15 Special Considerations for Intracranial Tumors

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Introduction

In this chapter, we will focus on special considerations when positioning the patient for intracranial tumor surgery for the most common approaches and most frequently encountered tumor pathology. Although tumor location plays an important role in positioning, tumor histopathology (i.e., vascularization), potential for brain swelling, blood supply, venous drainage, and the use of neuro-navigation should also be considered when planning the approach and positioning.

Intracranial tumors can be categorized in numerous ways. Tumors may be within the brain parenchyma (i.e., intra-axial) or may originate in structures outside the parenchyma (i.e., extra-axial). Intra-axial tumors may be primary (i.e., originating from the brain) or metastatic (arising from other organ systems and spreading to the brain). Extra-axial tumors include those arising from the meninges or skull which may compress or invade the brain.

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Regardless of the complexity of positioning, basic patient safety considerations must be considered prior to surgery. Beginning surgery with a patient in the ideal position is a key part to preparing for a successful neurosurgical operation.

This chapter provides special considerations when positioning patients for intracranial tumor surgery, particularly focusing on neoplastic lesions and highlights "tricks of the trade," pitfalls, and common mistakes. Positioning in neurosurgery is often an afterthought in textbooks and on daily teaching rounds; however, we cannot emphasize enough the importance of patient positioning to our field. Bearing in mind those special considerations and integrating key information such as patient comorbidities, patient positioning such as based on tumor location and presumed pathology lays the foundation for a safe and successful surgery.

Perioperative Considerations

In neurosurgery, there are five basic patient positions used to perform most procedures: supine, lateral, prone, three-quarter prone, and sitting position. For every position, there are slight variations; and inherent to every position, there are certain advantages and caveats that must be considered, such as changes in circulatory and respiratory physiology that may affect gas exchange and both body and cerebral hemodynamics [1]. The latter basic five patient positions

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are discussed as part of specific craniotomy approaches in this chapter.

Proper positioning serves two major purposes. First, providing patient safety during long surgeries with padding of all pressure points prevents skin decubiti ulcers and nerve damage (i.e., ulnar nerve palsy). Second, positioning, in particular the head position, is crucial for the neurosurgical exposure and trajectory to the site of interest within the brain or skull [2]. There are two main modalities for head positioning in neurosurgery: fixed (i.e., in a Mayfield head holder) or unfixed ("doughnut" or "horseshoe" head holder). For elective brain tumor surgery, the Mayfield head holder is the preferred way as a fixed head increases safety and is often necessary to use frameless stereotactic navigation systems. The duration of a brain tumor craniotomy surgery is commonly beyond 2–3 h, thus fixation to decrease head motion and to prevent scalp pressure ulcers is beneficial. Pin placement in the skull is a critical consideration as portions of the skull (the frontal and mastoid sinuses and squamosal temporal bone) are quite thin and may fracture when pressure is applied. Pins should be positioned well away from the eyes and ears. In patients with shunts, care must be taken to avoid pinning the valve and distal tubing as this may result in a shunt malfunction that can affect the outcome of the procedure. In children, smaller pins (and less pressure) should be used. An ideal position also takes into account the trajectory to access the lesion of interest: preferably it should minimize the amount of traversed healthy brain and eloquent cortex, as well as leveraging gravity to minimize brain retraction (i.e., malar eminence at highest point so frontal and temporal lobes are slightly pulled away by gravity to better access a deep lesion through the Sylvian fissure) and increase venous return to minimize bleeding and decrease intracranial pressure. Body and head positioning during a neurosurgical case can have lasting impact on postoperative care. Proper positioning is a key component of postoperative complication avoidance due to decreasing the incidence of pressure ulcers, peripheral nerve palsies, and rhabdomyolysis which in return decreases length of stay and postoperative rehabilitation times [3–6].

Intracranial Tumor Pathology

Intra-Axial Tumors

Intra-axial tumors are part of the brain and arise from precursor cells located within the brain parenchyma or from cells metastasizing to the brain parenchyma. The most common intra-axial primary brain tumor is a glioma (i.e., astrocytoma, oligodendroglioma, ependymoma) presumed to arise from the non-neuronal lineage and making up around 80% of all primary brain tumors in adults [7, 8] (Fig. 15.1). Standard of care for symptomatic gliomas is most often surgical resection and if higher grade is found on histopathology subsequent radiation and chemotherapy is recommended [9, 10]. The resection of solitary brain metastases, particularly large ones, is associated with increased survival and when coupled with postoperative radiation, has improved local control [11, 12] (Fig. 15.2). Metastasectomy is

