The full endoscopic endonasal approach to the occipital condyle and the jugular tubercle has been recently described.14 These authors call it “far-medial” in association with the classic “far-lateral” transcranial approach. The condylar and tubercular compartments are an additional lateral expansion to the endonasal approach to the inferior clivus, which is broadly described in the literature.9 From the anatomical viewpoint, Morera et al.14 quantified the lateral expansion that this approach entails in relation to conventional inferior clivus management. Other authors, including Dallan et al.4 and Falcon et al.5 anatomically described the management of the jugular foramen and the infratemporal region, respectively. Although this last approach had been described by Kassam et al.9 they considered and focused their work on the complex anatomical relations of the ET. To date, systematic surgical management of the ET has not been described. To our knowledge, from a strictly surgical viewpoint, this work is the first to describe a fundamental endonasal approach to the inferior clivus, the condylar and tubercular compartments, the prestyloid and poststyloid spaces, and ET transposition to expose the aforementioned structures without disrupting the ET in a mediolateral course.

Case Report

History and Examination. A 10-year-old boy with a history of chronic vomiting and, consequently, undernourishment was examined and found to have a clinically associated uncoordinated walk and vertigo that had evolved over the past year. The patient had undergone surgery at another institution for anatomopathologically diagnosed chondroid chordoma. Cranial CT and MRI detected a low-signal lesion encompassing the lower half of the midclivus, the lower clivus, the occipital condyle, and the left jugular tubercle. The lesion caused a compressive effect on the medulla oblongata and the superior cervical medulla. A sizeable submucosal and parapharyngeal tumoral component was closely associated with the left extracranial jugular vein and carotid artery and had a mediolateral growth pattern with respect to the stylopharyngeal diaphragm. Magnetic resonance images...
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showed a hypointense lesion with no enhancement on the T1-weighted images after contrast was administered and a hyperintense pattern on the T2-weighted images and diffusion restriction (Fig. 1).

Preoperative Planning. The approach considered was a full endoscopic endonasal mid- and inferior translacrimal expanded approach with transcondyolar and transjugular tubercular expansions. This approach was chosen because the lesion was medial to the lower cranial nerves and required resection of the parapharyngeal and retropharyngeal submucosal components.

Careful manipulation is necessary to avoid disrupting the surrounding neurovascular structures, including the parapharyngeal, petrous, lacerum, and paracaval segments of the ICA; vertebral arteries; internal jugular vein; lower left cranial nerves; and sixth cranial nerve in the cisternal and the interdural segments. Other nonneurovascular structures that must not be disrupted are the left ET and the C-1 condylar joint.

Operation. A Brainlab neuronavigation system was used with multislice CT images with contrast. After orotracheal intubation, the patient was placed in a supine position with his neck stretched and head turned 10° sideward toward the left shoulder, slightly turned rightward, and held in place with a Mayfield cephalostat. Povidone-iodine was applied to the perinasal area and to the anterolateral region of the right thigh (in case fascia lata extraction was needed during final reconstruction). Cottonoids were positioned at the middle meatus and paraseptal positions, and required resection of the parapharyngeal and retropharyngeal submucosal components.

The procedure was performed by using a Karl Storz 0° rigid endoscope and an Endo-Scrub 2 lens cleaning sheath (Medtronic) (Video 1).

VIDEO 1. Full endoscopic endonasal extreme far-medial approach with ET transposition used to treat a skull base chordoma in a 10-year-old boy. Click here to view with Media Player.

Click here to view with Quicktime.

The expanded position enabled use of 0° lenses during most of the surgery. Middle and inferior turbinectomies were done on the left side because the lesion specifically expanded toward the left structures. The middle conchae was fractured and dislocated laterally. The nasoseptal flap was then raised according to the technique described by Hadad et al.7 and later modified by Kassam et al.8 This flap has to be raised on the right side because the dissection of the pterygoid fossa, required in this case, entails coagulation of the arterial pedicle of the sphenopalatine artery, which would compromise the vitality of the ipsilateral flap. To avoid ischemia during surgery, at approximately 2-hour intervals, the nasoseptal flap was mobilized from its location.

