TECHNICAL NOTE

The Chopsticks Technique for Endoscopic Endonasal Surgery—Improving Surgical Efficiency and Reducing the Surgical Footprint

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■ BACKGROUND: **Variations and additions to the endoscopic endonasal exposure have been proposed around a modular strategy. These extensions are often necessary to provide additional working space and reduce conflict between the instruments and the endoscope. Resection of endonasal structures, which affects negatively the sinonasal quality of life, is thus undertaken not only to obtain tumor exposure but also to improve the maneuverability of the instruments.**

■ OBJECTIVE: **Our objective was to achieve the same skull base exposures and tumor resections and limit the surgical footprint on sinonasal structures and patients' quality of life.**

■ METHODS: **Our team developed a surgical technique in which the endoscope and a malleable rotative aspirator are held by the nondominant hand and the other main instrument in the dominant hand. This modification, which we call the chopsticks technique, allows the surgeon to use minimalistic exposures with an improved dynamic perception of the surgical field and reduced conflicts between the instruments. The endonasal structures that are left intact help support the instruments. The same surgical objectives, in terms of exposure and resection, are achieved. We describe our technique and a series of patients operated with this uninarial 3-instruments technique to discuss relevant operative nuances.**

■ CONCLUSIONS: **We propose a technical modification that allows the surgeons to benefit from the advantages of a bimanual technique while still holding the endoscope. In our opinion, this technique may improve dynamic understanding of the anatomy and surgical efficiency and reduce the footprint of the surgery.**

INTRODUCTION

Transnasal surgery of skull base disease dates back to the early twentieth century, with pioneers such as Hermann Schloffer and Harvey Cushing successfully applying the transsphenoidal approach to resect pituitary adenomas.[1] In the 1990s, building on the successes of functional sinonasal surgery and improved endoscopic technology, a few groups ventured into previously unreachable anatomic locations through transseptal and sublabial exposures. Among those groups, Jho and Carrau have been early pioneers and proponents of endonasal endoscopic surgery (EES) to treat diseases "from the crista galli to the foramen magnum."[2-4]

Variations and additions to the endonasal exposure have been proposed around a modular strategy to improve access in both the rostrocaudal and lateral directions.[5-7] For instance, middle turbinectomy and ethmoidectomy open up the transcribriform and transplanum windows and can be used to enlarge exposure in the transsphenoidal route. To increase exposure down the inferior clivus and upper cervical region, septectomy, resection of the parapharyngeal muscles, and drilling of the clivus can be performed. Laterally, maxillary antrostomy, a transpterygoid approach, and resection of the inferior turbinate and Eustachian tube can provide access to the sphenopalatine fossa, lacerum segment of the internal carotid artery (ICA), lower aspect of the petrous apex, parapharyngeal space, condyle, and jugular foramen. These extensions are needed to expose deep-seated

Key words
- Endoscopic endonasal surgery
- Minimally invasive surgery
- Skull base surgery

Abbreviations and Acronyms
EES: Endonasal endoscopic surgery
ENT: Ear, nose, and throat
ICA: Internal carotid artery
MRI: Magnetic resonance imaging
QOL: Quality of life

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lesions but are also often necessary to limit conflict between the instruments and the endoscope, especially when a binostril 4-hands technique is used. This setup, in which 1 surgeon navigates the endoscope and the other can use a bimanual technique, is what reproduces best the microscopic environment, to which most neurosurgeons are still more accustomed. However, it requires perfect coordination between the 2 surgeons to limit conflict between the endoscope and the instruments. Another option is to use an endoscope holder, which has the advantage of providing a fixed image but the surgeon has to work around a rigid pillar. This technique is typically used for the resection of pituitary tumors, in which the midline location and the soft consistency limit the need for extensive or complex movements of the instruments.

Although often labelled as a minimally invasive approach, the extended endoscopic endonasal approach and its modules are often maximally invasive on the nasal structures. Most investigators agree that there is, after extended endonasal approaches, a significant decrease in sinonasal quality of life (QOL) which, in turn, adversely affects overall QOL.[8] There is mounting evidence that the level of complexity of the surgical procedure, including the harvesting of a nasoseptal flap and middle or inferior turbinectomy, affects negatively the sinonasal QOL.[9-11]

Our objective was thus to achieve tumor resection and to limit the footprint of the surgery on sinonasal structures and patients' QOL. To do so, the senior author (S.F.) developed a surgical technique in which the surgeon holds the endoscope and the aspirator with a malleable rotative tip in his nondominant hand and the other main instrument in his dominant hand. This modification, which we call the chopsticks technique, allows the surgeon to work in narrow surgical corridors with less conflict between the instruments and an improved dynamic perception of the surgical field. The soft endonasal structures such as the inferior turbinates, middle turbinates, and nasal septum, which all have some degree of elasticity, play the role of the instruments and endoscope holder. Because the suction is held by the endonasal structures, minute movements of the suction by the fingers of the surgeon (rotation and back-and-forth movements) are transmitted to the tip of the suction with a high level of precision. The larger the surgical cavity, the more strength is needed to hold the endoscope and instruments with resulting loss of precision.

In this report, we describe our technique as well as a series of patients operated on with this uninarial 3-instruments technique to discuss relevant operative nuances.

METHODS

Rationale

The main rationale for the use of the endoscope in general, and in endonasal exposures in particular, is to be able to see in deep cavities through narrow corridors and to provide a panoramic view of the surgical field by bringing the eyes of the surgeon right into the area of interest, in the depth of the exposure. This goal can be achieved by exploiting the natural cavities provided by the paranasal sinuses. In principle, the use of the endoscope should thus provide improved visibility and limit the need for large skin incisions and resection of normal structures.

However, one difficulty that is associated with the use of the endoscope through the nose is that the nasal cavity is usually narrow and has a small volume and the anatomy of the nasal cavity and paranasal sinuses is complex. The endoscope occupies a precious space in the nose and limits the freedom of movement of other instruments. It adds a rigid pillar around which the instruments must be navigated. For ear, nose, and throat (ENT) surgeons specialized in endoscopic endonasal approaches, the usual technique involves holding the endoscope in the nondominant hand and 1 instrument in the dominant hand. The hand holding the endoscope remains mobile, moves in and out, rotates when is necessary and constantly adjusts its position according to the movement of the instrument in the dominant hand and vice versa. When doing so, close and adequate visualization is always maintained without conflict. If an angled scope is used, the rotation of the endoscope allows coverage of a larger field and provides multiple angles of view to a target.

With the dominant hand, the surgeon can use a variety of instruments, including the aspirator, dissectors, rongeurs, shavers, and so on, which are used in alternation.

For tumor resection and more delicate work in the depth of the exposure, a 2-handed technique becomes necessary because suction and traction of structures to be cut or dissected are often required continuously. The typical and most comfortable setup for neurosurgeons in microsurgery, with the suction in the nondominant hand and the main instrument in the dominant hand, is thus reproduced. Deep in endonasal exposures, the suction is even more necessary than in other kinds of surgery, because bleeding and irrigation fluid cannot drain away from the point at which the surgeon is working; it is also needed to aspirate smoke and fog. Usually, when the surgeon uses both hands, the endoscope has to be held by another surgeon or by a holding device (fixed or robotic). An alternative setup is that 1 surgeon holds the scope and works with the main instrument (e.g., the drill), while the other surgeon brings in and controls the suction or another instrument, to hold or retract for instance (**Figure 1A**). Another typical surgical setup is the 4-hands, 2-nostrils technique in which 1 surgeon navigates the endoscope and the aspiration and a second operator uses 2 other instruments to accomplish whichever task is at hand.

