper positioning are rooted in an understanding of the interaction of neurosurgical pathology with basic principles of neurophysiology, cardiovascular hemodynamics, and respiratory physiology. There are multiple goals when considering proper positioning in intensive care unit. These include minimizing postoperative pain and prevention of delayed complications and mitigating any intraoperative complications. In addition, positioning should optimize the postoperative physiologic conditions for liberation from mechanical ventilation and invasive monitors to shorten the overall ICU length of stay. This chapter will provide a review on basic concepts of ICU positioning with a specific review of postoperative positioning considerations in the neurocritical care unit using a framework based on type of neurosurgical procedure performed.

Review of Basic Positions and General Principles

The overwhelming majority of patients in the neurocritical care unit are supine in the immediate postoperative period with varying levels of reverse and standard Trendelenburg positioning. Other less commonly utilized positions include prone and more rarely prolonged or frequent lateral positioning. Independent of the position some of the common concerns for patients in a prolonged immobile state is development of compression neuropathy, deep venous thrombosis, and skin breakdown/pressure ulcers. These are rarely encountered in elective surgical patients with short ICU stays but are of major concern in acutely ill patients, like those with aneurysmal subarachnoid hemorrhage or severe spinal cord injuries, who often have prolonged intensive care units stays [1].

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In the supine position, the shoulders, elbow, wrist, and gluteal area need to be sufficiently padded to prevent compression neuropathy. Padding in the ICU is generally accomplished with foam blocks of various shapes and sizes. Towel rolls are also employed and can be placed under the knees with feet suspended by padding under calves to minimize venous restriction to prevent deep venous thrombosis. Air mattresses are the standard equipment to reduce pressure phenomenon on peripheral nerves and venous structures. In addition, the lower extremities should be positioned at the level of the heart to maintain venous return whenever the patient is not upright or actively being mobilized. This will maintain both cardiac output and prevent venous thromboembolism [2, 3]. Patients in the neurocritical care unit are one of the highest risk groups of any ICU patient population for deep venous thrombosis due to the immobility of one or multiple extremities that may accompany critical illness. It is important to emphasize that in addition to positioning use of pharmacologic venous thromboembolism prophylaxis is proven to be efficacious and safe in the immediate perioperative period for all neurosurgical pathologies including aneurysmal subarachnoid hemorrhage, traumatic brain injury, and brain tumors [4–9].

Common positions have predictable physiologic effects that are important to consider in concert with the completed surgery and patient comorbid conditions when recovering in the ICU. In the supine and Trendelenburg positions, there is cranial displacement of the diaphragm and abdominal compartment leading to reduced functional capacity. Atelectasis is also promoted and also worsens ventilation perfusion matching [10, 11]. Trendelenburg positioning with the head down is rarely employed in the NICU due to the deleterious effects of raised intracranial pressure. It has similar effects on pulmonary and cardiovascular physiology to supine positioning but are more pronounced in terms of increased venous return, mean arterial pressure, and cardiac output. Head down positioning can also precipitate airway edema if prolonged and is an important postoperative consideration for spine surgery that will be discussed further below [12, 13].

Prone positioning in the intensive care unit is employed almost exclusively for mechanically ventilated patients with severe hypoxia due to adult respiratory distress syndrome (ARDS). The most common preventable injuries in prone patients are disorders of peripheral nerve compression. Radial and ulnar neuropathies can be prevented by keeping arms in slightly flexed position which prevents excessive traction in either direction. Brachial plexus injuries can occur with rostral or caudal traction on shoulders. Another injury from inadequate padding is due to pressure on anterior superior iliac crest, which can lead to lateral femoral cutaneous neuropathy. Rarely vascular compression of external iliac artery can be seen as well due to prolonged compression in inguinal region. Ideally the face and head should be gently suspended without any site of compression and shoulders overhanging the chest rolls. Careful examination of male genitalia should be done to avoid any compression between thighs or gluteal folds [14].

