Pituitary (2009) 12:360–367
DOI 10.1007/s11102-009-0167-1

The implications of microsurgical anatomy for surgical approaches to the sellar region

Gustavo Rassier Isolan · Paulo Henrique Pires de Aguiar · Edward R. Laws · Atahualpa Cauê Paim Strapasson · Otávio Piltcher

Published online: 29 January 2009

Abstract The knowledge of the normal anatomy and variations regarding the management of tumors of the sellar region is paramount to perform safe surgical procedures. The sellar region is located in the center of the middle cranial fossa; it contains complex anatomical structures, and is the site of various pathological processes: tumor, vascular, developmental, and neuroendocrine. We review the microsurgical anatomy (microscopic and endoscopic) of this region and discuss the surgical nuances regarding this topic, based on anatomical concepts.

Keywords Pituitary · Surgical approaches · Anatomy · Tumor

G. R. Isolan
Department of Neurosurgery, Pontifical Catholic University of Paraná, Curitiba, Brazil

G. R. Isolan
Federal University of Rio Grande do Sul, Porto Alegre, Brazil

G. R. Isolan (✉)
Pontifícia Universidade Católica do Paraná. Rua Imaculada Conceição, 1155-Bloco CCBS-Prado Velho, Curitiba CEP 80215-901, Paraná, Brazil
e-mail: Gisolan@yahoo.com.br

P. H. P. de Aguiar
Department of Neurology São Paulo Medical School, State University of Sao Paulo, Sao Paulo, Brazil

E. R. Laws
Department of Neurosurgery, Brigham & Women's Hospital, Boston, MA, USA

A. C. P. Strapasson · O. Piltcher
Department of Ear, Nose and Throat, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

The sellar region is located in the center of the middle cranial fossa; it contains complex anatomical structures, and is the site of various pathological processes: tumor, vascular, developmental, and neuroendocrine. Comprehensive anatomical knowledge is essential for neurosurgeons who surgically approach this region. Our purpose is to review the microsurgical anatomy (microscopic and endoscopic) of this region and to discuss the surgical nuances regarding this topic, based on anatomical concepts.

Nasal cavity and sphenoid sinus

The nasal cavity, the main "route" to the sellar region, is a pyramidal-shaped structure open anteriorly at the face and posteriorly into the nasopharynx. The nasal cavity is divided sagitally by the nasal septum (anteriorly and superiorly constituted by the perpendicular plate of the ethmoid and inferiorly and posteriorly by the vomer; anterior to this bony segment, it is composed of cartilage) [1].

The lateral nasal wall is divided by three projections: the superior, middle and inferior conchae, which arise just above the three nasal meati (superior, middle and inferior). The upper half of the lateral nasal wall is composed of the frontal process of the maxilla, the lacrimal bone and the orbital plate of the ethmoid. The latter two are extremely thin bones (in which are located the ethmoid air cells), and represent the wall that divides the nasal cavity from the orbit. The lower half of the nasal cavity is composed of the maxilla, the perpendicular plate of the palatine bone and the medial pterygoid plate, from an anterior to posterior perspective. The superior nasal meatus shelters the frontal ostium (communicating the frontal sinus with the nasal cavity). The sphenoid ostium is located in the spheno-ethmoidal recess (just above and behind the superior nasal conchae and in front of the upper anterior aspect of the sphenoid bone) and is the communication between the sphenoid sinus and the nasal cavity. Passing downward in front of the middle nasal concha are the nasolacrimal groove (in which the lacrimal sac is located) and canal (in which the lacrimal duct is located). Its ostium opens into the inferior meatus. The maxillary sinus is located within the maxillary bone; its medial wall is bounded by the middle and inferior nasal meatui and the inferior concha. Its ostium opens into the middle meatus, just below the roof of the sinus and the middle concha. The eustachian tube opens into the nasopharynx along the posterior edge of the medial pterygoid plate. The roof of the nasal cavity (formed by the cribriform plate) and the medial orbital wall is divided by the frontoethmoidal suture. Above this site, the anterior and posterior ethmoidal foramina are found. Passing through them, are their respective arteries and nerves. The anterior ethmoidal artery is a terminal branch of the ophthalmic artery and irrigates the mucosa of the anterior and middle ethmoidal sinuses and the dura covering the cribiform plate and the planum sphenoidale. It gives origin to the anterior falcine artery intracranially. The posterior ethmoidal artery, which is inconstant (present in up to approximately 70% of cases), supplies the mucosa of the ethmoidal sinus and the dura of the planum sphenoidale [1].

Located in the center of the cranial base is the sphenoid bone. It is formed by a body (centrally); two lesser wings spreading outward from the superolateral part of the body; two greater wings, spreading upward from the lower part of the body; and two pterygoid processes, with their lateral and medial plates, directed downward from the body. The sphenoid bone is anatomically related to the orbit: the inferior surface of the lesser wings constitutes the posterior walls of the orbits, and the exposed surface of the greater wings constitutes a part of the lateral wall of the orbits—additionally, they form the floor of the middle fossa and the roof of the infratemporal fossa.