However, when an endoscope holder is used, and to a lesser extent when it is held by the assistant, conflicts between the endoscope and the instruments usually occur and are even more pronounced when the endoscope is close to the tip of the instruments. This conflict is increased when a mechanical holder is used, because there is additional rigidity in the setup. Perfect team dynamics between the surgeon holding the scope and the operating surgeon can significantly reduce this so-called sword fighting. Such a level of coordination usually takes time to reach and even with seamless team work, it still requires a significant amount of working space in the nose and thus resection of endonasal structures. A binostril technique is also necessary to separate the working

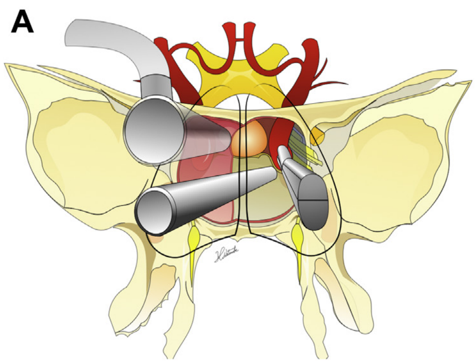


Figure 1. (**A**) Binostril and (**B**) One-nostril approach with angled instruments. The rotative shaft combined with the suction angle result in small finger movements being exaggerated in the depth of the exposure and allow for a 360° reach. The suction can also be moved in an anteroposterior direction when controlled by the thumb and second and third fingers.

cone of the endoscope and instruments and to help reduce the conflicts. The 4-hands, 2-nostrils technique is therefore by definition more invasive and increases the potential for nasal morbidity of the approach.

As stated previously, a common strategy used to help reduce conflict between instruments and facilitate endonasal work is to create working space by resecting or displacing normal structures. The inferior, middle, and superior turbinates, the anterior and posterior ethmoid, the anterior wall of the sphenoid sinus, the medial wall of the maxillary sinus, the pterygoid process, the nasal septum, and the Eustachian tube are some of the structures that can be resected in part or totally to provide additional volume and different trajectories for instrument navigation. The septum and turbinates can be lateralized or medialized instead of resected. Conversely, the posterior ethmoid can be resected to push the middle turbinate laterally.[12] However, there is still a need for additional working space because of the 4-hands technique.

To reproduce the work ergonomics with which most neurosurgeons are familiar (i.e., the nondominant hand holding the suction device while the dominant hand uses another instrument), the senior author thus started systematically holding both the suction and endoscope in his nondominant hand (**Figure 2A** and **B**). This way, the surgeon can perform bimanual work while maintaining control on the endoscope with continuous and almost instinctive adjustment of the relative position of the instruments and endoscope.

This technique does not bear any additional surgical risk and might even improve the safety profile of endoscopic endonasal surgery. The main surgeon is always in control of what the endoscope is centered on and retains the possibility to continuously adjust the relative position of the endoscope to other instruments. This reduction of the conflict between the endoscope and the instruments, in turn, grants the surgeon the closest possible view of the point of interest when delicate steps of the procedure are performed. It is when the

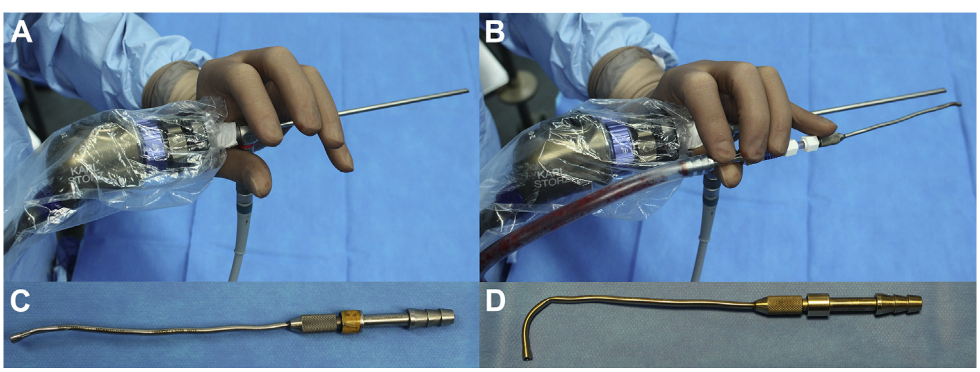


Figure 2. Holding the endoscope and aspirator in the nondominant hand. (**A**) The endoscope rests in the palm of the hand, between the thumb and the index finger. (**B**) The fingers manipulate the suction. (**C**) Integra MicroFrance rotative and malleable suction tips in a swan-neck configuration. (**D**) The malleable suction tips can be adapted to increase the reach and work around corners.

extremity of the instruments is not well seen that most incidents and neurovascular injuries happen (i.e., the Kerrison closing in on the ICA).

Principles and Tenets of the Chopsticks Technique

In endonasal surgery, the fact that all the instruments must go through the nostrils makes the use of multiple instruments by the same hand easier because the nostril and nasal fossa structures (especially the middle and inferior turbinates and nasal septum), which are to a certain extent supple and malleable, can act as buttresses. This way, the nasal fossa supports both the endoscope and suction while the surgeon guides them. By way of analogy, this method for holding both the endoscope and aspirator in one hand can be compared to how chopsticks are held (**Figure 3**).

One key principle is to apply as little force as possible on both the endoscope and suction and focus on providing finely tuned guidance. In a narrow space, the instruments find their ideal positioning more easily when the endoscope is lightly supported and guided and not held, or worse, grabbed. To do so, we have noted that the endoscope is best supported by the angle of the palm of the hand, between the thumb and the index finger (**Figure 2A** and **B**), which leaves the fingers of the nondominant hand free to manipulate additional instruments. Endonasal structures can serve as a conduit or scaffold that can help direct the instruments and the scope. The application of force usually increases conflict between the instruments and often results in additional trauma to the endonasal structures.

The thumb and fingers, freed from the duty of rigidly holding the endoscope, can be used to manipulate a variety of instruments, most commonly the suction. To maximize practicality, rotative and malleable suction should be used, because these properties grant additional maneuvers and increase reach in all directions. Straight suction provides fewer possibilities than curved suction. A rotative shaft combined with a bended tip, adapted to the width of the surgical field, result in small finger movements being amplified in the depth of the exposure which, in turn, allows for a 360° reach (**Figure 1B**). The suction can also be moved in an anteroposterior direction when controlled by the thumb and second and third fingers. We also noticed that using a suction that has multiple inflexions was easier to navigate around the endoscope and endonasal obstacles. In some situations, the suction can also be simply supported by the palm of the hand and a third instrument, such as a dissector, can be held between the thumb and the second and third fingers (see **Video 1** for an operative technique demonstration).

Video

Video available at WORLDNEUROSURGERY.org

Case Selection and Surgical Planning

As with any other surgical technique, there is a learning curve before reaching proficiency with the chopsticks technique and, although it can be used in all endoscopic endonasal cases, it is easier to use in certain situations. In our experience, we observed that it is easier to apply the chopsticks technique through minimalistic accesses. In larger openings, the endoscope as well as the aspirator have to be held a little more firmly because there is more room for unwanted movements.

Preoperatively, it is important to devise a surgical strategy that provides good visualization and a straight surgical corridor. We often use contralateral uninarial openings to expose lesions of the contralateral petrous apex or cavernous sinus along their long axis (see Case illustrations 2 and 3), for example. Planning for the reconstruction and vascularized mucosal coverage must also be part of the preoperative discussion.