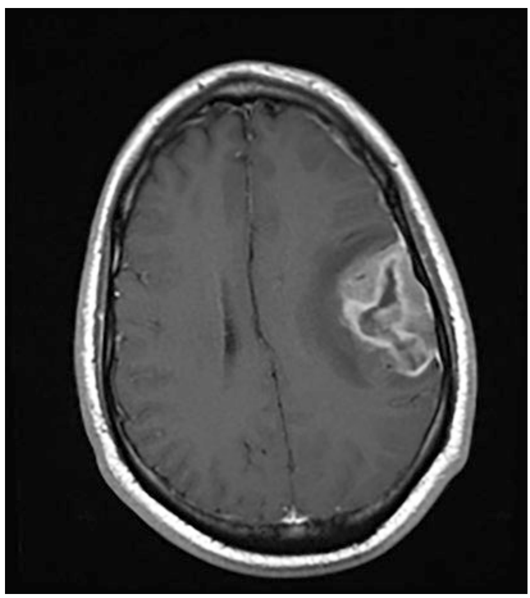

Fig. 15.1 MRI scan of a primary brain tumor, a left posterior frontal glioblastoma

Fig. 15.2 MRI scan of a metastatic brain tumor, a left temporal sarcoma

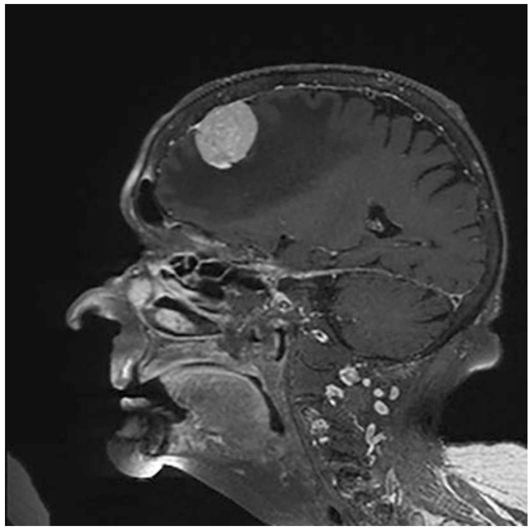

Fig. 15.3 MRI of an extra-axial meningioma. This secretory meningioma has significant perilesional edema

one of the most commonly performed procedures in neurosurgical oncology.

Even superficial lesions on the cerebral cortex require considerable thought with respect to positioning and the placement of an incision. Positioning is key when planning for a corridor to a deeper seated intra-axial mass while protecting eloquent brain. The trajectory is particularly important when considering adequate illumination from either a head light or microscope into the depth of the resection cavity. Adequate head position of the patient is of essence for gravity to open a natural corridor to the site of interest to minimize brain retraction. An elevated head position generally reduces parenchymal edema caused by brain irritation from retraction and surgical manipulation, often more so with intra-axial higher grade lesions since they are intimately associated with the brain and may be causing significant amounts of perilesional edema and inflammation and growth often occurs in a highly invasive fashion. Intra-axial metastases often cause significant amounts of edema due to displacement and compression of the brain parenchyma and possibly draining veins. Thus, for positioning for intra-axial highly invasive or inflammatory lesions, head elevation above the heart to support venous return and reduction of brain edema by reversing fluid extravasation, as well as leveraging gravity to minimize brain retraction is key. However, with too much rotation, venous drainage can be compromised by occlusion of the jugular veins. Care must be taken to ensure that venous obstruction is minimized in these situations.

Extra-Axial Tumors

Extra-axial intracranial tumors are located within the skull or at the skull base and reside outside the brain parenchyma, if deeper seated and arising from the skull base these can be some of the most challenging lesions to be surgically treated. In this paragraph, we will discuss the most common pathologies for extra-axial non-skull base tumors. These are most commonly masses arising from the meninges and dural based metastases and less frequently masses stemming from the bony skull. These types of tumors often displace the brain and rarely significantly invade the brain. Thus, they can cause significant edema and mass effect (Fig. 15.3). It is particularly challenging when those masses are adherent to the dural sinuses and/or compress major draining veins (i.e., veins going to the superior sagittal sinus, or the anastomotic veins of Labbé or Trolard). Interrupting a draining vein during surgery can cause rapid parenchymal swelling and cause venous hemorrhagic strokes resulting in major neurologic deficits and even death. Preoperative identification of veins is crucial as to identifying the best possible head position to obtain a corridor as to avoid those critical structures. Dural based masses often receive blood supply from dural vessels, thus identifying major feeding arteries early and to bipolar and cut them reduces intraoperative bleeding and operative time; however, feeding arteries must be identified on preoperative imaging and when positioning, this must be kept in mind as to have early feeding artery access.

