Subfrontal Approach

21

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21.1 Indications

Meningiomas arising in the midline of the anterior skull base (ASB) are generally separated in two main groups: (1) ventral ASB including the olfactory groove meningiomas and (2) dorsal ASB including the planum sphenoidale and tuberculum sellae meningiomas.

Among the different neurosurgical approaches commonly used for the management of ASB meningiomas, the subfrontal route, either in unilateral or bilateral fashion, is one of the most versatile and routinely performed. Indeed, using such route, it is possible to obtain an excellent midline orientation in order to expose the cribriform plate, the orbital roof, and the sellar, suprasellar, and parasellar areas.

The indications for a subfrontal approach to midline ASB meningiomas were firstly highlighted more the 100 years ago by Horsley [1] and Cushing [2]; afterward, Tönnies [3] described the first bifrontal craniotomy, with division of the anterior sagittal sinus and falx, with the aim of preserving the frontal brain tissue. Since then many advancements have been made in the development of this approach.

More recently, some other authors continue to use the bifrontal approach only for large meningiomas of the anterior cranial fossa, namely, Al-Mefty [4], Nakamura et al. [5], and Ransohoff [6]. The specific indications for a subfrontal bilateral approach are principally linked with the dimension of the tumor; as a matter of fact, this route is generally selected for large meningiomas involving the superior sagittal sinus due to the fact that this pathway gives direct access to both sides of the neoplasm. The direct access to the entire ASB and the opportunity to manage the sagittal sinus involvement and the possibility to create a large vascularized periosteal flap for reconstruction are key aspects to be considered when selecting a subfrontal bilateral approach. Moreover, retraction on the frontal lobes is usually minimal due to the ligation of the anterior aspect of the superior sagittal sinus.

On the other hand, the proposed surgical strategy for the unilateral subfrontal approach is quite

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P. Cappabianca et al. (eds.), *Midline Skull Base Surgery*, DOI 10.1007/978-3-319-21533-4_21

different from the bilateral one, and, actually, it represents the preferred route in many institutions, including our department. Historically, the unilateral subfrontal approach was firstly described in 1910, and, subsequently, Mc Arthur [7], Frazier [8], Krause [9], and, finally, Harvey Cushing [10] popularized this route. Regarding the specific indications, the unilateral subfrontal approach is preferred if the meningioma grows prominently on one side and does not possess an extensive basal dural attachment onto the contralateral side. However, this unilateral pathway can be safely performed also for wide ASB meningiomas after performing an extensive internal debulking of such neoplasm and if the contralateral olfactory nerve is expected to have a clear plane of dissection. This is an excellent, safe, and effective unilateral approach to midline structures; however, it allows a complex bilateral anatomical exposure. In some instances, retraction on the frontal lobe cannot be achieved safely or adequately without widely opening the sylvian fissure, increasing the temporal lobe, insula, draining veins, and middle cerebral artery dissection trauma. A simple frontal craniotomy, instead of extensive and time-consuming bilateral craniotomy that can be cosmetically disfiguring, offers some clear advantages.

In conclusion, subfrontal bilateral craniotomy is mostly used for large tumors and provides advantages such as wide symmetrical exposure that is useful when an extensive cranial base and vault reconstruction have to be performed. However, this strategy requires ligation of part of the superior sagittal sinus and exposes both frontal lobes to the risk of postoperative edema. Other disadvantages include the opening of the frontal sinuses and the possible late visualization of vital neurovascular structures such as the optic apparatus, the internal carotid arteries (ICAs), and the anterior cerebral-anterior communicating artery complex. Compared with the subfrontal bilateral approach, the unilateral frontal craniotomy allows sparing of the superior sagittal sinus and minimizes manipulation of the contralateral frontal lobe. The optic chiasm and ipsilateral carotid artery usually are identified early during the surgical procedure.

21.2 Neuroradiology

Several neuroradiological investigations may be performed in order to assess the main characteristic of anterior cranial base meningiomas [11].

Noncontrast computed tomography (CT) scans classically demonstrate a dural-based, homogeneous tumor of slightly increased density compared to the surrounding brain, with variable mass effect and surrounding edema. Hyperostosis of the adjacent skull base is a common feature, and it may be visualized also by means of simple radiography of the skull (Rx). Contrast agent administration determines an extensive homogeneous enhancement of the tumor in the majority of cases and often reveals the classical "dural tumor tail."

The gold standard diagnostic imaging for proper evaluation of anterior midline meningiomas is the magnetic resonance imaging (MRI). For preoperative and diagnostic evaluation, MRI is essential and provides very useful information to the surgeon (Fig. 21.1).

In T1-weighted scans, the tumor is of equivalent signal intensity compared to the surrounding brain, while in the T2-weighted scans, the meningioma usually shows a "sunburst" pattern with or without necrosis, cysts, hemorrhage, trapped hyperintense CSF clefts, and vascular flow voids. In FLAIR-weighted images, the hyperintense peritumoral edema can be identified, while T2-star gradient-echo sequences may detect calcifications. After the gadolinium injection, the tumor gains homogeneous and intense contrast enhancement; moreover, the possible presence of the "dural tail" (35–80 % of cases) can be detected.

Magnetic resonance angiography may provide essential information about blood supply and displaced arteries or even arteries embedded within the tumor.

Angiography, generally, has not been indicated unless preoperative embolization is planned. At any rate, the classic angiographic appearance of a meningioma is that of increasing hypervascular tumor blush throughout the arterial phase, persisting well into the late venous phase with slow washout.

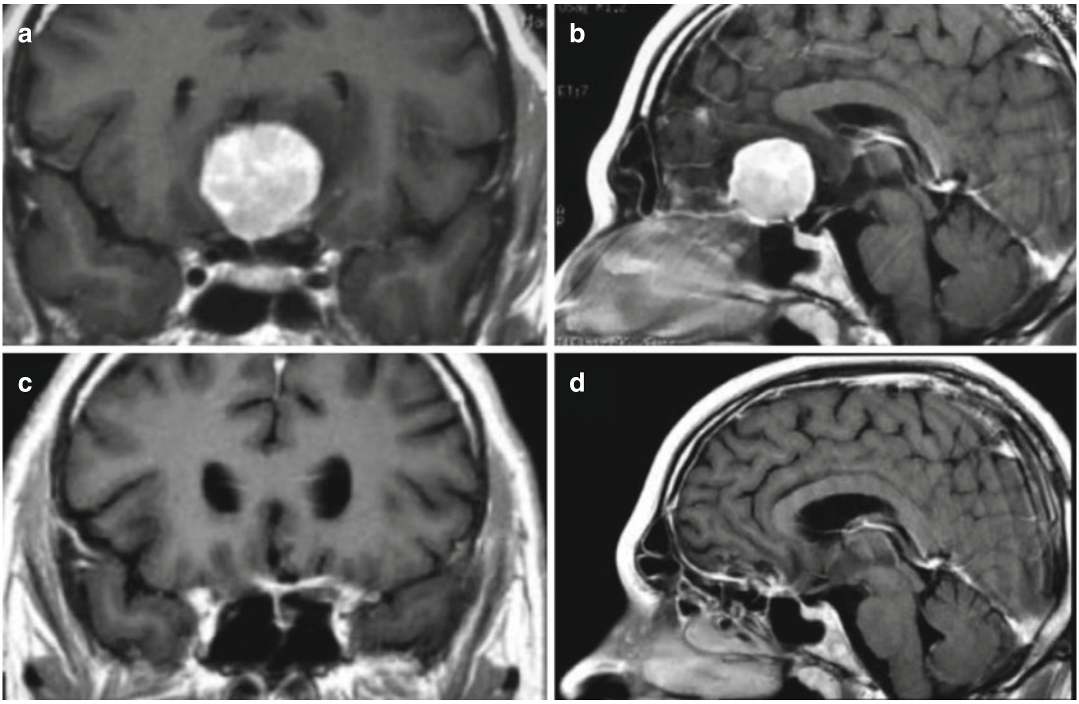

Fig. 21.1 T1-weighted MR images with gadolinium contrast enhancement showing a planum sphenoidale meningioma. Preoperative coronal (**a**) and sagittal (**b**) scans; postoperative coronal (**c**) and sagittal (**d**) scans

