



Surgical approaches to posterior third ventricular tumors

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Advanced microsurgical techniques combined with improved neuroanesthetic and postoperative critical care have made aggressive surgical resection a mainstay in the management of posterior third ventricular and pineal region tumors. Although a variety of approaches to the posterior third ventricle have been designed [1–7], three are in common use. The infratentorial-supracerebellar approach takes advantage of a natural corridor between the cerebellum and the tentorium. Supratentorial approaches include the interhemispheric-transcallosal and occipital-transtentorial approaches. Choosing the optimal surgical approach depends on the anatomic extent of the tumor as well as on the preference and experience of the surgeon. Refinements in surgical technique have led to a more favorable outlook for patients with these uncommon tumors.

Spectrum of pathology

The list of possible posterior third ventricular and pineal region lesions is extensive because of the histologic diversity of the area. Lesions may arise from within the posterior third ventricle itself, the pineal gland, the velum interpositum, the surrounding parenchyma (thalamus, midbrain, or splenium), the tentorium, the quadrigeminal cistern, or the posterior cerebral vasculature. The most common posterior third ventricular mass is tumor emanating from the pineal gland. Tumors of the pineal gland proper can be grouped into three principal categories: germ cell tumors, pineal

cell tumors, and glial cell tumors [8,9]. A continuum of histopathologic subtypes exists within each of these categories, ranging from benign to highly malignant. Additionally, tumors of germ cell origin may exhibit a mixture of cell types. Rarely, miscellaneous lesions, such as metastatic tumors [10,11], lymphoma [10], chemodectoma [12], and primary melanocytic tumors [13], present in the pineal gland. Benign pineal cysts are being discovered with increasing frequency as people undergo MRI scans for routine neurologic complaints [14].

In addition to tumors of the pineal gland, posterior third ventricular tumors include thalamic astrocytomas and ependymomas, choroid plexus tumors [15–17], epidermoids [18,19], craniopharyngiomas [20], and meningiomas arising from the velum interpositum [21–23]. Large falcotentorial meningiomas that extend anteroventrally may also impinge on the third ventricle [24]. Arachnoid cysts [25], arteriovenous malformations [26], vein of Galen malformations [27,28], and cavernous malformations [29,30] may also be found in the region.

Aims of the operation

The goals of surgery for posterior third ventricular tumors vary depending on the clinical circumstances of an individual situation. The first objective is to establish a histologic diagnosis [31–34]. Surgery may be avoided altogether in the presence of either serum or cerebrospinal fluid (CSF) α -fetoprotein or β -human chorionic gonadotropin. These markers are pathognomonic for malignant germ cell elements; affected patients are treated nonoperatively with radio- and

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chemotherapy [35,36]. In the absence of positive markers, a tissue sample is generally required. Although a limited amount of tissue can provide a histologic diagnosis, extensive sampling from various portions of the tumor is desirable to reduce the risk of sampling error. Most patients benefit from a more extensive resection of the tumor rather than a simple biopsy. Resection can provide immediate relief of mass effect exerted by large lesions and improve response to adjuvant therapy for malignant lesions. Gross total resection is a feasible goal in all patients with benign or encapsulated tumors.

Stereotactic biopsies of pineal region tumors are more complicated and have a reduced margin for error compared with tumors at other locations. The potential for misdiagnosis exists when limited sampling of a heterogeneous tumor occurs [37]. The risk of hemorrhage is increased because of the often vascular nature of the lesion and the proximity of the deep venous system [38,39]. The mortality rate of stereotactic biopsy of a pineal region mass was recently reported to be 1.3%, representing a two- to fourfold increase in risk of death compared with unselected stereotactic biopsies [40,41]. Stereotactic biopsy is generally reserved for patients with multicentric or disseminated disease or for those individuals with medical contraindications to open surgery. In the event that a stereotactic biopsy is warranted, a low frontal trajectory that crosses the posterior limb of the internal capsule and avoids the lateral ventricle is preferred. This approach comes inferior and lateral to the internal cerebral veins and reduces the risk of hemorrhage. Alternatively, a superior parietal lobule approach may be used. This approach crosses two ependymal surfaces in the lateral ventricle and is only recommended for tumors with significant lateral or superior extension.

Radiographic features

MRI with gadolinium enhancement is the diagnostic test of choice for posterior third ventricular tumors (Fig. 1) [42–46]. MRI reveals the degree of hydrocephalus and allows for the evaluation of tumor size, vascularity, homogeneity, and proximity to surrounding structures. The extent of tumor invasiveness can be estimated from the margination and irregularity of the tumor border; however, the true degree of tumor encapsulation only becomes apparent at surgery.

The relation of the tumor to the deep venous system may yield a diagnostic clue and influence

the choice of surgical approach. Pineal tumors generally displace the deep venous system superiorly along the dorsal periphery of the tumor. Notable exceptions are velum interpositum meningiomas arising from the superior leaf of the tela choroidea, anteroventrally directed falctenotorial meningiomas, and dermoids or other lesions arising near the corpus callosum. These tumors displace the deep venous system inferiorly. Despite the high resolution of MRI, tumor histology cannot reliably be predicted based on radiographic features alone. CT can complement MRI by allowing for an assessment of intralesional calcification [47]. Angiography is not necessary unless a vascular anomaly is suspected.

Pineal cell tumors, malignant germ cell tumors, and ependymomas of the pineal region are all prone to CSF dissemination. As such, preoperative spinal MRI screening is suggested, because blood products or operative debris may mimic spinal metastases in the early postoperative period.

Management of hydrocephalus

Pineal region tumors often present with obstructive hydrocephalus resulting either from tectal and aqueductal compression or from direct aqueductal plugging by the lesion. Consideration for CSF diversion is the initial step in clinical management. Patients with only mild asymptomatic hydrocephalus may be managed without a preoperative CSF diversion procedure if it is expected that complete resection of the tumor will restore aqueductal patency. In these instances, a ventricular drain is advisable at the time of surgery. In patients with symptomatic hydrocephalus, an endoscopic third ventriculostomy is desirable because it avoids shunt-related complications, such as infection, overshunting, and peritoneal seeding by malignant cells. Further, if aqueductal patency is restored and hydrocephalus remits, the patient is not rendered shunt dependent.

Anatomy

A thorough understanding of the anatomy of the third ventricle and posterior incisural space is required to plan a surgical approach to lesions situated in and around the posterior third ventricle appropriately (Fig. 2). The third ventricle is divided into anterior and posterior portions in a coronal plane extending through the massa intermedia and

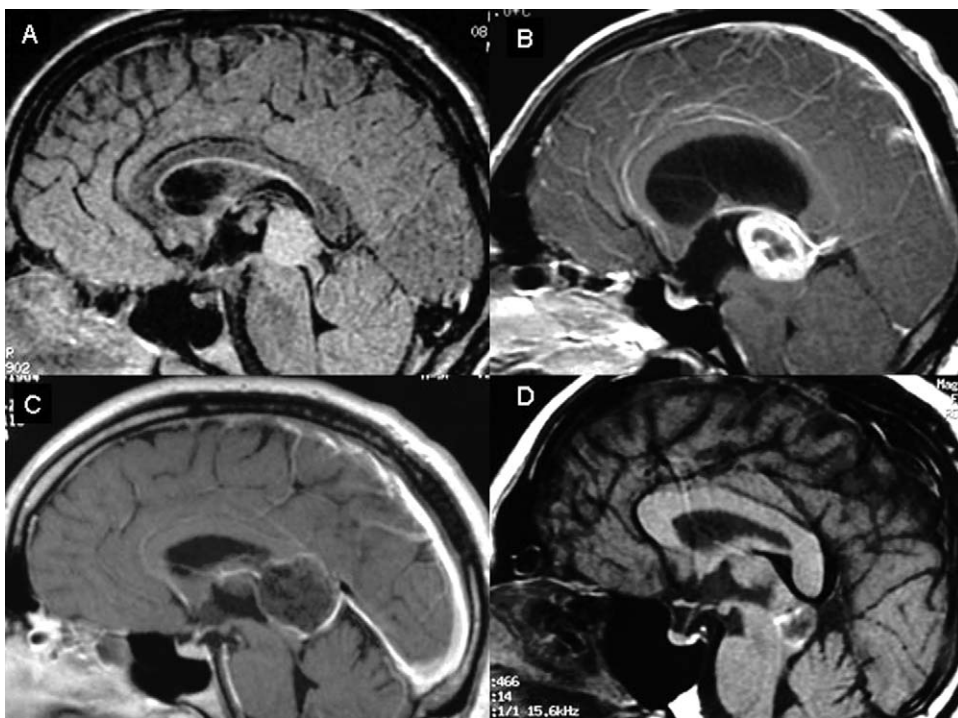


Fig. 1. Midsagittal gadolinium-enhanced MRI. (A) Germinoma with dorsal displacement of internal cerebral veins. (B) Pineocytoma with dorsal displacement of internal cerebral veins. The two lesions are best approached via the infratentorial-supracerebellar or occipital-transtentorial corridor. (C) Epidermoid tumor with ventral displacement of the internal cerebral veins. This lesion is best approached via the posterior-interhemispheric corridor. (D) Tectal glioma with extension into the cerebellomesencephalic fissure. The occipital-transtentorial approach provides the best trajectory to the inferior pole of the tumor.