Skull Base Tumors

Skull base tumors are often particularly challenging to operate on since they are adherent to vital structures (i.e., cranial nerves and vessels) passing through the skull base. Nerves and vessels intimately associated with bony canals are often fixed and adherent to the bone and fibrous tissue and thus minimal retraction can cause major injury. Typical skull base pathology encountered frequently in neurosurgery includes meningiomas (i.e., planum sphenoidale, tuberculum sellae, or petro-clival location) in all three cranial fossae as well as schwannomas (i.e., vestibular schwannoma or lower cranial nerve schwannomas), and frequently we encounter either primary or metastatic carcinomas of the skull base and nasopharyngeal cavities eroding the skull base and possibly invading the dura and brain. The skull base can be accessed in a 360-degree fashion (i.e., trans-sphenoidal from the front and below, far lateral for lesions of the foramen magnum or lower cranial nerves) with approaches tailored to every specific lesion and its relationship to the safest surgical trajectory. Special considerations for positioning for each of the major skull base approaches will be discussed in this chapter. Similar to intra- or extra-axial non-skull base lesions, the previously described general rules for positioning apply. In addition, for skull base tumor surgery, while positioning, extra thought must be given to adequate padding of the body due to the longer duration of skull base cases given their complexity. For example, the lateral position requires adequate axillary support with an axillary shoulder roll to avoid shoulder dislocation and postoperative arm pain and particular attention must be paid to padding of common nerve pressure points, such as median, ulnar, and peroneal nerves. During prolonged surgeries, the patient is also at greater risk for extremity deep venous thromboses and pulmonary embolisms. Thus, it is recommended to elevate the extremities whenever possible to support venous return and avoid pooling of blood in the large venous systems (i.e., lower extremities).

Comorbidities

As mentioned, metastatic brain tumors are the most common intracranial tumor diagnosed. These patients often present with comorbid conditions that warrant consideration during positioning. For example, patients with advanced metastatic disease will present not only with brain metastases, but also extensive lung metastases (or in the case of lung cancer, a primary tumor that is progressing) (Fig. 15.4). Compromised

Fig. 15.4 Chest X-ray of patient with metastatic cancer demonstrating significant pulmonary involvement

lung function may require additional ventilatory support but may also affect patient positioning. For example, a patient with tenuous respiratory status may not tolerate prone positioning given the increase in peak pressures. This may require lateral positioning with head rotation to access an occipital or cerebellar lesion, for example.

Patients with primary or metastatic tumors may also be corticosteroid dependent. These lesions present with significant perilesional edema requiring the use of steroids for symptomatic relief. Steroids are associated with significant side effects however, and can include immunosuppression which can compromise wound healing. As such, care must be taken to ensure adequate wound closure given the risk for wound healing complications. In general, we advocate the use of antibiotic-impregnated irrigation during the closure and the maintenance of sutures in place for at least two weeks before removal.

Patients may also require repeat surgery for the management of recurrent tumors. In this circumstances, systemic infections have been reported to occur at a higher rate in these patients as well after second craniotomy for recurrent tumors [13]. Planning for repeat craniotomy is not often considered for brain tumor surgery, but the value of re-resection for recurrent disease has been reported [14, 15]. Therefore, preoperative planning regarding the size of the incision and underlying craniotomy should be considered with the possibility of recurrent tumor and subsequent surgery.

Positioning for Common Approaches: Tricks of the Trade and Pitfalls

General considerations for every approach and position must include patient safety and room setup. Securing the patient to the operating room table is critical as patients may be rotated (tilted) in either direction and thus are at risk of falling off the table. Another important point is to fully position the patient before locking in the Mayfield as any partial operating table adjustment will cause pulling or pushing and may dislodge the Mayfield pins causing scalp or skull injury. During induction, paralytic agents can be used which may facilitate exaggerated head positions because of pharmacologically induced muscle laxity. However when these paralytics wear off, increased pressure on the head may result as muscle contractions resume, resulting in slippage and scalp lacerations. Once the patient is locked in position, it is best to use Trendelenburg (to lower the head) and reverse Trendelenburg (to raise the head) as this will avoid dislodging the pins. Placement of the neuro-navigation camera in the room and attachment of the three-point fixation head holder to the bed to leave ample room for attaching the navigation reference frame is critical. If the reference frame is blocked by the draping, nurse's Mayo stand, or the surgeon, it is rendered effectively useless. Operating room table selection is also a key consideration. Most tables allow for Trendelenburg and reverse Trendelenburg movement which is critical for various approaches but also to facilitate venous drainage (i.e., head elevation in the setting of significant cerebral edema). Similarly, most tables allow for tilting (left and right, also called "airplaning"). Care must be taken to ensure the patient is secured to the table as it is possible for a patient to fall off the operating table if too much tilt is used.