Many important orbital structures cross the sphenoid bone: through the superior orbital fissure (whose inferior and lateral margins are formed by the greater wing and whose superior margin is formed by the lesser wing) pass the oculomotor, trochlear, abducens and ophthalmic nerves and the V1 division of the trigeminal nerve. Above the fissure, separated by a bony bridge (the optic strut, which extends from the lower margin of the base of the anterior clinoid process to the body of the sphenoid), are the cone shaped (narrowest near the orbital end) optic canals, through which pass the optic nerves and the ophthalmic arteries. The sphenoid bone also contains the pituitary fossa, located in the central part of the body, and limited anteriorly by the tuberculum sellae and posteriorly by the dorsum sellae. In front of the tuberculum and behind the planum sphenoidale is the chiasmatic groove. Above the planum sphenoidale and the lesser wing lay the optic tracts and the frontal lobes. Along the lateral surface of the body of the sphenoid is the carotid sulcus, one on each side. The free edges of the lesser wings (the sphenoid ridge) separate the frontal and temporal lobes through the lateral fissure. The anterior clinoid processes are situated at the medial end of the lesser wings, the middle clinoid processes, lateral to the tuberculum sellae and the posterior clinoid processes, at the superolateral margin of the dorsum sellae. The clivus (which continues up to the dorsum sellae) is formed by the sphenoid bone superiorly and the occipital bone inferiorly. Above the greater wings, with their concave-shaped superior aspect, rest the temporal lobes. Near the junction of the greater wings and the body, from anterior to posterior can be found the foramina rotundum, ovale and spinousum. Considering the inferior aspect, the vomer (a separate bone) may frequently remain attached to the anterior half of the body of the sphenoid, and its most anterior portion separates the sphenoid ostia [1].

The sphenoid sinus varies in shape and size in different individuals and also according to age of the individual. During early life it is not well pneumatized and may contain only small cavities, which usually extend backward towards the presellar area. During development, it expands into the area below and behind the sella turcica and may partially encircle the optic canals, reaching its full development during adolescence. In individuals with larger sinuses, it may extend into the roots of the pterygoid process and the basilar part of the occipital bone. Rarely, there may be gaps in the sellar floor, with the sphenoid sinus mucous membrane lying directly against the dura mater. The adult sphenoid sinus may vary according to its degree of pneumatization. The most common configuration consists of several septated cavities in the large paired sinuses [1]. Imaging studies may provide definition of the relationship of the septae to the floor of the sella necessary for successful transsphenoidal surgery. Major septae may be found as far as 8 mm off the midline [2]. As the sphenoid sinus expands and its walls brief form, a prominence (originating from the carotid sulcus, and directly proportional to the degree of pneumatization of the sinus) may appear within the sinus wall below the floor and along the anterior margin of the sella [2, 3]. The so-called carotid prominence is divided into three parts. The first, the retrosellar segment, is located in the posterolateral part of the sinus and is visible in well-pneumatized sellar-type sinuses in which the air cavity extends laterally to the area below the dorsum. The second part, the infrasellar segment, is located below the sellar floor, and the third, the presellar segment, is located anterolateral to the anterior sellar wall [1]. According to Rhoton [4] in 98% of specimens analyzed, there was a presellar segment, in 80% an infrasellar segment and in 78% a retrosellar segment [2]. The presence of each part is independent from the other, and, when they are all connected they form a serpiginous bulge marking the full course of the carotid artery. In the normal sinus, the presellar part extends to the anterior sellar wall, but when the sella is greatly expanded by tumor, the anterior sellar wall extends anterior to the carotid prominence [1].

Some additional anatomical relationships are of note. The distance between the carotid prominences and the midline should be taken into account in pituitary surgery. Fujii et al. [3] have measured these values at different levels: the tuberculum sellae, anterior sellar wall, sellar floor, dorsum sellae, and clivus. They found the shortest distance was just below the tuberculum in 72% of specimens, at the level of the floor of the sella in 20% and at the clivus in 8%. The optic canals protrude into the superolateral portion of the sinus. In some areas no bone separates the optic sheath and sinus mucosa, and in nearly 80%, the bone layer separating it is less than 0.55 mm in thickness. This bony layer is thinner over the carotid arteries in comparison to the anterior margin of the pituitary gland [1]. Accordingly, one should be alert for any eventual exposition of these nerves or of the carotid artery during a transsphenoidal approach. The aggressive use of a speculum can fracture the lateral wall of the sinus and cause injury and the curetting of the walls of the sinus can damage exposed structures. Indeed, such injuries may explain some cases of unexpected visual loss and other deficits after transsphenoidal surgery [5, 6]. Another aspect to be noted is the presence of a pneumatized diverticulum of the sinus (the opticocarotid recess), which is located lateral to the optic strut between the optic canal and the prominence overlying the carotid artery and the superior orbital fissure. It may extend through the optic strut into the anterior clinoid process. This may create a channel through which cerebrospinal fluid can leak to form a fistula (causing rhinorrea) after an anterior clinoidectomy [1].