In conclusion, even if MRI has to be considered as the best diagnostic tool for the evaluation of a meningioma, cranial computed tomography (CT) and, in selected cases, angiography may be considered as important adjuncts to evaluate and characterize the involvement of the anterior skull base, the infiltration of the olfactory groove and ethmoid bone, the relationship of the major vessels, and the main vascular supply of the tumor, i.e., the ethmoidal arteries.

21.2.1 Surgical Planning

The knowledge of surgical anatomy is imperative for complex neurosurgical procedures in regions with vital structures nearby, as in skull base surgery.

In the field of neurosurgery, progress in neuroimaging studies, such as high-resolution CT scans, MRI studies, and digital subtraction angiography data, has certainly refined the visualization of the brain and skull base anatomy. On the other hand, the progress in computer technology and medical image processing techniques has enabled stereoscopic display of anatomical structures from computed imaging data. Indeed, three-dimensional (3D) imaging, which allows image manipulation and surgical simulation on-screen, has become an indispensable part of the neurosurgical planning and training.

Our surgical planning for skull base meningiomas generally provides two different methodologies: First of all, standard medical image data such as MRI and CT scan to obtain a general idea of the tumor and the surrounding structures is performed.

In a second step, a virtual preliminary exploration of patient's anatomy using the 3D reconstruction modules supported by the OsiriX software (Osirix®, advanced open-source PACS workstation DICOM viewer) in order to analyze the individual variability of the anatomy is performed. At the end of such step, the segmented objects (representing skin, tumor mass, vascular system, ventricular cavities) are displayed by a

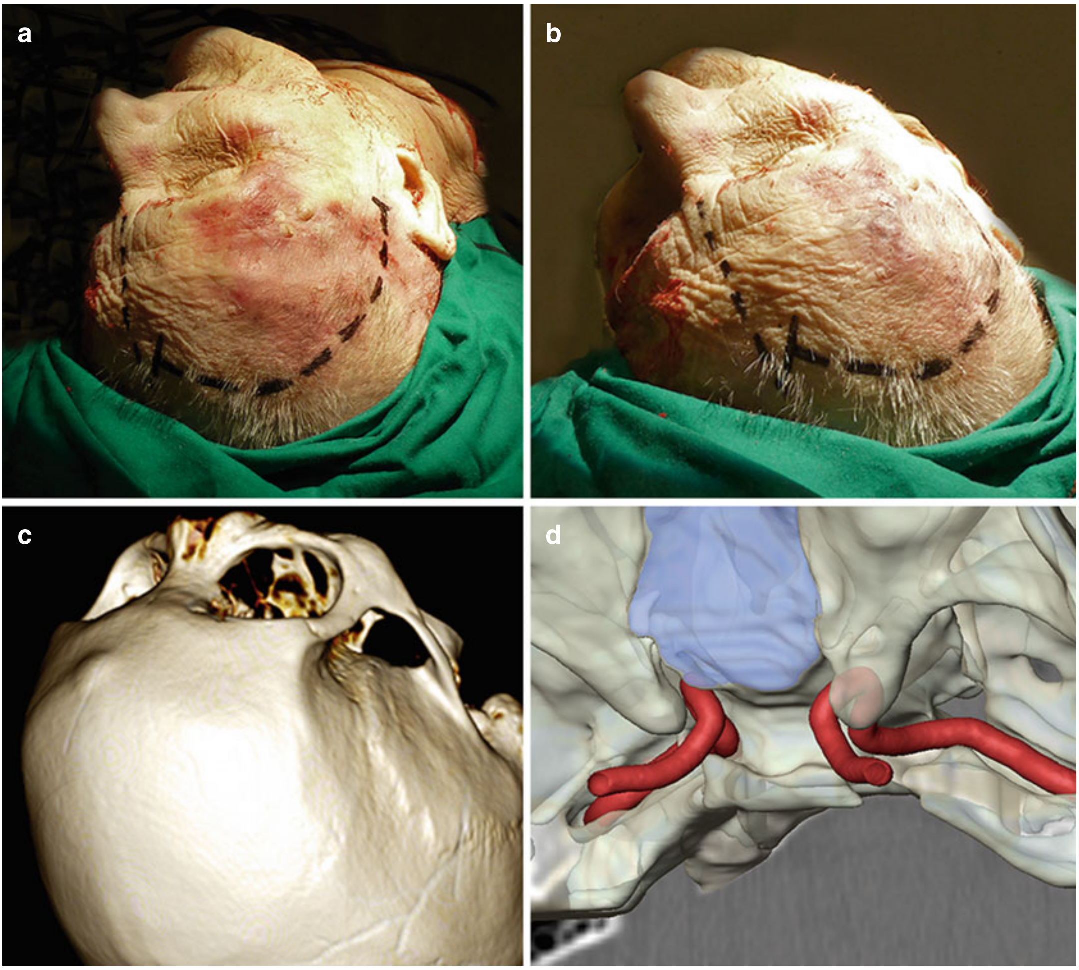

Fig. 21.2 Anatomical photographs (**a**, **b**) of a cadaveric dissection showing patient positioning and skin incision for a subfrontal unilateral approach. (**c**, **d**) Computed 3D virtual reality images showing CT reconstruction of the head (**c**) and the target area, i.e., anterior cranial fossa (**d**)

combination of volume rendering and polygonal iso-surfaces, ready to be manipulated.

Such types of 3D models have been previously utilized from recently published works of our group concerning the anatomy of microscopic and endoscopic skull base approaches [12–14] (Fig. 21.2).

21.3 Anatomy of the Approach

In order to perform a subfrontal approach, either uni- or bilateral, the anatomy of the anterior skull base and of the subfrontal pathway must be clearly understood.

First of all, it has to be remarked that frontal, parietal, temporal, zygomatic, and sphenoid bones, connected through their respective sutures, form the anterolateral region of the skull.