Supine Position

This is the most frequently used patient position in neurosurgery and carries minimal risks from anesthesiologic and neurosurgical perspectives as it is easily achievable and does not involve any awkward positioning of the anesthetized patient [1]. The face and endotracheal tube are accessible to the anesthesiologist. Placing the patient in the supine position assists the surgeon in maintaining orientation (Fig. 15.5). There is a slight risk with significant head rotation which decreases venous return and causes increased bleeding and intracranial pressure elevation. There is also a slightly increased risk of aspiration as compared to the lateral or prone position [16]. As a rule of thumb for supine positioning,

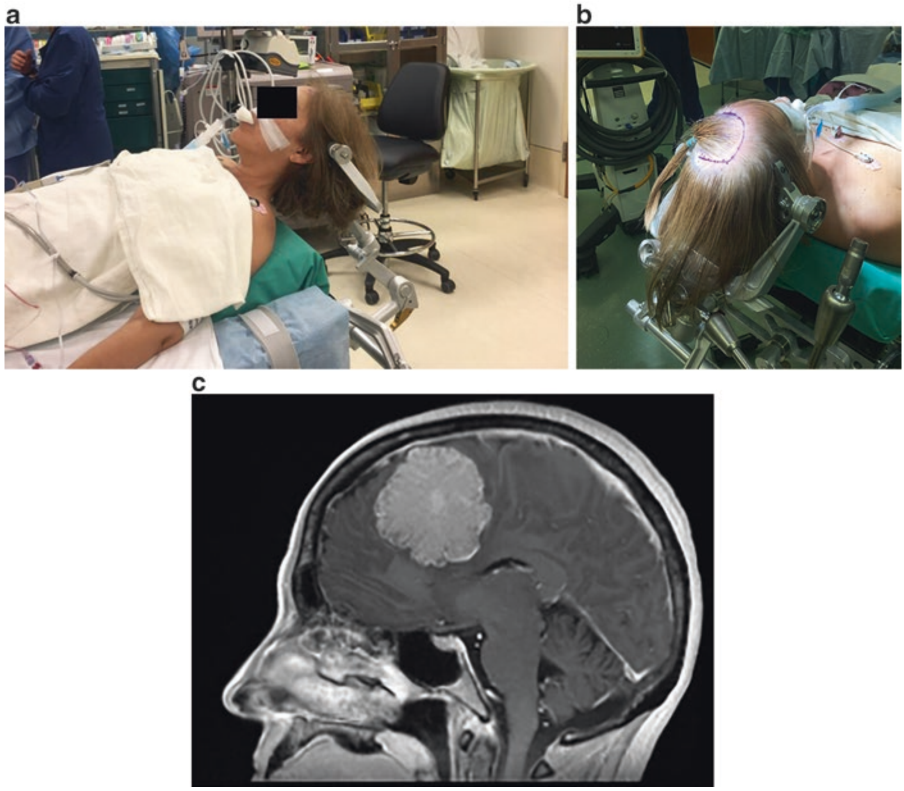

Fig. 15.5 Supine position (**a** and **b**) of patient undergoing a craniotomy for a lesion in the left frontal lobe depicted in the MRI (**c**)

the head of the patient is elevated, the hips in flexion and legs elevated as to prevent deep venous thromboses. Bony prominences (i.e., elbows, heels) and peripheral nerve pressure points (i.e., ulnar and peroneal nerves) must be adequately padded and "seat belt" or adhesive tape fixation prevents sliding of the patient when the operating table is tilted. There are circumstances for which the supine position may be preferred even if it does not give the best access to a particular intracranial lesion. In the setting of metastases, this may be preferred due to the fact that patients may present with concurrent lesions in the lung or mediastinum that may make ventilation more difficult (i.e., prone or lateral positions). Coordination with the anesthesiologist is critical to ensure proper patient care and mitigation of positions that may compromise adequate ventilator support.

Trans-Sphenoidal

Trans-sphenoidal approaches are more frequently being performed trans-nasal and less frequently sublabial. This is the primary approach for sellar pathology including functional or nonfunctional pituitary adenomas, Rathke's cleft cysts, craniopharyngiomas, and other anterior skull base pathologies including meningiomas. We use the Mayfield head holder with most commonly two pins on the left side and one pin on the right, about two finger breadths above the pinna, although others have described positioning the patient on a horseshoe head holder. Depending on the exact location and extent of the lesion that needs to be accessed, the head position varies; however, as a rule of thumb we position the head very minimally turned to the operator (5–10°), minimally extended and translated up in almost neutral or horizontal position. The neuro-navigation camera is most often positioned at the head of the patient, thus the Mayfield attached to the surgical table from the inside. We position the head of the patient slightly elevated above the heart to minimize bleeding and support venous return, this is particularly important when working around the cavernous sinus in a trans-sphenoidal approach.