Diaphragma sellae

The diaphragma sellae is the roof of the sella turcica above the pituitary gland, through which crosses the pituitary stalk. Its morphology has been studied by a number of authors. Kursat et al. [7] conducted an anatomical study of 16 specimens. They found that the diaphragma sellae was thicker at the periphery, becoming thinner toward the pituitary stalk. It was flat in 2 (12%) and concave inferiorly in 14 (87%) of cases. It had an oval shape in 10 (62%), triangular in 3 (19%) and rectangular in 3 (19%) specimens. Finally, it was shown that in 3 cases (19%) there was a complete and in 13 (81%) an incomplete membrane. The same authors report that the mean thickness of the medial wall of the cavernous sinus was 278.46 ± 162.79 μm in its upper third and 161.53 ± 53.86 μm in its lower third ($P < 0.001$). On histological examination with Masson's trichome stain it was observed that the pituitary capsule was tightly adherent to the pituitary gland and that the medial wall of the cavernous sinus was adherent laterally to the capsule The superior component of this wall was distinctly separate from the pituitary wall and merged with the diaphragma sellae. Removal of the gland revealed that the diaphragma was continuous with the superior wall of the cavernous sinus supero-laterally and with the medial wall infero-laterally. In fact, the medial wall of the cavernous sinus formed the lateral aspect of the pituitary fossa. It was equivalent to thin meningeal dura, impossible to separate into two layers, but easily separated from the capsule surrounding the pituitary gland. The diaphragma sellae had a looser structure as compared to the superior wall of the cavernous sinus, and the collagen fibers were sparse when they approached to the stalk.

Classical texts consider the diaphragma sellae a small, circular, horizontal reflection of dura mater, covering in the sella turcica and the pituitary gland [8]. Studies performed later reported that it is usually rectangular and concave [1, 2]. Renn and Rhoton [2] studied 50 specimens, and it was shown that, based on the lateral diaphragmatic line, the diaphragma was concave in 54%, convex in 4% and flat in 42% of cases. Considering its integrity, Sage et al. [9, 10] reported that it was complete in 46% of cases; Ferrieri et al. [11] reported that it was complete in 30%, incomplete in 65% and non-existent in 5% of cases. Nomura et al. [12] found an incomplete diaphragm in 42% of cases in a magnetic resonance imaging study. Another study conducted by Renn and Rhoton [2] showed an opening greater than 5 mm in 56% of samples. On the other hand, this number was 39% in autopsies conducted by Bergland et al. [13]. In the study by Kursat et al. [7], the opening was larger than 5 mm in 11 (85%) cases. When considering the width and length of the diaphragm sellae, Renn and Rhoton [2] found a mean width of 11 mm (6–15 mm) and a mean length of 8 mm (5–11 mm). Also, in 84% of cases, the width was greater than the length. Kursat et al. [7] found a mean width of 13.65 mm (±1.66 mm) and a mean length of 9.55 mm (±1.38 mm), and in only one case (6%), was the length greater than width.

Considering the anatomy of the sellar dura, two aspects are of great importance in tumor extension: its resistance, and the structure of the medial wall of the cavernous sinus. Yilmazlar et al. [14] reported that the medial wall was a thin barrier consisting of meningeal dura, disposed in a loosely arranged configuration of collagen fibers, becoming thiner as it extends posteriorly. The study by Kursat et al.

[7] also demonstrated that the thickness of the inferior segment of the medial wall was thinner than the superior segment. In a study by Peker et al. [15], it was observed that the mean thickness of the medial wall was 85 μm (10–180 μm), and in some cases there was a significant difference between left and right walls—which could explain asymmetric growth of tumors. None of the specimens in these studies showed defects in the medial wall. In contrast, Dieteman et al. [16] could not visualize, in an MRI study on cadavers, the dural wall separating the pituitary gland from the cavernous sinus, finding only a weak fibrous bed. Therefore, it can be argued that the regions of fragility demonstrated in these studies may play a key role in parasellar extensions of tumor or cavernous sinus infiltration. Considering the barrier formed by the medial wall, it becomes clear that the most likely direction of growth is into the suprasellar space through the natural opening through which the pituitary stalk passes and to the lower resistance of the cisternal space above the diaphragma sellae. Finally, it is of note that a normal pituitary may occasionally expand laterally towards the cavernous sinus. Rhoton [1] and Renn and Rhoton [2] found this asymmetry in 28%; Bergland et al. [13], in 22% and Destrieux et al. [17], in 29%. Therefore, some confusion may occur between this natural extension of the gland and eventual tumor extension. Cottier et al. [18] reported that it is safe to conclude that there is cavernous sinus invasion if and when the percentage of encasement of the cavernous segment of the internal carotid artery by the tumor is 67% or greater, using MRI.

Carotid artery

The transsphenoidal approach to the sellar region requires great care with regard to the internal carotid artery and its branches. First, it is important to note the distance between the carotid artery and the lateral surface of the pituitary gland. When the artery does not indent the gland (which may happen in 25% of cases), there was a mean distance of 2.3 mm (1–7 mm) [2, 19]. The proximity of the arteries to the midline is also of note. Renn and Rhoton [2] showed that the shortest distance between the two carotid arteries was found in the supraclinoid area in 82% of cases, in the cavernous sinus along the side of the sella in 14% and in the sphenoid sinus in 4%. Arterial bleeding may arise due to injury not only of the carotid artery, but also of its branches, such as the inferior hypophyseal artery or a small capsular artery [5].