Moreover, the normal anatomy of the anterior cranial fossa should be deeply recognized. From the endocranial view, the anterior cranial base has a flat surface that comprises the anterior border of the sphenoid wings and the roof of the orbita, laterally, and the planum sphenoidale, medially. The anterior cranial fossa is principally formed by the orbital process of the frontal bone that is convex and has a variable number of orbital crests. A most anterior bony ridge, i.e., the frontal crest, is located in the midline and separates the two sides and gives attachment to the falx cerebri, which contains the origin of the superior and inferior sagittal sinuses. The central portion of the anterior fossa is deeper and is composed of the ethmoid bone, with the medial portion represented by the cribriform plate – that shows multiple perforations transmitting the olfactory nerve filaments – and the lateral one that is the fovea ethmoidalis, i.e., the roof of the ethmoid sinus. The crista galli is positioned at the center. The foramen cecum, crossed by an emissary anterior nasal vein, is located between the frontal crest and the crista galli. Lateral to the cribriform plate, the cribroethmoid foramina gives passage to the anterior and posterior ethmoidal arteries. On the other hand, the posterior portion of the anterior fossa is formed by the upper part of the sphenoid bone, namely, its body and lesser wings. Centrally, lies the planum or jugum sphenoidale, which constitutes the roof of the sphenoid sinus, bordered posteriorly by the anterior chiasmatic sulcus. Laterally, the lesser wing of the sphenoid roofs the optic canal, which contains the optic nerve and its dural sheath. The anterior clinoid process, i.e., the medial end of the lesser wings of the sphenoid, gives attachment to the tentorium cerebelli and covers the anteromedial portion of the cavernous sinus which contains the supraclinoid portion of the internal carotid artery (ICA). Other key neurovascular structures that can be exposed during the access to the anterior cranial fossa are the following: the olfactory bulb and tract, optic nerves, optic chiasm and lamina terminalis, the anterior cerebral arteries and the anterior communicating artery, the posterior communicating artery, the anterior choroidal artery, the third cranial nerve, the superior hypophyseal artery, the pituitary stalk and the diaphragma sellae, the ophthalmic arteries, and Heubner's recurrent arteries. Moreover, the opening of the Liliequist's membrane permits to get inside the interpeduncular cistern in order to expose the basilar artery, the posterior cerebral arteries, the superior cerebellar arteries, and the origin of the third cranial nerve.

It has to be reminded that before performing a subfrontal approach, unilateral or bilateral, a precise knowledge of the main frontal anatomic landmarks must be obtained (i.e., midline, orbital rim, supraorbital foramen, temporal line, and zygomatic arch). The orbital rim is the frontal bone part that forms the roof of the orbits, the zygomatic process of temporal bone, and the temporal process of the zygomatic bone form the zygomatic arch. The supraorbital foramen is situated along the supraorbital margin, which is entirely formed by the frontal bone and is crossed by the supraorbital nerve and vessels (supraorbital artery and supraorbital vein). Finally, the superior temporal line of the parietal bone gives attachment to the temporal fascia, indicating the origin of the temporalis muscle.

21.3.1 Brief Consideration of Surgical Neuroanatomy

As already said, meningiomas of the midline anterior cranial base are classified based on an anteroposterior direction: olfactory groove, planum sphenoidale, and tuberculum sellae meningiomas.

Olfactory groove meningiomas arise in the midline of the anterior cranial fossa over the cribriform plate and frontosphenoid suture. Those tumors generally grow in a symmetric fashion around the crista galli and, subsequently, may involve any part of the planum of the sphenoid bone and/or, less frequently, extend predominantly to one side. The anterior and posterior ethmoid arteries drive the primary blood supply to these tumors. However, these tumors may be also vascularized by the meningeal branches from the ophthalmic artery, anterior cerebral arteries, anterior communicating artery, pial collaterals, and external carotid circulation, such as anterior branches of the middle meningeal artery. Generally, in these cases, the olfactory nerves either are displaced laterally on the lower surface of the tumor or are adherent, compressed, or even not visible due to a diffuse spread within the tumor capsule. It has to be minded that in smaller tumors, the post-communicating segments of the anterior cerebral arteries usually are not involved in the tumor capsule. However, in large tumors, these and additional segments, i.e., the frontopolar or other small branches originating from the anterior cerebral arteries, may adhere to the tumor capsule.

Regarding the planum sphenoidal meningiomas, it has to be taken into consideration that planum sphenoidale and tuberculum sellae are part of the sphenoid bone. However, it is often difficult to clearly separate these tumors simply based on their bony covering. Rather, their relationship to the optic nerves and chiasm can distinguish these tumors as to their most likely origin. While planum sphenoidale meningiomas usually push the optic nerves dorsally and caudally, tuberculum sellae meningiomas lead to an upward and/or lateral bulging of these structures. At any rate, both entities might grow between, around, and beyond the optic nerves.

Tuberculum sellae meningiomas arise from the dura of the tuberculum sellae, chiasmatic sulcus, limbus sphenoidale, and diaphragma sellae. The tuberculum sellae is a bony elevation ridge that lines up the anterior aspect of the hypophyseal fossa, dividing it from the chiasmatic sulcus. The lateral end of this structure is just inferomedial to the intracranial outlet of the optic canal, through which the optic nerve runs to join the contralateral optic nerve at the chiasm. Behind the optic foramen, the anterior clinoid process is directed posteriorly and medially. The primary blood supply to these tumors is principally from the posterior ethmoid arteries. According to a recent proposed classification of suprasellar meningiomas, based on the origin and location of the tumor, Liu et al. [15] identified four groups: (a) tumor originating from the planum sphenoidale, rarely involves the optic pathway or pituitary stalk; (b) tumor located at the tuberculum sellae, mainly involves the optic pathway but rarely involves pituitary stalk; (c1) tumor located at the diaphragma sellae, which involves both the optic pathway and the pituitary stalk, pushing the chiasm anteriorly in to "prefixed chiasm" position, resulting in minimal pre-chiasmatic working area; (c2) tumor located at the diaphragma sellae but pushing the optic chiasm posteriorly, putting it in to "postfixed chiasm" position, resulting in expansion of the pre-chiasmatic area.

21.4 Technique

Generally, as the majority of meningiomas are benign tumors (WHO I), extra-axial and well-defined, complete surgical removal (Simpson Grade I) should be the primary goal in most cases. For anterior midline meningiomas, complete tumor excision even with resection of infiltrated dura or removal of hyperostotic bone might be achieved with low morbidity in most instances. However, when tumors are hardly adherent to the anterior brain circulation vessels, the optic apparatus, or within and near the pituitary gland and stalk, complete removal might represent a high-risk procedure for damage of those important neurovascular and endocrine structures [4, 16, 17].

21.4.1 Subfrontal Unilateral Approach

The patient is placed in the supine on the operating table with the head fixed in a three-pin Mayfield head holder. The positioning largely depends on the involvement of the midline structures, the displacement and orientation of the main vessels, and the optic nerves. As a general rule, the head has to be rotated toward the contralateral side of 20–40° and slightly extended posteriorly, as the frontal lobes follow gravity, thus making a natural exposure of the anterior cranial base and facilitates good venous drainage during surgery. In other words, the patient's neck has to be retroflexed, in order to form an angle of approximately 20° between the plane of the anterior cranial base and the vertical plane of the axis (Fig. 21.2). Fine adjustments of the patient's position can be obtained by tilting the operating table.

After a precise definition of the frontal anatomic landmarks, already described in the "anatomy of the approach section," the line of the incision is marked on the skin.

A curved frontal skin incision, beginning at the level of the top of the helix of the ear or slightly anterior to it on the side of the craniotomy and behind the hairline, is performed and extends until the midline in a curvilinear fashion above the superior temporal line. The skin incision is posterior to the superficial temporal artery, in order to include the artery in the skin flap. The incision should not be extended below the zygomatic arch to avoid injury of the frontal branch of the facial nerve (Fig. 21.3).

