7 Intracranial Procedures in the Supine, Semi-Sitting, and Sitting Positions

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Introduction

Surgical positioning is the first decisive step of any neurosurgical procedure. When done well, it can create a direct angle of approach, maximize the surgical view and obviate brain retraction. Indifference sets the stage for unnecessary struggle and danger from position-related complications and adverse effects on surgeon ergonomics. The supine setting offers the most natural position for the human body while also permitting a wide variety of cranial approaches. It is ideal for avoiding dependency of the globes, pressure on the abdomen, and unnatural strain on the neck and limbs. Normal cervical range of motion allows the head to be rotated, flexed, or extended to further optimize the operative angle for each approach. The supine position is commonly used in anterior and anterolateral approaches such as the pterional and its variations, orbital, bifrontal, subfrontal, and interhemispheric. It is standard for trauma craniotomies as well as transnasal and transoral approaches to the sella, anterior fossa floor, and clivus. Less commonly, it is adapted to other skull base approaches such as pretemporal, petrosal, and retrosigmoid. The supine position also allows for patient comfort and ease of intraoperative communication during awake craniotomies. The sitting position, a variant of supine, allows for excellent venous drainage of the brain, cerebrospinal fluid (CSF) drainage, and gravity-assisted retraction of the brain. Approaches enhanced by these advantages include the supracerebellar-infratentorial, suboccipital, occipital-interhemispheric, and the combined occipital supra-infratentorial. The brain relaxation achieved through decreased venous congestion and improved CSF outflow also facilitates opening the parietal and occipital sulci [1]. As described by Yasargil, lesions posterior to the interauricular line are well suited to attack via the sitting position [1]. These include lesions of the fourth ventricle, vermis, foramen magnum, pineal region, cerebellopontine angle, tentorium, and tectum of the midbrain [1, 2]. In this chapter, we will review the fundamental aspects of the supine and sitting positions, and their variations for common neurosurgical approaches.

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General Setup

Supine Position

In our institution, we typically place the patient supine on a Skytron Jackson table before the induction of anesthesia. The table is appropriately cushioned to avoid pressure sores of the dorsal-dependent areas of the body. The head is elevated above the level of the right atrium of the heart to maximize venous drainage and avoid unnecessary intracranial venous congestion or bleeding. This is usually accomplished through head positioning, flexing the upper half of the operating table to elevate the back, or tilting the whole table (reverse Trendelenburg). For simple supine cases, the head may be positioned on a loose foam headrest placed directly on the operating table. To increase working space, the head of the operating table can be detached and replaced by a secured horseshoe-shaped headrest. These simple headrests allow for intraoperative repositioning of the head to alter the surgical perspective, but care must be taken not to disrupt the sterile drapes or the endotracheal tube. Although such headrests are effective in many cases, they do not secure the head enough to permit significant table rotation. Rigid fixation and additional control of the head can be achieved with devices such as the Mayfield three-pin fixation head holder, which offers excellent stability and versatility for delicate cranial procedures and frameless stereotaxy. During application, the pins are secured with appropriate force away from the surgical field on opposite sides of the head, perpendicular to the skull to avoid slipping. Thin squamosal temporal bone and thin bone over aerated sinuses should also be avoided. If the scalp is difficult to close, one must consider the possibility that a pin has slipped. A radiolucent head holder should be used if intraoperative magnetic resonance imaging or angiography is planned. This type of frame allows the head to be precisely rotated, flexed, extended, or tilted to facilitate a variety of approaches. Neurological complications may arise from extreme, or sometimes ordinary neck positions in certain patients. In the preoperative area, the patient should be asked to move their neck into the planned operative position to check for symptoms such as neck pain, radiculopathy, or myelopathy. If neck mobility is limited or significant rotation of the head is desired, then optimal positioning may require the use of a shoulder roll or rotation of the table. In some cases, neck immobility may necessitate conversion to a lateral position.

The upper extremities are usually placed on arm boards on the sides of the body with the palms facing the thighs (army position). Arm boards should form an angle of less than 60–90° of abduction from the torso to avoid axillary or subclavian vascular injuries and brachial plexopathies. The arms should be well padded, especially at the cubital tunnel. Excessive extension or supination should be avoided to prevent ulnar neuropathy. The arms can also be tucked-in against the torso with a sheet secured under the patient's body or the bed's mattress. If the ipsilateral shoulder is elevated, then the ipsilateral arm should be placed over the body towards the opposite side. The legs should be slightly flexed with pillows placed under the knees to relax the sciatic nerve, with the lateral aspect of the knee free of any compression to avoid peroneal neuropathy. The legs are elevated to prevent venous stasis (table in "reflex" positioning, or lawn chair position).

The heels should be padded with foam to mitigate against pressure ulcers. We place sequential compression devices on the calves for deep venous thrombosis prophylaxis. The body of the patient is secured with safety straps and silk tape to prevent its movement during table tilting. These straps should be appropriately padded, and under enough tension to resist shifting, but not so much that abdominal pressure is elevated or ventilation is restricted. For trans-sphenoidal and other skull base cases, the abdomen is prepped and exposed to allow for harvesting of a fat graft. Venous and arterial lines, sphygmomanometer hoses, and the oximeter cable should remain accessible to the anesthesiologist for troubleshooting.

The navigation captor device is connected to the Mayfield head holder after final positioning is completed. Minor modifications of the head may be performed without invalidating the registration if its relationship with the captor remains unchanged. However, we advise rechecking accuracy after any changes in head positioning are made since inadvertent manipulation can move the joints that secure the device, necessitating a repeat registration. The captor should be positioned within the line of sight of the navigation camera, but it should not impair access to the surgical field or make contact with the surgeon. Frameless stereotaxic navigation helps in planning an optimal skin incision and may occasionally influence a surgeon to alter the head position after registration.

Sitting Position

First introduced by French surgeon Thierry de Martel in 1913 and by Frazier in the USA in 1928, the sitting position in neurosurgery has classically been utilized for approaches to the posterior fossa and cervical spine [1]. The position capitalizes on gravity-assisted brain retraction and improved venous drainage due to reduced thoracic outlet pressure for improved visualization of the operative field [3]. It was also appreciated for easy access to the airway and observation of the face during surgery. It has fallen out of favor in many centers for its association with perceived catastrophic complications, most importantly venous air embolism.