Other vascular structures of note are the venous sinuses that interconnect the cavernous sinuses. These connections are: the anterior intercavernous sinus, which passes anterior to the pituitary, and the posterior intercavernous sinus, which passes posterior to the gland. It may be paid attention that these are inconstant and vary in position, that is, they can occur at any site along the anterior, posterior or inferior surface of the pituitary, and may be absent. The size of these sinuses varies—for example, the anterior sinus (usually larger than the posterior) may cover the whole anterior wall of the sella. When both sinuses coexist, the entire structure is named the circular sinus. When the anterior sinus extends downward in front of the gland, there is a risk of bleeding when reaching the sellar region during surgery, but it may be stopped with temporary compression of the channel with hemostatic foam or with light coagulation (in order to 'glue' the walls of the channel together). The basilar sinus is the largest and most constant sinus across the midline connecting the posterior aspects of the cavernous sinuses, passing posterior to the dorsum sellae and the upper clivus. The superior and inferior petrosal sinuses join the basilar sinus. The abducens nerve may enter the posterior part of the cavernous sinus by passing through the basilar sinus [1, 2].

The Figs. 1, 2, 3, 4, and 5 shows different views of the sellar region.

Endoscopic anatomy

We describe here the steps related to the endoscopic approach to the sellar region. The first step is to locate the ostia of the sphenoid sinus. One approach is to locate the inferior edge of the middle conchae and search for the ostium approximately 1 cm superior to it along the posterior nasal wall [20, 21]. The second step consists of the sphenoidotomy (enlarged initially in an inferior and medial

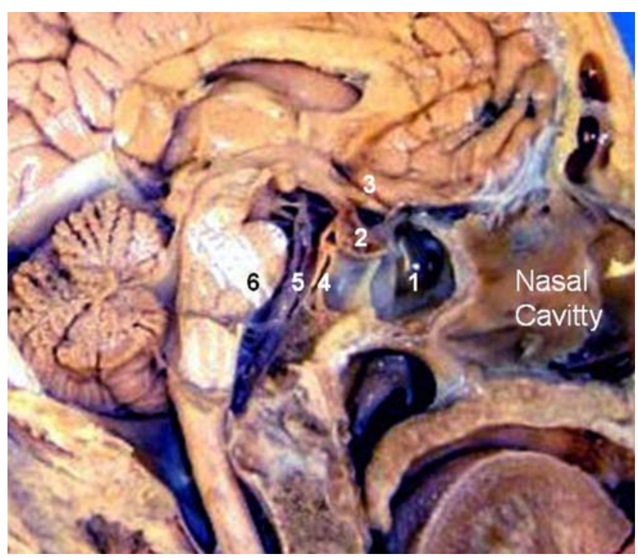

Fig. 1 Sagital view of the sellar region. 1 Sphenoid sinus, 2 pituitary, 3 optic nerve, 4 clivus, 5 basilar artery, 6 pons

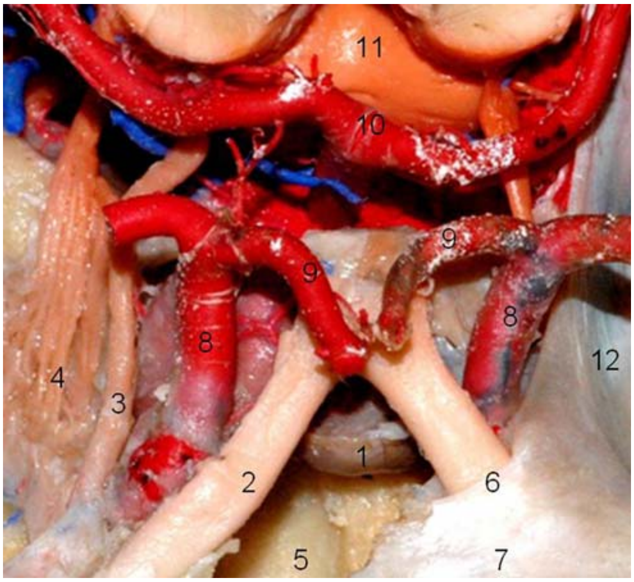

Fig. 2 Superior view of the sellar region. The roof of the ethmoidal and sphenoidal sinus was ressect. The right middle fossa dura was ressect to expose the cavernous sinus anatomy. 1 Pituitary, 2 optic nerve, 3 oculomotor nerve, 4 trigeminal nerve, 5 sphenoid sinus, 6 falciform ligament, 7 orbital roof, 8 internal carotid artery, 9 anterior cerebral artery (A1 segment), 10 posterior cerebral artery (P1 segment), 11 brainstem, 12 parasellar region