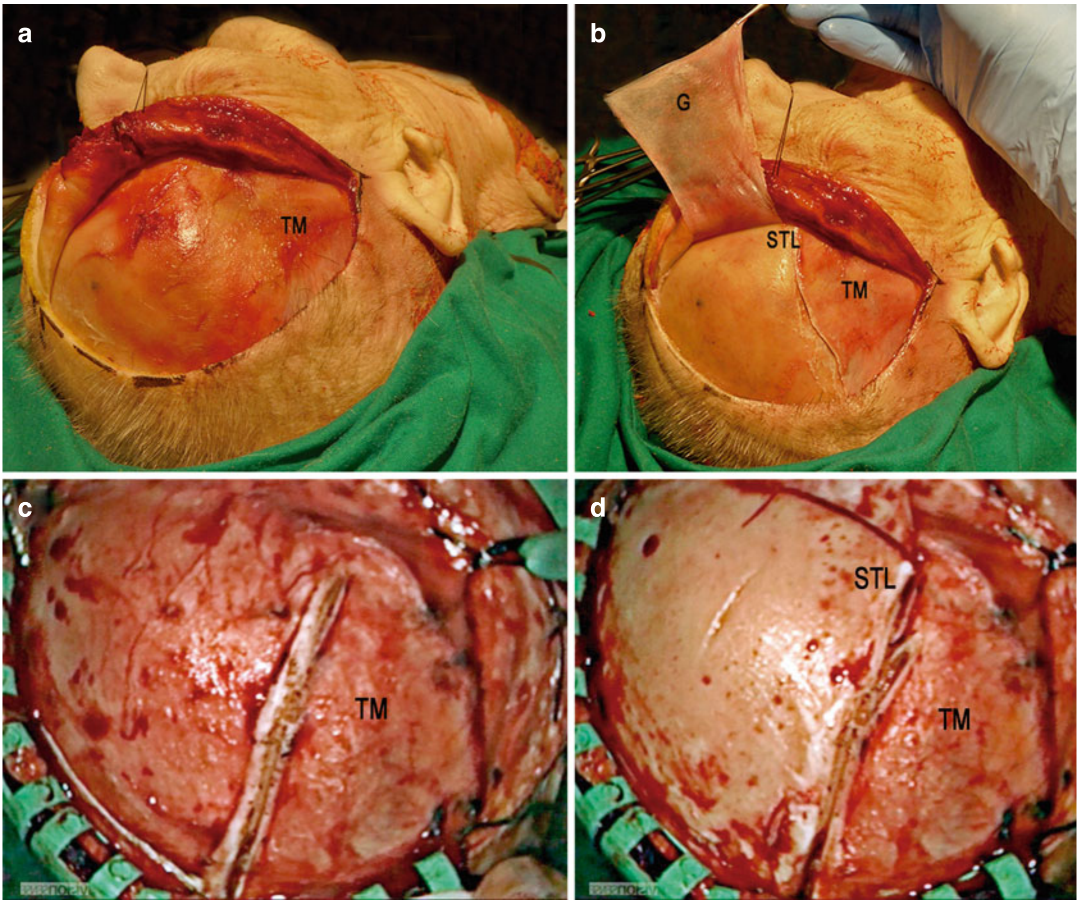

Fig. 21.3 Anatomical pictures of a cadaveric dissection showing the skin flap preparation; pericranium before (**a**) and after (**b**) its incision along the superior temporal line; corresponding intraoperative images (**c**, **d**). *TM* temporalis muscle, *G* galea capitis, *STL* superior temporal line

It is of utmost importance to preserve the pericranium for harvesting a potential flap that can be subsequently used in the reconstruction phase. As a matter of fact, a pericranial flap is usually prepared to cover potential dural tears or removed tumor matrix in case of anterior middle fossa involvement (Fig. 21.3).

The skin is reflected anteriorly along with the pericranium and retracted with temporary fishhooks. At the supraorbital ridge, care should be taken to identify and preserve the supraorbital nerve and the supraorbital artery passing along the medial third of the superior orbital rim.

Exposure and mobilization of the temporal muscle should be restricted to a minimum to avoid postoperative cosmetic and functional disabilities and chewing discomfort. Careful dissection of the temporal muscle from the superior temporal line should be sharply performed with the aim of exposing just the region of the keyhole (Dandy's keyhole) (Fig. 21.4). In other words, the temporalis muscle does not require elevation, although a small amount of dissection along the superior temporal line may be required to expose the keyhole for burr hole placement. Before starting the craniotomy, local hemostasis must be performed (Fig. 21.4).

The craniotomy is started using a high-speed drill, with the placement of a single frontobasal burr hole at Dandy's point, below the anterior aspect of the superior temporal line, just above the frontosphenoid suture.

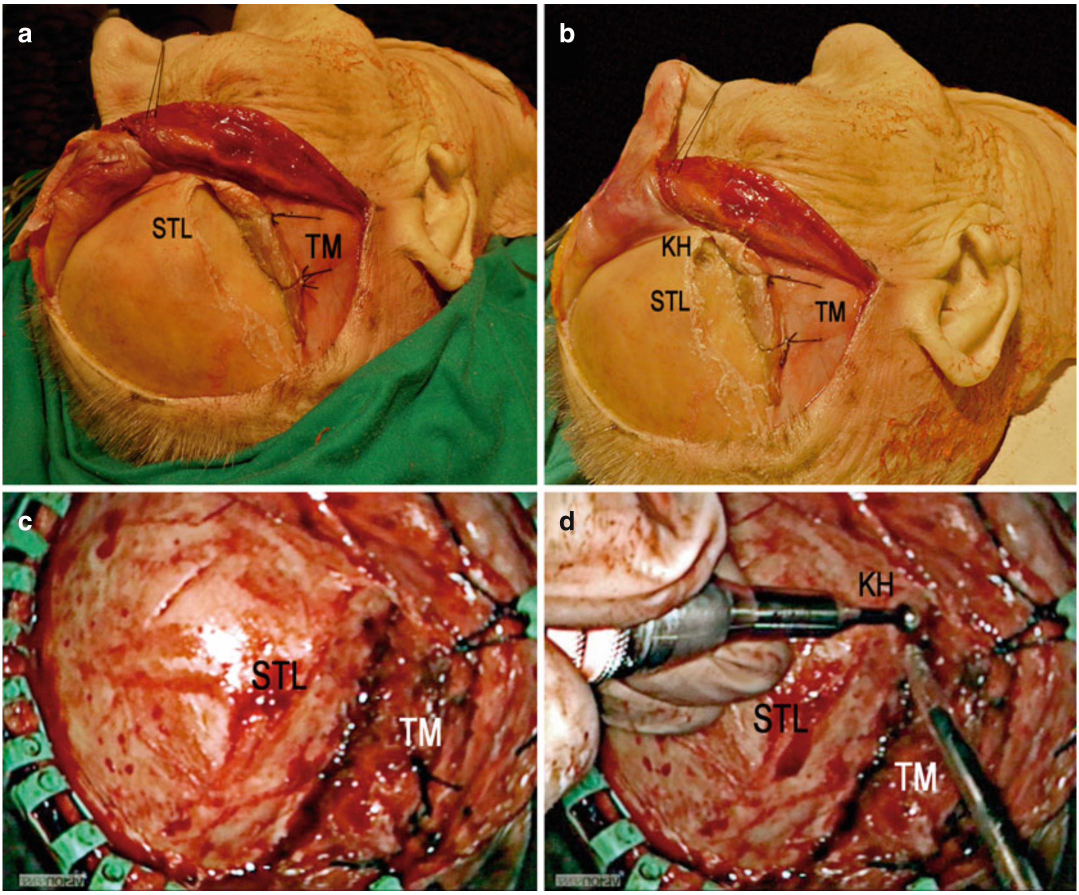

Fig. 21.4 Anatomical images of a cadaveric dissection. The temporalis muscle is slightly dissected from the superior temporal line in order to the site for the frontobasal burr hole; standard keyhole described by Dandy (**b**, *KH*); corresponding intraoperative images (**c**, **d**). *STL* superior temporal line, *TM* temporalis muscle, *KH* keyhole

A high-speed craniotome is then used to create the bone flap. The craniotome is directed anteriorly until the supraorbital foramen and it is then moved posteriorly to reach the superior temporal line (Fig. 21.5). Continuous irrigation during drilling avoids heat damage to the brain tissue and allows more precise bone cutting. It has to be stressed that the craniotomy should be shaped according to the expected irregularities of the frontal skull base.