the mammillary bodies. The posterior third ventricle is bounded by a roof, a floor, two lateral walls, and a posterior wall. The floor is formed by mesencephalic structures extending between the mammillary bodies and the cerebral aqueduct. Viewed from within the ventricle, this surface is smooth and concave. The posterior floor overlies the posterior perforate substance anteriorly and the medial part of the cerebral peduncles and the tegmentum of the midbrain posteriorly [48,49].

The lateral walls of the posterior third ventricle are formed inferiorly by the posterior hypothalamus and superiorly by the thalamus. The thalamic and hypothalamic surfaces are demarcated by the hypothalamic sulcus, an indistinct groove that extends from the foramen of Monro to the aqueduct of Sylvius. The massa intermedia often projects into the upper half of the posterior third ventricle (present in approximately 75% of specimens). The stria medullaris thalami extend from the foramen of Monro to the habenulae along the superomedial surface of the thalamus

and mark the superior limit of the lateral wall of the third ventricle. The teniae thalami, raised ridges along the surface of the stria medullaris, serve as the site of attachment for the inferior leaf of the tela choroidea. The habenulae are small prominences on the dorsomedial surface of the thalamus just anterior to the pineal gland. They receive the stria medullaris thalami and are connected by the habenular commissure in the rostral half of the stalk of the pineal gland [50,51].

The posterior wall of the third ventricle consists of the suprapineal recess, the habenular commissure, the pineal body and recess, the posterior commissure, and the aqueduct of Sylvius. The suprapineal recess extends posteriorly between the pineal gland and the inferior layer of tela choroidea. The pineal gland projects posteriorly into the quadrigeminal cistern from its stalk, which has cranial and caudal laminae. The habenular commissure crosses in the cranial lamina, whereas the posterior commissure crosses

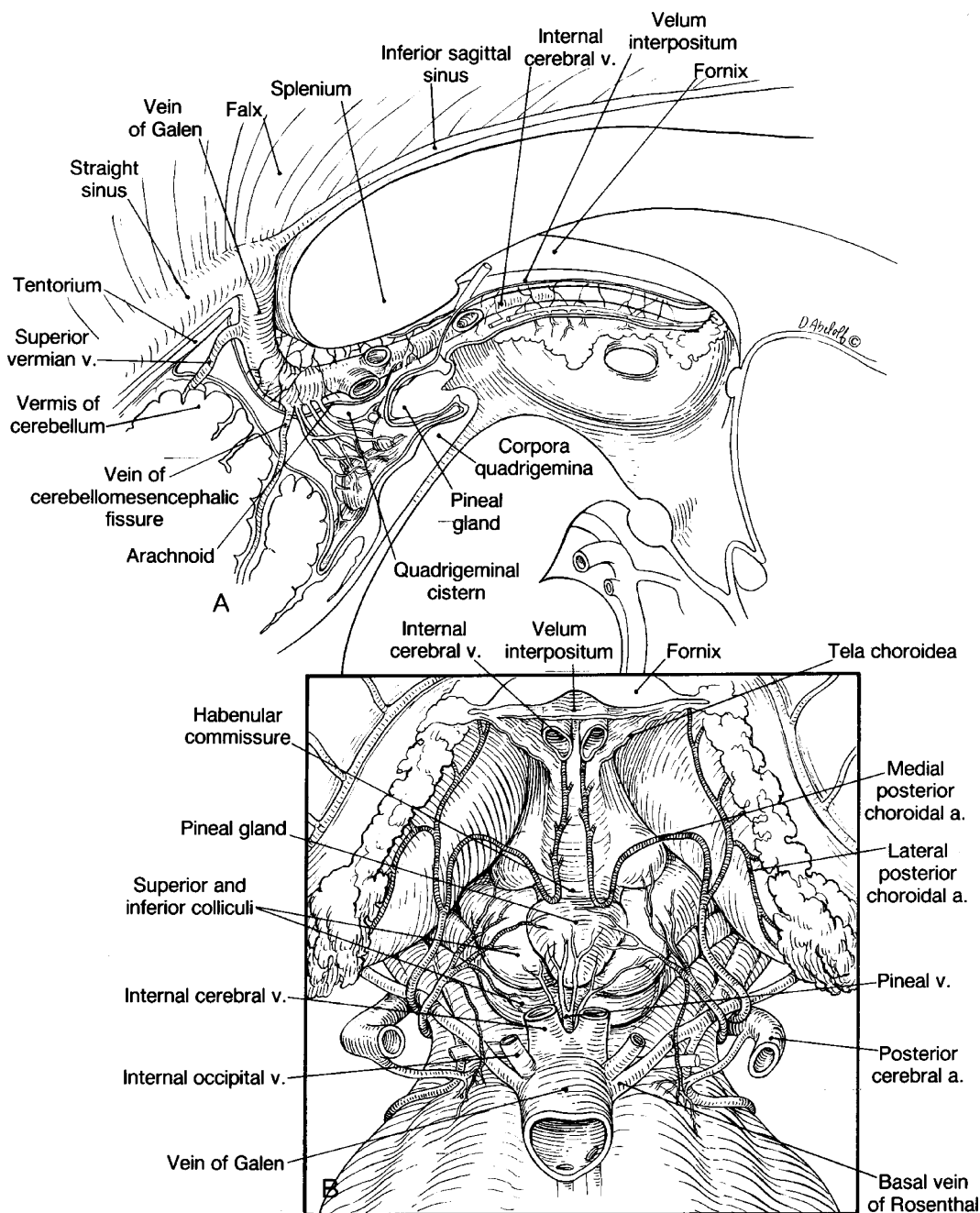


Fig. 2. Sagittal (A) and dorsal (B) views of the anatomy of the third ventricle and pineal region. (From Apuzzo MLJ. *Surgery of the third ventricle*. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 612; with permission.)

in the caudal lamina. The triangularly shaped cerebral aqueduct has its base on the posterior commissure; the other two sides are formed by the gray matter of the midbrain. When viewed

posteriorly, only the pineal body is visible in the quadrigeminal cistern. The gland and the rest of the posterior wall are concealed by the splenium of the corpus callosum above, the thalami

laterally, and the quadrigeminal plate and cerebellar vermis inferiorly [51,52].

The roof of the posterior third ventricle has four layers: the fornices superiorly, two thin membranous layers of tela choroidea, and a potential space between the layers of the tela choroidea called the velum interpositum. The body of the fornix is suspended from the body of the corpus callosum by the septum pellucidum. Posteriorly, the septum wanes and the body divides into crura that are directly attached to the undersurface of the corpus callosum. The superior layer of the tela choroidea is attached to the fornix. The inferior layer of the tela choroidea is attached to the teniae thalami and the pineal body. The velum interpositum harbors the internal cerebral veins and the medial posterior choroidal arteries. Although usually a potential space, it may occasionally communicate with the quadrigeminal cistern. The choroid plexus of the third ventricle is suspended from the inferior leaf of the tela choroidea. The lateral margins of the roof of the third ventricle are composed of the choroidal fissure superiorly and the stria terminalis thalami inferiorly [51,53,54].