Operative Technique

The head is positioned in a fixed head-holder and is flexed, rotated, and tilted toward the side of the surgeon. The degree of head flexion depends on the location of the disease, with increasing flexion providing better exposure of the lower clival and craniocervical junction region, whereas extension provides a more direct trajectory to the cribriform plate and planum sphenoidale. To ensure good venous outflow and to reduce bleeding, the head and thorax are elevated and the surgical table is placed in a slight reverse-Trendelenburg positioning. The height of the surgical table should be adjusted so that the surgeon's shoulders are relaxed and the elbows comfortable in a 90° flexion. Both arms should be relaxed and mobile in all directions, allowing anteroposterior movement and rotation of the 30° endoscope depending on the movement that is required to visualize the surgical target from the most adequate angle. These elements are important in keeping the nondominant hand relaxed and help achieve an optimal flow between the instruments.

We use almost exclusively 4 mm 30° and inverted 30° endoscopes (Karl Storz, Tuttlingen, Germany). Using the angled scopes from the beginning of the surgery helps gain an almost instinctive understanding of the anatomy under angled visualization, allowing full use to be made of the advantages of endoscopy in terms of panoramic exposure and leaving more room for instrument maneuvering away from the scope. Forty-five degree, 70°, and the Endocameleon scope (Karl Storz), with an adjustable viewing angle, are also helpful in dead angles and to increase the lateral and craniocaudal reach of the exposure. With these scopes, the suction tip curvature can be exaggerated up to 90° and beyond to reach behind corners (**Figure 2D**). Scopes with reduced diameter are available on the market, but they are more fragile and the low image quality they provide is still a limitation. The use of an irrigation sheath is also avoided, because it increases the volume occupied by the endoscope. Rather, when there are debris or blood on the lens that need to be cleared, the assistant can irrigate along the endoscope. When irrigation fluid droplets obstruct the view, the suction tip can be slightly retracted in the direction of the lens to clean it. This maneuver also has a learning curve but rapidly, this type of movement becomes instinctive and automatic.

We use Integra MicroFrance rotative and malleable suction tips, which we usually curve in a swan-neck configuration

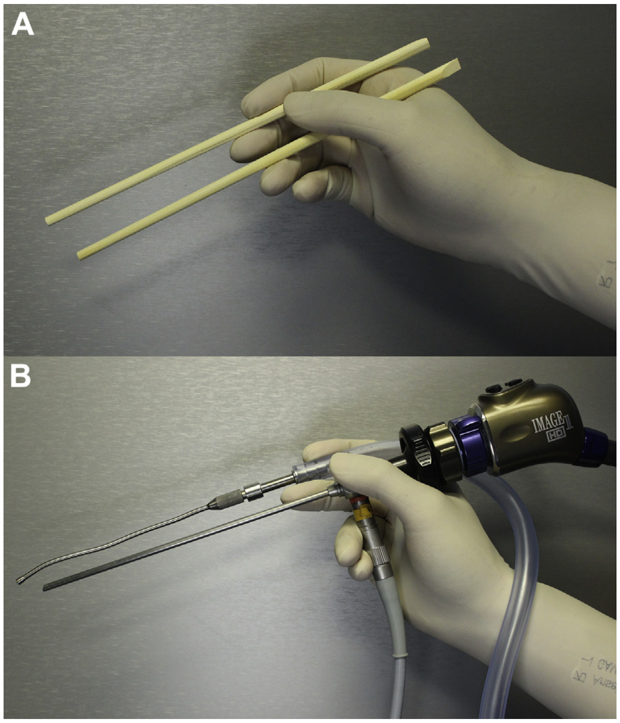


Figure 3. Chopsticks technique. (**A**) Chopsticks are held between the thumb and the fingers. (**B**) The endoscope and the suction (or another instrument) can be held similarly in the nondominant hand of the surgeon. A rotative shaft combined with a distal angulation of the suction tip can translate small finger movements into a 360° reach in the depth of the exposure.

(**Figure 2C**). A straight suction tip provides fewer possibilities than a curved one. The rotative shaft combined with the curved tip results in small finger movements being exaggerated in the depth of the exposure and allows for a 360° reach. The suction can also be moved in an anteroposterior direction when controlled by the thumb and second and third fingers. These 2 properties of the suction (malleability and rotation) allow the surgeon to partially dissociate the movements of the suction from those of the endoscope. Conversely, if straight and nonmalleable suction is used, this mobility of the suction tip in relation to the endoscope is lost and the suction is not doing much as it is mostly following the endoscope. We also noticed that using a suction tip that has multiple inflexions was easier to navigate around the endoscope and endonasal obstacles. Although other instruments such as curettes, scissors, and blades are also available in curved and endonasal-compatible formats, the aspiration device remains a cornerstone in endonasal surgery. It is required in maintaining adequate visualization and is, in most cases, the instrument most useful in tumor resection. The suction is usually inserted by the dominant hand and then transferred to the hand holding the endoscope if the need to use another instrument arises.

In a uninarial access, the middle and inferior turbinate can, if needed, be outfractured and lateralized to widen the corridor and preserve the mucosa. The posterior septal artery can be preserved if the mucosa overlying the rostrum of the sphenoid sinus is cut horizontally (rescue flap technique).[13] This strategy allows for the harvest of a nasoseptal flap on the side of the exposure if a vascularized reconstruction is needed at the end of the procedure. A large sphenoidotomy is important to have enough room to maneuver the endoscope, the suction tip, and an additional instrument.

Case Illustrations

A series of case illustrations are provided to show typical applications of the uninarial 3-instruments technique.

Case 1: Adrenocorticotropic Hormone—Secreting Pituitary Microadenoma. A 37-year-old woman was operated on for an adrenocorticotropic hormone—secreting microadenoma (Cushing disease). Preoperative magnetic resonance imaging (MRI) showed a 9-mm microadenoma located centrally in the sella (**Figure 4A** and **C**) and the computed tomography scanner showed presellar-type pneumatization of the sphenoid sinus (**Figure 4B**). After lateralization of the right middle turbinate, a wide sphenoidotomy was performed through a right uninarial access. After partial resection of the mucosa, skeletonization of the sellar dura was performed with the diamond drill. The dura was cut and the normal pituitary gland was incised to gain access to the tumor. The microadenoma was then dissected in the pseudocapsular plane in a macroscopically complete fashion. The chopsticks technique was found to be helpful in clearing blood from the operative field and dissecting the pseudocapsular plane. The fact that both the endoscope and suction were held by the same hand of the operator allowed for a close view of this very small surgical cavity while still being able to work and not only inspect. The resection was found to be macroscopically complete on the postoperative imaging (**Figure 4D**) and endocrinologic cure was accomplished.

Case 2: Petrous Apex Cholesterol Granuloma. A 47-year-old woman was referred for a right petrous apex lesion that presented with sudden deafness and right hemifacial pain, compatible with atypical trigeminal neuralgia (**Video 2**). On MRI, the lesion showed a homogeneous enhancement after contrast injection localized laterally and posteriorly in the petrous apex, below the cochlea and internal auditory meatus. Medially, the lesion took a nonenhancing T2-hypointense and T1-hyperintense aspect and displaced the right ICA and cavernous sinus anteriorly (**Figure 5A** and **B**).

