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The Learning Curve in Skullbase Surgery Part 2–From the Microsurgical Lab Training to the Operative Room

A Curva de Aprendizado em Cirurgia de Base do Crânio - Do laboratório de microcirurgia à sala cirúrgica

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Abstract

In this second part, the authors review and suggest a methodology for studies in skull base surgery and training in microsurgical laboratory, based on their experiences and reflections. Not only are the foundations for the acquisition of microsurgical skills presented, but also what is needed to be an effective skullbase surgeon with good results. The present article reflects in particular the philosophy of professor Evandro de Oliveira and also serves to present to the neurosurgical community a new state-of-the-art laboratory for hands-on courses in Brazil, at the Faculdade Evangélica Mackenzie do Paraná.

Keywords
- skullbase
- learning curve
- microsurgical laboratory

Resumo

Nesta segunda parte, os autores revisam e sugerem uma metodologia para o estudo em cirurgia de base de crânio e treinamento em laboratório de microcirurgia baseado em suas experiencias e reflexões. Não apenas os fundamentos para a aquisição de habilidades microcirúrgicas estão presentes, como também, o que é necessário para ser um eficiente cirurgião de base de crânio com bons resultados. Este artigo reflete, em particular, a filosofia do Professor Evandro de Oliveira, além de servir para apresentar a comunidade neurocirúrgica o novo "estado da arte" em laboratórios de cursos "hands-on" no Brasil, na Faculdade Evangélica Mackenzie do Paraná.

Palavras-chave
- Base de crânio
- Curva de aprendizado
- Laboratório de microcirurgia

This paper, divided in two parts, is a tribute to Professor Evandro de Oliveira, MD, PhD (1945 - 2021).

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Introduction

The second part of the present article addresses the foundations of neurosurgical training and their effect on surgery education and propose a guide to microsurgical laboratory training.

Microsurgical Laboratory Training

Part of Professor M.G. Yasargil's immeasurable contribution to neurosurgery[1–4] is an article reflecting on a life dedicated to neurosurgery.[5] In volume 147 of the 2005 Acta Neurochirurgica magazine, he published an editorial entitled "From the Microsurgical Laboratory to the Operating Theater." It describes the history of the use of the microscope in surgery and neurosurgery and the initial experiences of the author with this technology that revolutionized our concept of the surgical treatment of pathologies of the central nervous system (CNS). As a modern microneurosurgery pioneer, he also provides quite valuable advice for young neurosurgeons. First, a thorough knowledge of neurosurgical microanatomy and its correlation with imaging studies, especially cisterns, parenchymal, and vascular structures, is essential for determining the most appropriate surgical strategy. In addition, modern neuroimaging techniques, such as positron emission tomography (PET), single-photon emission computerized tomography (SPECT), spectroscopy, and molecular biology methods using immunohistochemical markers and molecular analyses have brought great advances to the diagnosis and management of certain groups of CNS diseases. Young skullbase surgeons must be aware of these options and obtain at least a basic knowledge of the indications for using each one. Another topic the professor addresses is that, thanks to microsurgical training and knowledge of the anatomy of the CNS and safe anatomical corridors (►Fig. 1), almost any brain injury can be addressed with a low risk of operative morbidity. He ends the editorial by advising young neurosurgeons to train for at least 1 year in a microsurgery laboratory to develop their knowledge of surgical microanatomy and their facility with a microscope. It must be remembered that, as he also wrote, one limitation of cadaver models is that brain retraction cannot be quantified with them. This is problematic, especially when studying new access routes into deep brain regions. On the other hand, anatomical specimens that are not prepared with formalin have more consistent hardening of the formalized brain tissue. This is especially useful for practicing access to the skullbase.

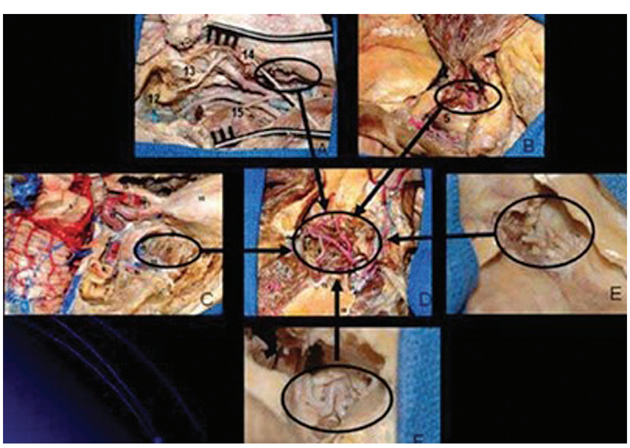

Fig. 1 We can approach the infratemporal fossa from several ways. Mastering microanatomy is fundamental to safe access deep neurovascular structures through the natural corridors of the brain (cisterns).

Fig. 2 Microanatomy laboratories around the world: (A) Skullbase Laboratory at Weill Cornell Brain and Spine Center; (B) Microsurgical Laboratory at the Hospital Beneficência Portuguesa de São Paulo; (C) Dianne and Gazi Yasargil Education Center at the University of Arkansas for Medical Sciences.

There are several microsurgery laboratories in the world today (►Fig. 2). Those who wish to dedicate themselves to skullbase microneurosurgery must be prepared to train in one of these locations. It should also be noted that, as important as the structure and size of the laboratory itself, access to anatomical specimens is essential. Before making this investment of time and money, young neurosurgeons must consider all the obstacles to gaining adequate training. A good way to do this is to talk with colleagues who have trained in one of these locations. It should not be forgotten, however, that as long as a room contains a surgical microscope, microsurgical instruments, and material to dissect or train on, microsurgical training is possible regardless of the location. Manual dexterity is developed with the dissection and microanastomosis of placental vessels (►Fig. 3 and 4), followed by vascular microanastomosis in the internal carotid artery of rats (►Figs. 5–7) and arterial bypass using the femoral artery of guinea pigs, to name a few examples. After all this training the surgeon would be able to perform his/her first bypass (►Fig. 8).

Laboratory Training to Access the Lateral Skullbase

In some microsurgery laboratories, microsurgical dissection exercises can be performed with blocks taken from regions of the skullbase. Temporal bones or skullbase central blocks are

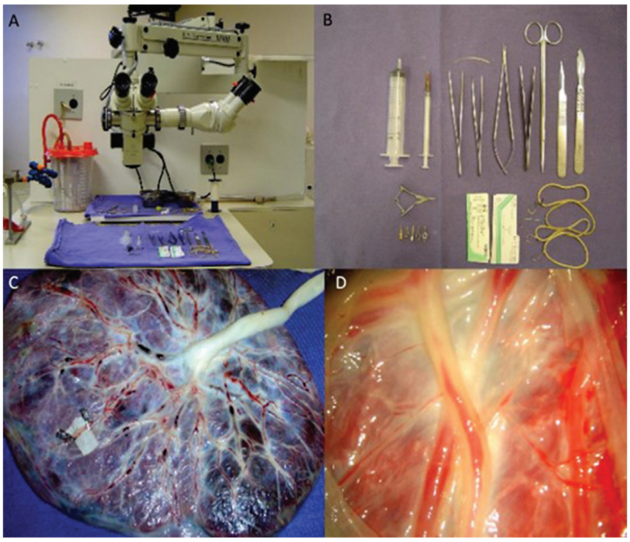

Fig. 3 (A) Desktop sugical microscope for dissection skill training; (B) simple surgical instruments for dissection training; (C) Placenta used for skill training. Notice 2 vascular clips and a microsuture; (D) Placentary vessels: Ideal for microanastomosis training.

