7

Neuroanesthetic Considerations for Patients Undergoing Posterior Fossa and Craniovertebral Junction Surgery

Dominic J. Nardi, Shamik Chakraborty, and Amir R. Dehdashti

Surgical conditions treated at the craniovertebral junction include tumors, cerebral vascular malformations, aneurysms, congenital craniovertebral anomalies, often with accompanying instability, and major trauma [1]. Anesthesia for such surgeries is also appropriately recognized as complex and presents unique challenges for the anesthesiologist as well.

For craniovertebral instability, maintaining proper cervical alignment is key during intubation and positioning. Patients who have suffered traumatic injury or chronic stenosis of the cervical spine are particularly at risk for neurologic sequelae when extending the head and neck during intubation. Congenitally lax joints resulting in subluxation and cord compression can also be present in patients with known Chiari malformation, Klippel–Feil syndrome, and Morquio's syndrome, just to mention a few [2]. Preoperative inquiry should be made as to the severity of nerve root or spinal cord impingement. If the patient shows significant signs and symptoms of myelopathy or cord compression, an awake fiberoptic intubation should be considered. A well conducted awake intubation need not be traumatic to the patient, and it would allow for post-intubation clinical assessment of upper and lower extremity function prior to the induction of general anesthesia and patient positioning. In all such cases, a member of the surgical team should be present during intubation to help assure neutrality of neck alignment as well as for the post-intubation evaluation.

If an awake fiberoptic intubation is indicated, preoperative patient education as to the necessity for the procedure and as to what is to be expected are key elements to ensure the successful cooperation of the patient. Major obstacles to awake intubation are language barriers and extremes of anxiety. However, with proper

---

D. J. Nardi (✉) · S. Chakraborty · A. R. Dehdashti
Department of Anesthesiology, Zucker School of Medicine, Hofstra University/Northwell Health, Hempstead, NY, USA

Department of Neurosurgery, Zucker School of Medicine, Hofstra University/Northwell Health, Hempstead, NY, USA
e-mail: DNardi@northwell.edu

E. Tessitore et al. (eds.), *Surgery of the Cranio-Vertebral Junction*,
https://doi.org/10.1007/978-3-030-18700-2_7

preoperative preparation and adequate topicalization of the oropharyngeal airway, intubation can be accomplished with minimal sedation. For an excellent example of technique, I would recommend viewing the following YouTube video: Dr. Michael Bailin demonstrates an awake endotracheal intubation at the Massachusetts General Hospital [3]. Following adequate pharyngeal-tracheal topicalization, awake intubation can be accomplished with a variety of fiberoptic devices including a number of newer video laryngoscopes. Post-intubation, the awake patient should be able to voluntarily cooperate in a clinical assessment of extremity strength, thus providing real-time monitoring of their function. Additionally, for patients considered to be at risk during positioning, the awake intubated patient may be allowed to self-position, thereby allowing for an awake post-position assessment of extremity strength and function prior to the induction of general anesthesia.

An alternative approach to the management of the airway for patients with less severe craniovertebral instability, or patients considered poor candidates for an awake technique, has been the use of an asleep fiberoptic intubation technique. This can be accomplished following the induction of general anesthesia with a fiberoptic scope through an intubating laryngeal mask device, such as an iGel, or with the use of a video laryngoscope. If an asleep technique is used, a member of the surgical team should be present to help confirm neutrality of neck position during the intubation. Successful intubation should be immediately followed by neurophysiologic monitoring, such as SSEPs and MEPs, to confirm integrity of cord function prior to patient positioning. The anesthesiologist must carefully consider his choice of induction of anesthesia so as to allow for post-intubation neurophysiological monitoring. So as to allow for post-intubation MEPs, a muscle relaxant free induction with the use of a combination of propofol, ketamine, and remifentanil is frequently used, immediately followed by a TIVA anesthetic for the remainder of the surgical procedure. Once the procedure is underway, it is not uncommon for our surgeons to request muscle relaxants while working on the surgical exposure so as to minimize muscular contraction during the use of electrocautery.

Obtaining post-intubation neurophysiological monitoring baseline data can prove invaluable prior to surgical positioning of the patient. Clinical experience has shown that the most common cause for neurophysiological degradation of potentials occurs during positioning of the patient, particularly the prone position. Vigilance and frequent communication between the anesthesiologist, surgeon, and neurophysiological monitoring personnel is particularly critical during this time. If significant changes are detected, the anesthesiologist should immediately assess his anesthetic choice and blood pressure so as to maximize perfusion of the cord. Should the neurophysiologic changes persist, the indication for a "wake-up" test should be considered, either while still in the surgical position or upon returning the patient to the supine position. In extreme situations where the degeneration of potentials persist, the surgical procedure may have to be aborted.