The nasoseptal flap was next lodged in the choana, so it would not interfere during the procedure, and was later placed in the right maxillary sinus by means of a right antrostomy. The posterior half of the septum was dissected to enable work using both nostrils and 4 hands. The purpose of all these maneuvers was to gain space at the nasal cavity level to enable finer handling and greater exposure of the anatomical structures involved. After these maneuvers were completed, a generous sphenoidotomy was performed, taking away the sphenoid floor all the way to the clival recess using a diamond drill with a Midas Rex motor (Medtronic). Next, a left antrostomy and rear maxillary sinus wall resection were performed to expose the pterygopalatine fossa content. The periosteal layer was preserved to avoid handling its content directly and to facilitate the approach to the sphenopalatine artery and its branches. After the pterygopalatine fossa was transposed, the anterior face of the pterygoid process was exposed. In the upper portion of the anterior face of the pterygoid process, the vidian foramen is excavated; the accompanying vidian nerve and the vidian artery pass through this foramen and canal. The vidian nerve is a fundamental reference for locating the lacerum segment of the ICA because it is found in the projection in the depth of the superior hemicircumference corresponding to the vidian canal. Therefore, drilling between 3 and 9 o’clock (on a clock centered in the vidian foramen and canal) is safe and avoids causing any vascular damage to this structure.

After locating the lacerum segment of the ICA, we established the level at which the petrous segment of the ICA is to be found, which is on a horizontal course toward the outlet through the carotid foramen. Then we completely drilled the medial and lateral pterygoid plates to expose the medial and lateral pterygoid muscles and the tensor veli palatine muscle, which is located anterolaterally to the ET. Next, we made an inverted-U incision at the rhinopharynx level, while the rhinopharyngeal mucosa, the basipterygoid fascia, and the rectus capitis muscles were inferiorly mobilized en bloc and dissected from the inferior clivus and the craniocephalic junction to the anterior C-1 arch. The dense and consistent setting of these tissues at the skull base makes this process quite tedious. Thus, we exposed the mid- and lower clivus and referenced the ICA in its petrous, lacerum, and paracaval segments, leaving the parapharyngeal segment of the ICA and the frontal plane of the jugular, condylar, and lateral C-1 mass compartments to be referenced later.

If referencing the previously described structures is to be accomplished, ET transposition is imperative for management of the ET and pterygoid muscle. Our approach consisted of inferolaterally reversing the ET insertion when it was implanted at the skull base (Trajectory 1). Dissection proceeded laterally from the dihedral angle formed by the posterior rhinopharynx wall (inferiorly dissected with the inverted-U flap) and the lateral wall on which the ET is found. The limitation lies in the hard fixation of the ET at the skull base, which is closely related to the anteroinferior wall of the lacerum segment of the ICA. We referenced this segment after vidian canal drilling, and in the final vidian drilling phases, a soft cartilaginous tissue corresponding to the ET, which is the drilling limit that predicts the location of the vascular element, began to show. Therefore, by maintaining the inferior vidian canal hemicircumference as a reference, we can perform an acute dissection with electrocoagulation, which separates the insertion of the ET cartilaginous portion from the skull base (Fig. 2).

As we advanced laterally, we performed ET disinser-
tion from the petrous bone, anteroinferiorly surrounding the intrapetrous carotid canal to avoid damage to the vascular structure. The inferolateral transposition of the ET enables a direct approach to the condylar and tubercular compartments. To approach the submucosal component, which displaces the parapharyngeal segment of the ICA, it is not sufficient to inferolaterally mobilize the lateral rhinopharynx wall and the ET included in it. We need to dissect the anterior wall of the ET cartilaginous portion from the pterygoid and the tensor veli palatini muscles (Trajectory 2) in an ascending-to-descending direction and parallel to muscle fibers to affect them to a lesser extent by displacing them laterally. This resection provides access to the stylopharyngeal aponeurosis, which separates the prestyloidal space from the poststyloid space, where the parapharyngeal segment of the ICA, internal jugular vein, and the inferior cranial nerves are located extracranially (Fig. 3).

To resect the tumor component behind these structures, we drilled the anterior C-1 arch and the medial third of the C-1 lateral mass. After exposing all of the aforementioned structures, we excised the extradural and intradural portions of the tumor in direct relation to the brainstem (Fig. 4). Closure was performed by using DuraGen (Integra LifeSciences) and fascia lata inlay and the nasoseptal flap and the inverted-U flap of the basipharynx as vascularized flaps.

Postoperative Course. Macroscopically, gross-total resection was possible. In a second-stage procedure, we performed posterior occipitocervical fusion to ensure stability of the occipitocervical segment. The patient experienced transitory paresis of the left sixth cranial nerve. No limitations in jaw opening or crossbite were observed. The ET was preserved, avoiding postoperative conductive hearing loss and recurring serous otitis (Fig. 5). Treatment was complemented with proton-beam irradiation.