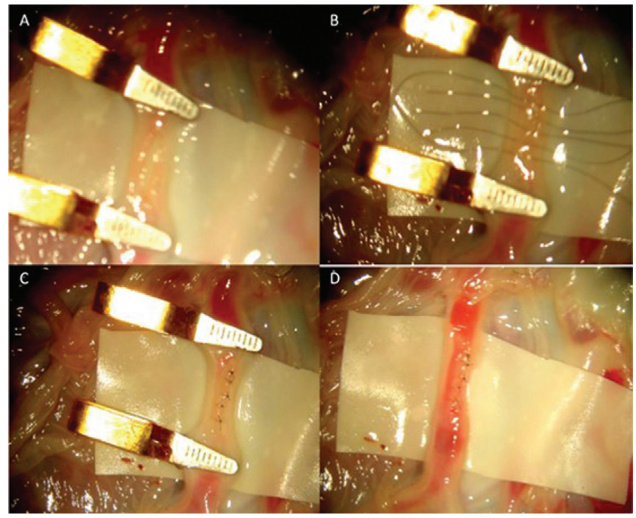

Fig. 4 Suture under microscope step-by-step. (A) dissected vessel with perpendicular incision between distal clips; (B) microsuture of arterial wall being performed; (C) sutured arterial wall; (D) perfused artery.

the most used anatomical preparations for studying the cavernous sinus. Although dissecting these regions is crucial for understanding the three-dimensional anatomy of all the intricate structures, one of the greatest insights that microsurgical laboratory training can provide is an excellent understanding of the relationship of the brain and nerves with the base of the skull as studied for a specific approach.[6–20] Studying the entire head of a corpse not only lets us perform different approaches to the same anatomical region, but also provides us with many neuroimaging insights (►**Fig. 9–11**).[6,20] To maximize training opportunities, such as that every possible access is explored in a single corpse, on the lateral skullbase hands-on access courses we have been providing at the Weill Cornell Medical Center we have been developing the following optimized dissection sequence.

We start the dissections with the cranio-orbito-zygomatic approach (►**Fig. 12**). After the skin incision, we perform a

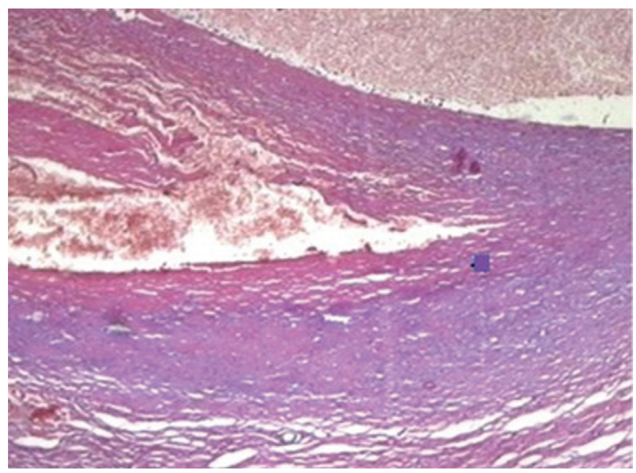

Fig. 6 Histological study of laboratory specimen of previous figure (rat B): blood clot formed within the anastomosed internal carotid artery.

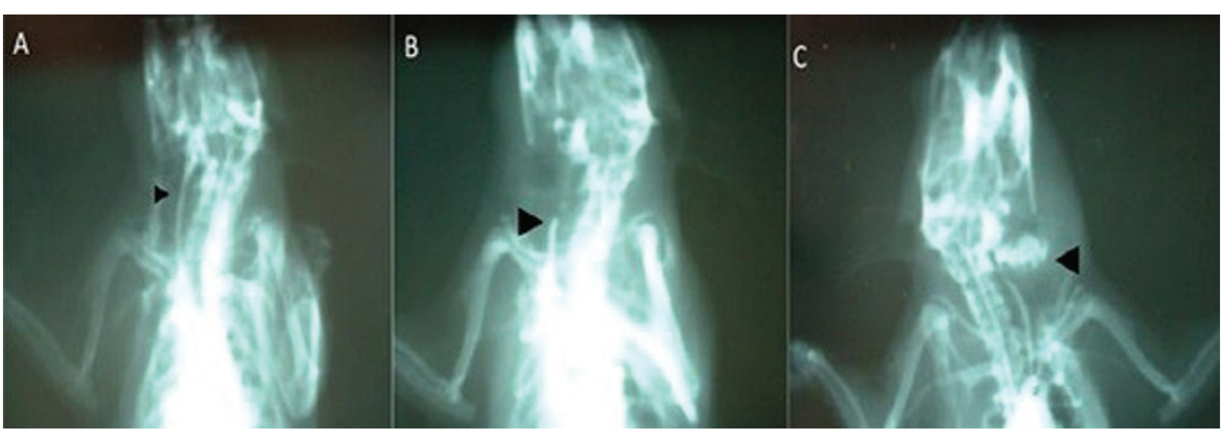

Fig. 5 Postoperative angiography of laboratory specimens; (A) end-to-end anastomosis of internal carotid artery: blood flow reestablished; (B) thrombosis of the microvascular anastomosis and interrupted blood flow; (C) anastomotic pseudoaneurysm formed in the internal carotid artery after microvascular procedure.

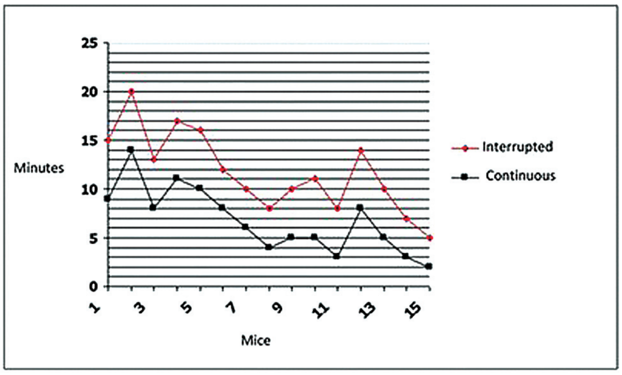

Fig. 7 The result of laboratory training in surgical procedures: less time needed to perform a microanastomosis as more trained becomes the surgeon.

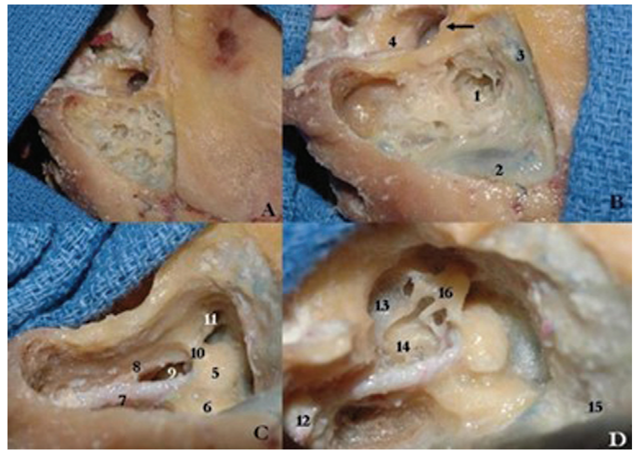

Fig. 9 Anatomical knowledge of the mastoid part of the temporal bone is crucial to perform petrosectomies; 1–mastoid antrum; 2–sigmoid sinus; 3–tegmen mastoideum; 4–external acoustic canal; 5–lateral semicircular canal; 6–posterior semicircular canal; 7–facial nerve; 8–chorda tympani nerve; 9–facial recess; 10–septum osseux; 11–epitympanum; 12–tendon of the posterior belly of the digastric muscle; 13–tympanic membrane; 14–promontory; 15–Citelli's angle; 16–incus.

subfascial dissection of the temporal muscle and expose the zygomatic process of the temporal bone. We use the Cranial-orbit zygomatic (COZ) approach in two pieces on one side of the skull and in three pieces on the other. After the craniotomy, an extradural peeling of the anterior fossa and at the beginning of the middle fossa is performed, exposing the anterior clinoid and part of the cavernous sinus. The clinoid is removed as a single piece, drilling its base. A good exercise in this step is to drill not only at the roof of the optic canal, but also the medial bone at the optic nerve to open the posterior ethmoidal cells. The next exercise is to explore the lateral wall of the cavernous sinus by peeling from anterior to posterior. Cranial nerves III and IV and V1, V2, and V3 branches of the trigeminal nerve are exposed at this stage. The cavernous sinus must be entered either through the