Before removal of the bone flap, careful dissection of the dura from the inner surface of the bone using a blunt dissector avoids laceration of the dura mater. If the frontal sinus is accidentally entered, the posterior wall and all sinus mucosa are carefully removed away by cranialization. Subsequently, a galeaperiostal flap from the forehead sealed with fibrin glue can be used to cover the basal parts of the frontal sinus.

At this stage of the procedure, an important step is the drilling of the inner edge of the orbital roof protuberances with a high-speed drill (unroofing) in order to optimize the angle of attack of the approach and, accordingly, the exposure of the anterior cranial fossa (Fig. 21.5).

The dural opening is anticipated by positioning many sutures alongside the edges of the craniotomy. Typically, the dura is opened in a “X-” or “C-”shaped fashion, under the operating microscope, and anchored with stay sutures. Few millimeters should be left clear between the bone margin and the dural incision, to facilitate its

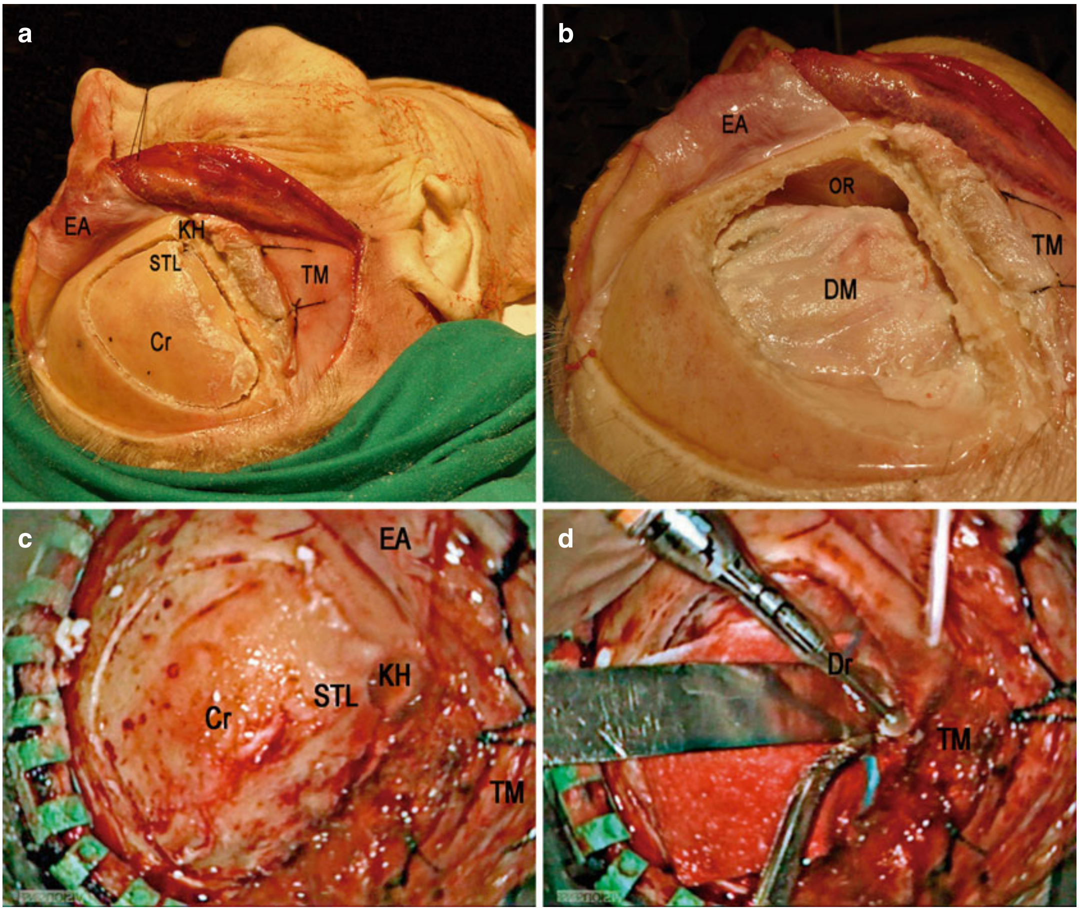

Fig. 21.5 Anatomical pictures of a cadaveric dissection demonstrating the frontal craniotomy (**a**, **b**). The unilateral subfrontal craniotomy extended anteriorly as close as possible to the supraorbital ridge and posteriorly along the convexity of the frontal bone; the removal of the bone flap shows the dura mater covering the frontal lobe; (**c**, **d**) intraoperative corresponding snapshots. *EA* epicranial aponeurosis, *KH* keyhole, *STL* superior temporal line, *Cr* craniotomy, *TM* temporalis muscle, *OR* orbital roof, *DM* dura mater, *Dr* drill

closure at the end of the procedure. Elevation and retraction of the frontal lobe pole will subsequently expose the target area at the frontal base of the skull.

Afterward, the sylvian fissure is dissected and opened in its most distal portion, exposing the first segment of the omolateral middle cerebral artery. As the release of cerebrospinal fluid (CSF) during sylvian dissection makes the brain relaxed, the frontal lobe starts to fall downward, following gravity. Further medial dissection of the arachnoid from the proximal sylvian fissure provides initial recognition of the tumor (Fig. 21.6). In this way, with the temporal lobe covered with cottonoids, only the ipsilateral frontal lobe is retracted.

The ipsilateral optic nerve should be compressed superiorly or superolaterally, angulated against the falciform ligament as it comes out of the optic foramen. The internal carotid artery is found lateral to the optic nerve (Figs. 21.6 and 21.7). When the optic nerve and the internal carotid artery are completely covered by the tumor, which occurs occasionally, dissection should first be carefully performed to identify the optic nerve and the carotid artery.