Discussion

The largest series of expanded endonasal approaches performed to date was recently published. The review suggests that the high complexity involved in paramedial approaches to the sagittal and the coronal planes should be considered. The review also offers a systematic anatomical and surgical division of the various approaches, which is most useful in clinical practice. The coronal plane approaches, Kassam Zones 5, 6, and 7, correspond to the infratemporal fossa, the coronal plane of the condylar and jugular tubercle compartments, and the styloid spaces, respectively. For these approaches, a transpterygoid route is considered. This is a basic concept when it comes to planning a surgical approach. According to our experience, the lateral wall of the choana (the medial pterygoid plate) and the medial maxillary sinus wall both constitute the lateral limit of expanding the transnasal route; thus, complete lateral expansion requires managing these structures. By means of antrostomy and resection of the posterior maxillary sinus wall, we add a transmaxillary route, which provides access to the pterygopalatine and infratemporal fossas and, in a deeper projection, to prestyloidal and poststyloid spaces. If we also perform transposition of the pterygopalatine fossa and drill the

Fig. 1. Preoperative cranial CT and MR images. A: Axial T2-weighted MR image showing a heterogeneous and hyperintense clival lesion that compresses the brainstem. B: Coronal T2-weighted MR image showing a lesion affecting the left condylar and tubercular compartments. C and D: Sagittal T2-weighted MR images showing medulla oblongata compression and extensive skull base invasion with a large parapharyngeal submucosal component. E: Axial CT image at the C-1 level showing the high cervical spine affected. F: Coronal CT image with contrast showing the relationship between the parapharyngeal segment of the ICA and the large submucosal tumoral component. G: Sagittal CT image showing the relationship between the tumor and the mid- and lower clivus. H: Sagittal CT image showing jugular tubercular and condylar invasion.
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medial and lateral pterygoid plates, thereby producing a transpterygoid route, after avoiding the ET, we can approach the immediate lateral region of the inferior clivus and the foramen magnum, also known as the jugular tubercle and the occipital condyle, which articulate with the lateral C-1 mass.

The endonasal endoscopic approach to the occipital condyle and the jugular tubercle, called the “far-medial” approach, in association with the transcranial approach to the condylar region, called the “far-lateral” approach, has been anatomically described to provide details of the intracranial and extracranial anatomical relations of the implicated structures. We have not been able to obtain an accurate and systematic description, surgical and not strictly anatomical, of performing approaches to more lateral regions like styloid spaces. This work provides a step-by-step description of the surgical technique used in our center and details anatomical concepts applied in the surgical practice to approach these more lateral regions.
Moreover, several anatomical works\(^4\,5\) have established that the ET is a reference structure that must be managed in these approaches. In these works, from a purely anatomical perspective, the ET is excised to assess this structure’s anatomical relationships.

During surgical procedures, the ET should be respected because its damage can lead to conductive hearing loss and recurring serous otitis. Although these complications are considered minor, given the complexity of the operation, they should be avoided. Other authors have shown that a lateral extension of the tumor at the level of the lower clivus (from the foramen magnum across the occipital condyle and hypoglossal canal to the jugular foramen) requires an endoscopic medial maxillotomy with, if needed, a Denker maxillotomy and resection of the ET.\(^13\) Therefore, we have described 2 working trajectories by means of which we can expose Kassam Zones 6 and 7 without interrupting the cartilaginous ET system or the pterygoid, levator, and tensor veli palatini muscles, generating the concept of ET transposition. To our knowledge, this is the first work that describes this concept and the surgical dissection of the ET because, depending on the anatomical features of each patient, the ET should be dissected, at least partially, to perform a far-medial approach. Trajectory 1 requires ET disinsertion to mobilize it inferolaterally to provide access to Zone 6. The vidian nerve is a basic landmark; drilling of the vidian canal must proceed along its inferior hemicircumference because this better avoids inadvertent injury to the ICA,\(^12\,13\,15\,19\) and locating the vidian nerve in preoperative tests is easy.\(^17\) In addition, this course offers a safe plane for dissection of the ET insertion from its riskiest attachment point, compared with the more lateral ET dissection, which goes beyond the lacerum foramen and is performed in relation to the petrous base. However, given the very large volume of soft tissue for which en bloc mobilization is limited, this first trajectory is insufficient for reaching Kassam Zone 7. This difference is important with regard to the far-medial approach, because the extreme far-medial approach enables us to reach anatomical areas beyond, because the lateral limit for the far-medial