A contralateral uninarial access was gained, a left nasoseptal flap was raised, and a wide sphenoidotomy was performed. Except for the sphenoid rostrum, all the other endonasal structures were preserved. The right paraclival ICA was skeletonized (**Figure 6A**) and the clival depression and the bone overlying the medial wall of the cavernous sinus were drilled to expose the medial margin of the tumor capsule (**Figure 6B**). After biopsy of the tumor capsule, which was consistent with cholesterol granuloma, the contents of the nonenhancing portion of the lesion were removed with the

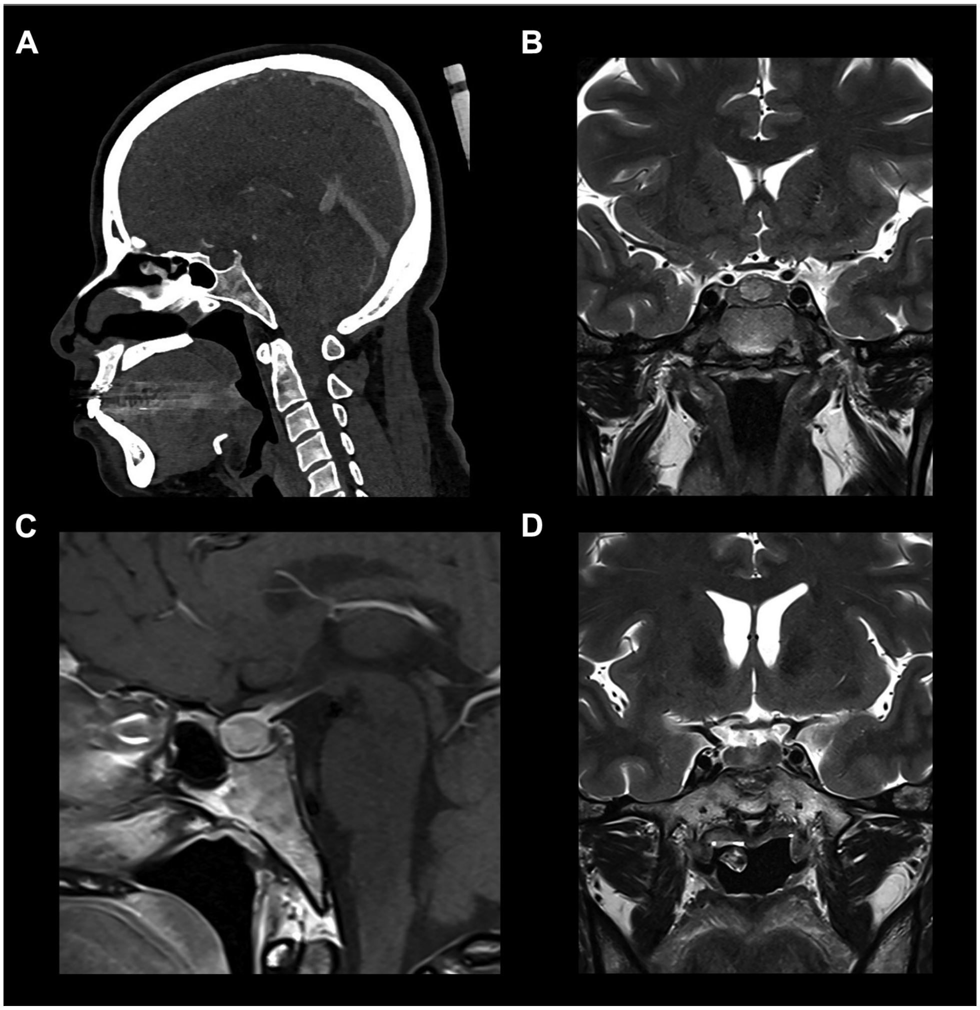


Figure 4. Case illustration 1: imaging. The computed tomography scanner showed a presellar-type pneumatization of the sphenoid sinus (**A**). The preoperative axial (**B**) and sagittal (**C**) gadolinium-enhanced T1-weighted images showed a 9-mm centrally located pituitary microadenoma. A macroscopically complete resection was achieved, as shown in this postoperative sagittal gadolinium-enhanced T1-weighted image (**D**).

aspiration (Figure 6C). The tumor capsule was then dissected, peeled away (Figure 6D and E) and removed subtotally (Figure 6F). The capsular dissection was made possible by the use of a contralateral trajectory. Both instruments, the aspiration and forceps, were in the perfect direction to maneuver in the long axis of the granuloma.

At this point, the dura of the posterior fossa was seen on the medial side of the exposure and the Meckel cave and the Gasserian ganglion on the lateral aspect. Figure 6G shows stimulation of the motor fibers of the trigeminal nerve with the electromyographic monitoring probe. The facial nerve was also stimulated in the lateral and posteriormost aspect of the exposure (Figure 6H). The drill was used to remove tumor capsule adherent to the petrous bone in this area (Figure 6I) but resection of the enhancing portion of the lesion, deep in the petrous bone, was deemed unsafe because of its close relationships with the nerves of the internal auditory meatus. After close inspection of the resection cavity with the Endocameleon (Karl Storz, Tuttlingen, Germany) endoscope (Figure 6J), closure was accomplished with TachoSil (Takeda France, La Defense, France), fibrin glue (Tisseel, Baxter France, Guyancourt, France) (Figure 6K), and the nasoseptal flap (Figure 6L).

Case 3 Jugular Foramen Chondrosarcoma. A 23-year-old man presented with right hypoglossal palsy and hemiatrophy of the tongue. A T2 hyperintense and osteolytic lesion centered on the jugular tubercle was found (Figure 7A and B; Supplementary Material 3). A contralateral uninarial access with a wide sphenoidotomy was undertaken (Figure 8A). Downward and lateral drilling of the clival bone allowed for widening of the surgical corridor and identification of the right vidian nerve

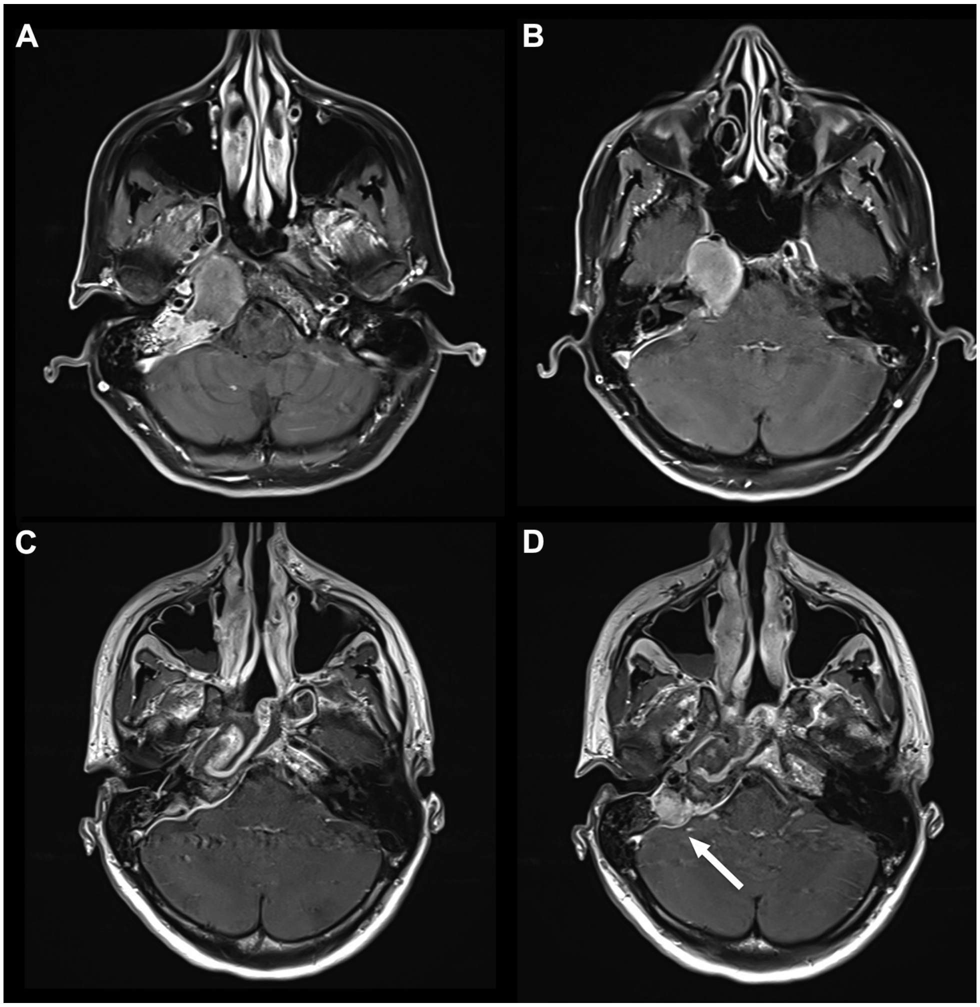


Figure 5. Case illustration 2. Gadolinium-enhanced T1-weighted preoperative (**A, B**) and postoperative (**C, D**) images showing subtotal resection of the lesion with demonstration of adequate positioning of the nasoseptal flap. A residual lesion in the posteriormost aspect of the petrous apex is shown (**C, D**, *arrow*). Note that except for the posterior two thirds of the nasal septum and the sphenoid rostrum, all the other endonasal structures were preserved.