Devascularization of the tumor is then performed. This maneuver permits easier debulking

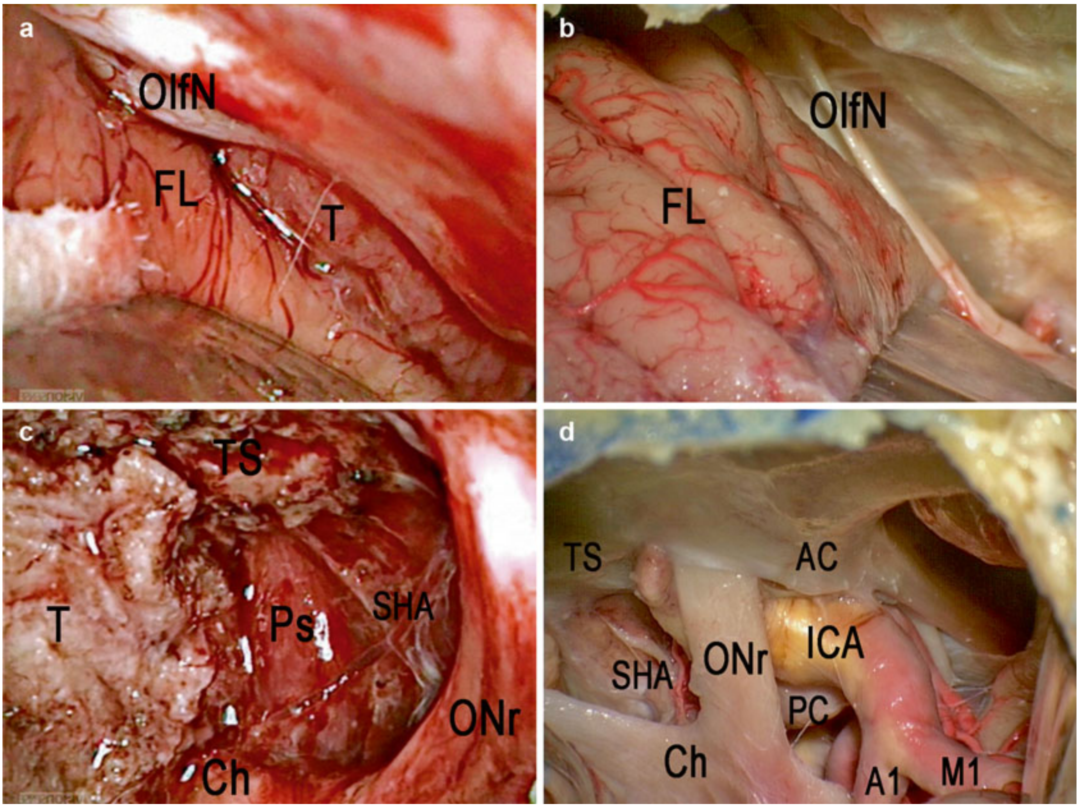

Fig. 21.6 Intraoperative microsurgical pictures showing the tumor (*T*) below the frontal lobe compressing the omolateral olfactory nerve (**a**) and adhering to the chiasm (**c**). Anatomical microsurgical images showing the key anatomical landmarks of the subfrontal unilateral approach (**b**, **d**). *OlfN* olfactory nerve, *FL* frontal lobe, *T* tumor, *TS* tuberculum sellae, *Ps* pituitary stalk, *SHA* superior hypophyseal artery, *Ch* chiasm, *ONr* right optic nerve, *AC* anterior clinoid, *PC* posterior clinoid, *ICA* internal carotid artery, *A1* pre-communicating segment of the anterior cerebral artery, *M1* pre-bifurcation segment of the middle cerebral artery

and further dissection of the tumor without bleeding (Fig. 21.7). Such maneuver starts from the most anterior part of the tumor, medial to the optic nerves, applying bipolar coagulation between the tumor and the underlying dura. Devascularization then proceeds posteriorly, with each devascularized part of the tumor detached and removed.

It has to be minded that the optic nerve is under significant tension, until enough decompression has been accomplished. Accordingly, it has to be protected with cottonoids, and frequent saline irrigation is recommended for cooling and cleaning during coagulation, thus avoiding thermal damage.

The tumor may be also debulked using an ultrasonic surgical aspirator or scissors.

After all these procedures have been carefully performed, the tumor capsule is meticulously spared from the surrounding neurovascular structure.

Special attention must be moved to the Heubner's artery or other perforating arteries. If these arteries are unintentionally injured, they should be repaired immediately by applying low-current bipolar cautery or by suturing the vessel wall. The medial aspect of the tumor is dissected from the contralateral optic nerve and the carotid artery by piecemeal removal. The contralateral optic nerve is usually displaced laterally. Finally, when sufficient decompression has been attained, the tumor is dissected and removed (Fig. 21.7).

Finally, after complete resection of the tumor, the involved dura around from which the tumor originated is excised, and the involved hyperostotic bone is also drilled, taking care not to enter the sphenoid or ethmoid sinuses.

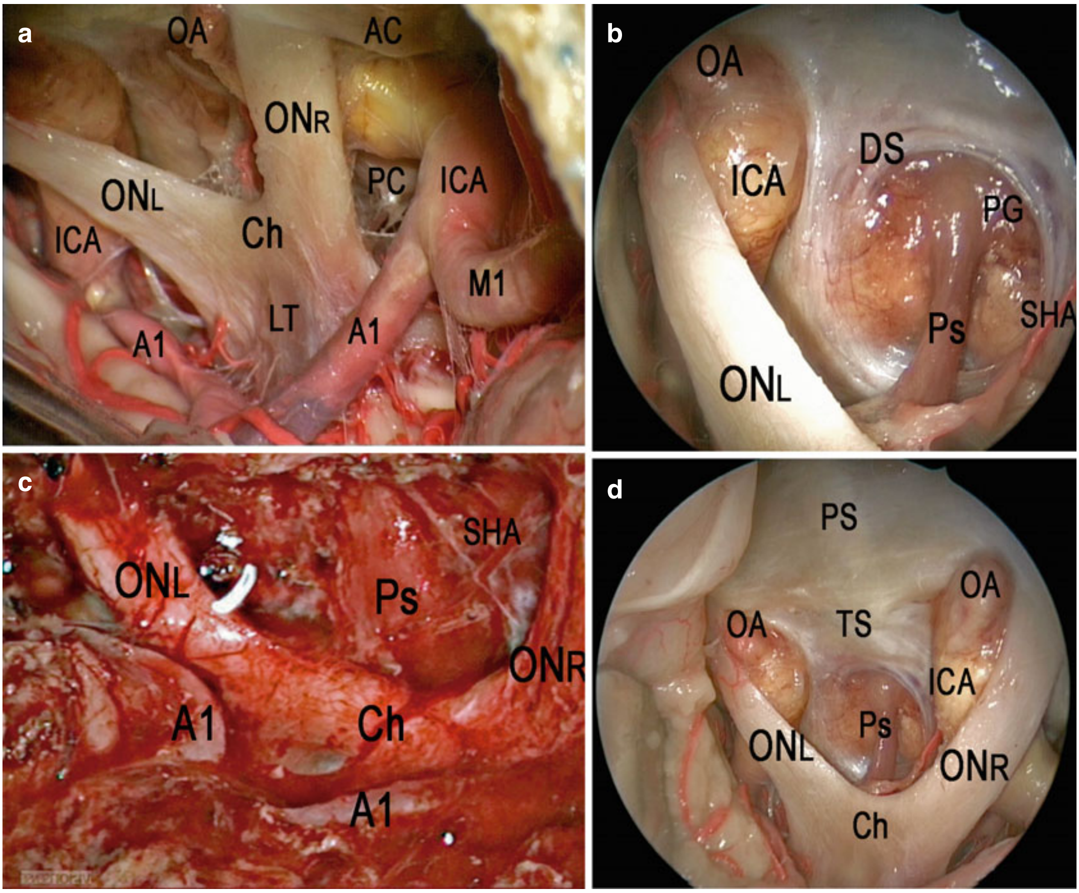

Fig. 21.7 Anatomical (**a**) and intraoperative (**c**) microsurgical images showing the exposure of the optic nerves, the chiasm, the carotid arteries, and the anterior communicating arteries complex; (**b**, **d**) endoscopic anatomical snapshots. *OA* ophthalmic artery, *AC* anterior clinoid, *PC* posterior clinoid, *ONr* right optic nerve, *ONl* left optic nerve, *Ch* chiasm, *ICA* internal carotid artery, *LT* lamina terminalis, *A1* pre-communicating segment of the anterior cerebral artery, *M1* pre-bifurcation segment of the middle cerebral artery, *PG* pituitary gland, *Ps* pituitary stalk, *SHA* superior hypophyseal artery, *DS* diaphragma sellae, *TS* tuberculum sellae, *PS* planum sphenoidale

In same cases, the unilateral subfrontal approach could be used for asymmetric midline lesions with the possibility of cutting the falx above the crista galli and saving the superior sagittal sinus, thus obtaining access to the contralateral side. In case of lesions such as meningiomas that involve the optic canal, a wider access could be gained by removal of the anterior clinoid that could be achieved via an extradural or intradural route.