Two of the three principal approaches to the posterior third ventricle pass through the posterior incisural space. This anatomically complex area is synonymous with the terms *pineal region* and *quadrigeminal cistern*. The posterior incisural space has an anterior wall, a roof, a floor, two lateral walls, and a posterior apex at the level of the tentorium. The superior portion of the anterior wall is formed by the habenular trigone, the habenular commissure, and the pineal body. The pineal body overlies the quadrigeminal plate of the midbrain, which is formed by the paired superior and inferior colliculi. Inferiorly, the anterior wall is formed by the lingula of the vermis in the midline and the superior cerebellar peduncles laterally. The roof of the posterior incisural space is formed by the splenium of the corpus callosum, the crus of the fornix, and the hippocampal commissure. The floor of this space is delimited by the anterior-superior surface of the cerebellum. This space extends inferiorly into the cerebellomesencephalic fissure. Each lateral wall is formed by the pulvinar anteriorly, the crura of the fornices, and the medial surface of the cerebral hemisphere posteriorly. At the tentorial apex, the quadrigeminal cistern is separated from the superior cerebellar cistern by a thick sheet of arachnoid that contains the precentral cerebellar vein [2,52,55,56].

The posterior incisural space houses the confluence of the deep venous system. The paired internal cerebral veins exit the velum interpositum along the superolateral surface of the pineal body. The union of the internal cerebral veins, forming the great cerebral vein of Galen, may be located above or posterior to the pineal body and inferior or posterior to the splenium. The basal veins of Rosenthal emanate from the ambient cisterns and may be received either by the internal cerebral veins or by the great vein directly. The precentral cerebellar vein emanates from the cerebellomesencephalic fissure and drains directly into the vein of Galen. It often receives the superior vermian vein. After the great vein is formed, it ascends in a superoposterior direction to join the straight sinus at the falcotentorial junction [52,54,55].

Selection of a surgical approach

The typical pineal region mass is located in the midline below the tentorial apex and displaces the deep venous system superiorly. These anatomic features give the infratentorial-supracerebellar approach several natural advantages (Fig. 3) [57]. The approach provides a midline trajectory that is ventral to the velum interpositum and deep venous system. The corridor between the cerebellum and the tentorium does not violate any normal tissue, and the ability to use the sitting position minimizes venous bleeding and facilitates dissection of the tumor from the deep venous system. In cases where the torcula is low lying or the lesion has significant lateral or supratentorial extension, the occipital-transtentorial approach in either the sitting or three-quarter prone position is preferred. This approach provides the widest exposure of both the supra- and infratentorial compartments. This approach is also useful if the tumor has significant inferior extension into the cerebellomesencephalic cistern; tumor in this cistern would be out of view if approached via the infratentorial corridor. For lesions that are truly in the posterior third ventricle and do not extend posterior to the splenium of the corpus callosum, the interhemispheric-transcallosal approach in the lateral position is useful. This approach follows the shortest route to the lesion and has the advantage of working anterior to the confluence of the deep venous system.

Patient positioning

Numerous patient positions have been described for approaching the pineal region and

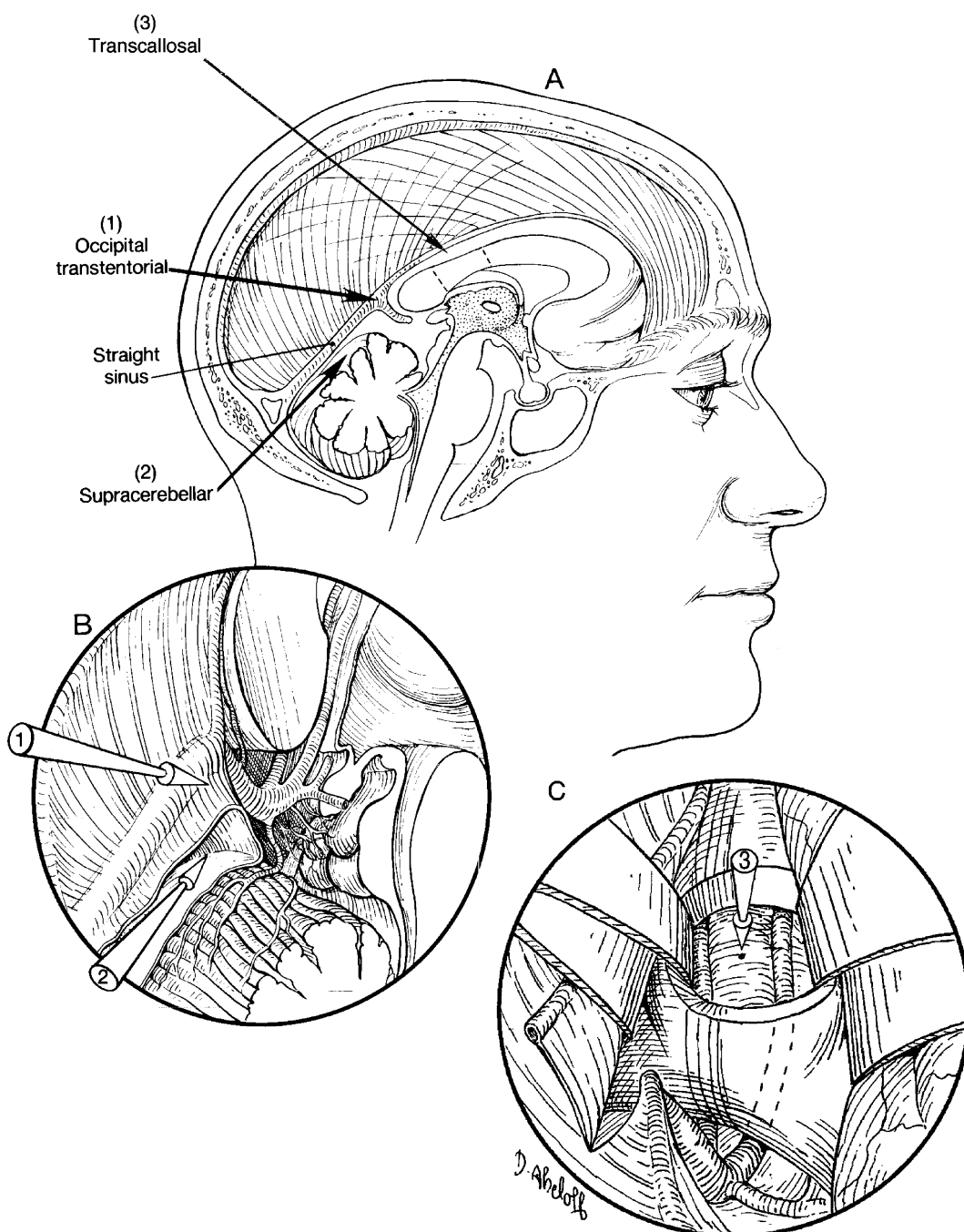


Fig. 3. Principal approaches to the posterior third ventricle and pineal region. Midsagittal (A) and trajectory (B) views along the operative corridors (arrows) provided by the occipital-transtentorial (1), infratentorial-supracerebellar (2), and interhemispheric-transcallosal (3) approaches. (*Adapted from Apuzzo MLJ. Surgery of the third ventricle. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 600; with permission. Adapted from Kaye A, Black P. Operative neurosurgery. London: Churchill Livingstone; 2000. p. 832; with permission.*)

posterior third ventricle. Each position offers advantages and disadvantages in terms of surgeon comfort, possible complications, and compatibility with the proposed operative corridor.

The sitting position

The sitting position is preferred for the supracerebellar-infratentorial approach and is also suitable for the occipital-transtentorial approach (Fig. 4). The position is initiated with the patient placed supine on a reversed motorized operating table. The head is grasped bitemporally with a three-point pin fixation device. The surgeon supports the head, and the table is manipulated to obtain a C-shaped configuration between the patient's head and knees. To do so, the table is brought into the Trendelenburg position with the back elevated and the foot slightly reclined, which achieves hip flexion. The patient's legs are slightly elevated to assist with venous return. The neck is then flexed to bring the tentorium parallel to the floor while maintaining two fingers' breadth between the patient's chin and sternum. The headholder is then rigidly fixed to a U-shaped bar extension mounted to the midsection of the operating table.