(**Figure 8B**, above the drill bit). After drilling of the paraclival ICA (**Figure 8C**), a cut through the lacerum ligament, inferior to the ICA, was made (**Figure 8D**). This cut provided ample access to the region of the right jugular tubercle (**Figure 8E** and **F**). The tumor was then debulked. In **Figure 8G**, the inferior aspect of the tumor is visualized and the contents of the pars nervosa of the jugular foramen can be distinguished by transparency. Closure was performed first with the application of a layer of TachoSil, fat graft (**Figure 8H**) and then, with a free mucosal graft harvested from the middle turbinate (**Figure 8I**). Postoperative imaging confirmed gross total resection (**Figure 7C**) and patency of the jugular foramen (**Figure 7D**). In this case, the chopsticks technique was helpful in the safe and effective drilling of the vidian nerve and paraclival ICA and maneuvering through the limited and tailored surgical path down to the contralateral jugular foramen.

Case 4: Clivus Chordoma with Extension into the Pterygopalatine Fossa. A 30-year-old man underwent MRI in the course of a *Haemophilus influenzae* meningitis and a clivus chordoma was discovered fortuitously. The lesion was centered on the right cavernous sinus and pterygoid bone and was encasing the ICA and abutting foramen rotundum and ovale on the right side (**Figure 9A** and **B**). A transsphenoidal biopsy was performed in the referring center, with the histopathologic diagnosis compatible with clival chordoma. A right uninarial endoscopic endonasal approach was undertaken. After right turbinectomy (the posterior aspect of the right turbinate was invaded by the chordoma), a maxillary antrostomy and

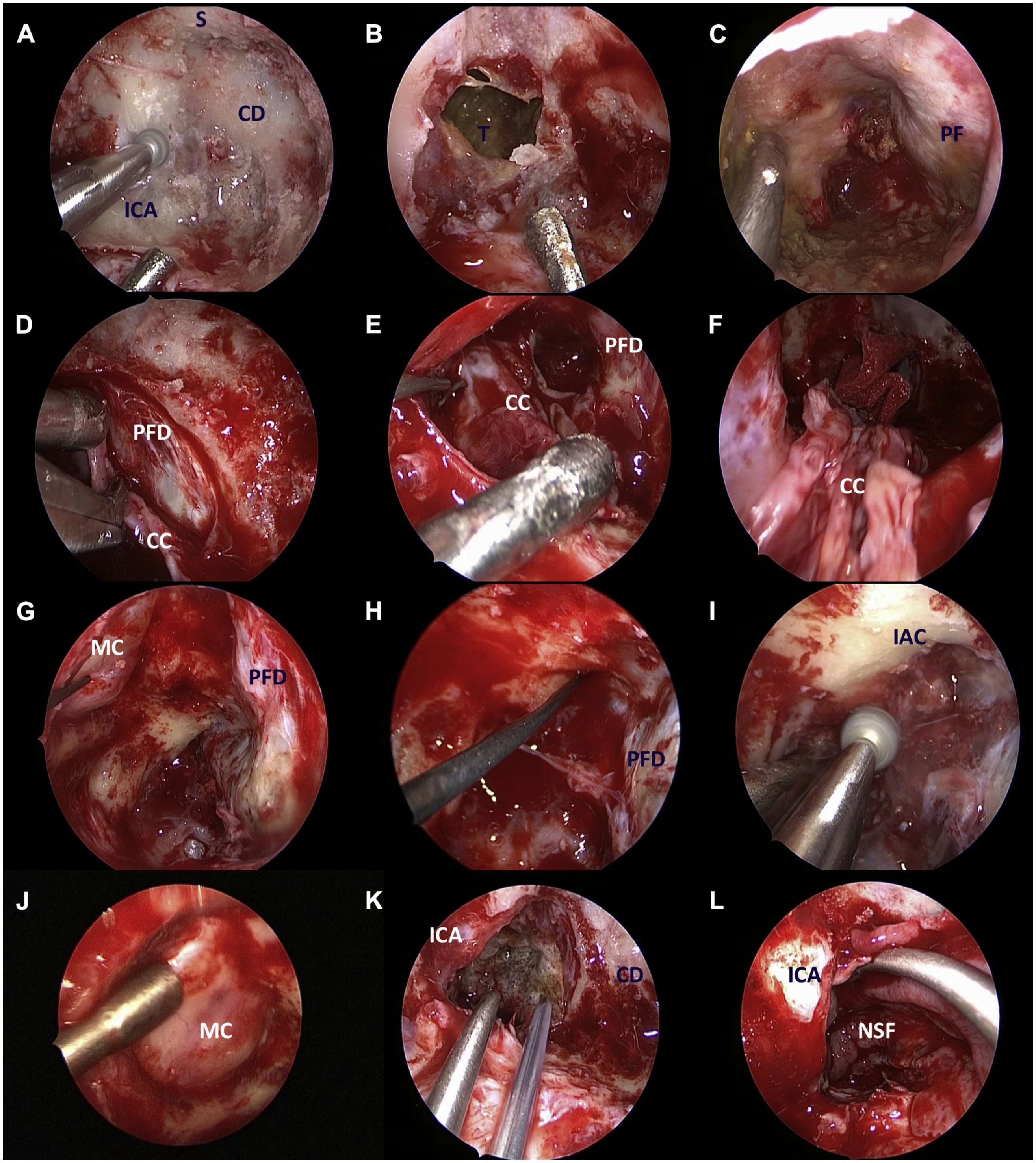


Figure 6. Case illustration 2: stepwise operative description. Through a contralateral uninarial access, a left nasoseptal flap was raised and a wide sphenoidotomy was performed. The right paraclival internal carotid artery (ICA) was skeletonized (**A**) and the clival depression (CD) and the bone overlying the medial wall of the cavernous sinus were drilled to expose the medial margin of the tumor capsule (**B**). The contents of the nonenhancing portion of the lesion were aspirated (**C**). The tumor capsule was dissected, peeled away (**D, E**), and removed subtotally (**F**). At this point, the dura of the posterior fossa was seen on the medial side of the exposure and the Meckel cave (MC) and the Gasserian ganglion on the lateral aspect (**G**). The facial nerve was also identified in the lateral and posteriormost aspect of the exposure (**H**). The drill was used to remove tumor capsule adherent to the petrous bone in this area (**I**) but resection of the enhancing portion of the lesion, deep in the petrous bone, was deemed unsafe because of its close relationship with the nerves of the internal auditory meatus (IAC). After close inspection of the resection cavity with the Endocameleon endoscope (**J**), closure was accomplished with TachoSil, fibrin glue (**K**), and the nasoseptal flap (NSF) (**L**). CC, cyst capsule; PFD, posterior fossa dura; S, sella; T, tumor.