After induction in the supine position, surgical, positioning, and anesthetic adjuncts are applied to the patient. Compressive garments or sleeves can be employed to decrease venous pooling in the lower extremities [2]. Precordial Doppler, transesophageal echocardiogram, arterial lines for blood pressure measurement, and central venous lines for medication administration and aspiration of air are placed based on the preferences of the surgical and anesthesia teams [4]. Typically, the Mayfield head holder is more easily applied while still supine. The patient is gradually transitioned from supine to sitting to avoid hemodynamic compromise [5]. Once the patient has reached the sitting position, the head holder is fastened anteriorly to a Mayfield cross bar adapter that is secured to the table [3]. The legs are elevated to increase central venous pressure and avoid hypotension, with flexion at the hips and knees to improve venous return [4, 6]. Arterial monitoring should be referenced to the head level for accurate measurement of cerebral perfusion pressures. The patient sits essentially upright on the operating table, with variations in the final position of the head as deemed appropriate for individual cases.

Variations of the sitting position include the "praying" or "forward somersault" position endorsed by Hernesniemi [2]. Here, the upper torso and head are bent forward and downward. This allows the surgeon to rest his hands on the patient's shoulders and back to reduce fatigue during surgery. This position also improves visualization of deeper structures in the posterior fossa, as the tentorium reaches a nearly horizontal position with about 30° of forward bending of the head [2] (Fig. 7.1a, b).

Complications

Supine Position

Compared to other positions in neurosurgery, the supine position has fewer adverse respiratory and hemodynamic effects. Nonetheless, the functional residual capacity decreases by about 25–30% compared to the upright position; and ventilation is more dependent on the abdominal muscles and the diaphragm. In elderly, obese, and pregnant patients, the closing capacity may exceed the functional residual capacity and lead to hypoxemia. Increasing PEEP may help solve the ventilation/perfusion mismatch, and the lawn chair position relaxes the abdominal muscles while improving peripheral venous return. Air embolism is the most feared cardiopulmonary complication of the supine or sitting position, as elevation of the head can lead to negative venous pressures that promote intake of air through venous structures around the brain and within the skull. Cardiac Doppler and end tidal CO_2 monitoring facilitate early recognition of this

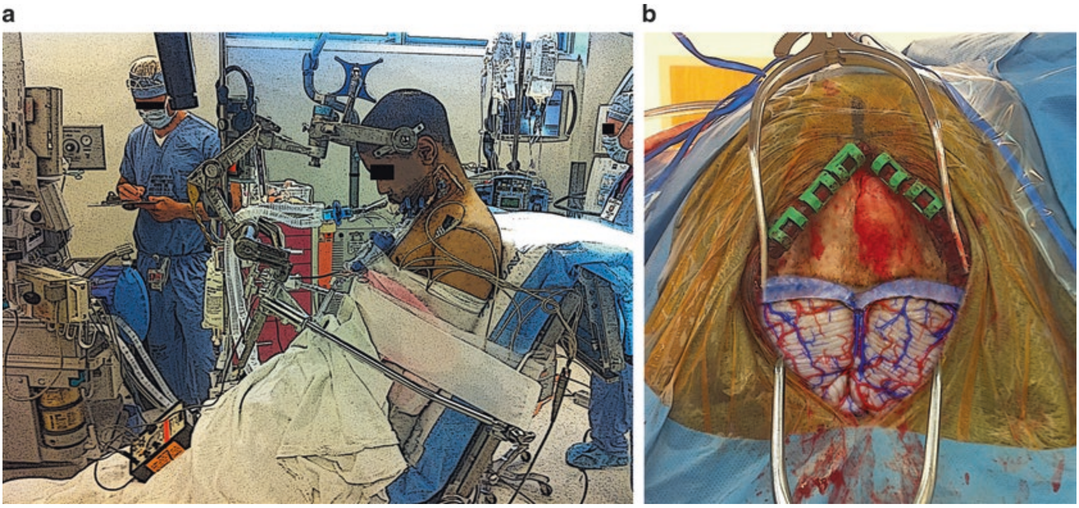

Fig. 7.1 (**a**) General setup for a craniotomy in the sitting position. Note the head flexion in this case to help bring the angle of the tentorium in line with the floor. The edge of the bed and the headrest can be used as an armrest to minimize surgeon's fatigue. (**b**) Artistic rendering of an operative photograph showing the location of the transverse sinuses and cerebellum. This position allows gravity-dependent retraction of the cerebellum, which widens the infratentorial corridor during a supracerebellar-infratentorial approach

complication. Aspiration of air from a central venous catheter in the right atrium, irrigation, and lowering the head to eliminate negative venous pressure are all potentially life-saving measures [7–10].

Neuropathies are among the more common complications of the supine position. Injuries related to intraoperative compression of the ulnar nerve at the medial condyle of the humerus may be further exacerbated by ischemia and hypoxia. Ideally, the forearm is supinated and slightly flexed to minimize stretching the nerve at the elbow. Brachial plexus neuropathies are also possible. To avoid lower plexus injuries, the arms should not be abducted more than 60–90°. Excessive traction of the shoulder with tape can lead to stretch injuries of the upper plexus. External rotation and posterior displacement of the arm should also be avoided.

The vertebral arteries must follow the transverse foramina of the cervical vertebrae as they are rotated, so extreme rotation of the head can cause impairment of flow, intimal dissection, thrombosis, or occlusion. The jugular veins may also be occluded from extreme neck positioning, which can lead to cerebral venous hypertension and related complications such as cerebral edema and hemorrhage. Patients with underlying cervical instability or stenosis are more susceptible to neurological injury with extreme or inattentive neck positioning [10].

Pressure sores, pressure alopecia, and skin breakdown in the areas of the occiput, heels, and sacrum are possible after prolonged surgeries. Backache is not infrequent and is caused by the combination of paraspinal muscle relaxation by the anesthetics and reversal of the lumbar lordosis due to lying flat, which together lead to increased ligamentous tension and pain.

Sitting Position

The sitting position has been associated with serious complications, most importantly venous air embolism [11]. With exposure of non-collapsible cerebral dural venous sinuses, the negative venous pressure gradient created by the sitting position facilitates atmospheric air entry into the head [12]. The lower venous pressures provided in the sitting position also make dural sinus violations less evident as there may not be as much bleeding. Most reported series of venous air embolism do not report significant untoward consequences, likely because of aggressive measures taken both from a surgical and anesthetic perspective once changes in adjunct modalities to detect air emboli are seen. Bone edges are waxed, the surgical field is flooded with irrigation, intermittent jugular venous compression is applied to improve detection of any violated venous structures with subsequent repair if possible, and aggressive hemodynamic support with fluids and/or vasopressors ensues by the neurosurgical and anesthesia teams [6, 12]. Ischemic complications have also occurred when blood pressure monitors are not referenced to the head. A blood pressure cuff on the leg may cause the anesthesiologist to severely overestimate cerebral perfusion.