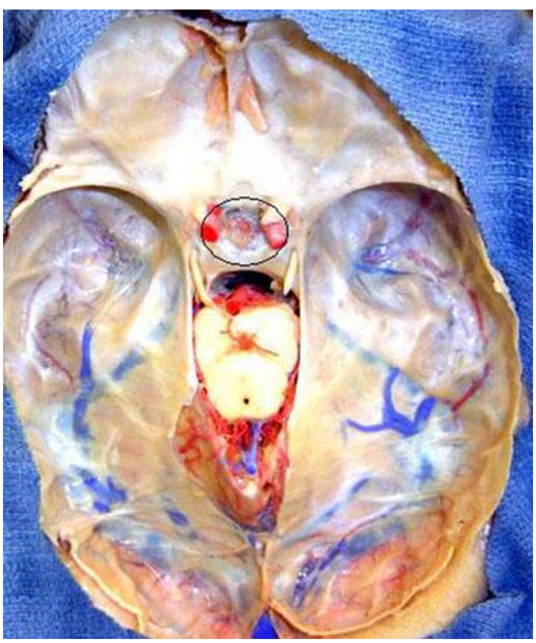

Fig. 3 The *circle* localizes the sellar region in the skull base

Fig. 4 Lateral view of the sellar region and adjacent anatomy. 1 Pituitary, 2 pituitary stalk, 3 superior hypophyseal artery, 4 sphenoid sinus, 5 meningohypophyseal trunk, 6 intracavernous internal carotid artery, 7 ophthalmic artery, 8 optic nerve, 9 inferolateral trunk, 10 V1, 11 V2, 12 lateral pterygoid muscle (superior head)—infratemporal fossa, 13 V3, 14 petrous portion of the internal carotid artery, 15 cochlea, 16 clivus (venous plexus), 17 dorsal meningeal artery, 18 VI cranial nerve, 19 lower cranial nerves, 20 vertebral artery, 21 superior petrosal sinus, 22 superior semicircular canal, 23 dorsum sellae

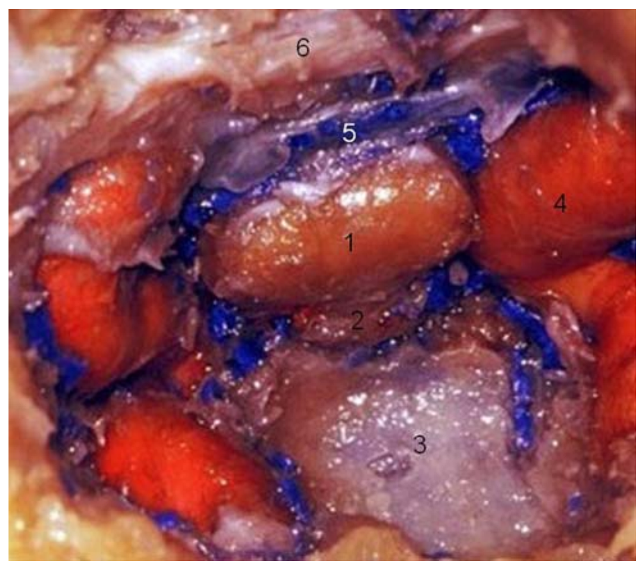

Fig. 5 Sellar region, anterior view. The medial wall of the cavernous sinus were ressect in both sides to expose the internal carotid artery. 1 Adenohypophysis, 2 neurohypophysis, 3 clivus, 4 internal carotid artery, 5 intracavernous sinus, 6 anterior fossa floor

direction to avoid the neurovascular structures located laterally) and the exposure of the sella. It is necessary to resect the rostrum of the sphenoid and a small portion of the posterior nasal septum, which allows a wide bilateral view of the sphenoid via either side of the nose. After that, the intrasinus septae are removed carefully removed avoiding injury to the carotid artery or the optic nerves, as the septum may insert over these structures. The final endoscopic view is the posterior wall of the sphenoid sinus and the floor of the sella [22].

The sella is a central reference point in the posterior wall of the sphenoid. Superiorly and anteriorly, the planum sphenoidale forms the roof of the sinus; inferiorly and posteriorly, the clivus forms the back wall of the sinus; laterally, the carotid artery forms two protuberances—an inferior one, the paraclival protuberance (usually more prominent), and a superior one, the parasellar protuberance. Superior to the parasellar protuberance, the bulge of the optic canal is found (the optic chiasm is located just above the planum sphenoidale). The triangular space between the optic nerve (superiorly) the carotid artery (medially) and the oculomotor nerve (inferiorly) is the optico-carotid recess, which extends into the cranial fossa as the anterior clinoid process. It is possible to identify the ophthalmic artery arising medially off of the carotid immediately below the optic nerve. The cavernous sinus apex and the maxillary and mandibular divisions of the trigeminal nerve delimitate other two triangular recesses: the V1-V2 and the V2-V3 recesses. They do not reliably correspond to any intracranial structure. Though the carotid artery and optic nerve are easly identified (covered by very thin or even dehiscent bone), the other surface landmarks may not be, and intraoperative bleeding may obscure these landmarks [22, 23].

The exposure of the sella turcica is accomplished after mucosal cauterization (to diminish bleeding and maximize exposure) and bone resection. An incision in the dura is made and the pituitary is exposed. Eventually, the tumor may prolaps through the created defect. It is important to leave the bone over the carotid artery intact, so that the risk of bleeding decreases. After dissecting, the infundibulum may be found. Posterior to it, opens the cerebral spinal fluid-containing space of the interpeduncular cistern. There, one can visualized the mammillary bodies superiorly, the cerebral peduncules posteriorly and the basilar tip over the pons inferiorly. The basilar tip may be best seen coursing up along the clivus after removing the dorsum sellae (which corresponds to the posterior bony border of the sella). Lateral to the pituitary is the C-shaped portion of the carotid artery curving anterolaterally. In the cadaver, careful medial retraction of the artery reveals the neural structures of the cavernous sinus (the oculomotor, trochlear and abducens nerves and the ophthalmic and maxillary divisions of the trigeminal nerve). The ophthalmic division goes to the superior orbital fissure, while the maxillary division passes to the Gasserian ganglion, through the foramen rotundum and to the sphenopalatine ganglion in the pterygomaxillary fossa. The mandibular division may be seen with more extensive dissection, laterally and inferiorly. Finally, the most inferior structure seen in the floor of the sphenoid sinus by this approach is the vidian nerve, which travels from the foramen lacerum to the vidian canal [22, 23].