The operating microscope is vital to the success of the procedure. The microscope is balanced with the objective parallel to the floor. A variable focal length objective is recommended, but a 275-mm fixed focal length lens provides adequate space

between the objective and the field to permit insertion of the long instruments that are required. The eye pieces should be rotated slightly upward to avoid cervical hyperextension for the surgeon.

The principal advantage of the position is that gravity aids with cerebellar retraction and dissection of the tumor off the deep venous system. Additionally, blood and CSF flow out of the operative field rather than pool in a field that is in a dependent position. Surgeons who are unfamiliar with the position may find the elevated operative field uncomfortable to work in. A freestanding table or chair-mounted armrest is essential to reduce arm fatigue, because the surgeon's forearms are in a nearly vertical position. Most surgeons rest their elbows or proximal forearms on the armrest and their wrists on the edge of a suitable self-retaining retractor frame.

Potential complications of the position include air embolism [58], pneumocephalus [59,60], supratentorial hemorrhage [61], midcervical flexion myelopathy [62,63], and shunt malfunction [64]. Precordial Doppler monitoring and constant monitoring of end-tidal Pco₂ can detect small amounts of entrained air before it becomes problematic [65]. The risk of air embolism is greatest during the craniotomy and dural opening. All cut bone surfaces must be meticulously waxed, and venous bleeding must be controlled before proceeding with deeper dissection. Some

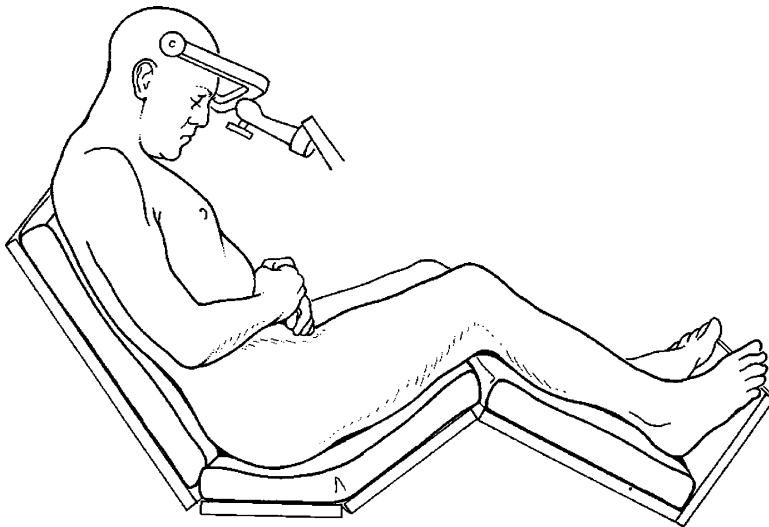


Fig. 4. The sitting position. (From Kaye A, Black P. *Operative neurosurgery*. London: Churchill Livingstone; 2000. p. 770; with permission.)

anesthesiologists prefer a central venous catheter for attempting to aspirate air from the right atrium in the event that a significant air embolism is detected, but the utility of this maneuver is quite limited [66].

The lateral position

Several variations of the lateral position exist (Figs. 5 and 6). In the lateral decubitus position, the nondominant right hemisphere is placed in a dependent position [67]. For the interhemispheric-transcallosal approach, the falx is positioned parallel to the floor and the head is then brought into 30° of left lateral flexion. This maneuver allows gravity to retract the nondominant hemisphere while the falx supports the dominant hemisphere. For the occipital-transtentorial approach, the head is rotated with the nose 30° toward the floor. A more desirable variation of this position is the three-quarter prone position [68]. To obtain this position, the patient is rotated from the supine position to rest on a supporting roll for the left hemithorax. The right arm is supported in a sling-like fashion beneath the patient. A right axillary roll is used to avoid traction on the brachial plexus. A three-point pin fixation device supports the head in a slightly extended position with the nose pointing 45° to the left of perpendicular to the floor. The patient is securely strapped to the table so that it can be rotated to gain additional exposure when necessary. The patient's legs are elevated slightly to improve venous return. Although this position is cumbersome to set up, many surgeons find it more comfortable than the sitting position, because the surgeon's hands work in the horizontal plane and do not need to be extended.

The prone position

The prone position is simple, safe, and suitable for supratentorial approaches (Fig. 7). The steep angle of the tentorium makes the position impractical for the infratentorial approach. The prone position is particularly useful in the pediatric population. The position is generally comfortable for the surgeon, although the operative field is considerably elevated, making it difficult for the surgeon to be seated. Using a microscope in a bridge configuration allows two surgeons to work together with simultaneous binocular vision. The Concorde position [69,70], a variation of the prone position in which the head is rotated 15° away from the side of the craniotomy, is particularly useful for the occipital transtentorial approach. Disadvantages of prone approaches are that venous drainage is not facilitated because of the dependent operative field and the brain tends to collapse into the tumor bed during the dissection.

Operative approaches

Infratentorial-supracerebellar approach

The infratentorial-supracerebellar approach was first described by Krause [71] in 1926. The technique was abandoned for many years because of unacceptable morbidity but was successfully reintroduced by Stein [57] in 1971 after the advent of the microsurgical era.

The infratentorial-supracerebellar approach is usually performed with the patient in the sitting position (Fig. 8) [34,72]. If a ventriculostomy is indicated, a catheter may be passed into the trigone of the lateral ventricle through a burr hole

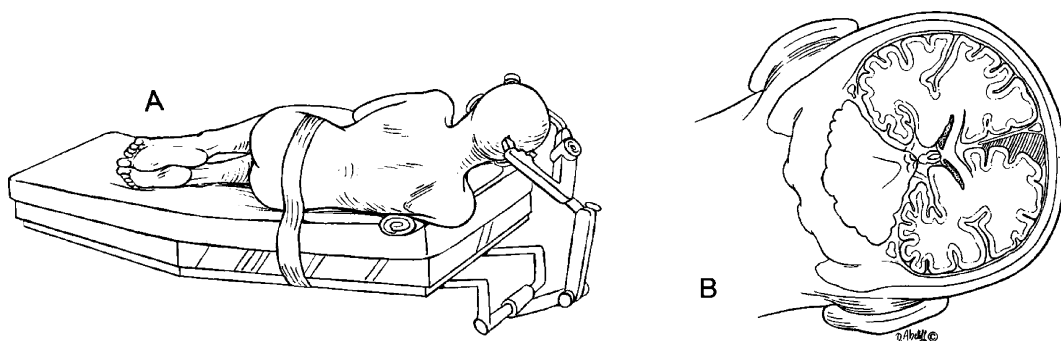


Fig. 5. (A) The lateral position with 30° of lateral flexion. (B) Coronal section demonstrates retraction of the dependent hemisphere by gravity and support of the opposite hemisphere by the falx. (Adapted from Apuzzo MLJ. *Surgery of the third ventricle*. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 624–5; with permission.)