After the lesion has been removed, the dural incision is sutured watertight using continuous sutures. The bone flap is positioned without significant bony distance to achieve the optimal cosmetic outcome and fixed with low-profile titanium plates and screws. After final verification of hemostasis, the galea and the subcutaneous layers are approximated with several interrupted absorbable sutures, and the skin is sutured as well. At the end of the procedure, the Mayfield is removed and general anesthesia is finished.

21.4.2 Endoscope-Assisted Technique

The endoscopic-assisted techniques have been developed to extirpate selected tumors that mainly involve the sphenoidal planum and tuberculum sellae areas. In the majority of cases, a 30- or 45-degree endoscope is used as an aid to excise tumor remnants in proximity of neurovascular structures such as the optic nerves, the pituitary stalk, and anterior cerebral arteries (Fig. 21.7). With the endoscope, a panoramic view of the sellar and suprasellar area is obtained. In selected cases, such as giant anterior skull base meningiomas or sinonasal tumors with large intracranial extension, a combined microscopic subfrontal and endoscopic endonasal transcribriform approach can be performed to optimize tumor resection. The main advantage of this approach is to combine the minimally invasive elements of the endonasal approach with the 3D view gained with the microscope. Moreover, a combined transcranial/endonasal procedure adds the significant advantage of a wide exposure of the intradural component of the lesion, especially over its lateral extension, together with a more accurate reconstruction of the bone and dural defects of the anterior skull base.

21.4.3 Subfrontal Bilateral Approach

The patient is placed supine with the head in the midline, slightly extended to bring the brows to the highest point of the surgical field. As already described for the subfrontal unilateral route, after a precise definition of the frontal anatomic landmarks, the line of the incision is marked on the skin.

A bicoronal skin incision, 13–15 cm from the orbital rim and 2 cm behind the coronal suture, is performed extending 1 cm anteriorly to the tragus on each side. Dissection continues in the immediate subgaleal plane taking care to preserve a thick and vascularized pericranial flap (Fig. 21.8).

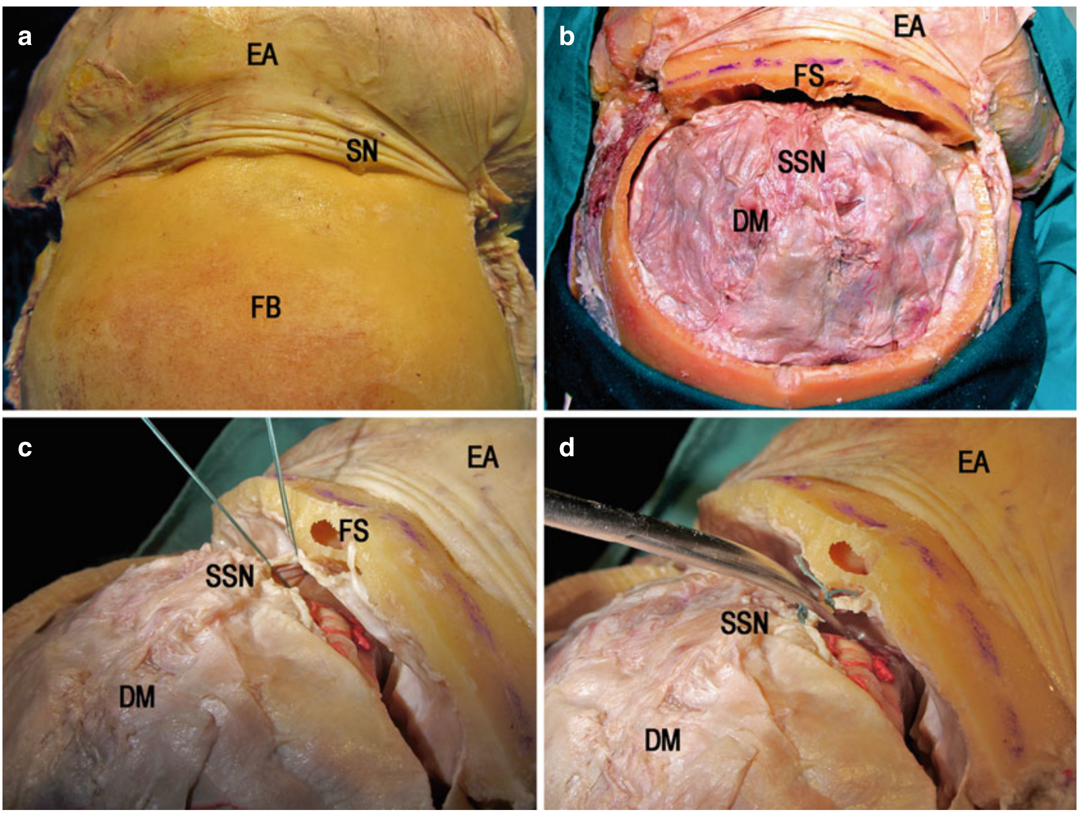

Fig. 21.8 Anatomical photographs of the subfrontal bilateral approach. The supraorbital nerve as it comes out from the supraorbital foramen (**a**), after the pericranium is taken up separately from the scalp flap; subfrontal bilateral craniotomy (**b**); (**c**, **d**) ligation and division of anterior third of superior sagittal sinus (*SSN*). *EA* epicranial aponeurosis, *SN* supraorbital nerve, *FB* frontal bone, *FS* frontal sinus, *SSN* superior sagittal sinus, *DM* dura mater

The skin of the posterior aspect of the incision is elevated, and the pericranial tissue is incised below the skin. The skin flap and underlying tissue, including the pericranial tissue, are then turned down together using fishhooks, taking care to preserve the supraorbital nerve as it comes out from the supraorbital foramen.

As already discussed, temporalis muscle does not require elevation, although a small amount of dissection along the superior temporal line may be required sometimes to expose the keyhole for burr hole placement.

The craniotomy is performed with two burr holes placed at the Dandy's keyhole bilaterally. After that, one or two additional burr holes are placed on the midline at the posterior aspect of the craniotomy straddling the superior sagittal sinus. After blunt dissection of the dura from the inner surface of the skull bone, particularly in the midline area, the bone flap is usually cut in one piece. The craniotomy is extended anteriorly as close as possible to the supraorbital ridge and posteriorly along the convexity of the frontal bone.

The frontal sinus is almost routinely encountered and requires cranialization if necessary as in the unilateral approach. The mucosa should be removed from the free flap, and cauterization is used to remove the accessible mucosa within the sinus. The sinuses are packed with bacitracin-soaked Gelfoam, and the pericranium is sewn in position over the open frontal sinuses.