Patients with ARDS may also require beds that continuously rotate from prone to supine positioning. There are multiple commercially available rotational beds that provide the above described whole body padding including the careful pelvic and cranial suspension. Rotational beds improve oxygenation in ARDS via recruitment of atelectatic lung segments and promote better ventilation perfusion matching and also increase the functional residual capacity. Although ARDS is rare in the neurosurgical population as a whole, it is not uncommon in patients who have poly-trauma including traumatic brain injury (TBI) or spinal cord injury (SCI) [15, 16]. Patients with these types of neurologic injuries who are prone require special attention to intracranial pressure and cerebral and spinal cord perfusion pressure due to disturbed autoregulation which can make cerebral blood flow pressure passive. Prone positioning may precipitate crisis of ICP and or cerebral perfusion if the patient is not properly positioned. The abdomen should be kept suspended to prevent venous compression which can lead to significant epidural venous hypertension which impairs blood flow to the spinal cord via retrograde venous hypertension. Additionally, abdominal compression may compress the vena cava and reducing blood return from the lower extremities impairing preload and as a result reducing the cardiac output. This reduction in cardiac output will in turn impair cerebral and spinal perfusion pressure, particularly when autoregulation is compromised [17].

Prone or rotational positioning poses additional challenge in the neurocritical care unit due to the increased sedation needs of these patients which in conjunction with pharmacologic paralysis severely limits the neurologic exam. For these reasons, prior to being placed in a prone position for ARDS the neurosurgeon and critical care provider must decide whether prophylactic procedures must be performed to minimize the risk of secondary neurologic injury. Predicting individual patient's tolerance for prone positioning must be done on a case by case basis. Generally, this is a last resort for patients who have exhausted all attempts at acceptable oxygenation. A simple trial of lying the patient flat may help indicate tolerability of prone positioning in terms of ICP but the hemodynamic effects of prone positioning are unique and unpredictable. Therefore, in the case of severe TBI maximal efforts like decompressive hemicraniectomy and pharmacologic paralysis with pentobarbital coma should be considered prior to prone positioning.

Transfer of Critically Ill Neurosurgical Patients

One of the first considerations with any operative procedure is the disposition of the patient at the completion of the case. This is institutionally dependent and protocols are useful regarding routine recovery either in the post-anesthesia care unit (PACU) or directly in the intensive care unit. Recovery directly in the NICU has the advantage of direct and fewer transports and improved bed flow. Another important advantage is that the NICU nursing staff is more familiar with early postoperative neurologic complications. However, this is balanced by less experience with managing the normal physiologic response to emergence from anesthesia and potential immediate post-anesthetic complications. Therefore, we feel that transfer directly to the NICU should only occur when a neurointensivist or advanced practice nurse is immediately available upon the patient's arrival to receive a complete handoff from the anesthesia provider. Delayed emergence is the most concerning post-anesthetic complication. This may be due to a number of factors including incomplete clearance of anesthetic, paralytics, opioids, or due to the presence of cholinesterase deficiency, or pre-existing or new neurologic injury [18, 19].

Once admitted to the ICU, transport for imaging or other diagnostic testing outside of the unit after the surgery is often necessary but should not be viewed as a risk-free endeavor. Transport from the ICU requires supine positioning with all of its attendant potential complications in regard to ICP, cardiovascular hemodynamics, and respiratory mechanics. Although routine postoperative CTs are commonly ordered by many neurosurgeons, this practice has not been demonstrated to improve outcomes or significantly reduce complications [20, 21]. On the contrary, several studies demonstrate that the more intrahospital transports a patient experiences the risk of invasive device failure, nosocomial infection, or severe physiologic derangements are increased [22]. Therefore, every diagnostic test should be performed in the ICU when possible and any other tests requiring travel should be minimized if not absolutely necessary.

Neurosurgical Procedures and Intensive Care Unit Positioning

Positioning of the patient post neurological surgery depends largely on the degree and type of pathology and the specific operative intervention performed. Given the large number and wide variety of neurosurgical procedures, it is beyond the scope of this chapter to discuss every surgery and the best postoperative strategy. Therefore, we will discuss positioning as it relates to some of the most common cerebrovascular, cranial, and spine surgeries as a framework to illustrate the key pathophysiologic principles that are common to all neurosurgical procedures with a focus on complication avoidance and management.