Discussion

The current frontal transcranial approach to the sella turcica was introduced in 1905 by Krause, and has served as the base for most later transcranial approaches [24]. Schloffer developed a transsphenoidal route as an alternative and probably safer route to the sella turcica [25] and in 1907 reported the first case of successful tumor excision using this technique [26]. Since then, the transsphenoidal approach has been the preferred technique to access sellar lesions, and recently its indications have been expanded to access lesions of the upper clivus [27, 28] and of the parasellar region [29–37].

The transsphenoidal approach has the following anatomic limits: (1) superiorly, the posterior cribriform region; (2), laterally, the cavernous sinus and carotid arteries; and (3) inferiorly, based on the inferior placement of the retractor and the extent of visualization of the clivus (commonly the region of the cervicoclival junction) [39]. When a lateral extension is needed, a transmaxillary route may be used [40–43]. Endoscopy may maximize the exposure in all directions [44–47]. In treating lateral extension, the carotid grooves are unroofed, and there is a exposure of the C3 portion of the internal carotid—the entrance to the cavernous sinus is made by opening the dura just medial to the carotid artery. By proceeding this way, there is a reduction in the need for blind curettage of tumor as performed by reaching the cavernous sinus via the sella [39]. When complete surgical resection is not possible, many surgeons [39] recommend the use of adjuvant radiosurgery. Their goal is to avoid potential cranial neuropathy. In occasional cases, hypophysopexy must be performed to enable the appropriate resection without losing pituitary function [48]. In the case of chordomas, primarily extradural and midline in location, the extended transsphenoidal approach is adequate in most cases. Even so, if there is a considerable lateral extension, a more lateral approach may be needed, and if there is a extension below the inferior clivus, a transoral route can be considered [39], or an extended transmaxillary/transsphenoidal approach can be used. This approach can reach all clival segments. The same is true nowadays with the advancement of endoscopic approaches.

When extensive dissection of the cavernous sinus is planned, a carotid balloon occlusion test should be performed, because of the high risk of carotid artery injury and hemorrhage (sometimes the only way of stopping the bleeding may be ligation of the artery in its cervical portion). If carotid rupture occurs during surgery, postoperative angiography should be performed to exclude the presence of a false aneurysm (a condition that may lead to delayed, potentially fatal epistaxis). If noted, the false aneurysm should be treated by endovascular approach. When no aneurysm is seen postoperatively, a new angiogram must be done in 7–10 days to exclude delayed aneurysm formation [39].

Ciric [49] emphasized that the use of intracranial navigation with computerized stereotatic guidance adds significant safety to the procedure, not only because it controls the vertical orientation, but also the horizontal orientation relating to the position of the carotid arteries, optic nerves and other structures. He emphasizes that after accessing the sphenoid sinus via an endonasal microsurgical approach, it is important to expose the entire anterior and inferior sella walls, the planum, clivus, and both carotid tubercles. Finally, this author notes that the recognition of the arachnoid membrane during the dissection in the suprasellar space is critical for a successful outcome, since the tumor is always located beneath the arachnoid, essentially regardless of its size.

Commenting on the same study, Cappabianca [50] maintains that the endoscope is superior to the microscope in providing wider and closer vision. On the other hand, the microscope allows better tridimensional vision, maneuverability with both hands, and better conditions for reconstruction of the cranial base defect. In order to reduce the risk of carotid artery injuries, it is useful to adopt regular intraoperative investigation with a microdoppler probe, which allows safe exposure of the medial and eventually of the lateral segment of the intracavernous internal carotid artery [51].

Approaches

The subfrontal approach to the suprasellar region is ideal for tumors located between, above or below the optic nerves and chiasm in the chiasmatic and lamina terminalis cisterns. Basically, it consists of a small frontal bone flap and frontal lobe elevation to expose the involved region. It should be selected when the sphenoid sinus is not pneumatized, the sella is small or not of sufficient size to reach the suprasellar portion of the tumor, or if there is an unusual suprasellar extension of the tumor that cannot be reached through the transsphenoidal approach. In addition, a pterional craniotomy can be considered if it is necessary to reach the area lateral to the anterior clinoid process and supraclinoid segment of the internal carotid artery, and an orbitozygomatic craniotomy would be suitable if there was a major involvement of the cavernous sinus [1].

The subfrontal approach starts with a bicoronal scalp incision behind the hair line, being the scalp flap reflected forward as a single layer. Then, a small frontal bone flap is created just above the supraorbital margin and extending up to the lateral edge of the superior sagittal sinus. The lateral burr hole is located above the orbital rim and the medial burr hole is located through the front and back wall of the frontal sinus [1]. Once the area below the frontal lobe is reached, the surgeon may follow four different routes: (1) the subchiasmatic approach, which extends between the optic nerves and below the chiasm (most often used, since tumors tend to elevate the chiasm and open this space); (2) the opticocarotid approach, which extends between the carotid artery and the optic nerve (suitable for tumors spreading through this space and difficult to reach by a suprachiasmatic approach); (3) the transfrontal-transsphenoidal approaches, which consist of drilling the planum sphenoidale in order to combine the approaches (used when there is a prefixed chiasm and a large portion of tumor in the sphenoid sinus); and (4) the lamina terminalis approach, which goes above the chiasm, medial to the optic tracts and above the anterior communicating artery (ideal when there is a prefixed chiasm and a tumor presenting through a thin stretched lamina terminalis) [1, 6].