For trans-sphenoidal approaches to the clivus and posterior fossa slight head flexion (15-degree flexion of the forehead-chin line) [17] is recommended to maximize the angle of exposure, it follows that exposure of the anterior skull base from a trans-sphenoidal route (i.e., tuberculum sella meningiomas) requires the patient's head to be positioned in slight extension (10–15° extension of the forehead-chin line) [18] to obtain a more anterior trajectory and thus preventing the endoscope and surgical instruments from hitting the thorax of the patient [19].

Frontal/Trans-Frontal Sinus Approach

Most frequently, a bi-coronal or extended bi-coronal incision is used to access lesions via a frontal or trans-frontal sinus approach with or without removal of the orbital rim. This approach offers excellent exposure for large midline lesions extending lateral bilaterally (i.e., large anterior skull base meningiomas), as well as for lesions of the medial orbits or lesions involving the frontal sinus (i.e., nasopharyngeal carcinomas), particularly if a lateral orbito-zygomatic osteotomy or classic pterional approach is expected to provide insufficient exposure towards the contralateral side. Prior to final positioning some surgeons may place a lumbar drain given difficulty for CSF drainage for brain relaxation using this approach. The patient is positioned supine with the head above the heart. The three-point fixation pins are commonly placed behind the ears as not to interfere with the incision. The head is translated up and slightly flexed on the chest and slightly extended on the neck [20], and this varies depending on the exact location of the surgical site of interest. Care must be taken not to drape towels right above the eyebrows to avoid downward pressure to the eyes when the forehead skin flap is elevated and retracted anteriorly.

Orbito-Zygomatic and Pterional Approaches

The orbito-zygomatic osteotomy (OZO) is an extended pterional approach and can be performed in one- or two-piece fashion [21]. OZO is most frequently used in skull base and vascular neurosurgery; however, it is the preferred approach as well for neoplastic lesions located in the petro-clival and spheno-orbital areas [22], as well as tumors located in the vicinity of the basilar apex (Fig. 15.6). The patient is positioned supine on the operating table, an ipsilateral small shoulder roll can be placed if higher degree rotation is needed, and the patient's neck is not supple enough; and the head generally rotated 30–60° to the side contralateral to the pathology. While rotation is increased for tumors located in the anterior and middle cranial fossae, rotation is reduced for lesions involving the clivus and posterior fossa. The head is slightly extended towards the floor, this together with the rotation will bring the malar eminence to the most supe-

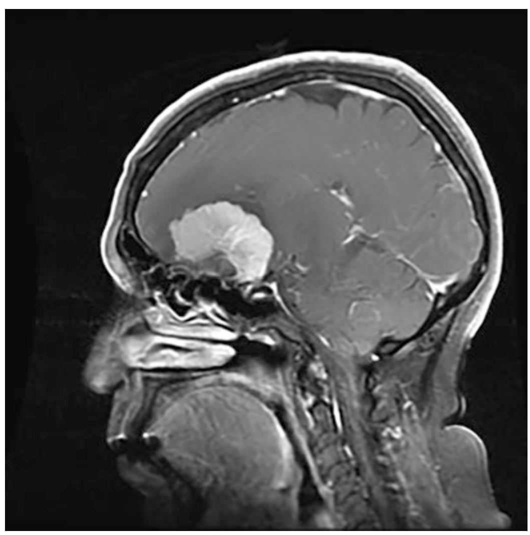

Fig. 15.6 MRI scan of a spheno-orbital meningioma that may be approached with an orbito-zygomatic approach

rior point in the operative field [22, 23]. This is identical to the classic pterional craniotomy and positioning, and having the malar eminence highest in the operative field is an indirect measure for the location of the Sylvian fissure and will take advantage of gravity to allow both the temporal and frontal lobes to naturally fall away, thus minimizing the need for retraction and thus retraction-associated injury.

In addition to the combined pterional/OZO approach, the pterional (frontotemporal) craniotomy alone is one of the most frequently used craniotomies in neurosurgery and is the work horse approach for internal carotid and middle cerebral artery aneurysms and a wide range of neoplastic lesions of the frontal and temporal lobes, Sylvian fissure or deeper lesions such as sphenoid ridge, tuberculum sellae, or third ventricular locations. The head is generally slightly extended and turned 30° away from the site of interest.

Temporal

For approaching a temporal lesion either a transtemporal or subtemporal route can be chosen; the patient is positioned supine with a shoulder roll behind the ipsilateral back to allow for 60–80-degree head rotation towards the contralateral side. Often a straight or slightly curved incision above the ear is chosen. For subtemporal approaches, a higher degree of head tilt is recommended and thus often lateral patient position is chosen. The approach to a temporal tumor, particularly one that requires access to the mesial temporal lobe is facilitated by placing the head with slight vertex towards the floor. This helps the surgeon reach the mesial temporal structures including the uncus. For subtemporal approaches, particularly those to the brain stem, placement of a lumbar drain is sometimes helpful to assist with superior retraction of the temporal lobe. Considerations for the lateral position will be discussed in the following paragraph.