Neuroendovascular Surgery

The explosive growth of neuroendovascular surgery in the last 30 years has fundamentally changed the practice of neurosurgery and neurocritical care. It has provided a method of treatment for patients with acute ischemic stroke, improved aneurysmal subarachnoid hemorrhage outcomes, and provided adjunctive multimodality treatments for arteriovenous malformations and brain tumors [23–27]. Despite the minimally invasive nature of these procedures, the postoperative course must be managed with the same care and attention to detail as open neurosurgical procedures. The arterial access point for neuroendovascular surgery is almost always the femoral site and usually ranges from a 4 to 9 French size arteriotomy [28]. Positioning of the leg should remain straight for a period of 4–6 h post procedure after sheath removal. The neurointensivists and nursing staff should note the manner of hemostasis (manual compression or closure device). Regardless of the mode of hemostasis, flexion at the hip or knee or sitting the patient up prematurely may precipitate bleeding from the access site. The sheath may also be sewn in place at the end of the procedure and placed on a pressure bag for blood pressure monitoring. Flexion at the hip may lead to dislodging of the sheath, kinking resulting in thrombosis and inaccurate blood pressures, or force it against the arterial wall which may cause dissection of the femoral artery with repetitive movement.

Mechanical Thrombectomy (MT): Autoregulation and Cerebral Blood Flow

Mechanical thrombectomy (MT) is the standard of care treatment in addition to IV tPA for acute ischemic stroke (AIS) caused emergent large vessel occlusion (ELVO) . Multiple randomized controlled trails (RCTs) and meta-analysis have shown absolute benefit of MT for selected ELVO patients [29–34]. It is rapidly becoming the most common neuroendovascular surgery seen in most NICUs. Post-MT positioning should be focused on optimizing the physiologic conditions for brain perfusion. Autoregulation is disturbed with cerebral blood flow becoming pressure passive in many AIS patients. Therefore, supine positioning is often advocated for these patients [35]. This is particularly important in cases of incomplete recanalization of the occluded artery where cerebral blood flow to vulnerable ischemic tissue is most affected by the pressure passive state. In this situation, it may be preferred to keep the patient supine to augment cerebral blood flow via collateral channels. However, completely supine positioning may be limited by other comorbidities common to the stroke patient such as congestive heart failure or chronic obstructive pulmonary disease [36, 37]. In patients who can't be supine immediately post procedure, reverse Trendelenburg positioning with the access site leg straight is often necessary. The systolic blood pressure from the femoral arterial sheath should be expected to be approximately 20 mmHg higher routinely and as the heart is elevated further above the femoral artery this discrepancy should increase [38].

Endovascular Aneurysm Coiling and Microsurgical Clipping in Subarachnoid Hemorrhage, Positioning for Optimizing Cerebral Blood Flow and Intracranial Pressure

Aneurysmal subarachnoid hemorrhage (aSAH) patients often have prolonged courses in the NICU with severe pathophysiologic derangements in multiple organ systems simultaneously. These include electrolyte and volume status disorders with cerebral salt wasting and SIADH, respiratory failure requiring mechanical ventilation, cardiovascular and cerebrovascular hemodynamic disorders with neurocardiogenic heart failure and cerebral vasospasm, as well ICP crisis. This makes positioning of the patient during the ICU stay crucial to optimal outcome.

All patients with aSAH should be head up to a minimum of 30° to mitigate ICP elevation. The neurointensivist or nurse should also maintain a neutral head position to minimize compromising venous return from the cranium which may raise

ICP. It is common to have anatomic variation with congenitally hypoplastic or absent transverse, sigmoid, and jugular system on one side which can lead to compromised venous return if the head is positioned unfavorably [39]. The disposition of the venous system may be obtained from the angiographer or from review on noninvasive cross-sectional imaging. Additionally, when an ICP monitor is available, the optimum head position can be easily determined by observing the variations of the ICP waveform and pressure with head positioning. The knowledge of a hypoplastic unilateral venous system guides not only the head position but also the site of placement of central venous lines. We prefer to place a subclavian catheter contralateral to the dominant venous drainage of the brain.