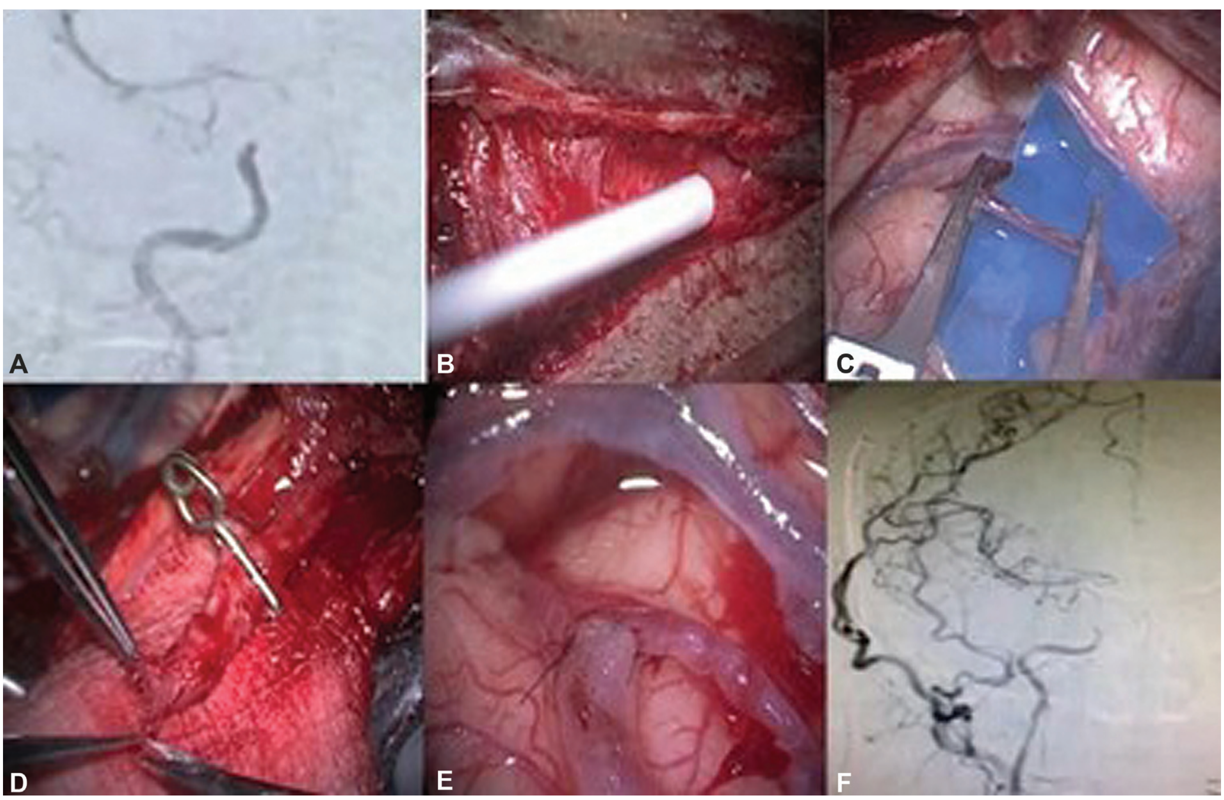

Fig. 8 Microanastomosis of the superficial temporal artery (STA) to the middle cerebral artery (MCA): from laboratory training to the operating room; (A) Preoperative arteriography showing significant occlusion of the internal carotid artery; (B) careful temporal skin incision; (C) checking if the graft measure is compatible with the proposed anastomosis; (D) temporary clip placed in the STA, followed by dissection of the vessel. The surrounding fascia is removed only in the border that will be anastomosed; (E) final aspect of the anastomosis; (F) postoperative arteriography showing significant brain reperfusion.

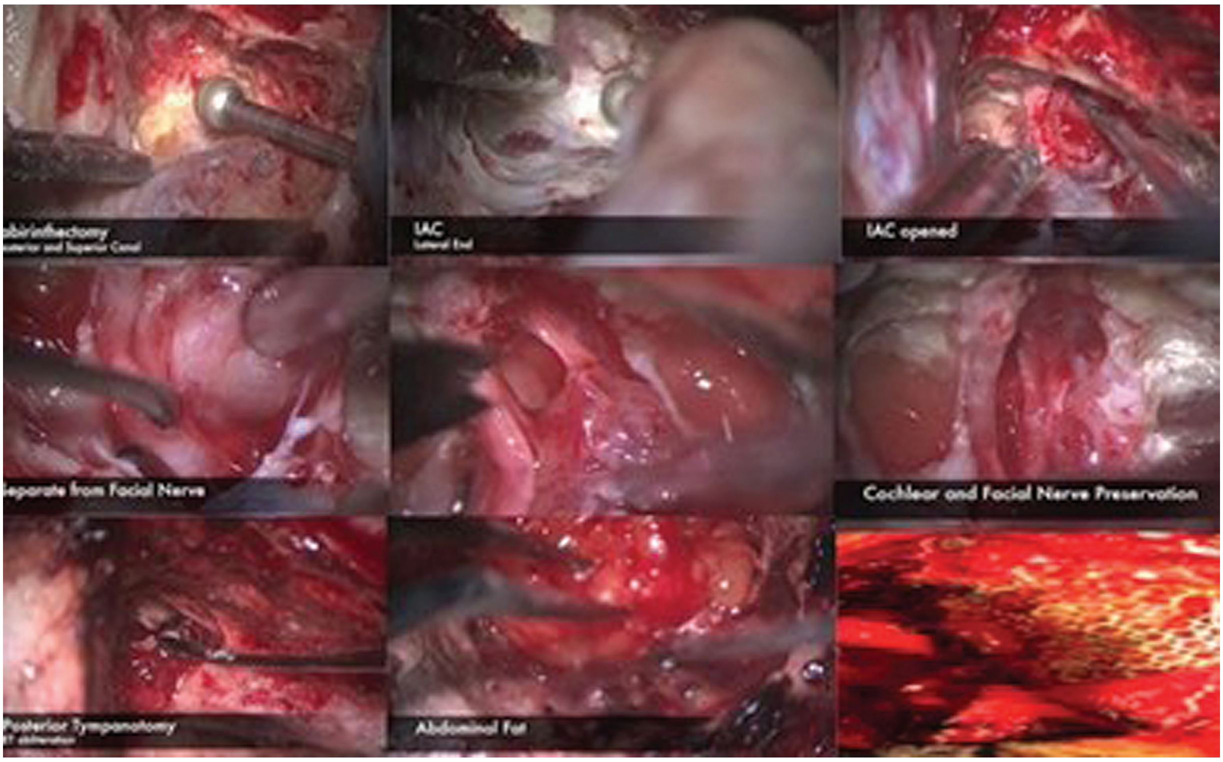

Fig. 10 From microanatomy laboratory training to the operating room: step-by-step mastoid dissection.

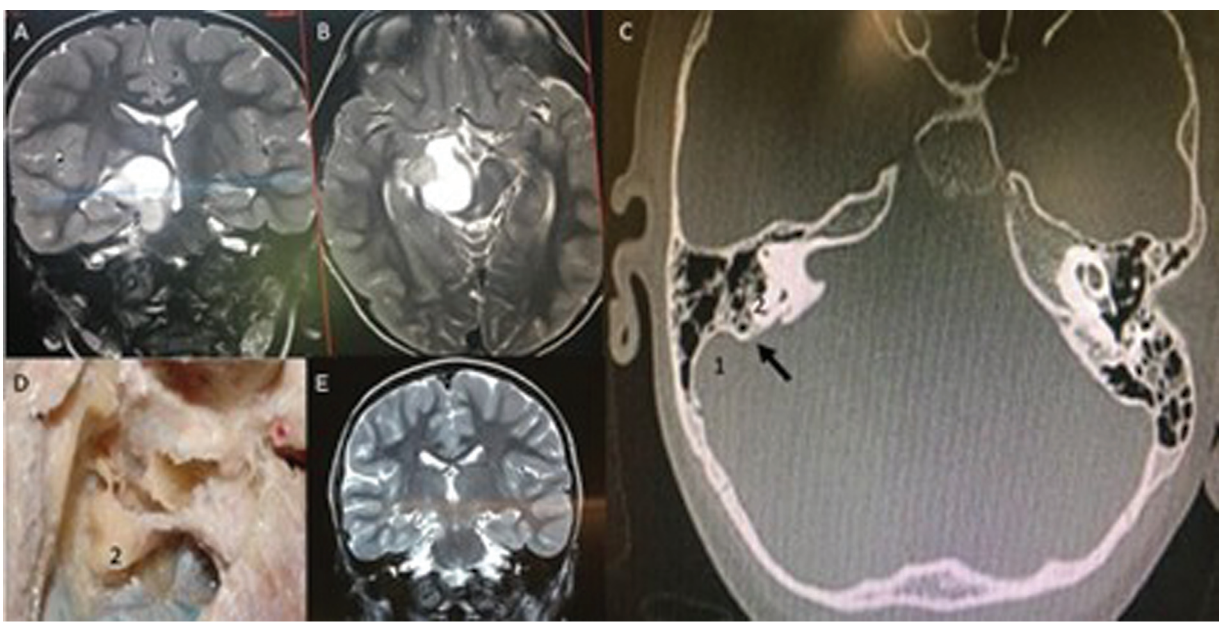

Fig. 11 Thalamic tumor. (A) coronal T2-weighted image showing cystic thalamic tumor; (B) axial T2-weighted image, same tumor; (C) axial computed tomography of the head bone window. A posterior petrosal approach is a possibility. However, in pediatric patients, the space between the sigmoid sinus (1) and the posterior semicircular canal (2) can be too narrow. Based on that, it was performed a transmiddle temporal gyrus approach with near total resection of the lesion and no postoperative deficits; (D) mastoid dissection showing the posterior semicircular canal; (E) coronal T2-weighted postoperative image

supratrochlear or infratrochlear triangles in the lateral wall or through the oculomotor or clinoidal triangles in the upper wall (►**Fig. 13**). Within the cavernous sinus, cranial nerve VI, the internal carotid artery, and the origin of the inferolateral artery and the meningohypophyseal trunk must be visible. After completing this extradural stage, the dura mater is opened in a conventional manner and the Sylvian fissure is dissected. Then, the internal carotid artery, the optic nerve, and the oculomotor nerve can be seen and dissected as far as they extend. This presents an excellent opportunity to continue dissecting the anterior extradural extension of the trigeminal branches and to drill through the anteromedial