Other theoretical disadvantages of the sitting position include that of supratentorial tension pneumocephalus. Lunsford proposed the "inverted pop bottle" analogy—where air bubbles rise to the top of a container as CSF and blood pour down—to explain how this phenomenon can occur, particularly in situations with increased CSF drainage through a ventriculostomy [5].

A recent large series of 1792 cases from the Mayo Clinic demonstrates a significantly higher incidence of complications in intradural compared to extradural sitting cervical spine cases. Specifically, tension pneumocephalus in their series occurred in intradural sitting cervical spine and suboccipital craniotomy cases, lending credence to Lunsford's theory. Their series demonstrated an overall low complication rate, with the highest risk seen in suboccipital craniotomy or craniectomy cases. With appropriate technological adjuncts, they demonstrate the safe modern use of the sitting position for attacking various pathologies [3].

Other rare complications have been reported with the sitting position. Subdural, epidural, and even remote intraparenchymal hematoma formation have been reported [1, 3]. Postoperative quadriplegia, most likely due to excess neck flexion, can be minimized by allowing for adequate distance between the chin and neck, and by preoperative screening for myelopathy or abnormal imaging findings. Macroglossia and recurrent laryngeal nerve palsies leading to postoperative airway compromise and hypoxia or hypercapnia can be minimized by using smaller diameter transesophageal echo probes and endotracheal tubes, and withdrawing these devices to the extent that their tips also serve as bite blocks in the final positioning [5]. Peripheral neuropathy, most often involving the common peroneal or sciatic nerves, is avoided with proper padding at the neck of the fibula and avoidance of thigh hyperflexion [3, 5].

Contraindications to the sitting position include significant atherosclerotic cerebrovascular disease, particularly if a patient is determined to be symptomatic in the sitting position preoperatively [2]. Severe cervical stenosis should raise alarm in avoiding excess neck flexion—a consideration for both the sitting and prone positions. Cardiac pathologies involving increased right- to left-sided shunting such as a patent foramen ovale, or the presence of a patent ventriculoatrial shunt should lead to discussing alternative approaches given the risk of systemic air embolism.

Rationale for Approach-Guided Positioning: Basic Mechanics and Nuances

The ideal neurosurgical approach provides wide exposure and requires minimal brain manipulation. Following the dictum of Yasargil, fissures, sulci, and cisterns can be dissected and surrounding bony structures drilled to reach deep-seated pathology while sparing normal brain tissue [1]. Therefore, the main goal of head positioning is to enhance the surgeon's ability to follow these natural operative corridors. The following aspects should always be kept in mind when positioning the patient: (1) mechanics of head and neck rotation, (2) surgical *perspectives* of natural anatomical corridors, (3) gravity-assisted retraction, and (4) ergonomic working angles. We will discuss these factors in general and then expand upon nuances of the supine position in several common neurosurgical approaches. Note that these factors are tailored to each patient, pathology and approach, and their modifications are guided by the surgeon's judgment and experience.

Head, Neck, and Body Mechanics

The supine position includes a wide range of possible body and head positions and can therefore accommodate a variety of cranial approaches.

The *head* may be in the neutral position—facing straight up—or it can be rotated in three planes. In the supine position, the axial and sagittal planes of the head are vertical, while its coronal plane is horizontal. (1) In the vertical sagittal plane, the head can be flexed or extended. Flexion elevates the head and facilitates exposure of the posterior parietal and occipital areas during the sitting and semi-sitting position. Conversely, extension promotes gravity retraction of the frontal lobes and improved access to the under surface of the brain, which is particularly useful in aneurysm and anterior skull base surgery. (2) The head can be rotated in its axial plane to match a natural operative corridor, or to bring the surface of the presumed craniotomy to the highest point, which helps maximize the surgeon's view and working space for superficial lesions. Contralateral rotation is often helpful for temporal, trans-sylvian, orbito-zygomatic, and lateral approaches [13]. (3) In the horizontal coronal plane, the head can be tilted right or left, which may help to level the surface of the craniotomy or widen the working space between the head and the shoulder. The surgeon should keep in mind that neck extension with tilting will likely exacerbate any preexisting cervical stenosis—central or foraminal.

Body positioning increases the effective range of head rotations—relative to the floor—beyond what can be safely or comfortably achieved from neck movements alone. Shoulder rolls can assist with head rotation in the axial plane and provide a "semi-lateral" or "oblique" setting when necessary, especially if the neck is not sufficiently mobile. The body can also be rotated ("airplaned") right or left, allowing further intraoperative head rotation. The torso and head can be elevated relative to the rest of the body to achieve a semi-sitting position, thus increasing the effective range of head rotation in the sagittal plane (Fig. 7.2). Reflex or lawn chair positions augment venous drainage and relax the abdominal musculature for easier ventilation. Similarly, the body can be placed into the reverse Trendelenburg position to obtain these advantages, but care must be taken to prevent the body from sliding inferiorly, which may result in untoward cervical traction or pin-related scalp lacerations. Therefore, only modest degrees of reverse Trendelenburg positioning are typically employed. The Trendelenburg position could be used to further expose the basal areas of the brain through gravity-assisted retraction of the frontal lobes, but the concomitant increase in venous pressure makes this position unappealing except for the case of an intraoperative air embolism.

Body positioning is particularly helpful for patients with limited neck mobility due to neurological complaints, fusion, or degenerative changes. If the neck is completely fused, such as in many patients with ankylosing spondylitis, then all head rotation must be accomplished via body rotation. Even in asymptomatic patients, excessive manipulation of the head and neck may cause vascular and neurological injuries. The vertebral arteries may be compromised by extreme ipsilateral rotation or hyperflexion, leading to spinal cord or brainstem ischemia. For this reason, and especially in patients with degenerative or atherosclerotic disease, a couple of fingerbreadths should be maintained in the thyromental space during neck flexion, and neck rotation of more than 45–60° should be avoided.