If cerebral vasospasm is suspected or confirmed, the standard medical therapy of "triple H," hemodilution, hypervolemia, and induced hypertension is the standard medical treatment. Modern understanding of triple H is that the goal is truly to augment cardiac output while maintaining euvolemia. Hemodilution with hemoglobin levels of approximately 10 g/dL is almost universal with serial phlebotomy required for monitoring in the ICU. In poor grade aSAH, HHG > 3, there is increasing data to support higher CPP goals [40]. Positioning can have important effects on cardiac output, blood pressure and therefore the efficacy of induced hypertension. Preload is maintained by having the lower extremities at the level or above the heart. Like ischemic stroke patients autoregulation may be disturbed in patients with aSAH. However, supine positioning is not recommended because of the concern of increasing ICP and thus reducing the cerebral perfusion pressure.

Craniectomy for Ischemic Stroke, Intracranial Hemorrhage, and Traumatic Brain Injury: Positioning Considerations for Intracranial Pressure Management

Large volume ischemic strokes, cerebellar strokes, intracranial hemorrhage, and traumatic brain injury with resultant edema can all result in lethal elevations of intracranial pressure despite maximal medical management. Randomized clinical trials of decompressive hemicraniectomy of supratentorial ischemic stroke have demonstrated reduced mortality compared to medically managed and improved neurologic outcome for patients less than 60 years of age [41–44]. Similarly, for large cerebellar ischemic and hemorrhagic strokes (>3 cm volume) suboccipital craniectomies are established to be first-line lifesaving procedures that should be performed prior to neurologic deterioration [45, 46].

Positioning after hemicraniectomy should maintain a neutral posture of the head to avoid venous outflow restriction and ICP elevation. Additionally, the head should be positioned to avoid compression of the craniectomy site as this will limit the beneficial effects of the craniectomy on ICP and may damage the brain due to direct pressure. Mechanical compression of the craniectomy site may also result in impaired perfusion in the peri-infarct tissue with expansion of ischemic infarct. Patients requiring craniectomy must also be maintained in an upright (30–45°) posture. After suboccipital decompression, head up positioning is also recommended.

In the subacute period, cerebrospinal fluid (CSF) leakage and pseudomeningocele are both well-known complication of posterior fossa surgery. Both CSF leaking and expanding pseudomeningocele (by virtue of wound breakdown) are risk factors for nosocomial meningitis and should be promptly identified and corrected. Both of these complications may happen spontaneously or be precipitated by attempts at clamping and weaning a ventriculostomy. In these situations, the ventriculostomy should be reopened and if the patient's ICP is able to tolerate supine positioning, a trial of this maneuver is often helpful to help the wound closure and avoid surgical revision of the wound.

Complex Spine Surgery: Positioning Considerations for Postoperative Airway Management and Cerebrospinal Fluid Leakage

Spinal surgery compromises the majority of elective neurosurgical practice. The increasing age and comorbidities of neurosurgical patients and the complexity of spinal instrumentation procedures have made admission to the intensive care unit a routine occurrence. Although the ICU stay is generally short, there are important considerations in regard to positioning for these patients. Morbidity and mortality after spinal fusion is not trivial and has been reported to approach 23 and 0.5%, respectively, and up to 10% of lumbar spine fusions will require care in an ICU [47]. Factors independently associated with increased morbidity after spine surgery include advanced age, male gender, and increased comorbidity burden. Patients who undergo long prone surgery (>4 h) may have extubation delayed due to facial and airway edema. Additionally, anterior-posterior surgeries, prone cases with large blood loss (>1 L), and cervical surgery near the airway should all be considered for delayed extubation due to increased risk of airway edema. At the conclusion of surgery and after flipping to the supine position with the head of bed elevated in the OR if edema is significant then the patient is maintained intubated. In the ICU, the patient should continue to be positioned with the head of bed elevated in reverse Trendelenburg. Most patients who remain intubated after spinal surgery will be extubated successfully within 24 h [48].