Positioning of the patient for posterior fossa and craniovertebral junction surgery has evolved significantly over the last several decades. Prior to the 1990s, the sitting position was the position of choice for the majority of posterior fossa and posterior cervical procedures. Venous air emboli (VAE) was a known and respected possibility as a result of the positioning, but the anesthesiologist and surgical team felt that the benefits far outweighed the risks. Surgical exposure was considered far superior to the alternative positioning options, and bleeding was significantly less secondary to the lower venous pressure. However, with the realization in the 1980s that over 25–30% of the general population are known to have “probe-patent” foramen ovale, the fear of paradoxical air emboli resulting in possible strokes, MI, or even death resulted in the sitting position being all but abandoned [3, 4]. This is important not only from an historical perspective, but also from the observation that positioning for such patients appears to have come full circle, with the return of the sitting position regaining popularity once again [4, 5].

Presently, the most commonly used position for the majority of posterior fossa and craniovertebral junction operations is a variation of the prone position, ranging from straight prone to three-quarter prone or full lateral. Unlike the sitting position, this positioning is associated with anegligible incidence of venous air embolism. However, it does have a number of downsides for the surgeon. The main one is a result of the increase in intrathoracic pressure associated with the prone or lateral position. The increased intrathoracic pressure is transmitted to the intracranial and cervical venous system resulting in venous bleeding during the operation. Another consideration to be contended with by the anesthesiologist is the inherent limitations in the case of an airway or cardiac emergency. Emergency airway management and performing CPR and chest compressions are next to impossible without flipping the patient onto another bed or stretcher. For these reasons, when in the prone or lateral position, the tolerance for placing external pacing electrodes on patients susceptible to cardiac events should be low, and a stretcher should always be made readily available with a sign indicating “PRONE POSITION—DO NOT REMOVE”.

Patients positioned prone for extended periods of time are also susceptible to a number of position- related complications. Unless the patients head is secured in pins, a brasions or skin tears of the face, particularly the pressure areas of the cheek bones, are not uncommon. This is particularly true if the patient’s face is placed in a dry foam or padded headrest. Applying a lubricant to the patient’s cheeks or foam headrest at the pressure points prior to positioning can minimize such risk. If a foam headrest is used, one in which the face and eyes can be easily visualized throughout the procedure by way of a mirror or video monitoring system is preferred. Avoiding compression of the eyes and maintaining patency of the airway and endotracheal tube throughout the case must be assured. The presence of conjunctival or airway edema postoperatively may warrant the patient remaining intubated for the swelling to subside. On rare occasions, patients have been reported to develop blindness secondary to retinal artery thrombosis and/or retinal venous hypertension while in the prone position [1]. However, most patients who undergo posterior fossa or craniovertebral junction surgery are placed in head-pins for additional stability, thereby minimizing the pressure on the eyes and face. In either case, the judicial management of fluid administration and constant vigilance as to the face and eye positioning should mitigate such risks.

As mentioned previously, the sitting position has been long known to provide excellent exposure and access to the posterior fossa and craniovertebral junction [6]. The superior drainage of cerebral spinal fluid as well as blood from the intracranial veins and sinuses allows for better access to anatomical structures by the surgeon, resulting in less manipulation of surrounding tissues and nerves. By avoiding the more commonly used prone position, the anesthesiologist has better visualization and access of the face and airway should an emergency arise. However, despite these obvious advantages, the potential risk of VAE in the sitting position continues to limit its adoption in most neurosurgical centers [6–8].

In one retrospective study of 4806 patients, the overall rate of venous air embolism during neurosurgery in sitting position, as detected by transesophageal echocardiogram (TEE), was 39% for posterior fossa surgery and 12% for cervical surgery [9]. These numbers, however, can be misleading in that TEE monitoring is known to be exquisitely sensitive at detecting venous air embolization that is of no physiologic consequence. In one such study using TEE for detection of venous air embolization in patients undergoing laparoscopic hysterectomy, the incidence of detected air was reported to be 100% [10]. Despite the high incidence of detected air, none of the cases of VAE resulted in hemodynamic changes or were found to be of clinical significance [10]. More recent reviews consider the risks of the sitting position to be relatively low: between 1 and 2% at high volume centers with experienced personnel [11, 12]. The highest risk of VAE complications are associated with suboccipital craniotomy and craniectomy, with a complication rate of 2.8%, and the lowest are cervical spine cases with complications of approximately 0.7% [11, 12]. It is important to note that air embolism has been reported in a variety of less likely neurosurgical procedures, including burr holes for deep brain stimulation as well as awake craniotomies in the supine position [13–15]. A common denominator in many of these cases was that the patient was breathing spontaneously, thereby facilitating the potential for entrainment of air. The possibility of VAE should always be on the anesthesiologists differential when hemodynamic instability of unknown origin occurs.