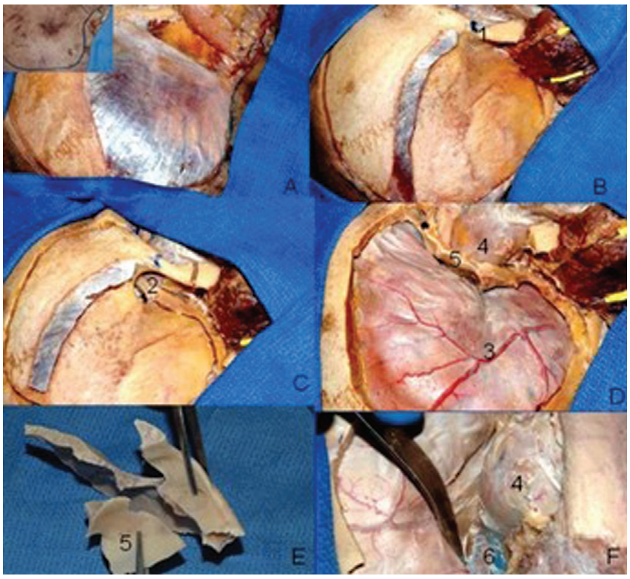

Fig. 12 Cranio-orbital zygomatic approach. (A) skin incision (head rotated to the left); (B) temporal muscle inferiorly mobilized following zygomatic osteotomy; (C) keyhole and craniotomy, bone still in place; (D) bone flap removed; (E) posterior part of the orbital roof removed (later reconstruction); (F) middle fossa dural peeling to expose the cavernous sinus; 1– frontozygomatic suture; 2–orbital roof; 3–middle meningeal artery; 4–periorbita; 5–posterior part of the orbital roof; 6–cavernous sinus.

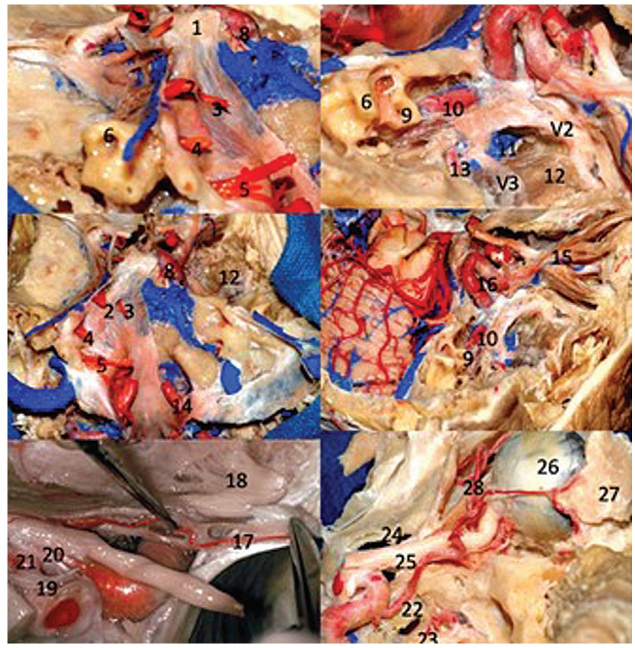

Fig. 13 Cavernous sinus neurovascular relations. 1–dorsum sellae; 2–trigeminal nerve; 3–abducens nerve; 4–facial, vestibular, and trochlear nerves; 5–low cranial nerves; 6–superior semicircular canal; 7–superior petrous sinus; 8–internal carotid artery, cavernous segment; 9–cochlea; 10–internal carotid artery, petrous segment; 11–pterygoid venous plexus; 12–lateral pterygoid muscle, superior head; 13–middle meningeal artery; 14–vertebral artery; 15–oculomotor nerve; 16–internal carotid artery, cavernous segment; 17–marginal tentorial artery (of Bernasconi-Cassinari); 18–Gasser ganglion; 19–distal dural ring; 20–proximal dural ring; 21–internal carotid artery, infraclinoid portion; 22–ophthalmic artery with unusual origin (from the intracavernous segment of the internal carotid artery); 23–sphenoid sinus; 24–ethmoid sinus; 25–optic nerve; 26–ocular globe; 27–lacrimal gland; 28–posterior ethmoidal artery anastomosing with ophthalmic and anterior ethmoidal arteries.

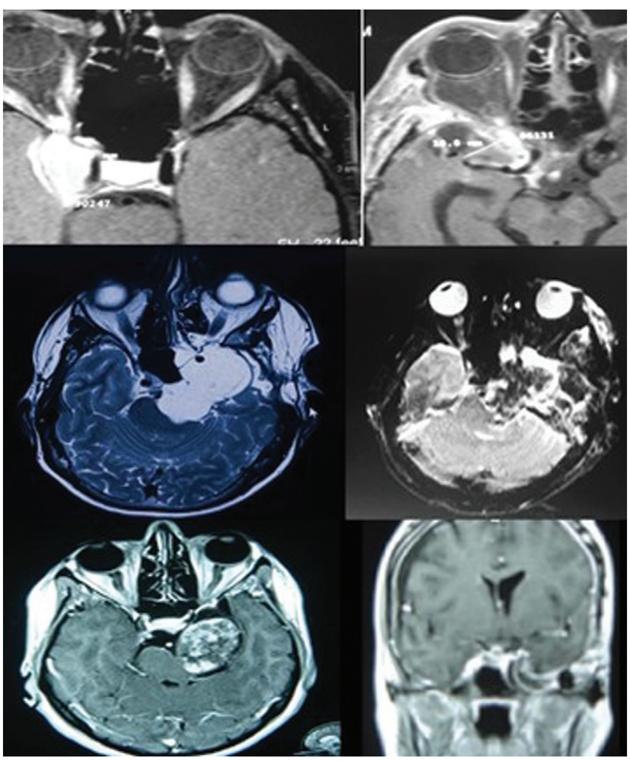

Fig. 14 Examples of cavernous sinus tumors. Preoperative (left) and postoperative (right). Cavernous sinus meningioma (above), cavernous sinus chondrosarcoma (middle), cavernous sinus schwannoma (below).

and anterolateral triangles that are between V1-V2 and V2-V3. This exercise is especially important not only for cavernous sinus tumor resection (►**Fig. 14**) but also for meningiomas in the sphenoid wing (►**Fig. 15**), where there is usually hyperostosis of the pterygoid plate that must be resected. In this intradural area, the posterior clinoid process can be drilled out to observe how it can block the view of the tip of the basilar artery.