Surgical Perspectives to Anatomical Corridors

Patient's positioning is largely dictated by the desired surgical approach. Ideally, the surgeon should have an unfettered view and working channel extending from the skin to a deep-seated target, created by opening natural brain corridors while avoiding injury to surrounding normal

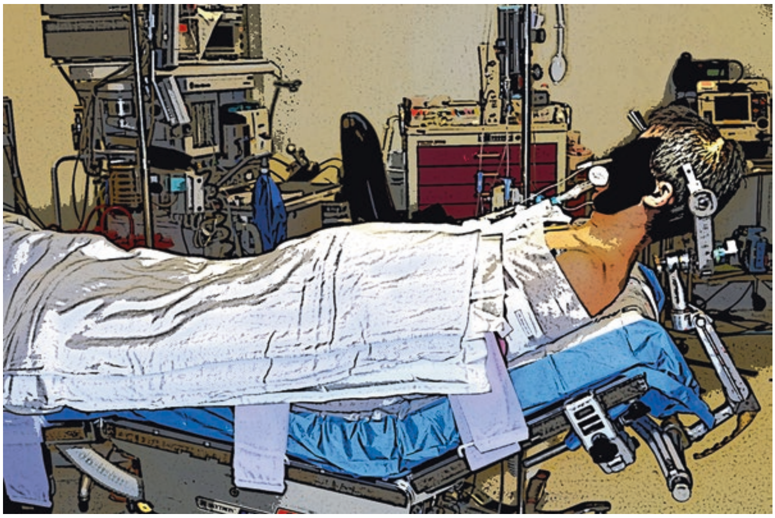

Fig. 7.2 Setup for a semi-sitting position during an interhemispheric approach. Note the head elevation and flexion

brain tissue. Neurosurgical approaches typically provide cone-shaped visual and working spaces that are larger on the surface and progressively narrow towards their deep apex. The optimal surgical cone is one with a wide base and a short neck, providing a wide variety of possible perspectives and a short distance to the target [14]. This is a particularly important concept in skull base surgery that has helped to inspire many of its classical approaches such as the petrosal, which shortens the distance to the cerebellopontine angle compared to the retrosigmoid approach. The fronto-temporal orbito-zygomatic approach (FTOZ) also provides a shorter working distance and wider surgical cone compared to a standard pterional craniotomy, but it also offers multiple anatomical corridors through which a lesion can be attacked. In order to take full advantage of this approach, however, the patient must be positioned in such a way that permits a wide variety of viewing angles—typically with the malar eminence at the highest point [15, 16].

When tackling superficial or lobar intra-axial lesions that do not require dissection through a fissure or cistern, it is often optimal to rotate the skull so that the highest point is closest to the lesion. In this case, the craniotomy surface is positioned in a plane roughly parallel to the floor, and the microscope is facing straight down at the lesion. The surgical ergonomics are advantageous as the surgeon's hands can easily rest on the head and a comfortable posture can be maintained. This rule does not necessarily apply if the lesion is deep-seated or if the approach requires a view that aligns with a natural corridor, such as the sylvian fissure, the transfacial sinonasal corridors, subfrontal space, interhemispheric fissure, or the pretemporal corridor. In these cases, the optimal head rotation must account for the anatomical orientation of these corridors. For instance, if a trans-sylvian approach is used, the head may be rotated to the contralateral side to bring the cisternal plane of the distal fissure into a perpendicular direction with the floor and thus in line with the microscopic view (Fig. 7.3). Of course, in many operations the perspective that is optimal for opening a fissure and obtaining initial exposure may not be the best perspective for attacking the lesion. In these cases, the surgeon should consider an "in-between" head placement that can be optimized for different phases of the operation with modest adjustments of the table or microscope. Thus, positioning for a posterior communicating artery aneurysm is typically different than for an anterior communicating artery aneurysm, even though both operations may initially gain exposure through a sylvian fissure dissection [17].

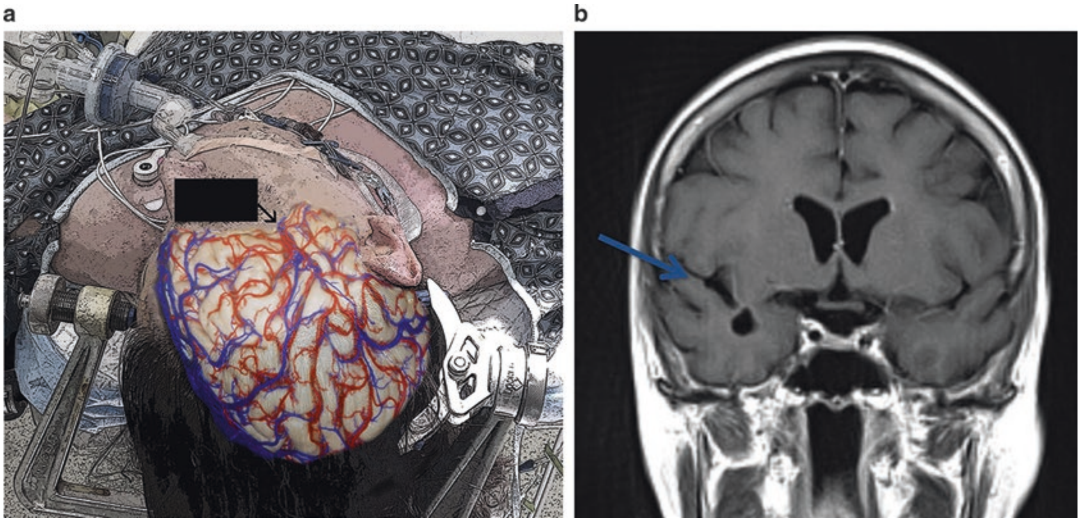

Fig. 7.3 (**a**) Artistic rendering of an operative photograph showing the head positioning for pterional trans-sylvian approach. Contralateral rotation and placing the malar eminence at the highest point of the head, aligns the surgeon's perspective with the sphenoid wing and the sylvian fissure (arrow). (**b**) Gadolinium-enhanced T1 sequence magnetic resonance imaging in the coronal view showing the trans-sylvian corridor to a medial temporal lesion inferior to the limen insulae

Gravity-Dependent Retraction

Rigid brain retraction can be helpful to open narrow surgical corridors to deep brain structures, but it may cause contact abrasions, ischemia, and cerebral edema. In an effort to avoid complications, the surgeon should strive to minimize brain retraction using modern techniques of neurosurgery, such as cerebrospinal fluid drainage, bone drilling, dynamic retraction with handheld instruments, and most importantly, strategic head positioning [13]. Head positioning should exploit "gravity-assisted retraction" by placing the dependent brain inferior to the surgical corridor so that it falls away [18, 19]. Placing the craniotomy at the most superior point, as described above, allows for gravity-dependent retraction, though cerebral edema may still result in brain extrusion. In the anterior interhemispheric approaches, the head can be rotated parallel to the floor, which promotes gravity retraction of the frontal lobe to widen the operative corridor with minimal or no retraction. Gravity retraction is often helpful in the subfrontal or pterional approaches, in which the neck is extended to permit the frontal lobe to fall away from the anterior skull base (Fig. 7.4). In the sitting position, the cerebellum will sag from the tentorium, further opening the natural corridor for the supracerebellar-infratentorial approach [18] (Fig. 7.1b). Blood and cerebrospinal fluid are naturally cleared from the surgical field, providing an optimized view of the pineal region

Fig. 7.4 Head extension allows gravity-assisted retraction of the frontal lobe and increased exposure of the circle of Willis

with good brain relaxation [20]. Gravity retraction has been shown to decrease blood loss, postoperative cerebral edema, and operative duration [18]. Therefore, head positioning should promote gravity retraction if possible.

