Endonasal neuroendoscopy: new horizons

Ahmed El-Guindy

Department of Otolaryngology-Head and Neck Surgery, Tanta University, Tanta, Egypt

Correspondence to Ahmed El-Guindy, Department of Otolaryngology-Head and Neck Surgery, Tanta University, 31511 Tanta, EGYPT
Tel: +20 128 498 8000; fax: +20 40 331 0054;
e-mail: aelguindy@yahoo.com

Received 20 October 2011
Accepted 5 November 2011

The Egyptian Journal of Otolaryngology
2012, 28:1–7

Egypt J Otolaryngol 28:1–7

1012-5574

Introduction

Transsphenoidal approaches have been used for a century for the resection of pituitary and other sellar tumors. This is because it is the least traumatic route to the sella turcica, avoids brain retraction, and provides excellent visualization of the pituitary gland and lesions related to that structure. As a result of these advantages, it offers a lower morbidity and mortality rate when compared with transcranial procedures and this also naturally leads to a shorter hospital stay.

Nevertheless, a variety of innovative skull base approaches (including anterior, anterolateral, and posterolateral routes, which often require extensive neurovascular manipulation to gain access to the lesion) have been developed to allow resection of lesions of the ventral skull base. In contrast to traditional cranial base surgical approaches, the endonasal technique offers a direct and minimally invasive approach that allows excellent midline visualization and access to the suprasellar, retrosellar, and retroclival spaces, while obviating brain retraction. This approach has recently been boosted by the use of the endoscope, coupled with the current sophisticated neuronavigation systems. The expanded endonasal approach evolved when these principles were then further augmented with the concept of team surgery, that is, a neurosurgeon and an otolaryngologist working simultaneously throughout all phases of the surgery (approach, resection, and reconstruction). With the advances in hemostatic and reconstructive techniques, we are now able to address a diverse array of intradural and extradural lesions of the midline skull base safely and effectively [1].

Aim

To provide a detailed description of the extended endoscopic endonasal approach to the ventral skull base, evaluate its advantages and limitations, and to understand better the complex anatomical relationships of the structures involved in the approach from an endoscopic perspective.

Anatomy of the ventral surface of the brain and brain stem

The ventral surface of the brain includes the orbital surface anterior to the lateral sulcus and the tentorial surface posterior to it. The olfactory sulcus that lodges the olfactory bulb and the olfactory tract divides the orbital surface into gyrus rectus medially and orbital gyri laterally. The orbital sulcus is an H-shaped sulcus that divides the orbital surface into four orbital gyri (anterior, posterior, medial, and lateral). In the tentorial surface, the occipitotemporal sulcus separates between the lateral occipitotemporal gyrus (laterally) and the medial occipitotemporal gyrus (medially). The collateral sulcus separates between the medial occipitotemporal gyrus laterally and the parahippocampal gyrus medially.

The olfactory bulb is an oval reddish-gray mass, lies below the anterior end of the olfactory sulcus, and rests on the cribriform plate of the ethmoid bone. The olfactory tract is a white band, which extends from the posterior end of the olfactory bulb and runs on the olfactory sulcus. Its expanded posterior end is termed the olfactory trigone, which divides into a lateral olfactory root to end in the uncus and anterior part of the parahippocampal gyrus, an intermediate olfactory root into the anterior perforated substance pierced by the central branches of the anterior and middle cerebral arteries, and a medial olfactory root into the paraterminal gyrus in front of the anterior commissure and lamina terminalis.

The ventral surface of the brain stem consists of the midbrain, pons, and medulla oblongata. The midbrain shows the interpeduncular fossa, which is a rhomboid-shaped area bounded anteriorly by optic chiasma, posteriorly by the upper border of the basilar part of the pons, anterolaterally by the optic tract, and posterolaterally by crus cerebri. The contents from anterior to posterior are tuber cinerium, to which the infundibulum of the pituitary gland, the two mammillary bodies situated behind the tuber cinerum, the posterior perforated substance pierced by the central branches of the posterior cerebral arteries, and the oculomotor nerves are attached. The fossa lodges the arteries of the circle of Willis.