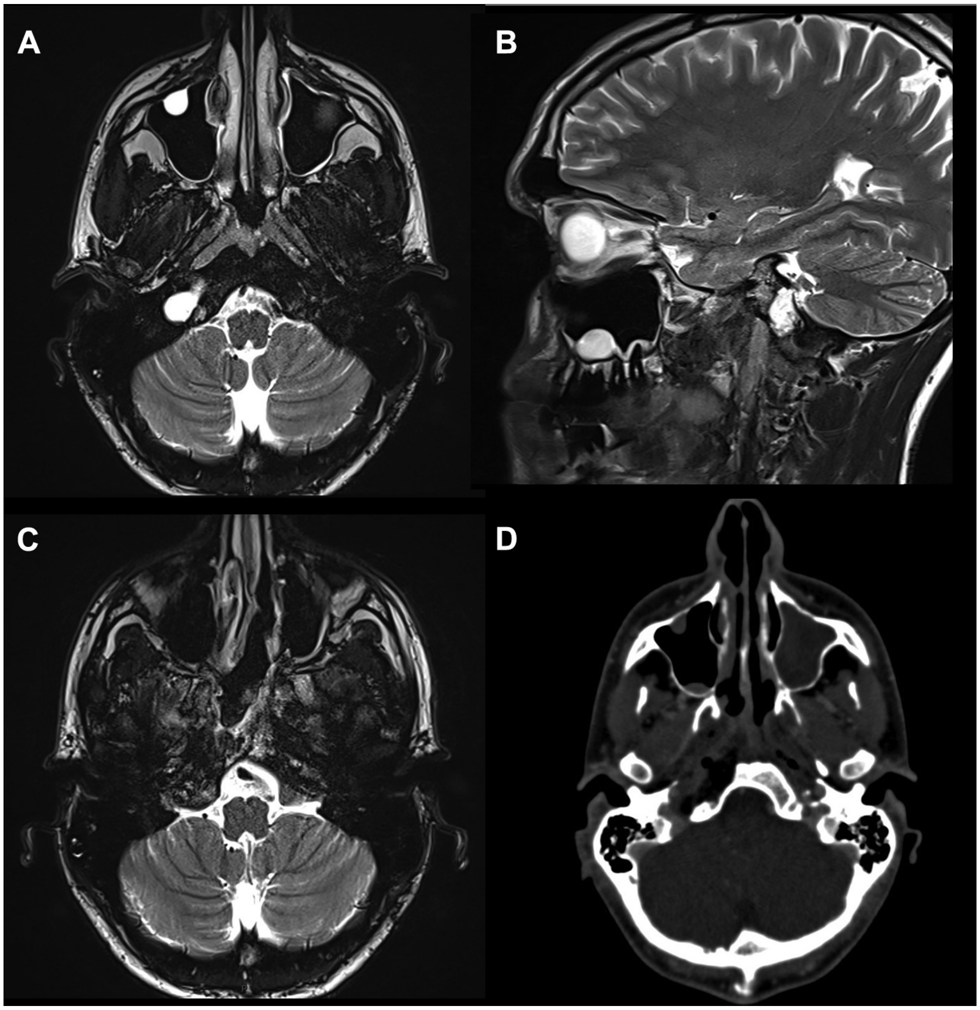


Figure 7. Case illustration 3: imaging. The preoperative axial (**A**) and sagittal (**B**) T2-weighted images showing a hyperintense lesion centered on the right jugular tubercle, medial to the jugular foramen. The postoperative axial T2-weighted image (**C**) showed a macroscopically complete resection of the chondrosarcoma. The postoperative computed tomography scan (**D**) showed the limited disruption of the endonasal anatomy and the surgical corridor used to gain access to the jugular tubercle.

posterior ethmoidectomy were completed on the right side. This procedure allowed exposure of the chordoma, which protruded anteriorly from the sphenoid sinus. Dissection of the pterygopalatine fossa and drilling of the residual pterygoid bone were performed to unroof the vidian nerve and locate the lacerum segment of the ICA. The ICA was also dissected from the tumor in its cavernous and paraclival segments. However, the chordoma was found to be highly adherent in the lacerum segment of the ICA.

The tumor was then followed laterally, where it was found to be adherent to the 3 branches of the right trigeminal nerve. Extensive drilling of the greater wing of the sphenoid and unroofing of the periorbita, superior orbital fissure, foramen rotundum, and foramen ovale allowed exposure of normal dura, facilitated careful dissection of the tumor from the dural sheaths of the trigeminal branches in their foraminal and extracranial segments, and allowed removal of a large tumor compartment in and around the bone of the middle cranial fossa (Figure 9G). The chopsticks technique was helpful in the close-up drilling and dissection of the tumor laterally (Figure 9H and J). It was also invaluable in the intradural stage, to clear cerebrospinal fluid and produce countertraction to safely remove tumor adherent to the basilar artery and perforating vessels (Figure 9I). A small tumor remnant was left close to the foramen lacerum to avoid ICA injury (Figure 9K). Using a 2-surgeons and 3-hands technique, closure was obtained with the fascia lata, which was sutured with 7-0 monofilament suture (Figure 9L) and supplemented with a left nasoseptal flap (the pedicle of the right septal mucosa was compromised by tumoral invasion). Postoperative MRI confirmed subtotal resection of the chordoma (Figure 9C–F)