Ergonomic Working Angles

Surgeon comfort is a very important factor to consider in choosing the optimal patient positioning. Whether sitting or standing, the shoulders should be relaxed, and the arms resting comfortably. The surgeon's spine should be as neutral as possible. A suboptimal working angle into the operative corridor may result in increased brain manipulation and operative time. Moreover, an uncomfortable posture may discourage the surgeon from taking the necessary time to perform a meticulous dissection. If an assistant surgeon is involved, then the head position and orientation of the microscope should account for the comfort of both surgeons, which may be different from the optimal position for a single surgeon. For instance, in the pterional approach, instead of directing the microscopic visual angle in line with the sylvian fissure, as is the case for a single surgeon in the sitting position, the eyepieces are perpendicular to the fissure when two surgeons are standing across from each other.

The Pterional Approach (Yasargil)

The pterional approach was devised by Yasargil to exploit the natural dissection planes of the sylvian fissure, the sphenoid wing, and the orbital roof. The approach is centered on the pterion, which overlies the sylvian fissure and the sphenoid wing. The surgical corridor between the frontal and temporal lobes is expanded by drilling the sphenoid wing and opening the proximal sylvian fissure to provide access to the deep structures in the basal areas of the brain—mainly the circle of Willis and the parasellar area [1]. This provides a working area shaped like a pyramid, with its apex near the anterior clinoid process (Fig. 7.3).

The head holder is traditionally attached with one pin behind the ipsilateral ear above the mastoid and two contralateral pins above the superior temporal line to minimize the risk of bleeding, fracture of squamosal temporal bone and instability. Alternatively, the two pins may be placed above or behind the ipsilateral ear while the contralateral pin is on the forehead lateral to the mid-pupillary line. Proper positioning of the head allows the mobilized frontal and temporal lobes to drop away from the skull base, necessitating less retraction. Yasargil advocates turning the head to the opposite side about 30° to align the surgical perspective with the sylvian fissure and the sphenoid wing, with a direct view of the anterior clinoid process and suprasellar area. The head is also elevated, and extended with the vertex down about 20°, to bring the malar eminence to the highest point of the surgical field. This inclination will bring the basal parts of the brain into more direct view and allows gravity retraction of the frontal lobe [1]. Some surgeons also tilt the head away (lateral torsion) to further open the space between the head and the shoulder and allow further "horizontalization" of the fronto-temporal craniotomy.

The preferred head orientation varies between surgeons. Rhoton summarized the basic head movements in the pterional approach as follows: (1) elevation of the head, (2) contralateral rotation, (3) neck extension, and (4) lateral neck extension (head tilt) [21]. Contralateral rotation (20° by Rhoton, 30° by Yasargil) with lateral neck extension (head tilt) places the sylvian fissure on the convexity parallel to the surgeon's view. Excessive rotation makes the temporal lobe fall over the frontal lobe, which can make splitting the sylvian fissure more difficult. Further rotation also deepens the proximal part of the sylvian fissure, which has a different orientation than its distal segment [21]. Spetzler has recommended 60° of head rotation for anterior communicating aneurysms (ACOMM), 45° for middle cerebral artery (MCA) aneurysms, and 20–35° for posterior communicating (PCOMM) or basilar aneurysms [22] (Fig. 7.5). The training and practice of the senior author has followed a similar scheme. Although neck exten-

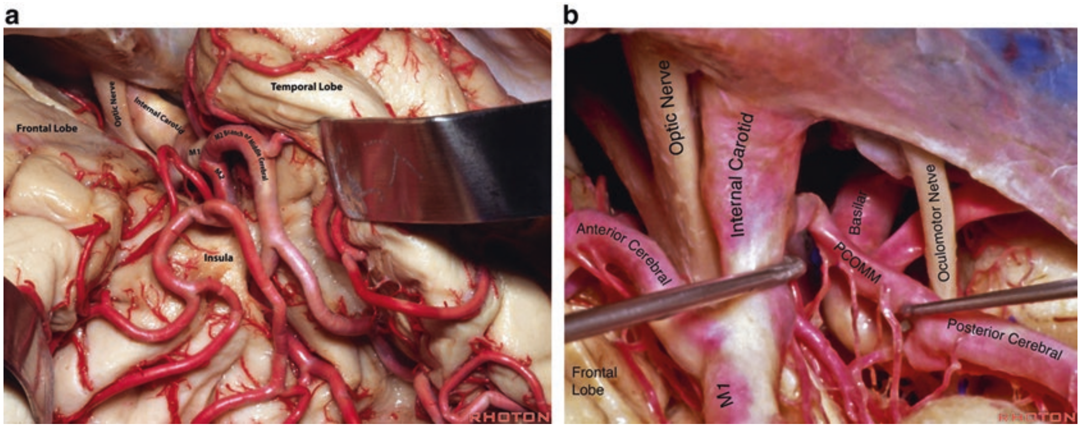

Fig. 7.5 (**a**) Increased head rotation with a lateral perspective to the sylvian fissure shows the branches of the middle cerebral artery well, but not the proximal circle of Willis. (**b**) The circle of Willis (including the posterior communicating artery and the basilar apex) is seen through the proximal sylvian fissure from an anterolateral perspective, with less head rotation

sion is helpful in a pterional exposure as described above, excessive extension may place the orbital roof and ridge further into the line of sight, and the anterior clinoid process deeper into the surgical view. In one cadaveric and clinical study, optimal head orientation was measured for various anterior circulation aneurysms. The authors concluded that proximal aneurysms (ophthalmic, posterior communicating) require less extension to keep the orbital roof out of the surgical view [17].

We believe that head orientation should be individualized for each patient and pathology, as should bone drilling and cerebrospinal fluid diversion. Three-dimensional angiographic reconstructions can be helpful in assessing the geometry of aneurysms and their associated vessels. Often, the vascular anatomy is rotated or otherwise altered from normal. This information is often useful in planning an approach and head position that provides the best surgical view and angle of attack.