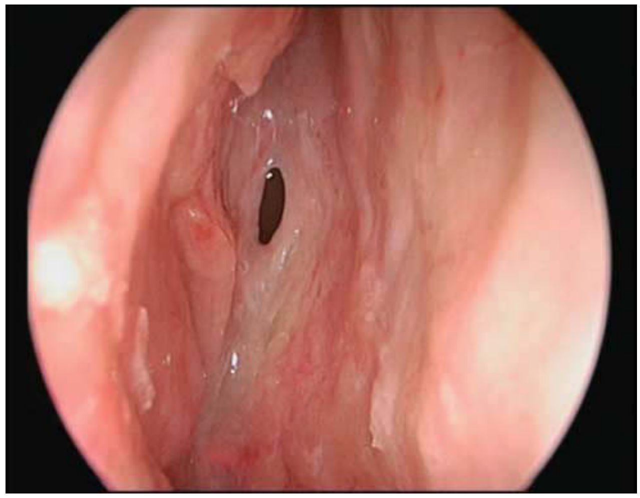
The pons shows the basilar sulcus, which lodges the basilar artery, the transverse striations, which are made of the transverse pontine fibers, the superior cerebellar and posterior cerebral arteries, which lie at its upper border, the anterior inferior cerebellar arteries, which lie at its lower border, the cranial nerves III and IV, related to its upper border, and the cranial nerves VI, VII, and VIII, related to its lower border.

The medulla oblongata shows the anterior median sulcus, the pyramid on each side of the anterior median sulcus, the anterolateral sulcus, which contains the rootlets of hypoglossal nerve (XII), and the olive lateral to the sulcus. Posterolateral to the olive, there is the inferior cerebellar peduncle. Both are separated by the 9th, 10th, and 11th cranial nerves.

The extended endoscopic endonasal approach

In the standard endoscopic approach to the sellar region, the endoscope is introduced through the right nostril, close to the floor of the nasal cavity. The middle turbinate is pushed laterally to widen the space between the middle turbinate and the nasal septum and to create an adequate surgical corridor to the posterior nasal cavity. As the endoscope advances into the nasal cavity, it reaches the choana. The endoscope is then angled rostrally, along the roof of the choana and the sphenoethmoid recess, until it reaches the sphenoid ostium, which is usually located approximately 1.5 cm above the roof of the choana (Fig. 1). In a well-pneumatized sphenoidal sinus, the ostium cannot be visualized because it is covered by the superior turbinate. In this case, the superior turbinate is removed to expose the ostium and gain access to the sphenoidal sinus. The sphenoid cavity is then entered through this thin portion of the anterior wall. After identification of the sphenoid cavity, the nasal septum is disarticulated from the sphenoid rostrum. The whole anterior wall of the sphenoidal sinus is enlarged circumferentially, taking care not to enlarge the sphenoidotomy too much in the inferolateral direction, where the sphenopalatine artery and its major branches lie. The medial turbinate of the left naris is then lateralized but not resected. The natural sphenoid ostium on the left is opened and widened so that there is communication with the previous sphenoidotomy on the right side, thus creating wide bilateral sphenoidotomies. The lateral margins of the sphenoidotomies are extended to the level of the medial pterygoid plates. The endoscope is then returned to the right naris and a small portion (1–2 cm) of the posterior nasal septum is resected. This represents the most critical step in the binasal approach because it creates a single large rectangular window into the sphenoid sinus, facilitates bilateral instrumentation without deviation of the septum into the path of the endoscope and compromise of visualization, and allows for the progressive placement of the endoscope closer to the target, which is critical for visualization and illumination. To optimize the available space, the endoscope is positioned superiorly at 12 o'clock, with the suction entering into the 6 o'clock position in the right naris. Dissecting instruments can be introduced into the nasal cavity through the left naris.

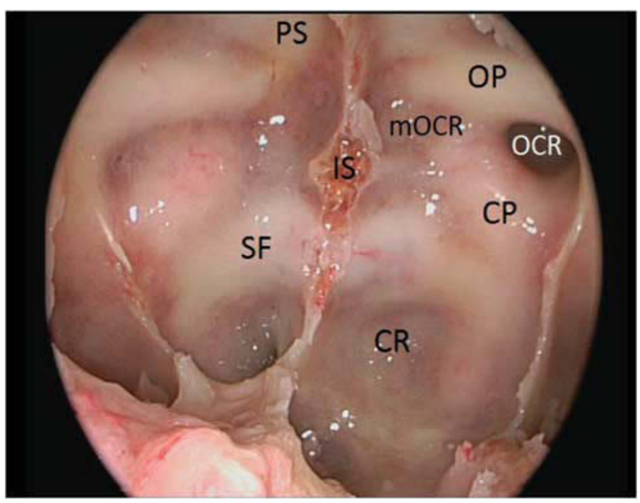
Figure 1



Endoscopic picture of the ostium of the right sphenoid sinus.