If the sitting position is to be used, it is highly recommended that the patients have a preoperative workup for the presence of a patent foreman ovale (PFO). However, recent evidence suggests that the decision to avoid the sitting position based solely on the presence of a diagnosed PFO should be reconsidered [9, 16]. The relationship between a PFO and the risk of a paradoxical air embolism is not existent [16]. In all patients at risk of VAE, the sensitivity of the device used for early detection of air, the experience of the anesthesia team in caring for such patients, and the rapid response by the anesthesiologist and surgical team in response to air detection is paramount in avoiding serious complications.

Over the years, there have been many methods advocated for the detection of VAE intraoperatively, ranging from the gasp reflex in the spontaneously breathing patient, to the detection of a mill-wheel murmur using an esophageal or precordial stethoscope, precordial dopplers and most recently by the use of intraoperative TEE [1, 17]. Although the relative sensitivity of the techniques used for the detection of air should be considered, it should not be the only factor in the choice of monitoring technique used. For example, the use of TEE, though exquisitely sensitive in the detection of VAE, has been shown to be more of a hindrance due to the resultant frequent and unnecessary interruption of the surgery whenever air is detected. Furthermore, the availability of a TEE device and the skill required for proper insertion and positioning of the probe can also be limiting factors.

The early detection and termination of VAE when it occurs is critical. The surgical team should communicate when they believe the patient to be at risk of VAE based not only on positioning but on the proximity of critical structures, such as major intracranial sinuses or venous plexuses. The anesthesia team must maintain constant vigilance during such cases for the possibility of VAE by the application and use of appropriate monitors and constant communication with the surgeons during the progression of the case.

A precordial Doppler is likely to be the most commonly used method of monitoring for air embolism, used in conjunction with end tidal CO_2 ($ETCO_2$) [1, 18]. A properly positioned precordial Doppler is more sensitive to the detection of VAE then a drop in the $ETCO_2$ by a factor of 10. When used together, the precordial Doppler should be considered a qualitative device, indicating the early detection of VAE, and the $ETCO_2$ a more quantitative device, indicating the beginning of physiological changes due to the presence of air in the right ventricle and pulmonary circulation. Unless a large amount of air is entrained into the venous system quickly, the precordial Doppler will detect the presence of VAE long before a drop in $ETCO_2$ is noted. This early detection should allow the anesthesiologist ample time to alert the surgeon of the VAE, terminate the use of N_2O, and provide 100% oxygen to the patient. The surgical team should consider applying bone wax or flooding the surgical field with fluid, depending on the point of surgery, so as to stop further VAE. A systematic search for the source of air embolization should be immediately conducted. The anesthesiologist can assist the surgeon by applying gentle compression to the jugular veins if needed. This maneuver will not only raise the venous pressure in the cerebral venous vasculature, frequently allowing the surgeon to identify the source of the air but will also result in an attenuation of the entrainment of air [1]. The application of a Valsalva maneuver to increase cerebral venous pressure should be avoided as it may result in a rise in the right atrial pressure and theroetically promote a right to left intra-atrial shunt, possibly resulting in a paradoxical arterial embolization [5]. If the source of the VAE is not detected and air continues to accumulate in the lungs, the $ETCO_2$ will begin to drop. This is the result of the air accumulating in the pulmonary circulation and an increase in physiologic pulmonary dead space. At this point, every effort should be made to identify and stop further VAE, lest the patient become hemodynamically unstable or worse [3, 11]. As a last resort, if the source of air remains undetected, the patient's head should be lowered below the level of the heart to stop further entrainment of air and allow the surgeon to identify the source. There has been much debate as to the usefulness of central-line aspiration during VAE, with some evidence that aggressive aspiration may actually result in a lowering of central venous pressure, and resultant worsening of VAE. Should central-line aspiration be considered, it is essential that the placement of the tip of the line be verified as being at the atrial-SVC junction prior to the beginning of the surgical procedure [1, 5]. At our institution, a central line is reserved for those patients with medical issues warranting central pressure monitoring intraop and for patients with known patent foramen ovale, though we consider the last to be a soft indication.