Fronto-Temporal Orbito-Zygomatic Approach (FTOZ) and Supraorbital Modification

The FTOZ approach is an extension of the pterional craniotomy to include the orbital roof, superolateral orbital rim, and the zygomatic prominence. This creates a significant increase in surgical exposure, adding excellent pretemporal and subtemporal corridors while enlarging the subfrontal corridor. This approach is particularly helpful for lesions located at the orbital apex, parasellar region and cavernous sinus, interpeduncular fossa and basilar tip, and anterior and middle fossa floor (Fig. 7.5b). The malar eminence is typically positioned at the most superior point in the surgical field to allow relatively straightforward access to all of the surgical corridors that this versatile approach provides. To achieve this position, the head is rotated 30–60° to the contralateral side and the neck is slightly extended [15, 16]. A modified supraorbital orbito-zygomatic approach, or orbito-pterional approach has also been described [23]. Head positioning and rationale are typically the same as in the FTOZ approach, but only the orbital roof and ridge are removed.

Lateral Supraorbital and "Eye-Brow Incision" Approaches

The lateral supraorbital approach was described and widely used by Hernesniemi as a simple, less invasive, and faster alternative to the pterional approach [24]. It uses a more anterior, subfrontal corridor compared to the pterional approach. In a supine position, the head is elevated above the heart, rotated 15–45° to the opposite side and slightly tilted. As opposed to the "eye-brow incision" the skin is opened behind the hairline, but with a smaller and more anterior and frontal incision than with the pterional approach. The craniotomy flap is also smaller and more frontal than the pterional flap, but can be used for anterior fossa tumors, sella and anterior circulation aneurysms.

The supraorbital keyhole approach through an eye-brow incision was described as a minimally invasive ("Keyhole") substitute to the subfrontal and pterional approaches for addressing certain well-confined pathologies [25]. It employs a subfrontal corridor and is best suited for smaller straightforward midline lesions. Examples include anterior skull base meningiomas, craniopharyngiomas, and even anterior circulation aneurysms. The incision can be supraciliary, transciliary, or transpalpebral, and it is important to place it lateral to the supraorbital nerve to avoid its injury. The head is fixed in a three-pin holder with the two pins placed posteriorly on the ipsilateral side and the one pin on the contralateral frontal bone. Given the small corridor used in this approach, head positioning is crucial in accessing skull base lesions. The head is slightly extended to about 15–20°, allowing gravity retraction of the frontal lobe, and rotated about 15–45° to the contralateral side. Additional rotation is typically needed for midline lesions, such as olfactory groove meningiomas. It has been recommended to use 10–15° of rotation for suprasellar and medial temporal lobe lesions, 30° for planum sphenoidale pathologies, and 45° for the cribriform plate [26]. The bed can be further rotated for intraoperative adjustments as needed.

Pretemporal Approach

First described by Dolenc, the pretemporal approach combines the exposure provided by the pterional approach with that of the temporopolar and subtemporal approaches [27]. Extending the craniotomy to the temporal side facilitates extradural mobilization of the temporal pole and exposes the middle fossa floor from an anterolateral perspective. While most middle fossa approaches are approached in a lateral position, the pretemporal approach offers access to the Kawase rhombus in a supine position [28]. The pretemporal approach is particularly beneficial for access to the cavernous sinus and parasellar area, basilar artery and interpeduncular fossa, anterior tentorial incisura, Meckel's cave, petrous apex and orbito-sphenoid regions [29, 30]. Removing the anterior and posterior clinoid and opening the cavernous sinus, dividing the tentorial incisura, drilling Kawase's space, and mobilizing the temporal pole significantly enlarges the deep working area to the posterior fossa when accessed from the supratentorial space. Different degrees of orbito-zygomatic osteotomies can be performed to increase the superficial exposure. Head positioning is similar to that of a traditional pterional approach with elevation of the head, contralateral rotation of the head of 20–30° (Fig. 7.5), neck extension (which can be increased to 30° for basilar aneurysms) and lateral extension of the neck. The sphenoid ridge and the sylvian fissure remain at the center of the approach. After the sylvian fissure is split through a traditional pterional perspective, the table can then be adjusted to gain more pretemporal and subtemporal access.

Temporal and Subtemporal Approaches

The temporal approach is oriented more posteriorly and inferiorly than the pterional approach. It is designed to access the temporal lobe, particularly for tumors or anterior temporal lobectomy for epilepsy. The patient is placed supine with a shoulder roll placed ipsilaterally to help with head rotation. The head is extended and rotated about 45° to the opposite side. Two pins are placed at the level of the inion and the contralateral pin at the frontal bone anteriorly. Head positioning places the temporal lobe in an almost horizontal plane and tilting the head downwards allows the temporal pole to fall away from the greater sphenoid wing [21].

The subtemporal approach uses the intradural corridor under the temporal lobe to access the tentorial incisura, the crural and ambient cisterns, parasellar area, and the basilar and posterior cerebral arteries. This approach is typically performed through a lateral position, but a supine position with a shoulder roll may be used if the neck has sufficient mobility. The head is effectively rotated 90°, but also tilted slightly downward below the horizontal plane to optimize the subtemporal surgical corridor and minimize retraction. Retraction is a common cause of morbidity in this approach as it can easily produce cerebral contusions and cortical vein injuries [31].

Parieto-Occipital Approaches

Pathologies of the parieto-occipital region are most commonly approached in the prone, lateral, or sitting positioning. Occasionally, patients for which the prone position would provide the best exposure are precluded from this position by extreme obesity or difficulties with ventilation and oxygenation. In such cases, the supine position with a shoulder roll or a supine semi-sitting position might be used even though it may be suboptimal because of the limits of neck range of motion. As a basic principle, the cranial opening should be as close to perpendicular to the surgeon's line of sight as possible, even if it is not positioned at the highest point.

Midline Approaches

Bifrontal Craniotomy and Subfrontal Approach

The midline subfrontal approach evolved through the works of Durante (1885), Frazier (1913), and Cushing for the resection of anterior skull base, sellar, and suprasellar lesions. The approach can also be used for frontal tumors, traumatic and non-traumatic hematomas, hypothalamic and anterior third ventricular lesions (through the lamina terminalis), CSF leak repair, and anterior cerebral artery aneurysms [32, 33]. The head is slightly extended to about 15° to allow the frontal lobe to fall away with gravity and open the subfrontal corridor with minimal retraction. Depending on the location and extent of the pathology, a midline approach with bilateral exposure may be chosen with the head kept neutral. If a unilateral approach is chosen, the head can be turned to the opposite side by about 20°. For this approach, the Mayfield head pins should be placed more posteriorly, with the two pins in a vertical position, so they do not encroach upon the bicoronal skin incision (Fig. 7.6).