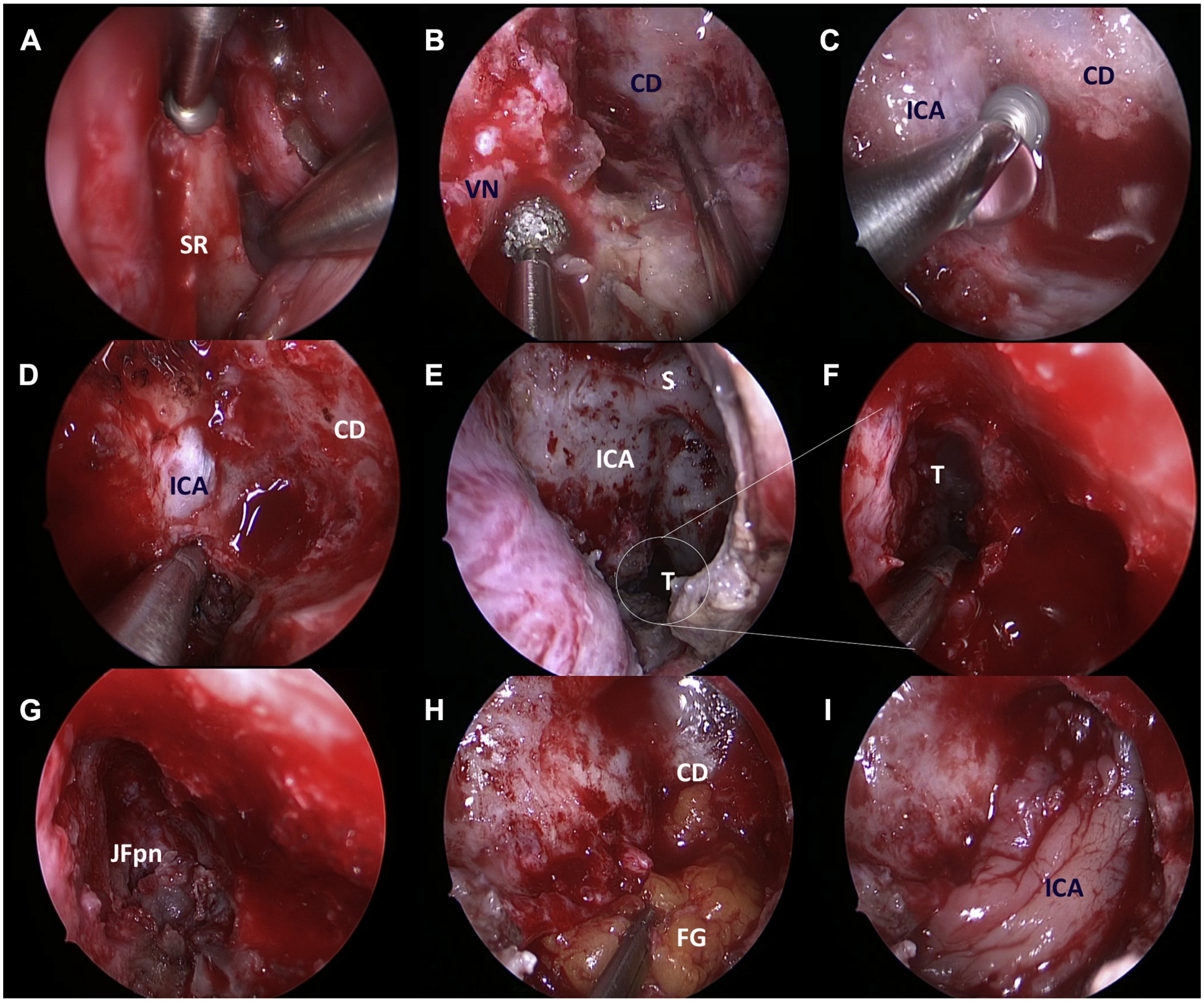


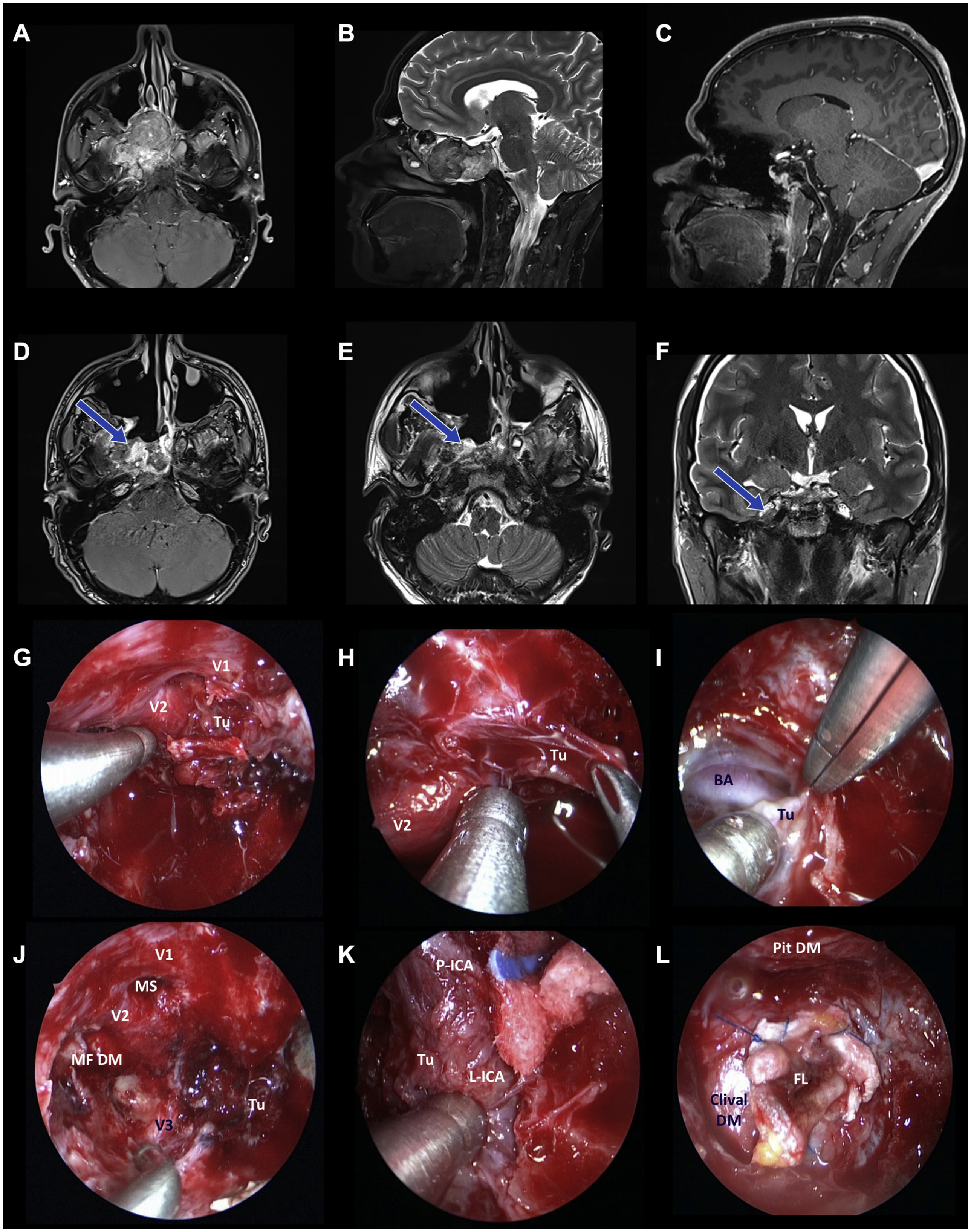
Figure 8. Case illustration 3: stepwise operative description. A contralateral left uninarial access with a wide sphenoidotomy was undertaken (**A**). Downward and lateral drilling of the clival bone allowed identification of the right vidian nerve (VN) (**B**, above the drill bit). The paraclival internal carotid artery (ICA) was skeletonized (**C, D**), a cut through the lacerum ligament, inferior to the internal carotid artery was made (**D**). The tumor was then debulked (**E, F**). The contents of the pars nervosa of the jugular foramen (JFpn) (**G**) was identified with electromyographic stimulation. Closure was achieved first with the application of a layer of TachoSil, fat graft (FG) (**H**), and then with a free mucosal graft harvested from the middle turbinate (**I**). CD, clival depression; S, sella; SR, sphenoid rostrum; T, tumor.

and a small chordoma remnant abutting the lacerum ICA (**Figure 9D–F**, *blue arrow*). The patient underwent subsequent proton beam irradiation and is under close follow-up.

DISCUSSION

Most ENT surgeons perform functional endoscopic sinus surgery with the endoscope held in the nondominant hand and the main instrument in the dominant hand, in alternation with the suction. However, the involvement of an assistant is required in some situations to ensure adequate aspiration of the irrigation fluid, to control more significant bleeding, or to hold the endoscope. In skull base surgery, a 2-surgeons 4-hands technique is considered standard because this allows for bimanual work. In this article, we have described and shown a technique that allows a single surgeon to benefit from the advantages of bimanual work and still to have control over the endoscope. The main advantage of this setup, which we called the chopsticks technique, is being able to work in an extremely small corridor and to preserve the normal anatomy.

Although we still use 3-hands or 4-hands 2-surgeons setups on many occasions, most notably for intradural fine dissection, we consider that holding and maneuvering the endoscope provide a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dynamic understanding of the anatomy that is difficult to achieve otherwise. This dynamic perception of the surgical field partly compensates for the loss of three-dimensional visualization that is associated with the use of the endoscope. Similarly, it allows the surgeon to turn the endoscope when it is needed to have a closer and safer view of the tip of the instrument. Using different working angles is not optional when performing endoscopic skull base work. When a Kerrison rongeur is used, being able to see the tip of the instrument is important to avoid dangerous maneuvers and neurovascular injury. A simple rotation of an angled endoscope can provide the exact dynamic view of the instrument tip that is needed to perform these precise maneuvers safely. Although rotation of the endoscope can be disorienting when it is performed by another surgeon, it can be performed instinctively and without disorientation by the operating surgeon.