Anesthesiologists caring for patients undergoing posterior fossa and craniovertebral junction surgery must be aware of the potential for the sudden onset of cardiac arrhythmias, acute hemodynamic changes, or respiratory pattern alterations in the spontaneously breathing patient. Such hemodynamic and respiratory changes may be centrally mediated by the surgical manipulation of the brainstem or the traction of intracranial nerves. It is imperative that the anesthesiologist communicate these changes immediately to the surgeon before the initiation of intervention. As intracranial anatomy can be obscured by lesions, the surgeon often views the report of such physiologic changes as important information as to the proximity and location of important anatomical structures. The use of pharmacologic interventions by the anesthesiologist, such as atropine to block bradycardia, should ideally be conveyed and discussed with the surgeon prior to administration less he lose this valuable feedback.

Also, the anesthesiologist should be alert to the possible intraoperative manipulation and/or damage to the ninth and tenth cranial nerves responsible for the patient's gag and swallow reflexes, either unilaterally or bilaterally. If it is suspected that the nerve may have been either compromised or injured during the surgery, then prior to extubation an assessment of the patient's gag reflex of the posterior pharynx should be tested bilaterally with the use of a suction catheter. If there is any doubt as to the integrity of the gag and swallow reflex postop, consideration should be given to the patient remaining intubated. This problem has been minimized recently, however, by the monitoring of the cranial nerves intraoperatively when indicated.

Neurophysiologic monitoring has become an integral part of many neurosurgical procedures, and nowhere is this more true than during procedures of the posterior fossa. The most commonly used neuromonitoring modalities for patients having surgery of the posterior fossa and craniovertebral region include somatosensory evoked potentials (SSEP), motor evoked potentials (MEP), brainstem auditory evoked response or potentials (BAER/BAEP), and EMG monitoring of various cranial and cervical nerves. A thorough discussion must be had between the anesthesiologist, surgeon, and neuromonitoring personnel as to what is being monitored and at what phase of the surgery it is being monitored. Only by being fully appraised as to the proposed monitoring can a plan for a safe and complementary anesthetic be devised. It is important that the anesthesiologist be fully knowledgeable and conversant as to the type of anesthesia to be provided so as to allow for the monitoring to be maximally predictive of neurologic compromise. BAERs are the least sensitive to anesthetic interference allowing for the use of any anesthetic technique and muscle relaxants. Ideal anesthesia for SSEP monitoring requires the use of no more than one half MAC of inhalation agent with propofol supplementation, no N_2O, and the use of muscle relaxants as needed. MEPs are the most susceptible to inhalation effects. As such, a pure TIVA anesthetic is frequently administered, without the use of muscle relaxants. EMGs of cranial nerves require the absence of muscle relaxants during the monitoring phase. During the course of the surgical procedure, it may be necessary for the anesthesiologist to adjust his technique to accommodate the monitoring modality in use during that particular phase of surgery [19]. The author appreciates, however, that the accepted anesthetic technique used during neurophysiologic monitoring may vary considerably from one institution to another, so it is important for the anesthesiologist to have a thorough discussion with the monitoring team and surgeon prior to the commencement of anestheisa.

With the advent of intraoperative neurophysiological monitoring, the monitoring of spontaneous breathing under anesthesia as an indicator of brainstem function has become increasingly rare. That having been said, there are certain lesions for which the monitoring of spontaneous ventilation as a complement to BAERs may be requested by the surgeon as the preferred intraoperative monitoring technique [20, 21]. Monitoring of spontaneous ventilation has been shown to provide additional information while operating on lesions located at the base of the fourth ventricle, adjacent to the respiratory center, as well as during vertebrobasilar circulation surgery requiring temporary or permanent blood vessel occlusion [20, 22].

The anesthesiologist must be open to all positioning and monitoring modalities that will allow the surgeon to perform the most definitive procedure and ultimately provide the best possible outcome for the patient. More than perhaps in any other type of surgery, communication between the anesthesiologist, surgeon, and neurophysiologic monitoring personnel is imperative. Only with intimate knowledge of the risks and benefits associated with each requested technique, as well as a thorough understanding of the physiologic and anesthetic challenges posed, can the neuroanesthesiologist best devise a plan for the optimal anesthetic care of the patient.