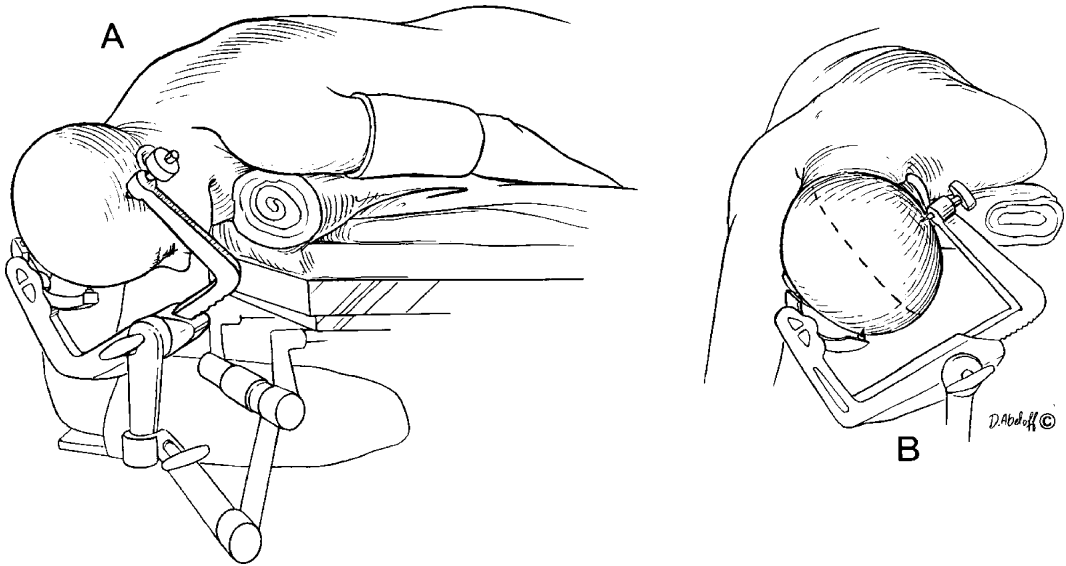


Fig. 6. The three-quarter prone position. (Adapted from Apuzzo MLJ. *Surgery of the third ventricle*. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 627; with permission.)

placed at the intersection of the midpupillary line and the lambdoid suture. The exposure begins with a midline incision extending from approximately 6 cm above the external occipital protuberance to the level of the C4 spinous process. The suboccipital musculature is dissected through the avascular nuchal ligament and retracted laterally, usually with a single curved self-retaining retractor placed from above. The suboccipital plate is exposed to a level just above the foramen magnum; the suboccipital muscles inserting on the spinous processes of C1 and C2 are left undisturbed. The craniotomy is centered just below the torcula. The bony opening must be adequate to allow sufficient illumination from the operating microscope and to provide access for the long surgical instruments that are employed. A craniotomy is preferred over a craniectomy because it reduces the incidence of aseptic meningitis, fluid collections, and posterior fossa syndrome [73]. Slots are drilled over the superior sagittal sinus approximately 2 cm above the external occipital protuberance, over the transverse sinus 3 to 4 cm off the midline, and over the occipital sinus 1 to 2 cm above the foramen magnum. A craniotome is used to connect the slots, and the rectangular bone flap is elevated. There should be sufficient bone removal above the transverse sinus to ensure that the view along the tentorium is not obscured. Bone edges should be waxed meticulously, and all venous bleeding should be controlled to protect

against air emboli. The dura is then palpated to assess the intracranial pressure in the posterior fossa. If the dura is tense, CSF may be released from the ventricular drain or the foramen magnum and mannitol may be administered.

A semilunar durotomy is created by beginning at the lateral aspects of the exposure and working toward the falx cerebelli and occipital sinus. If the occipital sinus is patent, it may be divided between titanium clips. The falx cerebelli is then divided, and the occipital sinus is secured with silk ligatures. The dural flap is reflected superiorly and placed in slight tension with tenting sutures suspended from rubber bands attached to the retractor frame. Excess retraction may occlude the transverse sinuses and should be avoided. Cauterizing and dividing arachnoid adhesions and bridging veins between the dorsal surface of the cerebellum and the tentorium open the infratentorial corridor to the pineal region. Extensive collateral circulation in the posterior fossa minimizes the risk of complications from venous sacrifice [74]. Care must be taken not to divide bridging veins too close to the tentorial surface, because subsequent dural bleeding can be difficult to control with cautery. When these attachments are divided, the cerebellum drops away from the tentorium, providing an excellent corridor with minimal retraction. The dorsal surface of the cerebellum is protected with padding (eg, Telfa, The Kendall Compant,

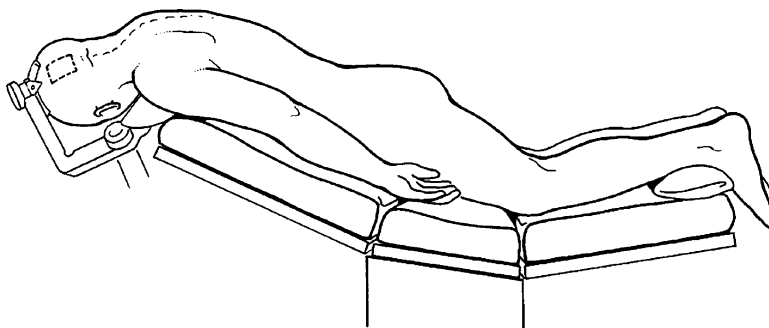


Fig. 7. The prone position. (From Kaye A, Black P. *Operative neurosurgery*. London: Churchill Livingstone; 2000. p. 613; with permission.)

LTD., Mansfield, MA). A small malleable retractor is used to provide additional cerebellar retraction in a posterior and inferior direction. Additional adhesions and bridging veins near the anterior vermis may be encountered as the cerebellum is retracted; they, too, are cauterized and retracted.

Deeper dissection is performed under the microscope. A freestanding armrest is useful at this point to support the surgeon's arms in an outstretched position. The opalescent arachnoid of the quadrigeminal cistern is recognized and opened using an arachnoid knife, long bayonet scissors, and irrigating bipolar cautery. The precentral cerebellar vein is encountered in the midline extending from the anterior vermis up to the vein of Galen; it can be cauterized and divided with minimal risk. In the case of a pineal region mass, the posterior aspect of the tumor can now be visualized. Small branches of the choroidal and superior cerebellar arteries often cover pineal region tumors. Although these vessels may be taken with impunity, it is essential to avoid damaging the vessels of the deep venous system. The trajectory up to this point has been in line with the vein of Galen. Because further pursuit of this trajectory leads to damage of the vein of Galen and the confluence of the deep venous system, the trajectory must be redirected several degrees inferiorly such that it is in line with the center of the lesion. With the quadrigeminal arachnoid opened, cerebellar retraction can be maximized. Typically, it is only necessary to retract the cerebellum until the inferior portion of the tumor is visualized. This goal is facilitated by widely opening the arachnoid laterally where the cerebellum is tethered.

The tumor is initially internally debulked through its posterior surface. Specimens are taken

from within the capsule and sent for frozen section examination. The accuracy of frozen tissue diagnosis may be unreliable, and this fact should be taken into consideration during intraoperative decision making regarding the extent of resection. Internal debulking then continues with a variety of instruments, such as suction, cautery, cupped forceps, and ultrasonic aspiration. Most tumors are of a soft consistency that is amenable to removal with pressure-adjustable macrosuction. After an adequate internal decompression has been achieved, the capsule can be separated from the surrounding thalamus. Most vessels along the capsule wall are of choroidal origin and need not be preserved. The lateral or central dissection eventually leads to the third ventricle, which becomes apparent as CSF floods the operative field. The tumor is then dissected off the midbrain. This maneuver is often the most difficult portion of the tumor dissection and can be facilitated by retracting the tumor superiorly and bluntly dissecting the mass off the collicular plate under direct vision. The final tumor attachment is superiorly along the velum interpositum and deep venous system. Although these attachments are cauterized and sharply divided, a rent in the deep venous system must be avoided. Bleeding from the deep venous system is profuse, usually only controllable by direct tamponade, and often heralds disastrous consequences for the patient.