After the dura mater is closed, the next exercise is the peeling of the dura mater of the middle fossa, from anterior to posterior, to perform an anterior petrosectomy (►**Fig. 16**). In this step, the head is rotated 90° and an incision is made running posteriorly from the middle of the previous incision. The craniotomy performed in the COZ approach is then extended to the temporal region. The peeling of the middle fossa starts at the level of the external auditory canal and extends anteriorly and medially. The first visible structure should be the middle meningeal artery exiting the spinous foramen. As the trigeminal branches were dissected in the previous approach, at this point the Gasser ganglion is dissected until reaching the petrous apex. In the more posterior region, the greater superficial petrosal nerve (GSPN), the geniculate ganglion, and the superior petrous sinus are exposed (►**Fig. 17**). The arcuate eminence is reached and, in most cases, correspond to the upper

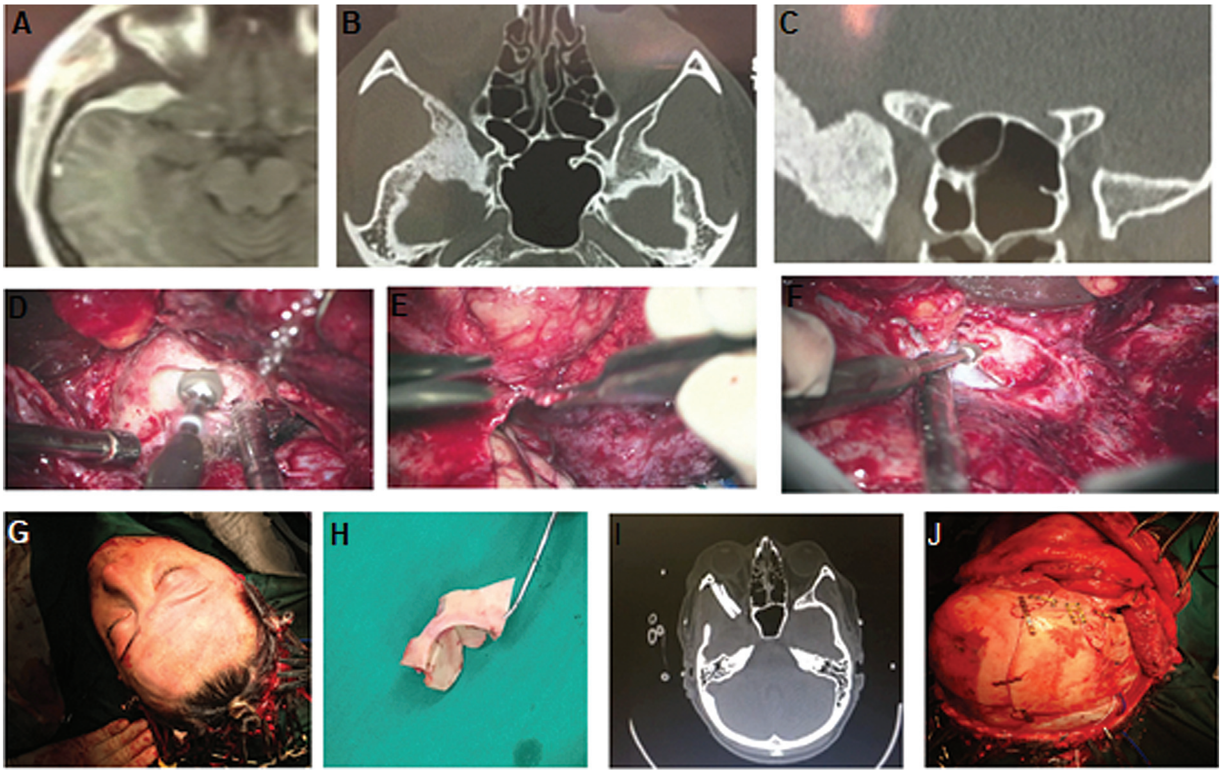

Fig. 15 A multidisciplinary approach is crucial to acquire good results in skullbase surgery. In this case, an en-plaque sphenoid wing meningioma was resected by the neurosurgical team while the cranial and orbital reconstruction was performed by the craniofacial surgery team. (A) magnetic resonance imaging (MRI) showing an en-plaque meningioma; (B) axial computed tomography (CT) scan showing a hyperostosis of the pterygoid plate; (C) coronal CT scan showing large hyperostosis not only of the pterygoid plate but also in the anterior clinoid process; (D) intraoperative view of the hyperostotic anterior clinoid process being drilled; (E) intraoperative view of the reconstruction of the lateral and superior orbital walls; (F) intraoperative view of the cranial reconstruction using the inner table of the parietal bone; (G) patient's position; (H) orbital wall reconstruction with parietal bone flap; (I) postoperative CT scan showing a part of the inner table of the parietal bone that was placed in the lateral wall of the orbit to avoid enophthalmos; (J) final cranial reconstruction.

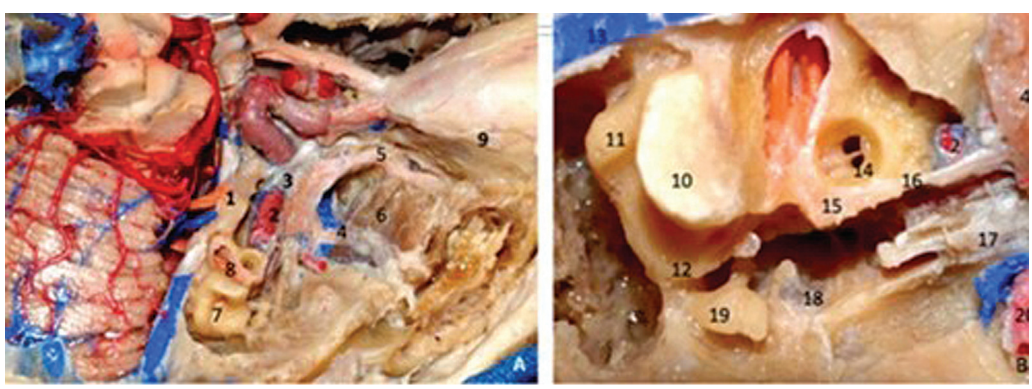

Fig. 16 Anterior petrosectomy performed in a cadaveric specimen. 1–petrous apex; 2–internal carotid artery, petrous segment; 3–petrolingual ligament; 4–V3; 5–V2; 6–lateral pterygoid muscle; 7–otic capsule; 8–internal acoustic canal; 9–orbit; 10–superior semicircular canal; 11–posterior semicircular canal; 12–lateral semicircular canal; 13–superior petrosal sinus; 14–cochlea; 15–geniculate ganglion; 16–greater superficial petrosal nerve (GSPN); 17–chorda tympani nerve; 18–tympanic membrane; 19–incus; 20–middle meningeal artery.

semicircular canal (►**Fig. 18**). The petrous apex is drilled, its lateral limit being the petrous portion of the Internal carotid artery (ICA), its posterior limit being the internal acoustic meatus, its anterior limit V3 and the trigeminal ganglion, and its medial limit being the dura mater of the posterior fossa. Although the petrous apex has no neurovascular structure, it has a varying degree of pneumatization. Special care must be taken not to open the cochlea, which is located at the angle between the internal auditory canal and the GSPN. Studying the middle fossa is important for the treatment of diseases such as superior semicircular canal dehiscence (SSCD) (►**Fig. 18**), petrous apex chondrosarcoma or dermoid cyst (►**Fig. 19**), proximal control of the carotid in its intrapetrous portion, facial nerve or vestibular meatus schwannomas, as well as creating an access corridor for intradural tumors such as petroclival and incisural meningiomas.

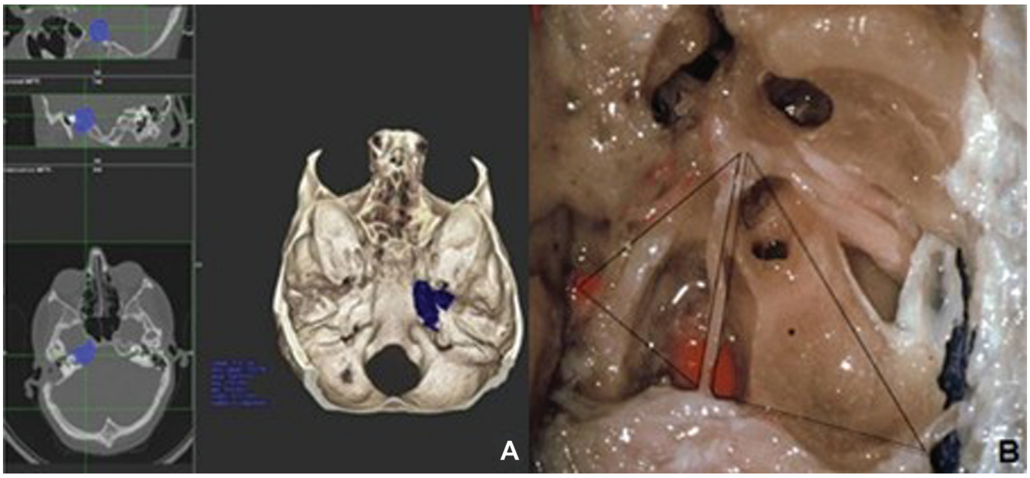

Fig. 17 Middle fossa anatomy. (A) volumetry of the petrosal apex shows the versatility of petrosectomy to reach different portions of the posterior fossa; (B) superior view of the floor of the middle fossa. The bone covering the malleus, internal carotid artery and internal acustic meatus was drilled. To the left, the posterolateral middle fossa triangle (Glasscock's triangle) and, to the right, the posteromedial middle fossa triangle (Kawase's triangle).