References

1. Smith DS. Anesthetic management for posterior fossa surgery. In: Cottrell JE, Young WL, editors. Cottrell and Young's neuroanesthesia. Amsterdam: Elsevier; 2010. p. 203–17.
2. Geetha L, Radhakrishnan M, Raghavendra BS, Rao GSU, Indira Devi B. Anesthetic management for foramen magnum decompression in a patient with Morquio syndrome: a case report. J Anesth. 2010;24:594–7.
3. YouTube. "Dr. Michael Bailiin demonstrates an awake endotracheal intubation at the Massachusetts General Hospital: December 21, 2009." Online video clip.
4. Engelhardt M, Folkers W, Brenke C, Scholz M, Harders A, Fidorra H, Schmieder K. Neurosurgical operations with the patient in sitting position: analysis of risk factors using transcranial Doppler sonography. Br J Anaesth. 2006;96:467–72.
5. Feigi GC, Decker K, Wurms M, Krischen B, Ritz R, Unerti K, Tatagiba M. Neurosurgical procedures in the semisitting position: evaluation of the risk of paradoxical venous air embolism in patients with a patent foramen ovale. World Neurosurg. 2014;81(1):159–64.
6. Dilmen OK, Akcil EF, Tureci E, Tunali Y, Bahar M, Tanriverdi T, Aydin S, Yentur E. Neurosurgery in the sitting position: retrospective analysis of 692 adult and pediatric cases. Turk Neurosurg. 2011;21:634–40.
7. Albin MS, Carroll RG, Maroon JC. Clinical considerations concerning detection of venous air embolism. Neurosurgery. 1978;3:380–4.
8. Gottdiener JS, Papademetriou V, Notargiacomo A, Park WY, Cutler DJ. Incidence and cardiac effects of systematic venous air embolism. Echocardiographic evidence of arterial embolization via noncardiac shunt. Arch Intern Med. 1988;148:795–800.
9. Fathi AR, Eshtehardi P, Meier B. Patent foramen ovale and neurosurgery in the sitting position: a systematic review. Br J Anaesth. 2009;102:588–96.
10. Chang SK, Ji YK, Ja-Young K, Seung HC, Sungwan N, et al. Venous air embolism during total laparoscopic hysterectomy: comparison to total abdominal hysterectomy. Anesthesiology. 2009;111:50–4.
11. Himes BT, Mallory GW, Abcejo AS, et al. Contemporary analysis of the intraoperative and perioperative complications of neurosurgical; procedures performed in the sitting position. J Neurosurg. 2016:1–7.
12. Saladino A, Lamperti M, Mangraviti A, Legnani FG, Prada FU, Casali C, Caputi L, Borrelli P, DiMeco F. The semisitting position: analysis of the risks and surgical outcomes in a contemporary series of 425 adult patients undergoing cranial surgery. J Neurosurg. 2016:1–10.

13. Edelman JD, Wingard DW. Air embolism arising from burr holes. Anesthesiology. 1980;53(2):167–8.
14. Hooper AK, Okun MS, Foote KD, Haq IU, Fernandez HH, Hegland D, Robicsek SA. Venous air embolism in deep brain stimulation. Sterotact Funct Neurosurg. 2009;87(1):25–30.
15. Blake M, Manninen PH, McGuire GP, El-Beheiry H, Bernstein M. Venous air embolism during awake craniotomy in a supine patient. Can J Anesth. 2003;50(8):835–8.
16. Marshall WK, Bedford RF. Use of a pulmonary-artery catheter for detection and treatment of venous air embolism: a prospective study in man. J Neurosurg. 1980;55:610–4.
17. Standefer M, Bay JW, Trusso R. The sitting position in neurosurgery: a retrospective analysis of 488 cases. Neurosurgery. 1984;14:649–58.
18. Gildenberg PL, O'Brien RP, Britt WJ, Frost EA. The efficacy of Doppler monitoring for the detection of venous air embolism. J Neurosurg. 1981;54:75–8.
19. Watabnabe E, Schramm J, Strauss C, Fahlbusch R. Neurophysiologic monitoring in posterior fossa surgery. II. BAEP-waves I and V and preservation of hearing. Acta Neurochir. 1989;98:118–28.
20. Schramm J, Watanabe E, Strauss C, Fahlbusch R. Neurophysiologic monitoring in posterior fossa surgery. I. Technical principles, applicability and limitations. Acta Neurochir. 1989;98:9–18.
21. Radtke RA, Erwin CW, Wilkins RH. Intraoperative brainstem auditory evoked potentials: significant decrease in postoperative morbidity. Neurology. 1989;39:187–91.
22. Radtke RA, Erwin CW. Intraoperative monitoring of auditory and brain-stem function. Neurol Clin. 1988;6:899–915.