Anterior Interhemispheric Transcallosal Approach

The interhemispheric approach utilizes the surgical corridor between the cerebral hemispheres and the falx. This approach can be used to access the medial frontal lobe, the cingulate gyrus, and the distal pericallosal branches of the anterior cerebral artery [1]. The transcallosal approach allows access to the lateral and third ventricles. This approach is considered to follow the shortest distance to the third ventricle and is often used for colloid cysts and tumors of the third ventricle. The patient is positioned supine, which allows an assistant to participate, or less fre-

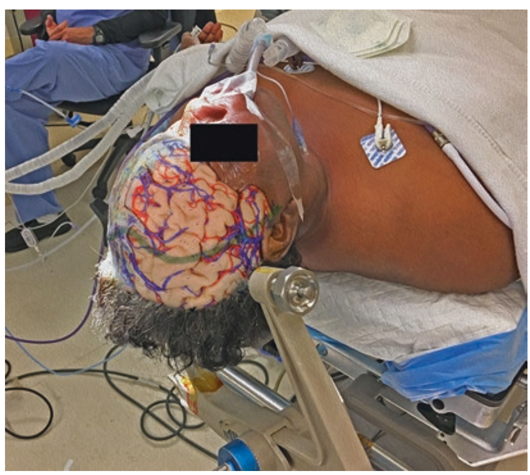

Fig. 7.6 Artistic rendering of an operative photograph showing the head positioning for a bicoronal approach

quently three-quarters lateral for a single surgeon with the advantage of gravity retraction of the dependent frontal lobe. The torso is elevated and the head is flexed to bring the vertex into a near horizontal plane. Midline approaches, such as this, expose the superior sagittal sinus and increase the risk of venous sinus injury with bleeding and air embolism. If an air embolism is suspected, copious irrigation should be used to flood the surgical field and any visible openings in the sinus should be occluded. The patient should be placed in a Trendelenburg position to increase venous pressure, and the anesthesiologist should attempt to aspirate the embolus through the central line placed in the right atrium.

Cranio-Facial Approaches

Transnasal and Trans-Sphenoidal Approaches

First described for the resection of pituitary adenomas by Schloffer, Cushing, and Hirsch, trans-sphenoidal surgery has evolved to include surrounding areas, including the clivus, anterior cranial fossa, and suprasellar areas. It can be performed either through a sublabial or transnasal routes, using either the microscope and/or the endoscope. Griffith and Veerapen introduced the transnasal approach in the 1980s. It is performed in the supine position with the head secured with either a three-pin or horseshoe head holder. For a right-handed surgeon, the endotracheal tube should emerge from the left corner of the mouth and the head is tilted about 30° to the left. The head is elevated relative to the heart with modest reverse Trendelenburg positioning to optimize venous drainage and decrease bleeding from multiple venous sinuses around the sella. The transnasal route to the sella typically forms an angle of about 20° with the maxilla. For sellar lesions, the head is usually neutral or slightly flexed. For infrasellar and clival lesions, 10–15° of neck flexion may be beneficial. Slight extension may be necessary for suprasellar and anterior fossa lesions (10–15°). The head is rotated to the right side (towards the surgeon) and tilted to the opposite side. This will place the patient's right nostril face to face with the surgeon to begin the exposure through the microscope [34, 35] (Fig. 7.7). Frameless stereotactic navigation of transnasal cases are typically performed with a magnetic system at our institution since it allows freedom to reposition the head. The abdomen is also typically prepped for these cases to allow a fat graft to be harvested if needed.

Transnasal approaches are increasingly performed with an endoscope, which decouples the surgeon's line of sight from the surgical corridor, since the video monitor can be placed in any ergonomic position. This relaxes many of the constraints discussed above for surgery through a microscope. Nonetheless, a supine position with the head slightly elevated is still desirable for anterior endoscopy [36].

Transoral Approaches

Transoral approaches are traditionally used to address midline craniovertebral junction lesions, between the lower clivus and C2 vertebral body [37, 38]. These mainly include extradural clival chordomas, chondrosarcomas, giant cell tumors, and rheumatoid or degenerative pannus. The approach provides direct access to the anterior cervico-medullary junction using the shortest route without requiring brain retraction. Important issues are manipulation and retraction of the tongue, healing of the soft palate and pharyngeal soft tissues, and achieving a watertight dural closure for intradural pathologies. Gardner-Wells tongs and traction may be employed to attempt reduction prior to surgical intervention, and traction may be maintained during surgery. Jaw opening should be evaluated prior to surgery because restricted movement may necessitate a more involved median labial mandibulo-glossotomy.

The patient is positioned supine with the head either stabilized with a Mayfield head holder or resting on a doughnut pad. The neck is slightly extended to bring the craniovertebral junction in line of sight of the surgeon. Oral intubation is

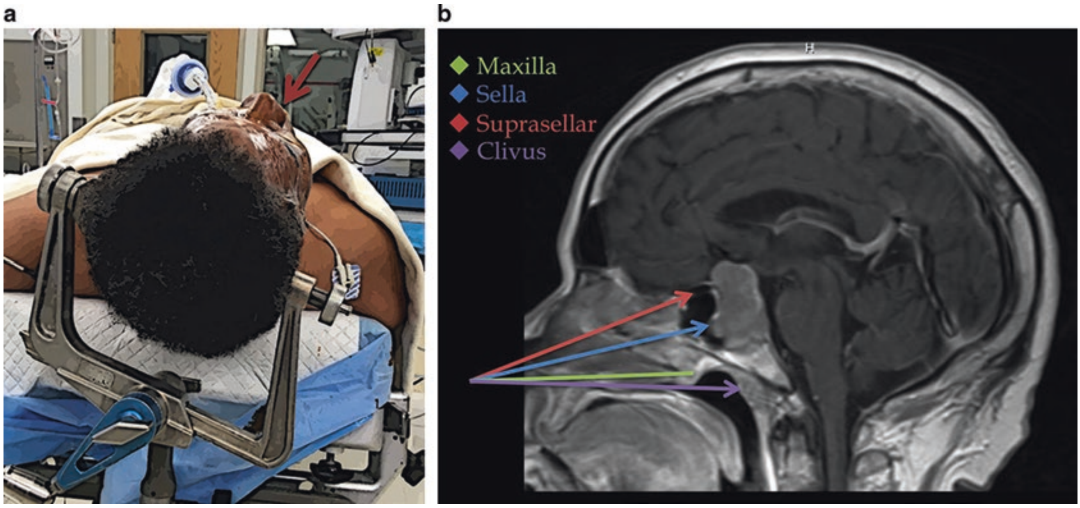

Fig. 7.7 (**a**) Head positioning for a right-sided transnasal approach. (**b**) Gadolinium-enhanced T1 sequence magnetic resonance imaging in the sagittal view showing a pituitary adenoma extending to the suprasellar space. Also shown are the angles of the maxilla and the microsurgical transnasal routes to the clivus and suprasellar regions. While extension may be needed for suprasellar lesions, more flexion is necessary for clival targets

typically used and topical steroids are administered to prevent tongue swelling. Many centers use the Spetzler-Sonntag transoral retractor system or the Crockard or Dingman mouth retractors. The retractor is fixed and secured to the operating table. The endotracheal tube is attached at the corner of the mouth to avoid excessive tongue compression and obstruction of the surgical view. Teeth guards are used with the retractor frame for protection. After closure, the patient can be turned prone to complete the posterior instrumentation and fusion if necessary.