An experienced surgeon can appreciate the degree to which a tumor is invasive or encapsulated. Invasive tumors cannot be completely resected without significant morbidity. Some malignant lesions exhibit pseudoencapsulation that can be exploited for radical removal. Although radical removal reduces the risk of postoperative hemorrhage and improves the efficacy of adjuvant therapy with regard to tumor

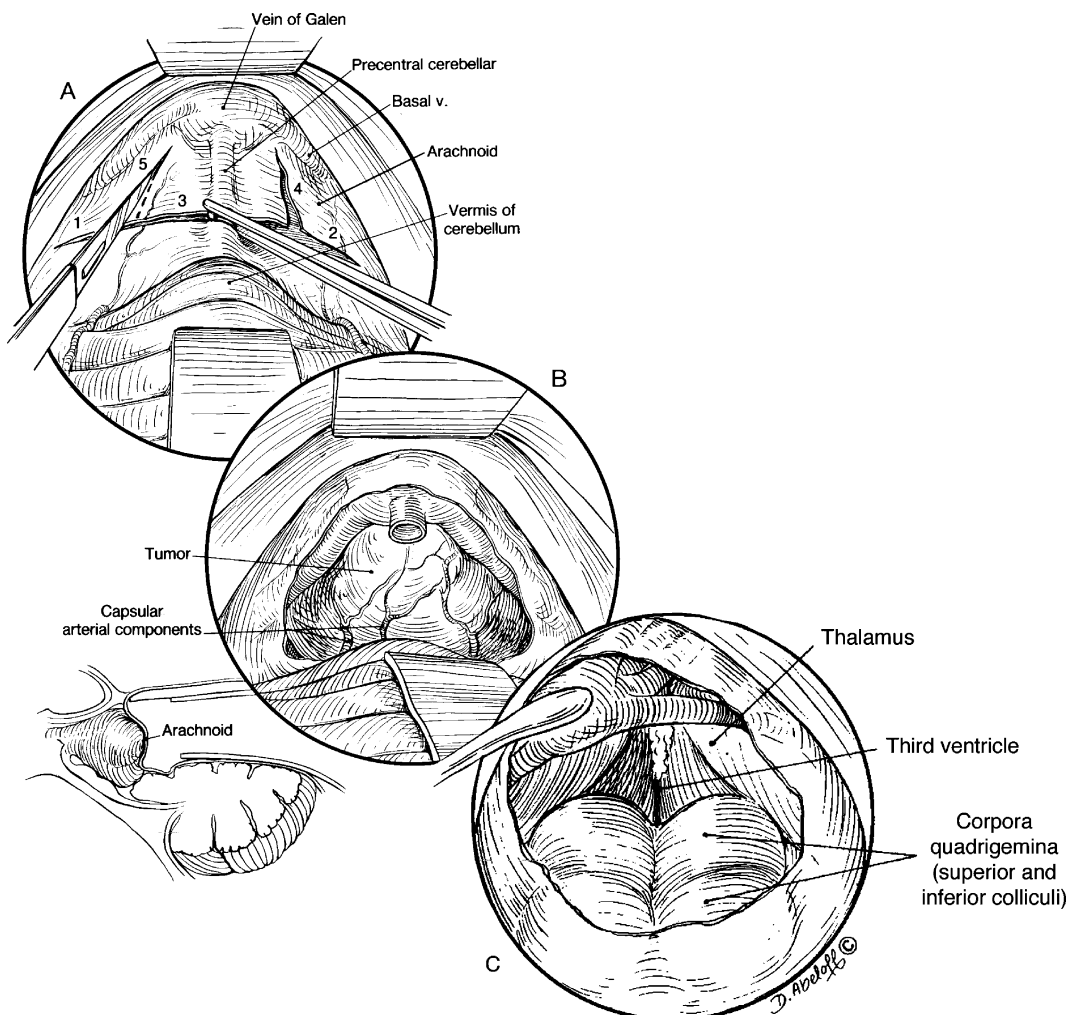


Fig. 8. Infratentorial-supracerebellar approach. (A) Numeric sequence of incisions of regional arachnoid; the precentral cerebellar vein is sacrificed to permit further relaxation of the anterior vermis. (B) Exposure of a pineal tumor with the basal veins and vein of Galen overlying the mass. (C) View into the posterior third ventricle after tumor removal. (Adapted from Apuzzo MLJ. *Surgery of the third ventricle*. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 582, 586; with permission.)

recurrence, its impact on long-term survival remains debatable.

After tumor removal, the surgeon has an excellent view into the posterior third ventricle. A flexible mirror may be used to inspect the inferior portion of the tumor bed and to examine the orifice of the cerebral aqueduct. Meticulous hemostasis must be obtained, because there is little tissue turgor to tamponade bleeding in the tumor bed [64]. Direct low-intensity cautery is the method of choice. Extensive use of hemostatic agents should be avoided because they may float

into the ventricle and cause obstructive hydrocephalus, shunt malfunction, or chemical meningitis. If necessary, long strips of Surgicel (Ethicon, Somerville, NJ) draped over the surface of the cerebellum and onto the tumor bed can provide hemostasis at minimal risk.

After hemostasis is obtained, an attempt is made to close the dura in a watertight fashion. The craniotomy flap is secured with titanium miniplates. As a general rule, the more complete the dural and bone flap closure, the lower is the risk of postoperative headaches and wound

complications. To avoid excessive brain shift, the patient should be extubated and maintained with a significant degree of head elevation and flexion.

Interhemispheric-transcallosal approach

First described by Dandy in 1921, the interhemispheric-transcallosal approach established a corridor between the falx and the hemisphere along the parieto-occipital junction [75]. Dandy's early contributions to this approach recognized the importance of the deep venous system and the cortical bridging veins between the hemisphere and the superior sagittal sinus [76]. This approach can be used in a variety of patient positions, but the lateral or three-quarter prone position is generally preferred (Fig. 9).

The positioning of the bone flap depends on where the tumor is positioned within the third

ventricle [77]. A wide craniotomy, approximately 8 cm in length, provides flexibility in identifying a corridor that minimizes the sacrifice of bridging veins. Although a variety of skin incisions may be used, a U-shaped flap extending across the midline and reflected laterally provides adequate exposure. The craniotomy is centered over the vertex with the inferior margin being 2 cm above the apex of the lambdoid suture. Slots are drilled over the superior sagittal sinus anteriorly and posteriorly, and a craniotome is used to turn a generous biparietal craniotomy that is usually eccentric to the nondominant hemisphere. It is important that 1 to 2 cm of bone be removed on the dominant side to facilitate operative illumination. Bleeding from the sinus may be brisk but is nevertheless under low pressure and easily controlled with hemostatic agents.

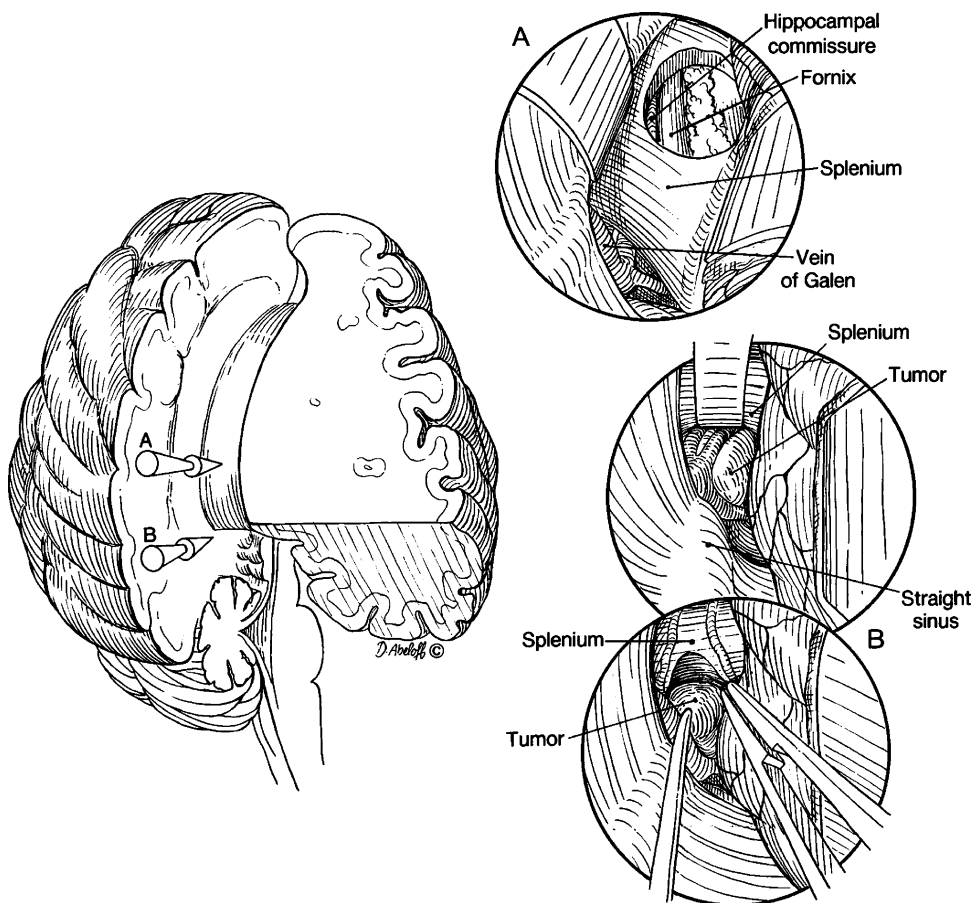


Fig. 9. Options for tumor exposure using the posterior interhemispheric corridor. (A) Transcallosal approach. (B) Retrocallosal and transsplenial variations employing a slightly more posterior trajectory. (Adapted from Apuzzo MLJ. *Surgery of the third ventricle*. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 617; with permission.)