**Fig. 4.** Postoperative cranial CT and MR images. A: Sagittal T1-weighted MR image with contrast. Solid white arrow indicates reconstruction with the nasoseptal flap; broken white arrow indicates reconstruction with inverted-U basipharyngeal flap; white arrowhead indicates brainstem reexpansion. B: Axial T1-weighted MR image with contrast. Solid white arrow indicates reconstruction with the nasoseptal flap. C: Axial T1-weighted MR image with contrast at C-1 level showing resection of the submucosal and spinal tumoral components. D: Sagittal CT image. Solid black arrow indicates upper half midclivus. E: Coronal CT image. White arrowhead indicates right hypoglossal canal; solid white arrow indicates occipital condyle drilled; broken white arrow indicates left lateral C-1 mass drilled. F: Axial CT image. Solid white arrow indicates left-side anterior C-1 arch drilled.

**Fig. 5.** A–C: Postoperative cranial axial CT images 1 month after surgery, demonstrating postoperative pneumatized mastoid cells and lack of fluid in the middle ear. D: Audiogram 3 months after surgery, proving bilateral normoaucousia.
approach is the lateral wall of the nasopharynx and the ET. For this reason, we have described a second trajectory, in which the dissection is made lateral to the ET and medial to the pterygoid and tensor veli palatini muscles. This trajectory generates sufficient space to treat lesions, especially prestyloid ones, while preserving the stylopharyngeal aponeurosis to avoid vascular damage to the parapharyngeal segment of the ICA and the internal jugular vein. Thanks to these 2 courses, we can transpose the ET and reach Kassam Zones 6 and 7 while viewing with a 0° lens, which is more intuitive and practical during surgery. On the basis of our experience, however, approaching retrocarotid poststyloid structures via these courses is insufficient or, at least, does not enable the fine dissection needed to deal with such important structures as the internal jugular vein and the lower cranial nerves, because they are laterally forced approaches. Therefore, the endoscopic Denker approach could prove most useful, specifically for lesions with lateromedial growth patterns with respect to the stylopharyngeal diaphragm. In our routine surgical practice, we always choose the extreme far-medial approach when the tumor growth pattern is mediolateral with respect to the stylopharyngeal diaphragm. On this point we concur with Al-Sheibani et al., who describe a nasopharyngectomy through a transpterygoid course; however, our works differ in 2 major ways: Al-Sheibani et al. propose transecting and removing the ET in all cases, and they treated only sinonasal malignancies. Consequently, their approach has not been proven in cases of intracranial extension and has not been raised as an approach for treating deeper regions (the clivus and the lateral foramen magnum). Our work complements and expands other studies.

The necessity for occipitocervical fusion is controversial. Although no biomechanical studies addressing the stability of the atlantooccipital joint after ventromedial condyle resection have been performed, in the case reported here significant hypermobility was generated by the important preoperative condylar insufflation and the extensive condylar drilling, the C-1 anterior arch and lateral mass drilling, and the intraparotid disruption of the alar ligament and capsule of the atlantoaxial joint. Therefore, we think that occipitocervical fusion, not only C1–2 fusion, should be considered.

Proton-beam radiation seems to extend survival times and to achieve better disease control, but its effects on patients with no identifiable residual tumor is unclear. The patient reported here had undergone previous surgery at another institution and had been evaluated for proton-beam therapy; however, such therapy was not possible because the tumor had progressed, enlarging significantly and compressing the brainstem. After the second surgical procedure, the patient was referred for proton-beam therapy because of the tumor’s tendency to regrow.

The standard endoscopic approach to the inferior clivus can be laterally expanded by the far-medial approach to reach the condylar and tubercular compartments and at the same time extended more laterally to the styloid spaces by the extreme far-medial approach. The ET is an essential anatomical element and its surgical management is critical.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. Author contributions to the study and manuscript preparation include the following. Conception and design: Simal-Julián. Acquisition of data: Simal-Julián, Miranda-Lloret, Beltrán-Giner, Plaza-Ramírez. Analysis and interpretation of data: Simal-Julián, Miranda-Lloret, Beltrán-Giner. Drafting the article: Simal-Julián, Botella-Asunción. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Simal-Julián. Administrative/technical/material support: Botella-Asunción. Study supervision: Beltrán-Giner, Botella-Asunción.

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