Lateral Position

The lateral position is used for patient requiring subtemporal, skull base (including approaches to the apical portion of the petrous bone), peripetrous, and posterior fossa approaches. For supratentorial brain tumors, particularly those in the parasagittal location just lateral to midline, the lateral position can be very helpful. We find that having the tumor side dependent (i.e., towards the floor) can facilitate brain retraction as gravity will naturally let the ipsilateral hemisphere retract away from the falx (Fig. 15.7). General risks include brachial plexus injury, stretch injuries (axillary trauma), and pressure palsies (i.e., suprascapular nerve injury), and direct compromise of upper extremity perfusion caused by compression

Fig. 15.7 Tumor on the right side of the falx is approached with the tumor side down. The patient is positioned in the right lateral decubitus position

by an axillary roll. From the anesthesiology standpoint, ventilation-perfusion mismatch can occur [1]. Lateral, as compared to supine, positioning may lead to decreases in mean arterial pressure, venous return, stroke volume, and cardiac output; it may also decrease total lung capacity and the jugular venous resistance. In return, heart rate, systemic vascular resistance, and V/Q mismatch may increase [1]. Thus, particularly with significant neck flexion, intracranial pressure may increase dramatically. Attention is required for positioning the patient's lower arm due to potential injury to brachial plexus and axillary artery. We place an axillary roll under the upper chest as to alleviate the axilla from direct pressure and the dependent arm is positioned below the operating table on a low arm board or pillow padded on the three-point fixation extension which connects to the table. The upper arm is positioned on a pillow or high arm board and is taped to the body and operating table. Proper functioning of intravenous and arterial lines after positioning must be ensured and nonfunctional arterial lines of the dependent arm can indicate that the axillary roll was incorrectly placed. A pillow is placed between the legs and as a rule, also for the lateral position, a V-shaped body configuration must be aimed for as to elevate the head above the heart and support venous return from the lower extremities as to minimize risk for deep venous thromboses.

Retrosigmoid

The retrosigmoid approach is commonly used for lesions of the cerebellopontine angle (e.g., vestibular schwannomas, epidermoid cysts, meningiomas) [24]. Some surgeons advocate supine or sitting position; however, most frequently a lateral or three-quarter prone position is chosen as to minimize head rotation. Mayfield three-point fixation is used and generally three movements for head positioning are performed: first, contralateral rotation for positioning the temple parallel to the floor; second, contralateral bending so the vertex is slightly tilted towards the floor; and third, slight neck flexion as to open the cervical-suboccipital angle [25]. This also minimizes the soft tissue depth over the foramen magnum and will allow for more direct access for CSF drainage. As described above, attention must be paid to adequately pad the dependent axilla and correctly placing an axillary roll as well as taping down the superior shoulder towards the patient's legs without causing brachial plexus stretch injury. In addition to using a bean bag, we suggest placing at least two belts or using silk tape to secure the patient, which is performed in anticipation of tilting the operating table during the procedure to maximize visualization of the lesion.

Far Lateral

The far lateral approach is an extension of the retrosigmoid approach. The patient position is commonly lateral (park bench) or three-quarter prone and is best suited for lesions lateral and anterior to the brain stem, foramen magnum, and jugular foramen region [26]. The patient's head is tilted slightly towards the floor and also slightly translated superiorly to open up the space between the edge of the mastoid and the transverse process of the atlas [26]. Lesions requiring a far lateral approach are often near cranial nerves (i.e., lower cranial nerves for jugular foramen pathology) and thus, if neuromonitoring is used, attention must be paid to properly test and secure electrodes before starting the case. Electrodes often get dislodged if the patient is repositioned or signals can be lost if the patient is not properly positioned (i.e., compression of the axillary artery by direct pressure from an improperly placed support roll for axilla and shoulder). Thus, careful electrophysiology baseline assessments and testing of the hardware is key prior to starting the case.

Parieto-Occipital

Parieto-occipital areas in the brain can commonly be approached with the patient in either prone or three-quarter prone position. For the latter patient position, similar principles apply as for the lateral position. Either a bean bag or sufficient padding is required and extra attention must be paid to the dependent arm and adequate shoulder support using a properly placed axillary roll. If the lesion approached is close to midline even with a three-quarter prone position, the head must be significantly turned and this is best used for patients with a sufficiently supple neck. Careful attention must be paid to pinning the patient's head, whereas the single Mayfield head clamp pin goes to the ipsilateral lateral forehead avoiding the supratrochlear nerve and vessel bundle; the dual pin side of the clamp goes to the contralateral mastoid region as far off midline as possible. This will avoid blocking a skin incision past midline for lesions that are attached to midline structures (i.e., superior sagittal sinus) or crossing midline. Of note, particularly when pinning in the retro-auricular or mastoid region, ventriculo-peritoneal shunt catheters passing the region must be avoided.