A U-shaped durotomy is reflected medially with its base on the sinus. The bridging veins are inspected, and an approach is chosen that minimizes the number of veins scarified. The depth of the operative corridor allows for several possible angles of approach through a small superficial opening; the optimal corridor for a given patient features as a trajectory that is as close to perpendicular to the corpus callosum as possible. It is unlikely that sufficient exposure can be achieved without sacrificing one bridging vein, but sacrificing more than one increases the risk of cortical venous infarction and should be avoided if possible. The exposed hemisphere is protected with Bicol (Codman, Piscataway, NJ) or Telfa, and two malleable retractors are used to mobilize the parietal lobe laterally in a gentle arc. A third retractor may be used along the falx, which may be divided inferiorly to gain additional exposure. There are generally no adhesions between the medial hemispheric surface and the falx within the interhemispheric fissure, although the cingulate gyri may adhere to each other below the falx. The remainder of the dissection is performed under the microscope.

The cingulate gyri are separated, and the corpus callosum is identified by its striking white appearance. The paired pericallosal arteries are noted and, depending on their location, may be retracted to one side or to each side with separate retractors. The corpus callosum may be attenuated over the tumor, and a bulge in its dorsal surface may reveal the location of the tumor. MRI-based frameless stereotactic guidance may be helpful for positioning the callosotomy. A 2-cm opening in an anterior-posterior direction is sufficient to remove most tumors. The lateral extent of the opening is less critical and need only be limited by what is sufficient to resect the tumor without injuring the pericallosal arteries. In most cases, the corpus callosum is relatively avascular and can be opened with cautery and gentle suction. A 2-cm opening in the posterior body of the corpus callosum is not likely to lead to cognitive impairment or a disconnection syndrome. Section through the splenium, although acceptable in most patients, produces a left hemi-alexia in some. Splenial section combined with a left occipital injury or any lesion producing a right hemianopsia leads to alexia without agraphia, a severely disabling disconnection syndrome for patients with any degree of literacy [78].

The retractors are now shifted to retract the medial and lateral margins of the callosotomy. The dorsal surface of the tumor is visualized through

the tela choroidea. This layer is opened, and a small biopsy is taken for frozen tissue diagnosis. It is important to identify and preserve the internal cerebral veins early in the dissection. Lesions in this region tend to displace the internal cerebral veins off the midline favorably, although they are occasionally found overlying the tumor in the midline separated by only a few millimeters of connective tissue. It is usually possible to separate the two veins and displace them laterally; however, if it is absolutely necessary, one may be divided. Once the deep venous system has been appreciated, internal debulking may proceed as described for the supracerebellar-infratentorial approach. In patients with large masses or significant hydrocephalus, surprisingly little dissection may be needed to enter the third ventricle; with small lesions and little hydrocephalus, the third ventricle is encountered deep within the operative corridor. As the tumor is removed, the entire content of the third ventricle is available for inspection; the foramen of Monro and the aqueduct of Sylvius provide familiar landmarks. Care must be taken not to damage the anterior roof of the third ventricle, where the bodies of the fornices are located. The degree of difficulty in attempting a complete resection is determined in part by the tumor's point of origin. Exophytic tumors of the thalamus must be pursued with caution. Tumors stemming from the pineal gland itself or from the velum interpositum may be resected more aggressively.

Occipital-transtentorial approach

The occipital-transtentorial approach was originally described by Jamieson [79] in 1971. Although the procedure may be performed in the sitting position, the three-quarter prone position is generally preferred, because gravity helps to retract the occipital lobe. In almost all cases, the exposure is between the right occipital lobe and falx cerebri. A right-sided approach protects the dominant visual cortex from the potential for retraction injury. The principal anatomic advantage of this approach is that no bridging veins cross from the occipital lobe into the superior sagittal sinus [80]. This fact limits the risk of cortical venous infarction that accompanies the interhemispheric approach as long as the inferior cerebral vein is preserved. Although this vein drains much of the occipital lobe, it usually lies in a safe harbor lateral to the operative exposure. Division of the tentorium provides excellent exposure of the collicular plate, thus making the approach well suited for tumors with substantial

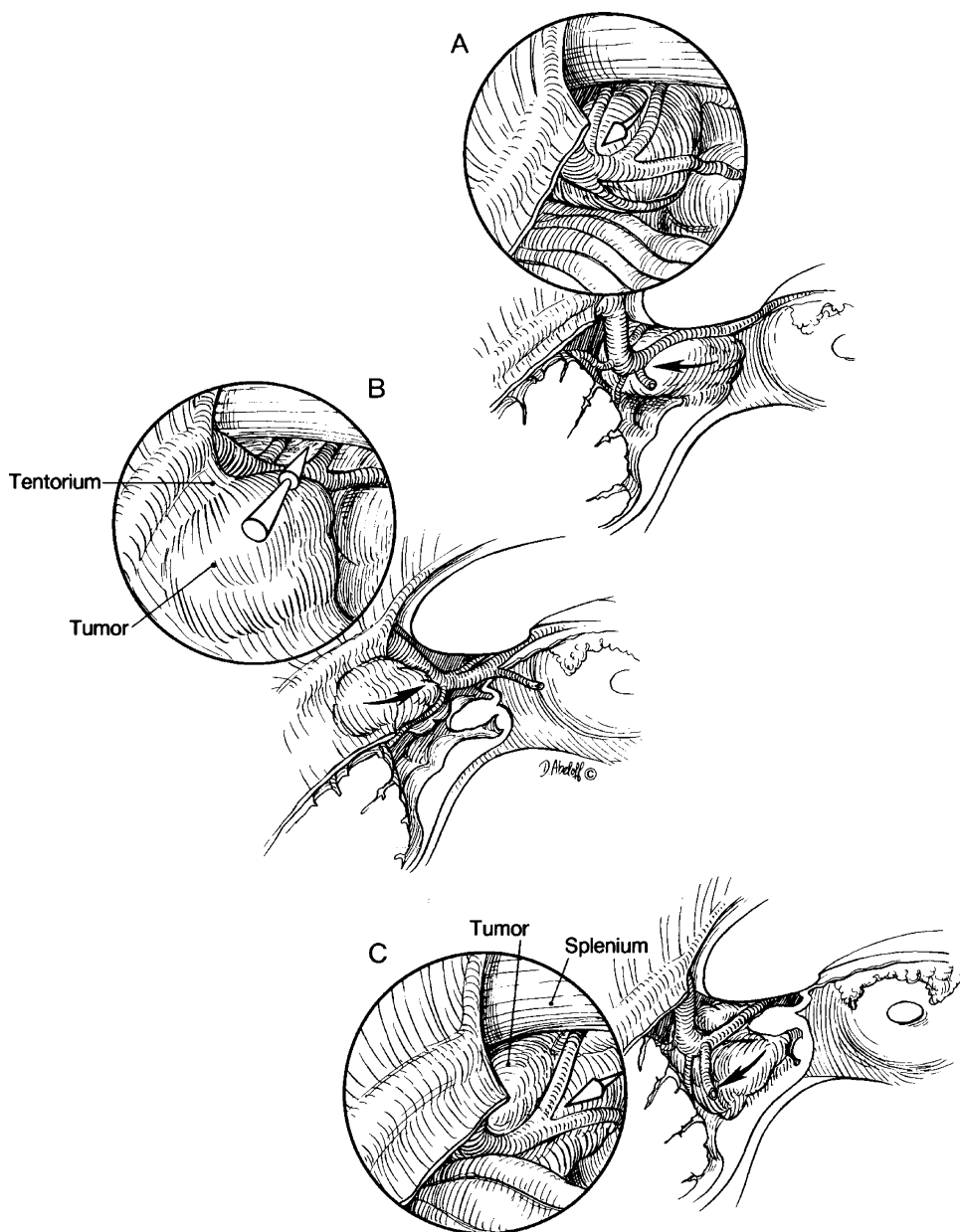


Fig. 10. Occipital-transtentorial approach. The location of the deep venous system when the tumor arises from the pineal gland (A), the falcotentorial junction (B), and the quadrigeminal plate (C). (Adapted from Apuzzo MLJ. *Surgery of the third ventricle*. 1st edition. Baltimore: Williams & Wilkins; 1987. p. 603; with permission.)

inferior extension. A potential disadvantage of the approach is that it uses an oblique trajectory for lesions that are essentially midline, creating the potential for the inexperienced surgeon to become disoriented. As with other approaches to the pineal region, mannitol and ventricular drainage are useful for gaining brain relaxation.