Another key advantage of dynamic control of the endoscope is that it allows the surgeon to get closer and zoom in with less conflict between the instruments in the nasal cavity. This proximity with the anatomic structures is paramount on certain occasions, such as when drilling near the ICA, unroofing the optic nerves, or during intradural dissection. This procedure is similar to the microscope being used to zoom in when performing more delicate maneuvers. In **Figure 6**, for example, we can appreciate how close the endoscope is to the drill while the paraclival ICA is being dissected from the bone (**6A**), the cyst capsule dissected from the dura (**6D**), or the bone under the cochlea is drilled (**6I**). This technique combines the advantages of both ENT and neurosurgical gestures.

However, the main interest remains the less invasive nature of this technique. Minimal invasiveness in endoscopy comes because the surgeon's view is brought closer to the surgical target. The opening can then be made smaller and less invasive physiologically, while achieving the same results in terms of exposure and resection. The chopsticks technique is probably not quicker than using an endoscope holder or than a standard 2-surgeons 3-handed or 4-handed technique. It is not necessarily more time efficient. However, we believe that it allows better use of the surgical space and it might therefore be more space efficient.

In laparoscopic or thoracoscopic procedures, access, visualization, and surgical maneuverability inside the peritoneal or thoracic cavities is obtained through 2 or more ports. In this type of setup, the surgeon can benefit from triangulation between the instruments and the endoscope and it is easier to avoid conflict between them. In other endoscopic setups (e.g., ventriculoscopy or cystoscopy), a single port is used but curved instruments provide room away from the endoscope and from each other to manipulate, dissect, and cut. However, compared with endonasal endoscopy, the instruments are guided along the trajectory of the endoscope through a sheath, thus avoiding conflict and loss of direction. Nonetheless, the nostrils and the nasal fossa compensate in part for the absence of a sheath and it is possible to use them to support and direct the endoscope and instruments. Again, and although initially it might appear counterintuitive, we have noticed that preserving the endonasal structures maintains intact a funnel that helps navigate the endoscope and instruments in the proper surgical corridor and made the chopsticks technique easier to apply (their preservation thus improves maneuverability with this technique).

We believe that the potential applications of the chopsticks technique are numerous because it allows navigation of small spaces and maintains optimal surgical maneuverability. Adequate surgical planning, including definition of the best surgical trajectory, is the first and foremost step. In case illustration 4, we show a case in which a deep-seated lesion of the craniovertebral junction was approached contralaterally through 1 nostril.

As in microsurgery, surgical ergonomics have to be learned and improved to increase both surgeon comfort and procedure efficiency. There are data to the effect that most surgeons performing EES have physical discomfort or symptoms attributable to EES.[14] In our experience, positioning the surgical table at the appropriate height and maintaining an adequate position of both shoulders and elbows were important elements in achieving a comfortable position for the surgeon, which, in turn, made it easier to navigate the endoscope while manipulating an instrument with the nondominant hand.

Nevertheless, preservation of endonasal structures must not take priority over achieving better resections and we therefore do not hesitate to resect turbinates or the nasal septum if we are convinced that it will provide a better chance of attaining an optimal resection. The goal of minimal invasiveness is to achieve the same results with less morbidity. Moreover, there is a need for objective data on the clinical impact of this technique, and others that claim to be less invasive, on the postoperative outcome and on the QOL of patients after endonasal skull base procedures. We are collecting prospective data with the intention of documenting the postoperative evolution and impact of endonasal surgery on QOL in our cohort of patients.

One limitation of this technique is the learning curve that it mandates to reach proficiency. Still, this is not different from other procedures and surgical skills. Progression is paramount, and we have found that it is easier to manipulate the aspirator when the opening is kept as small as possible, requiring the surgeon to only provide finer direction for the suction. A small uninarial access for resecting a pituitary adenoma is ideally suited to begin experimenting with this technique. Once comfortable manipulation of the aspirator is mastered, the next steps could then be to apply this technique to extended endonasal approaches to resect extradural tumors such as

Figure 9. Case illustration 4. The preoperative axial T1-weighted gadolinium-enhanced image (**A**) and the sagittal T2-weighted image (**B**) showing a lesion centered on the right cavernous sinus. The postoperative sagittal T1-weighted gadolinium-enhanced (**C**), the axial T1-weighted gadolinium-enhanced (**D**), the axial T2-weighted (**E**), and the coronal T2-weighted images (**F**) showed partial resection of the chordoma with a small residual abutting (**D, E**) and lateral (**F**) to the internal carotid artery (ICA) (*blue arrow*). Dissection of the chordoma from the dural sheaths of the ophthalmic branch of the trigeminal nerve (V1) and the maxillary branch of the trigeminal nerve (V2), in and around the bone of the middle cranial fossa (**G, H**). Removal of the tumor adherent to the basilar artery (BA) and perforating vessels (**I**). A small tumor residual was left close to the foramen lacerum to avoid internal carotid artery injury (**K**). Closure was obtained with fascia lata, which was sutured with 7-0 monofilament suture (**L**) and supplemented with a left nasoseptal flap. Clival DM, clival dura mater; L-ICA, lacerum internal carotid artery; MF DM, middle fossa dura mater; MS, maxillary strut; P-ICA, paraclival internal carotid artery; Pit DM, pituitary dura mater; S, sella; Tu, tumor; V3, mandibular branch of trigeminal nerve.

chordomas and chondrosarcomas and to perform intradural work, in craniopharyngiomas for instance. Transcranial endoscopic assistance can also benefit from the use of the chopsticks technique. However, it is probably also the context that makes this technique the most challenging to master. It is more difficult to maintain control of the aspirator in this situation and the endoscope has to be controlled more precisely in the absence of the nasal cavity scaffold. Besides, this is a surgical skill that can benefit from training in a cadaver laboratory setting and on trainer models, similar to what is done for laparoscopic surgery.

Another significant limitation of this technique is that it is less adequate for finer intradural dissection than is the 2-surgeons technique. In many cases of craniopharyngioma or in more adherent intradural extensions of chordoma, for example, we have reverted to a 2-surgeons 3-hands or 4-hands technique to be able to perform more precise dissections. The 2-surgeons 3-hands/4-hands technique remains the gold standard for delicate dissection of intradural critical structures. Similarly, in cases of profuse bleeding, the second surgeon can also use the other nostril through a small incision in the septal or sphenoidal mucosa. Still, we believe that both techniques have their own sets of advantages and disadvantages. The chopsticks technique should be seen as another way to perform certain tasks in narrow corridors while preserving the anatomic structures and not necessarily a replacement of the 2-surgeons setup.

Using this technique has also taught us that significant improvements to endoscopic endonasal instrumentation are still required. The recent introduction of malleable and curved instruments, notably drill bits, is a significant stride in the right direction. We think that new designs for the endoscopes are also required. In addition to improved image quality, future generations of endoscopes should be lightweight and have better and more relaxed holding systems. Perhaps, there may be ways to liberate the hand holding the endoscope to manipulate an additional instrument. The visualization device has to be at the service of the specific needs of each case and adapted to the way surgeons are used and most comfortable to work. It should not be the other way around, when surgeons have to adapt to the device. It is also paradoxic that normal anatomy should be sacrificed to make space for the visualization device. It shows either inadequate surgical setup and movements or faulty design of the device, which is not adapted to the constraints of the anatomy and specific environment of the nose.

CONCLUSIONS

We have described and provided case illustrations for a technical modification to the standard endoscopic endonasal setup that allows the surgeons to benefit from the advantages of a bimanual technique while still holding the endoscope. This technique may improve dynamic understanding of the anatomy and surgical efficiency and reduce the footprint of the surgery.

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