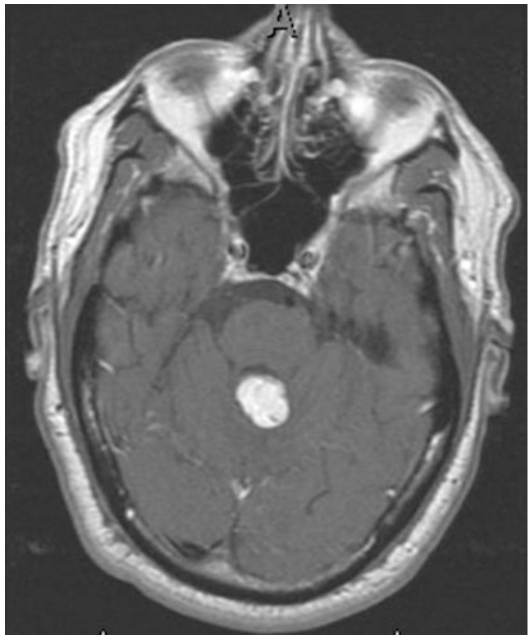

Fig. 15.8 MRI scan of a patient with a hemangioblastoma in the midline involving the cerebellar vermis

Prone and Sitting Position

Suboccipital

The suboccipital craniotomy is most often performed with the patient in prone position, less frequently a sitting position can be used. This is surgeon preference and guided by specific safety and monitoring concerns with sitting position (i.e., venous air embolism and need for precordial Doppler monitoring). In this paragraph, we will focus on the classic prone position and also discuss the sitting position.

Prone position is generally the choice for approaches to the posterior fossa, suboccipital region, and posterior approaches to craniocervical junction and spine in neurosurgical oncology (Fig. 15.8). These approaches include tumors in the vermis, medial aspect of the cerebellar hemispheres, and dorsal or dorsolateral lesions at the foramen magnum or craniocervical junction. Prone position provides excellent exposure for the abovementioned regions without having an increased risk for venous air embolisms as compared to the sitting position [1]. Prone position is one of the more challenging positions in neurosurgery from the standpoint of our anesthesia colleagues since it requires disconnecting the intubated patient from the circuit and rotating the patient prone onto the operating table. Positioning an intubated patient prone challenges hemodynamics as well as simple physical logistics such as keeping in place venous and arterial lines, Foley catheter, the endotracheal tube, and possible neuromonitoring electrodes amongst others. Other caveats are access to patient's airway, pressure sores, vascular compression, restrictive pulmonary compromise (i.e., overly tight taping of the patient to the operating table), brachial plexus injuries, and blindness [1, 27]. Turning the patient prone from the supine position increases intra-abdominal pressure, decreases venous return to the heart, and may increase systemic and pulmonary vascular resistance [28]. Although the cardiovascular responses to positioning prone mostly have been characterized in the setting of acute respiratory distress syndrome [29], yet, data suggest that left ventricular ejection fraction and cardiac index may decrease and thus causing hemodynamic instability [30]. Tissue oxygenation, however, may improve with prone positioning because of improved matching of ventilation and perfusion [1, 29, 31]. The patient is anesthetized in the supine position, and then turned prone with the head in neutral position onto soft chest rolls, a special frame, or operating table (e.g., Wilson frame, Jackson table). Cranial tumor procedures may benefit from the assistive positioning devices providing support to the patient's chest while reducing pressure to the abdomen, which in return improves ventilation, avoiding hypercapnia and decreasing bleeding by optimizing venous return [32]. For patients who are morbidly obese, operating room tables that can accommodate these patients may be used. For prone position patients, care must be taken to use wide gel rolls or padding in order to ensure that a large pannus is not compressed as this may increase intrathoracic pressure and make ventilation more difficult.