The approach is initiated with a U-shaped right occipital scalp flap that is reflected inferiorly. The medial limb of the incision is placed just to the left of the midline, beginning at the level of the torcula. A slot is drilled across the superior sagittal sinus just above the torcula, and a second slot is drilled 6 to 10 cm higher in the midline. A craniotome is

used to turn a generous craniotomy extending 1 to 2 cm across the midline. The dura may be opened as a U-shaped flap based on the sagittal sinus or as a pair of triangular leaves based on the sagittal sinus and the inferior margin of the craniotomy.

Dissection within the occipital corridor is performed under the microscope. With gravity retracting the occipital lobe, the straight sinus is identified and the tentorium is divided adjacent to it. The initial incision is made near the junction of the straight sinus and the torcula and is carried forward toward the incisura. The tentorium may contain venous channels that can be controlled with bipolar cautery or hemoclips. A retractor can be placed on the falx to gain additional exposure; the falx and inferior sagittal sinus may be divided to gain further exposure. Retention sutures may be placed on the cut tentorial edge to retract it laterally. At this point, the arachnoid overlying the tumor, the galenic system, and the quadrigeminal cistern are visualized.

The arachnoid over the pineal region is dense, and great care must be taken not to injure the deep venous system during the dissection. The dissection is performed sharply with an arachnoid knife and microscissors. The vein of Galen is usually encountered first, followed by the right basal vein of Rosenthal, the internal cerebral veins, and the precentral cerebellar vein. A right-sided arachnoid dissection is often sufficient to resect the lesion; left-sided dissection and division of the precentral cerebellar vein may be added for a more generous exposure. Once the arachnoid dissection is complete, lesions of the superior vermis, collicular plate, posterior third ventricle, pineal gland, and splenium are readily accessible.

Most of the aforementioned lesions displace the deep venous system posteriorly and superiorly toward the surgeon. This arrangement facilitates identification of the deep veins and necessitates that tumor dissection proceed between them. In contrast, lesions that arise from the posterior leaf of the tela choroidea, the free edge of the tentorium, or the falcotentorial junction displace the galenic system anteriorly or inferiorly and out of the surgeon's view. In this case, the tumor must be internally debulked, knowing that these critical veins are located just beyond the deep capsule. After an adequate decompression is achieved, the tumor capsule may be cautiously dissected and the underlying veins identified. Generally speaking, capsular dissection should begin laterally and inferiorly and proceed medially and superiorly. The tumor type, specific location, and degree of

invasiveness determine the degree of resection that can be achieved (Fig. 10).

Intraoperative tumor management

For the typical pineal region tumor, the lesion should be biopsied and a frozen section diagnosis obtained. When a germinoma is identified, the value of aggressive resection is controversial, given the radiosensitivity of this tumor, and this must be considered when deciding how much tumor to remove. For invasive tumors, such as glioma of the brain stem or thalamus, debulking should proceed cautiously, because a gross total resection may be associated with a high likelihood of incurring a neurologic deficit. Re-establishing the CSF circulation is a reasonable goal.

With benign tumors (eg, teratoma, well-differentiated pineocytoma, pilocytic astrocytoma, dermoid), the surgeon must strive for a gross total resection in either piecemeal or en bloc fashion. If a total resection is achieved, the third ventricle should be inspected to ensure that there is no obstruction of the CSF circulation.

If the lesion is a meningioma of the velum interpositum or the tentorium, a complete resection is desirable. These tumors are usually benign in their behavior; accordingly, the surgeon must rely on good judgment when efforts to achieve a total resection may threaten the patient's neurologic function.

If the lesion extends inferiorly under the superior cerebellar vermis, this structure may be divided to facilitate dissection and removal of the mass. If the tumor extends superiorly into the splenium, it may be possible to mobilize the capsule without sacrificing the splenium. If unavoidable, the splenium may be divided, but restraint should be exercised, because a partial disconnection syndrome may follow.

Dissection may proceed toward a goal of total resection as long as the surgeon can identify a plane between the tumor and surrounding normal structures. The adequacy of a subtotal resection is a matter of judgment and experience. Possible goals of a subtotal resection beyond diagnosis include cytoreduction in preparation for adjuvant therapy, relief of mass effect, and re-establishment of the CSF circulation.

Postoperative care

The most significant immediate problems include bleeding within the tumor bed, hydrocephalus, shunt malfunction, pneumocephalus, and

subdural hematoma [64]. All these are potentially reversible problems; thus, vigilant clinical examination and a low threshold for obtaining a postoperative CT scan are warranted. Tumor bed hemorrhage is usually only seen in patients with invasive tumors that are subtotally resected. De novo hydrocephalus may arise as a result of operative debris within the third ventricle; likewise, such debris may lead to a shunt malfunction or failure of a third ventriculostomy. Pneumocephalus is a frequent consequence of the sitting position that may lead to postoperative confusion, but its course is generally self-limiting [59]. Subdural hematomas may occur from shifting of the brain within the cranial vault and tearing of bridging veins. Most often associated with the sitting position, acute postoperative subdural hematomas generally need to be evacuated. In contrast, hygromatous collections can usually be managed conservatively.

Patients should remain on high-dose steroids until their clinical condition is stable. Generally a 2-week Dexamethasone (Decadron) taper is advisable. A slow steroid taper also mitigates against the development of aseptic ventriculitis. Patients who have undergone supratentorial approaches benefit from perioperative seizure prophylaxis, although long-term use of antiepileptic agents is not warranted.

Complications

Most patients display some degree of impairment of extraocular movements, particularly upgaze and difficulty with convergence [81]. Any preoperative oculomotor deficit should be expected to be exacerbated by the surgery. Fortunately, these problems are generally transient and tend to resolve over weeks to months. Permanent deficits are rare, although a mild limitation of upgaze may persist, usually with limited clinical consequences.

Complications resulting from brain retraction may occur with all three approaches. After the supracerebellar-infratentorial approach, a brief period of ataxia may occur. Rarely, cerebellar infarction has been observed [74]. In the parietal region, brain retraction during the transcallosal approach may lead to contralateral sensory deficits or, rarely, to hemiparesis. Sacrifice of bridging veins may lead to cortical infarction, particularly if more than one vein is taken. Occipital lobe retraction during the transtentorial approach may result in cortical visual field deficits [81].

Disconnection syndromes may occur if the splenium is divided [78].

Summary

A variety of surgical approaches to the posterior third ventricle and pineal region exist. The choice of approach is influenced by the exact location of the lesion, its expected pathologic findings, and the comfort level of the operating surgeon with the approach that is being considered. For most pineal region masses that are situated in the midline below the deep venous system, we favor the supracerebellar-infratentorial approach in the sitting position. For pineal region lesions that displace the deep venous system inferiorly or have significant lateral extension, we prefer the occipital-transtentorial approach in the three-quarter prone or sitting position. For lesions that are truly in the posterior third ventricle without extension posterior to the splenium, we prefer the interhemispheric-transcallosal approach in the lateral position.

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