References

1. Rhoton AL Jr (2002) The sellar region. Neurosurgery 51(suppl 1):335–374. doi:10.1097/00006123-200208000-00007
2. Renn WH, Rhoton AL Jr (1975) Microsurgical anatomy of the sellar region. J Neurosurg 43:288–298
3. Fujii K, Chambers SM, Rhoton AL Jr (1979) Neurovascular relationships of the sphenoid sinus: a microsurgical study. J Neurosurg 50:31–39
4. Rhoton AL Jr (2000) Anatomy of the pituitary gland and sellar region. In: Thapar K, Thapar K, Kovacs K, Scheithauer BW, Lloyd RV (eds) Diagnosis and management of pituitary tumors. Humana Press Inc., Totowa, pp 13–40
5. Laws ER Jr, Kern EB (1976) Complications of trans-sphenoidal surgery. Clin Neurosurg 23:401–416
6. Rhoton AL Jr, Maniscalco JE (1977) Microsurgery of the sellar region. In: Glaser JS (ed) Neuro-Ophtalmology. C.V. Mosby co., St Louis, pp 106–127
7. Kursat E, Yilmazlar S, Aker S, Aksoy K, Oygucu H (2008) Comparison of lateral and superior walls of the pituitary fossa with clinical emphasis on pituitary adenoma extension: cadaveric-anatomic study. Neurosurg Rev 31:91–99. doi:10.1007/s10143-007-0112-6
8. Williams PL (1995) Gray's Anatomy, 38th edn. Churchill Livingston, Edinburg
9. Sage MR, Blumbergs PC, Fowler GW (1982) The diaphragma sellae: its relationship to normal sellar variations in frontal radiographic projections. Radiology 145:699–701
10. Sage MR, Blumbergs PC, Mulligan BP, Fowler GW (1982) The diaphragma sellae: its relationship to the configuration of the pituitary gland. Radiology 145:703–708
11. Ferrieri AJM, Garrido SA, Markarian MG, Yañez A (1992) Relationship between the development of diaphragma sellae and the morphology of the sella turcica and its content. Surg Radiol Anat 14:233–239. doi:10.1007/BF01794946
12. Nomura M, Tachibana O, Yamashima T, Yamashita J, Suzuki M (2002) MRI evaluation of the diaphragmal opening: using MRI parallel to the transsphenoidal surgical approac. J Clin Neurosci 9:175–177. doi:10.1054/jocn.2000.0920
13. Bergland RM, Ray BS, Torack RM (1968) Anatomical variations in the pituitary gland and adjacent structures in 225 human autopsy cases. J Neurosurg 28:93–99
14. Yilmazlar S, Kocaeli H, Aydiner F, Korfali E (2005) Medial portion of the cavernous sinus: microsurgical anatomy. Clin Anat 18:416–422. doi:10.1002/ca.20160
15. Peker S, Kurtkaya-Yapicier O, Kilic T, Pamir MN (2002) Microsurgical anatomy of the lateral walls of the pituitary fossa. Acta Neurochir (Wien) 147:641–649. doi:10.1007/s00701-005-0513-7