A slightly curved dural incision is performed over each medial inferior frontal lobe adjacent to the anterior edge of the craniotomy opening but leaving a sufficient rim for safe and convenient closure of the dura. At this stage, attention should be moved toward the anterior portion of the superior sagittal sinus and the falx cerebri, and, generally, retraction on the mesial surface of each frontal lobe is needed for visualization of the falx cerebri below the sinus. The anterior portion of the superior sinus is then ligated between two silk sutures and then cut down together with the falx cerebri until its inferior margin as anteriorly as possible to disclose the operative field. As a rule, the inferior longitudinal sinus makes little or no bleeding, so that bipolar coagulation is enough (Fig. 21.9).

The frontal lobes are then gently retracted slightly laterally and posteriorly to open the view to the anterior and superior surface of the tumor, lying in the midline with attachments to the falx and crista galli.

The tumor is readily identifiable and often covered by a thick capsule. It is important to dissect within the arachnoid plane surrounding the tumor to avoid damage to the surrounding neurovascular structures. The capsule of the tumor is coagulated to shrink the lesion, and the process of devascularizing the tumor begins.

Small feeders along the skull base continue to supply the tumor; these can be divided as the dissection proceeds along the cranial base from anterior to posterior. Large tumors have usually displaced the frontal lobes superiorly and posteriorly, and brain retraction should be avoided as much as possible to prevent postoperative cerebral edema.

Internal tumor debulking with the ultrasonic aspirator may be useful. The olfactory nerves should be identified laterally to the tumor and can be preserved. As the tumor is debulked further, its superior, posterior, and inferior margins can be dissected in sequence with identification of the anterior cerebral artery and optic apparatus. Feeding vessels from the anterior cerebral circulation can be divided, but care must be taken not to mistake these vessels for perforating arteries that supply the optic chiasm and hypothalamus. The anterior cerebral vessels can become incorporated into very large tumors, and careful sharp dissection is required to free them from the tumor.

The blood supply typically enters from below the tumor. Thus, initial debulking of large tumors is necessary to expose the base of skull to interrupt the blood supply. Extensive internal decompression allows the surrounding structures to be identified and separated from the tumor capsule. Subsequentially, attention must be paid to the posterior aspect of the tumor. The surgeon must be vigilant to identify the anterior cerebral arteries and their respective branches. The capsule is followed posteriorly to expose the sphenoid wing. The edge of the sphenoid wing can be traced medially to the anterior clinoid process and optic apparatus. The posterior arachnoid

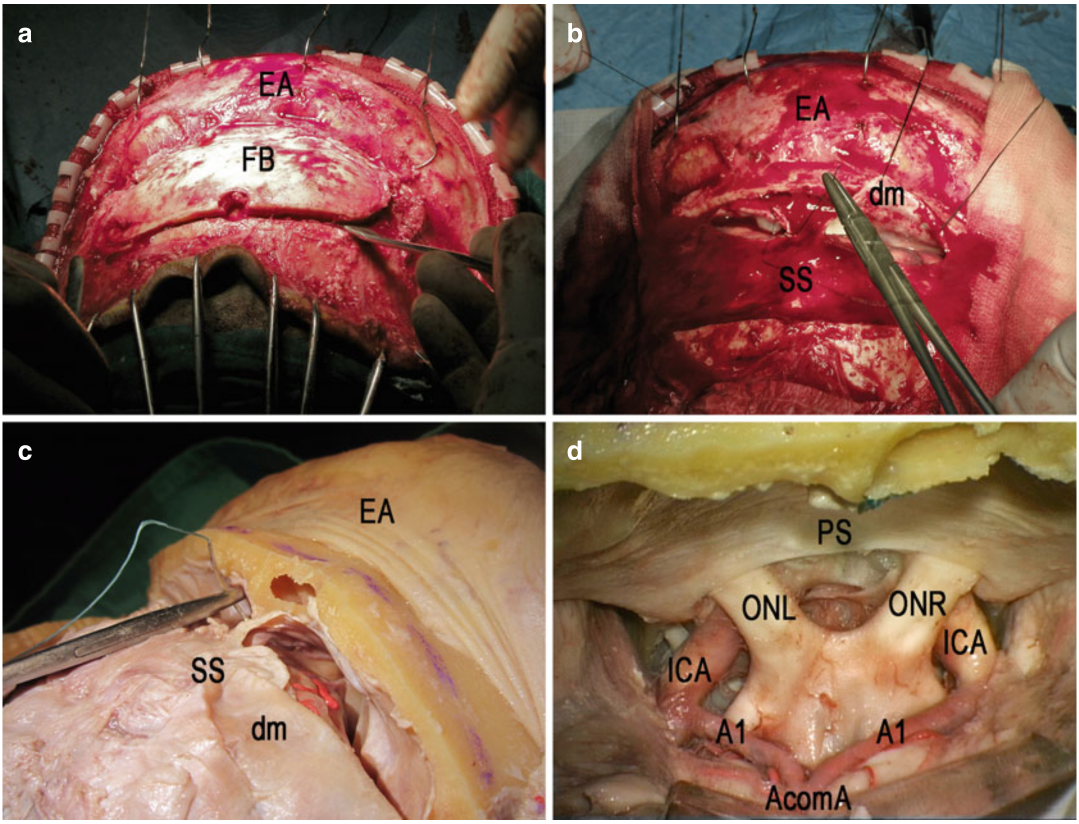

Fig. 21.9 Intraoperative images showing, respectively, bone flap removal (**a**) and superior sagittal sinus ligation (**b**) during a subfrontal bilateral approach; anatomical picture demonstrating the superior sagittal sinus ligation (**c**); anatomical pictures showing the wide and symmetrical anterior cranial fossa exposure of this approach (**d**). *EA* epicranial aponeurosis, *FB* frontal bone, *dm* dura mater, *SS* superior sagittal sinus, *PS* planum sphenoidale, *ONL* left optic nerve, *ONR* right optic nerve, *ICA* internal carotid artery, *A1* pre-communicating segment of the anterior cerebral artery, *AcomA* anterior communicating artery

plane must be preserved, allowing complete removal of the tumor after internal debulking.

After the bulk of the tumor has been removed, its dural attachment must be incised. Simple cauterization of the attachment is insufficient and is thought to leave the patient at high risk for a recurrence. Involved dura must be resected as completely as possible. After the tumor has been resected, attention should be turned toward the floor of the anterior cranial fossa. Any hyperostotic bone should be removed by drill curettage, and the dura of origin removed to reduce the risk of recurrence. Tumor extension into the ethmoid sinuses, nasal cavity, or orbits should be completely resected. A careful reconstruction of the anterior skull base with absorbable hemostatic gelatin sponge and fibrin glue can be necessary at this point. A large piece of vascularized pericranium that was preserved in the initial portion of the procedure is then brought down over the floor of the anterior cranial fossa and secured in place using holes drilled in the planum sphenoidale.

At the end of the procedure, the dural incision is sutured watertight using continuous sutures. The bone flap is positioned medially and frontally without bony distance to achieve the optimal cosmetic outcome and fixed with low-profile titanium plates and screws. After final verification of hemostasis, the galea and the subcutaneous layers are approximated with several interrupted absorbable sutures, and the skin is closed. At the end of the procedure, the Mayfield pin headrest is removed, and general anesthesia is reversed.

It has to be highlighted that for recurrent tumors where the pericranium has been previously utilized or disrupted, the galea can be harvested as a vascularized pedicled graft. Other methods of repair include use of fascia lata, dural substitutes, autologous fat, or fibrin glue. Rarely, in a multiply operated patient with no viable local options for reconstruction, free tissue transfer may be required.

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