After any cervical surgery, careful monitoring for development of a hematoma is a basic part of the postoperative care. Proper positioning is crucial to help mitigate compromise of the airway if a hematoma develops. Supine positioning should be avoided particularly if a hematoma develops as immediate airway obstruction may occur from a rapidly expanding neck hematoma. If the patient is in distress, the difficult airway cart should be brought to the bedside and the surgical site opened immediately prior to lying the patient supine to attempt intubation.

Cerebrospinal fluid leakage occurs due to incidental durotomy in approximately 6.8% of spinal surgeries. Fortunately, the rate of spontaneous resolution of CSF leaks is high with rates reported ranging from 80 to 95% [49]. A persistent leak implies a pressure imbalance between the subarachnoid and epidural compartments. Surgical revision is always an option but has its own intrinsic failure rate of approximately 5–9% [50]. An epidural blood patch will increase the pressure over the closure and can lead to cessation of CSF leaking. The subarachnoid compartment can be addressed by giving medications to reduce CSF production (i.e., acetazolamide), CSF diversion by using drains, or by altering the patient's positioning. The basic principles of fluid dynamics inform positioning. The dural tear site should be elevated to further reduce subarachnoid pressure. Animal studies have demonstrated a 29% reduction in cervical subarachnoid pressure with change of positioning from 0 to 90° [51]. Therefore, after cervical and high thoracic procedures reverse Trendelenburg is preferred in contrast to lumbar or lower thoracic surgeries were Trendelenburg, supine, or prone positioning is standard if CSF leak is suspected. This positioning will reduce CSF volume at the site of surgery and thus minimize subarachnoid pressure across the site of dural injury and encourage wound closure [12].

Cranial and Skull Base Surgery Tumor Surgery: Positioning Considerations for Optimizing Intracranial Pressure and Management of Brain Edema

Postoperative elective brain tumor patients spend a short period in the ICU, generally less than 24 h, principally to ensure that emergence from anesthesia is safe and the airway is stable. However, patients with large tumors or those who present with significant mass effect may have prolonged ICU stays. Management of intracranial pressure and edema in this group of brain tumor patients requires careful attention. Brain tumor patients can manifest both vasogenic edema due to increased capillary permeability and also interstitial edema due to obstructive hydrocephalus and trans-ependymal flow of CSF [52, 53]. The guiding principle for the management of brain edema and intracranial pressure is maintaining neutral head up position at a minimum of 30°. Medical therapy with steroids and hyperosmolar therapy (i.e., mannitol and/or hypertonic saline) are often continued and slowly tapered after surgery reduces mass effect. Head up or reverse Trendelenburg positioning is also important in terms of controlling blood pressure within the desired range to avoid postoperative tumor bed hemorrhage. Due to the edema and the pathologic state of the tumor bed vasculature, regional autoregulation is often disturbed and may be pressure passive similar to the hemodynamic situation encountered in acute ischemic stroke patients. Head up positioning in conjunction with blood pressure control is important to maintain hemostasis of the electrosurgically coagulated blood vessels [54].

Large tumor resections, particularly posterior fossa surgery/skull base surgery, invariably generate some degree of pneumocephalus. The efflux of CSF during surgery produces a negative pressure that is filled by the entry of air. The overwhelming majority of intracranial air is asymptomatic and will resolve spontaneously. Rarely, in the presence of a continued CSF leak a ball valve mechanism is created that allows air to enter but is unable to escape resulting in a tension pneumocephalus. These patients will become symptomatic 2–4 days after the operation due to mass effect. These patients should be positioned supine or head up to minimize CSF leaking and the ball valve effect. Additionally, administration of 100% oxygen will promote movement of nitrogen rich intracranial air due to the gradient of partial pressure favoring nitrogen reabsorbtion into the blood stream. This may stabilize the situation until definitive surgical repair is undertaken [55].

An additional concern in regard to medical treatment of pneumocephalus is rapid removal of air which can theoretically promote venous bleeding.

Conclusions

Positioning of patients in the neurocritical care unit is essential to ensuring the best postoperative outcomes. Proper positioning requires neurocritical care providers to have a fundamental understanding of the surgical procedure, pathophysiology of the treated conditions, and potential complications. We hope the discussion in this chapter has illustrated the important physiologic manipulations that can be attained by proper positioning and how these can mitigate and prevent complications.

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