The sitting position was commonly used for posterior fossa surgery and for posterior cervical approaches; however, many neurosurgeons are shifting away from sitting position due to the additional risk of hemodynamic instability and venous air embolisms [33, 34], which in return requires additional monitoring such as precordial Doppler and possibly a right atrial central venous catheter to aspirate air emboli. The sitting position provides little benefit over the prone position, except significantly lower cranial venous pressure and thus decreased risk of bleeding [32]. The sitting position can help with retraction, particularly for infratentorial supracerebellar approaches. However, lower venous pressure and pooling of blood in the lower extremities carries significant additional risk for hypotension, venous air embolism, and lower extremity deep venous thromboses [35]. Sitting position also increases the risk for pneumocephalus and subdural hematoma [36], thus most surgeons may consider the sitting position to carry greater risks than benefits. The mechanisms of venous air embolism include negative venous pressure and exposure of veins and venous sinuses to air during surgery. A large venous air embolism may decrease cardiac output by creating a right ventricular outflow air trap [37] and provoke acute right heart strain and significant myocardial ischemia. The incidence of venous air embolism in the sitting position may be estimated at 20–50% when precordial Doppler monitoring is used for detection [33], and 76% when transesophageal echocardiography is used for detection [38]. A patent foramen ovale should be excluded before every case [39], as it is a source of paradoxical air embolism and stroke [40]. In addition to standard monitoring, such as pulse oximetry and end tidal carbon dioxide, precordial transthoracic Doppler is used for early detection of venous air embolisms [41]. If a Doppler is not available, attention must be paid to acute decreases in end tidal carbon dioxide concentrations in the presence of hypotension as a warning sign for venous air embolism. In case of a venous air embolism, the surgical wound must be extensively irrigated, the site of venous air entry must be lowered relative to the patient's heart (usually by placing the patient in Trendelenburg), the patient has to be placed in left lateral decubitus position (left side down) to potentially untrap the right atrial outflow tract, if possible air can be aspirated from the right atrium via a central venous catheter, and cardiovascular support with vasopressors must be initiated in case of hypotension [42].

Despite the associated risks, sitting position is the preferred position for many neurosurgeons to access the posterior fossa and posterior cervical spine, bearing the pathophysiology and diagnostic signs of venous air embolisms in mind, as well as being prepared to respond in case of such an emergency, will create a safe environment to carry out the operation.

Awake Craniotomies

Awake craniotomies deserve special discussion due to the unique requirements. We typically employ the lateral or supine with a bump behind the ipsilateral shoulder. Significant care is taken to ensure that the patient is comfortable prior to intubation. For patients in the supine position, we will place a gel roll underneath the ipsilateral shoulder so that the patient is lying at a 45-degree angle. The head is then rotated further to the contralateral side. In our experience, patients will complain during the procedure of pain in the dependent hip and the dependent shoulder. We place a pillow between the legs. Recently, we have employed the technique of placing a sequential compression device stocking underneath the gel padding directly under the dependenthip. The device inflates and deflates during the procedure and this has provided significant relief to our patients during surgery. After the patient verifies that he or she is not experiencing any discomfort in our preferred position, we then place the patient under anesthesia using a laryngeal mask airway (LMA). The LMA technique has proven valuable to us because it is not as uncomfortable as an endotracheal tube and it allows us to proceed with the portions of the procedure prior to exposure of the brain with efficiency as the patient is unlikely to feel discomfort or pain. Care is taken during draping to ensure that the anesthesiologist has access to the patient's face. The head may be slightly extended to allow for easy placement and removal of the LMA. A neutral position is also favorable; however, we try to avoid flexion as this position makes it difficult to place the LMA. We use three-point fixation for our awake craniotomy patients and the single pin is positioned such that the patient's vision is minimally obstructed. Once the brain is exposed, we then ask the anesthesiologist to proceed with removal of the LMA. This is generally a very smooth process. Once the LMA is removed, the patient is given time to wake up and cooperate with testing. We generally try to keep the patient awake for testing no more than 2 h as fatigue will set in and the patient will have difficulty cooperating. When having the patient awake is no longer necessary, the anesthesiologist will typically replace the LMA after sedating the patient. The LMA remains in place until the operation is completed.

Summary

Positioning for procedures in neurosurgical oncology has special considerations. Proper positioning has direct implications to safety and efficiency of the actual surgery, perioperative care, and has lasting implication on postoperative morbidity and long-term follow-up. Many patients will present with increased intracranial pressure from their tumors. Thus, positioning to minimize cerebral edema is a key consideration. Taking advantage of gravity (placing the patient and tumor in a dependent position) may be helpful. Positioning the head such that the tumor is most accessible (often at the highest point of the field) is also useful for tumor resections. The location of the tumor is key to proper positioning and should dictate the approach. Unlike other neurosurgical procedures that have potentially predictable locations of pathology (e.g., temporal lobectomy for mesial temporal sclerosis), slight variations in tumor location can significantly alter the positioning and approach.

Patient positioning in neurosurgery, frequently under-emphasized in the literature, is a key part of neurosurgery and an absolute necessity to safely conduct and perfect the neurosurgical operation. The most fundamental neurosurgical principles such as immobilizing the patient's head in a head holder, properly registering the neuronavigation, illumination of the surgical field, exposure of the brain tumor leveraging gravity to reduce brain retraction, hemostasis, CSF drainage, and brain relaxation as well as optimizing hemodynamics and creating an environment for safe anesthesia all depend on proper positioning of the patient and careful preoperative planning by the neurosurgeon.

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