Endoscopic approaches have been gradually replacing microscopic transoral approaches as they have the advantage of decoupling the surgeon's view from the surgical corridor [39]. This allows many of the operations that were traditionally done transorally to be done endoscopically through a transnasal approach without requiring splitting the soft palate or retracting the tongue, and with fewer constraints upon surgical positioning. An angled endoscope is often used for the best perspective.

Infratentorial Approaches

In addition to anterior endoscopic transclival approaches, the versatility of the supine position also allows lateral and posterior approaches to the posterior fossa. The choice of positioning can differ widely between surgical centers. Even the lateral supracerebellar-infratentorial approach, which is classically accomplished in the sitting or lateral positions, was described in the supine position with gravity-assisted retraction [40].

While we prefer to perform the retrosigmoid craniotomy in the lateral position, many surgeons feel more comfortable with a supine-oblique arrangement (Ojemann) [41]. The patient is placed supine with the ipsilateral shoulder elevated with a roll. The head is turned to the contralateral side as much as possible (more than 45°) until it is parallel to the floor. This will allow the cerebellum to fall away with gravity from the cerebellopontine cistern. It is also slightly flexed and tilted slightly towards the floor to widen the space between the head and the shoulder. Care must be taken to avoid excessive tension on the neck, and the head should be elevated above the level of the heart. The head holder is secured with two pins on the contralateral occipito-mastoid area and one pin in the ipsilateral frontal region. The shoulder is gently retracted with tape, if necessary, to prevent obstruction of the surgical view. The surgeon is usually sitting and positioned behind the patient's head with the chair at an optimal height so that a surgical perspective through the corridor between the cerebellum and the posterior petrous bone can be achieved. The table can be rotated during surgery to adjust the operative angle towards the cerebellopontine cistern and brainstem. The supine position can be used in this way if the patient has sufficient neck mobility; otherwise, a lateral position will be necessary. We prefer the lateral position in our academic center because it allows two standing surgeons to work opposite to each other at the same time.

The supine position can also be used for petrosal approaches, which entail a mastoidectomy to create a presigmoid working channel that can provide more direct access to cerebellopontine lesions. The degree of bone removal is typically tailored to the precise exposure that is needed, with the translabyrinthine variant being very common for tumors involving the internal auditory canal. The mastoid bone is at the center of the surgical field and its surface is typically positioned parallel to the floor [42]. The same considerations for the retrosigmoid approach apply.

The jugular foramen is usually approached through a combined distal cervical postauricular transtemporal approach, which is performed in the supine position. The head is turned to the opposite side, but a shoulder roll is usually not necessary. In order to allow adjustments for the different steps of this combined approach, the head is not fixated with pins. For example, further rotation is helpful as dissection is carried out towards the mastoid. Care must be taken to avoid compressing the contralateral jugular vein, especially in glomus jugulare tumors where it is dominant. The abdomen should also be exposed for a potential fat graft. For a preauricular transtemporal infratemporal fossa approach, the patient is also placed supine. The head is placed in a three-point Mayfield headrest and elevated, slightly extended and turned contralateral to the pathology [43, 44].

Asleep-Awake Craniotomies

Asleep-awake craniotomies are not commonly used in all neurosurgical centers. They are particularly indicated in addressing lesions located in or very close to eloquent brain cortex; or in epilepsy surgery, where localizing the seizure focus may be hindered by general anesthesia. Understanding the anatomy of eloquent areas is important in planning the surgical approach, patient's positioning and the steps of the awake procedure. Because the patient will have to communicate with the anesthesiologist or the neurologist during the awake phase, most of these craniotomies are done in a comfortable supine position [45–47].

Anesthesia is typically performed in three phases: asleep, awake, and sedation stages. During the asleep phase, the patient's airway is secured with LMA, and he is anesthetized with short-acting agents such as propofol and remifentanil. LMA is more suited for awake craniotomies to prevent coughing and agitation associated with endotracheal extubation at the beginning of the awake phase. Requisite local anesthetic infiltration of skin, galea, and pericranium, prior to pinning the head holder and to skin incision is necessary to maximize analgesia. Head positioning should allow constant access to the airway and to the laryngeal mask. The anesthesiologist should be able to easily remove the LMA before the awake procedure, and even to reinsert it if needed during the sedation phase. It should also permit the patient to see his examiner during the awake phase so that the anomia test can be performed. Patient's neck should be in the most comfortable position possible, his joints flexed and relaxed and his body well secured to the table. The drapes should not cover the patient's eyes, and adequate lighting should be provided under the drapes to minimize patient's anxiety.

Patient positioning during the awake phase can be problematic. The patient's comfort should be optimized, and continuous communication and reassurance maintained to prevent precarious movements. Table movements should be made slowly with the patient's eyes closed to avoid worsening of nausea. The patient should be continuously assisted with joint movements, temperature adjustments, and addressing his complaints to minimize any discomfort. Patient's ease is crucial for the smooth progression of surgery and of the cortical mapping procedure. Antiepileptic medications should be at therapeutic levels because the risk of seizure from cortical stimulation is higher in an awake patient. Wild movements from seizure activity can inflict neck trauma or scalp laceration from the head pins [47].

After the awake procedure is completed, sedation is necessary to avoid confusion and agitation while the patient is still in the Mayfield headrest. If the airway is lost, it is managed with correcting any obstructive position, including pulling the chin forward, especially in medication overdose. If endotracheal intubation is necessary, a fiberoptic approach may be employed, or the head should be removed from the Mayfield head holder for direct visualization. During the last phase, the patient should be adequately sedated to prevent confusion and agitation while avoiding medication overdose and possible loss of airway. If sleep doses of propofol are required, the LMA should be reinserted for the rest of the procedure [45].

Conclusion

The supine position is extremely versatile, allowing for a wide variety of neurosurgical approaches. Although the complexity and potential complications require additional attention to details, the sitting position remains useful for particular approaches to the posterior fossa. Optimal positioning should consider the desired surgical corridor, the patient's neck mobility, venous drainage, gravity retraction, and the surgeon's comfort. Increasing use of endoscopes and exoscopes that decouple the surgeon's line of sight from the surgical corridor will greatly reduce positioning constraints imposed by the surgeon's comfort, so that only patient-related factors will need to be considered.

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