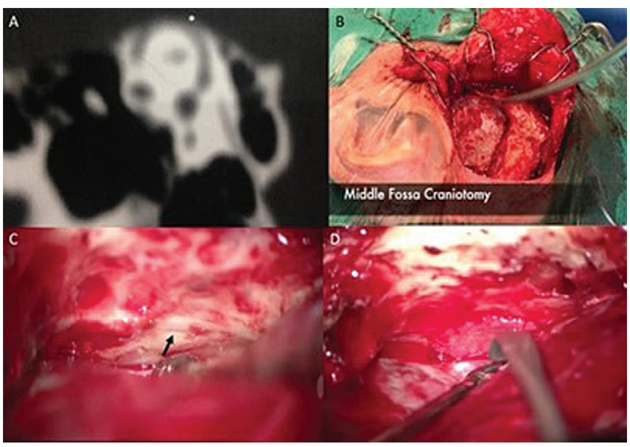

Fig. 18 Middle fossa anatomical knowledge applied to treat a superior semicircular canal dehiscence. (A) axial head bone window computed tomography; (B) middle fossa craniotomy; (C) exposed superior semicircular canal dehiscence (black arrow); (D) surgical repair result.

The next stage is mastoidectomy and labyrinthectomy (►**Fig. 9**). For this, the head is repositioned at a 45° angle and the posterior incision of the anterior petrous approach is extended inferiorly to the cervical region to expose the posterior fossa. After the incision is made, the skin flap is folded anteriorly over the ear. The tip of the mastoid is palpated and a line following the posterior portion of the temporal line is drawn indicating the upper bone limit of the mastoidectomy. The different stages of dissection must be performed as shown in ►**Fig. 9**. After exposing the presigmoid dura mater, the limits of the triangle of Trautmann are identified. This type of laboratory knowledge provides the surgeon great insight and aid in understanding neuroimaging exams to accurately predict what may be found later in the operating room, especially given anatomical variations. At this point in the dissection, a labyrinthectomy should not be performed to avoid reducing the integrity of the internal auditory canal before the next approach, the retrosigmoid. To

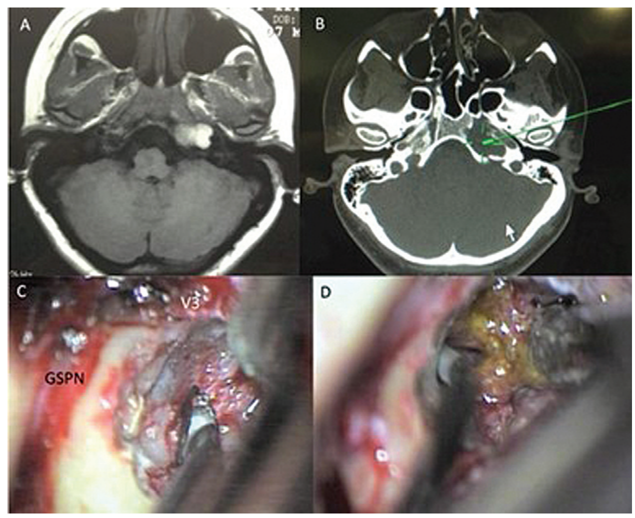

Fig. 19 Cholesterol granuloma of the petrosal apex. (A) axial T1 weighted showing high signal image; (B) axial head bone window computed tomography showing bone erosion of the petrosal apex; (C) intraoperative anterior petrosectomy in-course; (D) exposed tumor.

accomplish this, the bone posterior to the sigmoid sinus is skeletonized and removed, and then the dura mater is opened, and the cisterns explored. In this stage, the three neurovascular complexes of the posterior fossa are identified, and the opening of the internal auditory canal is performed. The next step is to observe from various angles the access that the presigmoid and rectosigmoid approaches provide to the internal acoustic meatus, focusing on its bottom, and to the cistern of the pontocerebellar angle.

The next step is to connect the upper petrous sinus and to section the tentorium, parallel to the petrous part of the temporal bone and toward the incisural space. This exercise is similar to the supra-infratentorial presigmoid approach, also known as posterior petrosectomy. The head is rotated again to view the same anatomical region from different angles and approaches. Even at this stage of dissection, it is

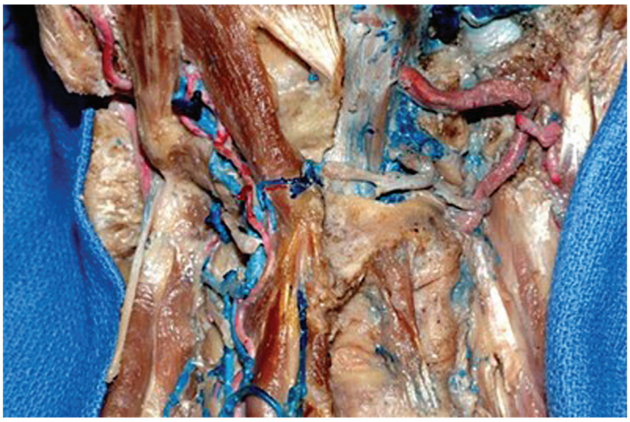

Fig. 20 Anatomical knowledge of the posterior cervical region and the craniocervical junction is important for a safe transcondylar approach.

possible to observe the exposed operative field after resection of the petrous apex and of the presigmoid dura, which is called the "double petrosal approach". The last stage of this review of lateral accesses to the skullbase consists of conducting transcondylar approaches to the craniocervical junction (►**Fig. 20**) and dissecting the jugular foramen as well as the cervical region.

The cadaver head can still be used for endoscopic endonasal approaches and extended endoscopic endonasal approaches.

Laboratory Training to Acquire Microsurgical Skills

Proper training in microvascular techniques requires great concentration and persistence and can be very frustrating at first. The surrounding environment should be calm and, ideally, prevent any kind of interruption. To make the most of this training and diminish physiological tremors, which almost everyone has to some degree, caffeine and nicotine should be avoided 24 hours before training, as any exercises impacting the appendicular muscles. In addition, training should be interrupted for 5 minutes every hour to reduce fatigue.[21–24]

The instruments used for microvascular anastomoses consist of jeweler's micropenets, microscissors, microclamps, a 10-ml syringe with insulin needle and a 90° angled blunt tip, clip holders, number 11 scalpels, retractors, and monofilament nylon threads. 11–0 nylon thread should be used for 0.5 mm diameter vessels, 10–0 for 1.0 mm vessels, and 9–0 for 2.0 mm vessels. The neurosurgeon must be thoroughly familiar with the instruments and the lens system of the surgical microscope and should be able to recognize the magnification that provides the most appropriate visual field: a standard combination is a 12.5x magnification lens on a 200-mm objective, which allows zooming from 4x to 25x. Using binocular vision to work in the center of the visual field is also crucial for good technique.

Placenta Exercises

The placenta has a fetal and a maternal side, and the fetal side has placental vessels that are closely related to the chorionic membrane in much the same way that cerebral vessels are related to the arachnoid membrane. After removing part of the chorionic membrane with microsurgical instruments, arteries and veins can be identified. The former are recognized by three main characteristics: the arteries cross over the veins, have a smaller diameter and a thicker vascular wall.

One of the first exercises to be done is the incision (arteriotomy) and suturing of the arterial wall. After identifying an appropriate artery, microdissection is conducted in the transition between the selected vessel and the placental stroma along a length of ~ 5 cm. Two microclamps are then put in place, first on the proximal and then on the distal end. The next step is to gently separate the tunica externa from the vessel wall, so that the arteriotomy can be made. After that, the arteriotomy is closed with simple sutures. The microclamps are released and the patency of the anastomosed vessel is tested. Another artery is then selected for the next exercise, an end-to-end anastomosis. The steps are the same as in the previous exercise up to the placement of the microclamps, when the microscissors are used to make a single, firm transversal incision through the artery wall, followed by irrigation of the two vascular stumps with saline solution. An end-to-end anastomosis is then performed, in which the first 2 sutures are placed oppositely at the base and the apex of the vessel, that is, at 6 and 12 o'clock positions.