16. Dietemann JL, Kehrli P, Maillot C, Diniz R, Reis M Jr, Neugroschl C et al (1998) Is there a dural wall between the cavernous sinus and the pituitary fossa? Anatomical and MRI findings. Neuroradiology 40:627–630. doi:10.1007/s002340050653
17. Destrieux C, Kakou MK, Velut S, Lefrancq T, Jan M (1998) Microanatomy of the hypophyseal fossa boundaries. J Neurosurg 88:743–752
18. Cottier JP, Detrieux C, Brunereau L, Bertrand P, Moreau L, Jan M et al (2000) Cavernous sinus invasion by pituitary adenoma: MR imaging. Radiology 215:463–469
19. Harris FS, Rhoton AL Jr (1976) Anatomy of the cavernous sinus: a microsurgical study. J Neurosurg 45:169–180
20. Jho HD (1999) Endoscopic pituitary surgery. Pituitary 2:139–154. doi:10.1023/A:1009991631761
21. Alfieri A, Jho HD (2001) Endoscopic endonasal approaches to the cavernous sinus: surgical approaches. Neurosurgery 49:354–360. doi:10.1097/00006123-200108000-00017
22. Bassim MK, Senior BA (2007) Endoscopic anatomy of the parasellar region. Am J Rhinol 21:27–31. doi:10.2500/ajr.2007.21.2994
23. Alfieri A, Jho HD (2001) Endoscopic endonasal cavernous sinus surgery: an anatomic study. Neurosurgery 48:827–836. doi:10.1097/00006123-200104000-00027
24. Krause F (1905) Hirnchirurgie (Freielung Do Hypophyse). Dtsch Klin 8:953
25. Schloffer H (1906) Zur frage der Operationen an der Hypophyse. Beitr Klin Chir 50:767–817
26. Schloffer H (1907) Erfulgreiche operation eines hypophysentumors auf nasalem wege. Wien Klin Wochamschr 20:621–624
27. Laws ER Jr (1984) Transsphenoidal surgery fortumors of the clivus. Otolaryngol Head Neck Surg 92:100–101
28. Weiss HM (1997) Transnasal transsphenoidal approach. In: Appuzo MLJ (ed) Surgery of the third ventricle. Williams & Wilkins, Baltimore, pp 476–494
29. Couldwell WT, Weiss HM (1998) Transnasal transsphenoidal approach. In: Appuzo MLJ (ed) Surgery of the third ventricle. Williams & Wilkins, Baltimore, pp 553–574
30. Kaptain GJ, Vincent DA, Sheehan JP, Laws ER Jr (2001) Transsphenoidal approaches for the extracapsular resection of midline suprasellar and anterior cranial base lesions. Neurosurgery 49:94–101. doi:10.1097/00006123-200107000-00014
31. Kato T, Sawamura Y, Abe H, Nagashima M (1998) Transsphenoidal-transtuberculum sellae approach for supradiaphragmatic tumors: technical note. Acta Neurochir (Wien) 140:715–719. doi:10.1007/s007010050167
32. Kern EB, Pearson BW, McDonald TJ, Laws ER Jr (1979) The transseptal approach to lesions of the pituitary and parasellar regions. Laryngoscope 84(Suppl 15):1–34
33. Kouri JG, Chen MY, Watson JC, Oldfield EH (2000) Resection of suprasellar tumors by using a modified transsphenoidal approach. J Neurosurg 92:1028–1035
34. Laws ER Jr, Onofrio BM, Pearson BW, McDonald TJ, Difrrenberger RA (1979) Successfull management of bilateral carotid-cavernous fistulae with a transphenoidal approach. Neurosurgery 4:162–167. doi:10.1097/00006123-197902000-00010
35. Mason RB, Nieman LK, Doppman JL, Oldfield EH (1997) Selective excision of adenomas originating in or extending into the pituitary stalk with preservation of pituitary function. J Neurosurg 87:343–351
36. Sasaki CT (1984) Transseptal-transsphenoidal approach to the sella. In: Sasaki CT, McCabe BF, Kirchner JA (eds) Surgery of the Skull Base. Lippincott, Philadelphia, pp 79–93
37. Tindall CT, Barrow DL (1986) Disorders of the Pituitary. C.V. Mosby Co., St Louis
38. Cushing H, Eisenhardt L (1938) Meningiomas of the sphenoidal ridge: part A—those of the deep or clinoidal third. In: Cushing H, Eisenhardt L (eds) Meningiomas: their classification, regional behavior, life history, and surgical end results. Charles C. Thomas, Spriengfield
39. Couldwell WT, Weiss MH, Rabb C, Liu JK, Apfelbaum RI, Fukushima T (2004) Variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. Neurosurgery 55(3):539–550. doi:10.1227/01.NEU.0000134287.19377.A2
40. Couldwell WT, Sabit I, Weiss HM, Giannotta SL, Rice D (1997) Transmaxillary approach to the anterior cavernous sinus: a microanatomic study. Neurosurgery 40:1307–1311. doi:10.1097/00006123-199706000-00040
41. Fraioli B, Esposito V, Santoro A, Iannetti G, Giuffre R, Cantore G (2008) Transmaxillosphenoidal approach to tumors invading the medial compartment of the cavernous sinus. J Neurosurg 82:63–69
42. Rabadan A, Conesa H (1992) Transmaxillary-transnasal approach to the anterior clivus: a microsurgical anatomic model. Neurosurgery 30:473–481
43. Sabit I, Schaeffer S, Couldwell WT (2000) Extradural extranasal combined transmaxillary transsphenoidalapproach to the cavernous sinus: a minimally invasive microsurgical model. Laryngoscope 110:286–291. doi:10.1097/00005537-200002010-00019
44. Alfieri A (1999) Endscopic endonasal transsphenoidal approach to the sellar region: technical evolution of the methodology and refinement of a dedicated instrumentation. J Neurosurg Sci 43:85–92
45. Cappabianca P, Alfieri A, Thermes S, Buanomassa S, de Divitiis E (1999) Instruments for endonasal transsphenoidal surgery. Neurosurgery 45:392–396. doi:10.1097/00006123-199908000-00041
46. Jho HD, Carrau RL (1997) Endoscopic endonasal transsphenoidal surgery: experience with 50 patients. J Neurosurg 87:44–51
47. Laws ER Jr (1997) Endoscopic pituitary surgery: an early experience. Surg Neurol 47:222–223. doi:10.1016/S0090-3019(97)80750-1
48. Couldwell WT, Rosenow JM, Rovit RL, Benzil DL (2002) Hypophysopexy technique for radiosurgical treatment of cavernous sinus pituitary adenoma. Pituitary 5:169–173. doi:10.1023/A:1023313232296
49. Ciric IS (2004) Comment on: variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. Neurosurgery 55:548
50. Cappabianca P (2004) Comment on: variations on the standard transsphenoidal approach to the sellar region, with emphasis on the extended approaches and parasellar approaches: surgical experience in 105 cases. Neurosurgery 55:549
51. de Divitiis E, Cappabianca P (2003) Endoscopic endonasal transsphenoidal surgery. Springer, New York