Excess thread is left at the suture for subsequent traction to inspect the pairing of the vessel edges and obtain a symmetrical suture. The next suture locations are to be performed with simple sutures at 9 o'clock, then 7:30 and 10:30 positions on the posterior wall of the vessel. To do this, a 180°4rrrrrt04tg rotation of both clamps has been performed to expose this wall. The next step is to unwind this rotation and suture its anterior wall with simple sutures at 3 o'clock, then 1:30 and 4:30 positions. Finally, the microclamps are removed and this section of the artery is refilled with fluids and the patency of the vessel is verified by observing whether any leaks appear through the suture points.

Experimental Animal Exercises

Every ethical and conscientious society must be concerned with the care and use of any living species. Individuals who work with animals in research, teaching, or laboratory tests should value animal life, consider animals to be sensitive beings, seek to reduce their suffering, and take responsibility to ensure that they are always given excellent care.[21–24] Therefore, it is essential to use techniques that provide, in addition to adequate chemical restraint, anesthetics and analgesics so that the animal does not endure pain to the best of our ability to recognize it.[21–24] Rats are the animal species most commonly used in microsurgical training. After studying the anatomy of the rat and anesthetic techniques for experimental animals, the following exercises can be performed.

The procedure begins by performing a trichotomy of the inguinal and cervical regions. When an angiographic and/or histological study of anastomoses is the goal, typically no tracheostomy is performed, as it is difficult to successfully conduct postoperative procedures on these animals. However, when neither of these are the goal, a tracheostomy is performed, which is, in itself, an excellent microsurgical exercise. This begins with a midline incision from the chin to the sternum, followed by a delicate dissection of the subcutaneous tissue and the placement of retractors at the edges of the incision. The following elements must be recognized: on the midline, the sternohyoid muscle covering the tracheal rings above and bilaterally to the thyroid glands which, when elevated, will allow a view to the triangle formed by the sternohyoid muscle (medial), the sternocleidomastoid (inferolateral) and the omohyoid (superolateral). The carotid artery can be found in this triangle. After making an incision in the sternohyoid muscle, retractors are put in place and the tracheal rings are identified to perform a tracheostomy at the 2nd and 3rd rings. In this way, we obtain a patent airway.

End-to-end Anastomosis

Using opening movements with the microscissors, the carotid artery and the carotid sheath are identified. The rat's carotid artery is usually 1 mm in diameter. At this stage, the vagus nerve must be carefully separated from the carotid artery, avoiding the vagal reflex. Manipulation of the vessels must be minimized to avoid spasm and damage to the vascular wall, and the vessel must always be mobilized by its tunica externa. This is followed by the placement of the distal and proximal microclamps, respectively, and a complete transversal incision to the common carotid artery with the microscissors. It is expected that this should cause a retraction of ∼ ⅓ of the vessel. The interiors of both arterial stumps are then irrigated with heparinized saline. The anastomosis is performed as described in the placenta exercises, keeping in mind that the best practice of a microvascular suture is the passage of the needle through all layers of the arterial wall. After the anastomosis is completed, the distal clamp is removed first, and, with a cotton swab, a slight compression is made on the suture site for 2 minutes to wait for platelet aggregation. If there is blood leakage between the sutures, replace the clamp and correct it with another suture. The same procedure is performed again after removal of the proximal clamp.

End-to-side Anastomosis

This type of anastomosis may be arterial or venous and is the most important because it is the most used in neurosurgery. After harvesting the femoral artery from the inguinal area or the internal jugular vein (located in the subcutaneous cellular tissue, lateral to the sternocleidomastoid muscle), two elliptical horizontal incisions are made on the upper surface of the carotid artery, the size of which corresponds to the donor vessel. In the donor segment, a small longitudinal incision of ∼ 1 to 1.5 mm is made in one end to split the vessel and increase its diameter. Proceed with anastomosis, suturing both flaps of the donor vessel, starting with the posterior face followed by the anterior face, with 3 to 4 simple sutures on each. Once the exercise is finished, the patency of the anastomosis is verified.

Other Exercises

Several other microanastomosis exercises can be performed on the mouse. In addition to those presented here, end-to-end anastomosis of the femoral artery itself can be performed in the inguinal region, where it has a diameter of 0.5 mm. This is an important exercise that simulates direct cerebral revascularization procedures in children with Moya-Moya. Another exercise consists of performing an end-to-side anastomosis between the left and right carotid arteries, one of which is transposed over the anterior region of the neck for anastomosis with the contralateral artery and connected to its distal surface. Finally, another exercise that can be performed is a laparotomy, which is done by placing the viscera outside the abdominal cavity and then proceeding to anastomose the abdominal aorta. In addition, with the dissection of the membranes surrounding the abdominal vessels, an inflammatory reaction occurs. After 7 days, these membranes become thicker and quite similar to the subarachnoid cisterns at the base of the brain, thus offering more training opportunities. When the main objective is to train for work in deep brain regions, such as when bypassing the superficial temporal artery with the superior cerebellar artery or the occipital artery with the inferior anterior cerebellar artery, place an inverted, 15-cm deep basin with a 4-cm diameter central hole over the rat. The distance between the hole and the carotid artery must be between 6 and 10 cm. Longer instruments must be adapted for this type of training.

The Art of Being a Neurosurgery Assistant

There are many challenges that neurosurgeons-in-training face, such as stressful situations with patients and family members, gaining a complex understanding in treating various diseases and patients under difficult personal circumstances, developing manual skills, confronting careless advisors, finding one's own professional mindset and demeanor, and forming relationships with colleagues both within and beyond one's own specialty. Among all of these, perhaps the greatest challenge is mastering the difficult art of assisting in surgery. It is difficult because, in the anxious rush to acquire psychomotor skills by pursuing any opportunity to train/use them, young neurosurgeons often hinder treatments instead of helping them. Once, when a surgeon was aspirating a skullbase tumor, I saw the aspirator of the assistant enter the surgical field without authorization and begin aspirating another region of the same tumor. The resident must not forget that manual dexterity is only one part of neurosurgical training and can be best acquired in the laboratory.

According to American surgeon Frank Spencer, an operation consists of two areas of activity. The first, which accounts for three-quarters of all significant events during surgery, depends on decision making. The second, accounting for just one quarter of the significant events during surgery, depends on manual dexterity. Lord Moynihan, an English surgeon, mocked his colleagues who overestimated their dexterity in surgery at the expense of other important aspects by saying that they should limit themselves to performing tricks with billiard balls. The great Brazilian surgeon Benedicto Montenegro criticized the honorific phrase often attached to his profession, 'hands of gold'. He considered surgery to be far more mental than manual since much of surgical procedure is based on decision making. Clearly, manual dexterity is key to surgical procedures, but the dictum "the hand does not tremble when the brain does not waver" states very well the relationship of manual and mental labor in the operating room.

Assisting in surgery is a fundamental part of building a solid foundation of experience. The assistant must always focus on two tasks: first, do not cause any disturbance in the operative field, and second, provide exposure. The best assistants are able to work unnoticed. They should speak to communicate only what is essential, and in a way that does not hinder the progress of the surgery. Comments such as "the aneurysm has ruptured" must be withheld when everyone present can clearly see profuse bleeding in the operating field. Trivial conversation and crass comments are unacceptable. Long conversations unrelated to the procedure intrude on the environment and are disrespectful to the patient. Only with understanding and careful observation of what it means to be an assistant will residents in neurosurgery be able to instill similar behavior in their own assistants when they become surgeons. Learning the art of assisting is fundamental to neurosurgical training and establishes good habits of physical and mental control in future surgeons.

Cognition – Clinical and Multidisciplinary Knowledge

Although it may seem redundant, skullbase surgeons in training must never forget that they are, first of all, doctors and not "operators." Excessive focus on the many potential diagnoses for disorders that are treated with neurosurgery may lead us to overlook the neurological, metabolic, and even psychiatric disorders from which a symptom may arise. This can cause the wrong treatment to be selected, and perhaps leave a patient with serious and disabling sequelae. This is especially important at the beginning of the training of a resident physician, when managing complications and handling clinical dilemmas with proper decision-making is a daily necessity.

Students of skullbase surgery should branch out and deepen their neurosurgical abilities, but never at the expense of basic medical knowledge. This knowledge is particularly valuable when you are part of a team of specialized clinicians facing a patient's rapidly declining condition. For example, an elderly patient presenting with sudden confusion and a brain injury caused by cerebrovascular disease, or a tumor previously diagnosed by imaging should be considered, from an investigative point of view, as being in an "acute confusional state" to be examined and evaluated, rather than a "confusional state due to cerebral tumor," because an infectious or metabolic process is more often the cause of this condition. Many such scenarios could be used to illustrate this point,

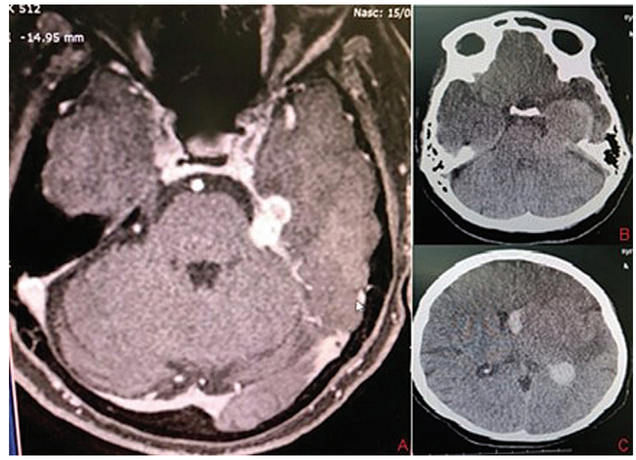

Fig. 21 Illustrative case that shows the importance of a multidisciplinary team. A: Presumed tentorial incisure meningioma, incidental finding. The patient was referred directly to radiotherapy in another hospital, without any neurosurgical evaluation; B: 18 months later, the patient was admitted in the emergency room at our hospital in a coma. Brain computed tomography showed (B) important tumor growth and (C) tumoral hemorrhage. The patient died within 48 hours.

and as a general principle, skullbase surgeons should always remember to initially regard their patients with a clinical mindset.

Skullbase surgeons must also develop knowledge of related fields such as neurology, neuroradiology, neuropathology, physiotherapy, speech therapy, and neuropsychology, among others. A doctor training in skullbase surgery should clearly not delve too deeply into these areas, but a little understanding will do much more than simply aid in administering treatment to patients. It will help to foster appreciation and trust among colleagues in these associated fields by allowing a neurosurgeon to "speak the language" and communicate more clearly and directly. This is vital in multidisciplinary teams to avoid wrong treatments (►**Fig. 21**).

Another subject a surgeon should explore is transference and countertransference in relating with patients and their families. A practical understanding of this is especially helpful for anyone treating critically ill and terminal patients as our field is, or course, usually focused on this aspect of care. In a similar way, understanding the psychological stages that terminal neurological patients and their families typically go through – denial and isolation, anger, bargaining, depression, and acceptance – will alleviate the resident's own suffering and foster a surprising amount of learning to humility in facing incurable disease. It will also help them empathize with patients and family members.

Affect – Doubt and Anxieties Surrounding the Doctor-Patient Relationship

Proposed by Professor Roberto Veatch in 1972, the four models of the doctor-patient relationship are: Priestly, Engineering, Collegial, and Contractual.

In molding their professional characters and demeanors, young neurosurgery physicians must be careful to avoid adopting a counterproductive model. The Priestly Model is traditional and is based on the Hippocratic tradition. Here, the doctor assumes a paternalistic attitude toward patients and disregards their wishes. The Engineering Model, unlike the Priestly, places all the decision-making power in the hands of the patients. They are seen as clients procuring a service. The Collegial Model does not differentiate between the roles of doctor and patient in the context of their relationship. This makes the decision-making process highly involved because the physician assumes no authority as a professional, and, instead, power is shared equally. The largest drawback of this model is the loss of purpose for the doctor-patient relationship because it is regarded as a simple relationship between equals who behave as if they possess equal amounts of medical knowledge. Finally, in the Contractual Model, the doctor maintains authority, possess certain skills and knowledge, and assumes responsibility for making technical decisions. Here, patients actively participate in the decision-making process and exercise control as befits their lifestyle and their moral and personal values.

Today, the doctor-patient relationship is no longer guided by the trust of the client and the conscience of the professional. It has become, in many cases, an impersonal contract-for-services in which clients, aware of their rights, demand quality and efficiency in delivery and may become indignant if they perceive any lapses. Even the Code of Hammurabi, established in 1754 BCE, threatened Babylonian physicians with various punishments for injuring their patients. Since then, the doctor-patient relationship has become quite complex and dynamic, particularly in its interpersonal and legal aspects. From the start of training, doctors must be very careful to set aside any personal biases. Ethics and human dignity require us to treat all patients equally, regardless if they have private health insurance, are enrolled in a public healthcare program, or are paying out-of-pocket. This attention to our own feelings and behavior is fundamental to the set of skills we must develop in conducting the doctor-patient relationship. This bond, which has been regarded as almost sacred since the times of Hippocrates, is under threat today. The future success of our profession requires us to address this.[1]

A New "State of Art" Microsurgical Laboratory Training in Brazil

In order to disseminate the culture of microsurgical laboratory training, the southern region of Brazil has since 2022 a modern training center in microsurgical anatomy (►**Fig. 22**). Located in the city of Curitiba, capital of Paraná, at the Universidade Evangélica Mackenzie do Paraná, the microsurgery laboratory has 10 training stations with the most modern medical equipment and another professor's station. In addition, it has modern 3D technology for classes. With an investment of more than 2 million reais, the microsurgical laboratory expects to receive neurosurgeons and otologists from all regions of Brazil not only for its hands-on courses, but also for the development of master's and doctoral research in microsurgical anatomy as part of the postgraduate program in principles of surgery at Paraná Evangelical Mackenzie University (FEMPAR). Being coordinated by the university professors and authors of this article (Isolan G. R. and Bark S. A), the microsurgical anatomy courses will follow the legacy of Professor Evandro de Oliveira's courses and will have a special part dedicated to the correlation of microsurgical anatomy with neuroimaging. Research and thesis in microsurgical anatomy will be guided by professors of neurosurgery and otology at the university and by postgraduate coordinators (Malafaia O. and Filho J. M. R.).

Final Comments

As much as any specialization, skullbase surgery, when conducted with deliberation and sound ethics, is a fascinating and extremely rewarding profession. However, serving our neighbors without being entirely sure that we have chosen the best possible course in light of current knowledge

Fig. 22 Laboratory training at the Universidade Evangélica Mackenzie do Paraná (FEPAR).

Fig. 23 Professor Evandro de Oliveira and his students in the Microsurgery Laboratory at the Hospital Beneficência Portuguesa de São Paulo. More than 5,000 neurosurgeons took Prof. Evandro de Oliveira's microsurgical anatomy courses.

could be a source of unending torment for us. For resident physicians who want to surgically treat pathologies as challenging as brain aneurysms and skullbase tumors, at least 1 year of microsurgical laboratory training is essential. Depending on the subspecialization, they should complement their training in institutions anywhere in the world that are well-regarded for their expertise with specific pathologies.

Understanding that our knowledge is built not only with Cartesian principles, like evidence-based medicine, but also with feelings regarding the social and personal situation of our patients is paramount. Following a rational step-by-step skullbase dissection in the laboratory to achieve the best utility of the cadaveric head, as well as to develop surgical skills performing vascular techniques in placentas and experimental animals is crucial in the skullbase surgeon education.

Anxiety and concern about results are the most powerful resources neurosurgeons have in guiding their conduct in a course of treatment. Approaching each case individually, as if it were their first, benefits the patient. However obvious this may seem, it must be said: the patient should be esteemed above any technique or the gaining of any experience.

Accompanying one of the greatest living icons of neurosurgery, one of the author's (Isolan G. R.) realized that several times, after concluding various surgical procedures that he already possessed a great deal of experience with, he would exclaim: "This was the most difficult case I have ever had." This was the greatest lesson, albeit unintentional, that we have ever received. Every patient is unique and deserves our full attention. We deserve the capacity to give our full attention, and also to reap the personal rewards of it, together with our patients. Always striving for that capacity for attention, for knowledge and skill, is the key.

Finally, Prof. Evandro de Oliveira's legacy will echo in eternity.[25] His school represents what state-of-the-art microsurgery is for most of our patients: simply the best treatment option (►**Fig. 23**).

Note

Some small parts of the present article were published previously in Portuguese by the senior author in a previous article*, but with a focus on the learning. Following ABNT (Brazilian Association for Technical Standards) and copyright rules (law number 9,610), these parts are identified by quotation marks.

*Isolan GR. A construção do conhecimento pelo jovem neurocirurgião: ética, ciência e a importância do treinamento em laboratório de microcirurgia. J Bras Neurocirurg 20 (3): 314–334

Conflict of Interests

The authors have no conflict of interests to declare.

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