After the wide anterior sphenoidotomy has been performed, any intrasphenoidal septations are removed with care, because the paramedian septations often lead to the vertical canal of the internal carotid artery (ICA). The key anatomical landmarks within the sphenoid sinus cavity are identified (Fig. 2) as follows: the sellar floor at the center, the sphenoethmoid planum above it, and the sphenoid rostrum and clival recess below, the lateral walls of the sphenoidal sinus with the carotid and the optic protuberances, and the medial and lateral opticocarotid recesses. The medial OCR represents the ventral surface

Figure 2



An endoscopic picture showing both the sphenoid sinus cavities. CP, carotid protuberance; CR, clival recess; IS, intersphenoid septum; mOCR, medial opticocarotid recess; OCR, lateral opticocarotid recess; OP, optic protuberance; PS, planum sphenoidale; SF, sellar floor.

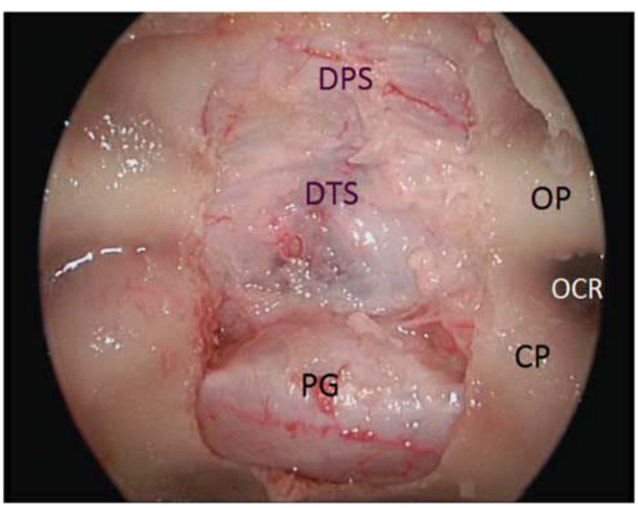
of the medial clinoid and is the key anatomical landmark in this region. The lateral OCR recess is molded by the pneumatization of the optic strut of the anterior clinoid process. Bone removal is then started over the sellar face to expose dura over the pituitary gland [2].

The extended approaches require the creation of a wider surgical corridor to expose and work in the different areas around the sella. The creation of such surgical corridors requires removal of the middle turbinate on the right side, lateralization of the middle turbinate in the left side, and removal of the posterior portion of the nasal septum.

Transtuberculum/transplanum approach

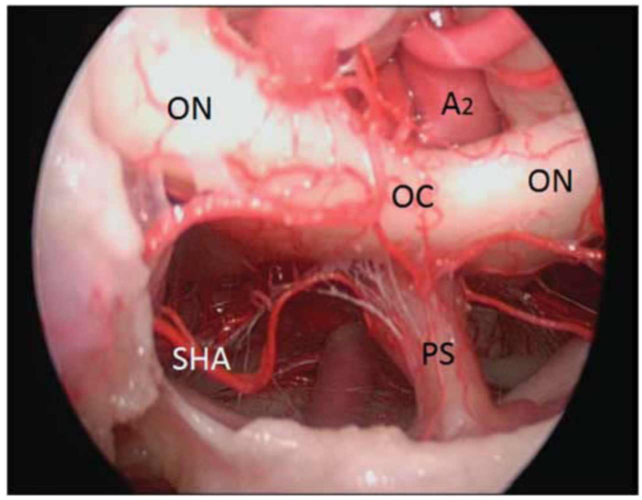
Access to the suprasellar region and the sphenoid planum is gained through a more anterior trajectory compared with the one used to reach the sellar region. This route requires a wider opening of the anterior wall of the sphenoidal sinus, which is obtained by removing the superior turbinates and the posterior ethmoid air cells located lateral to these turbinates. During the course of such maneuvers, particular attention must be paid to avoid damage to the posterior ethmoidal artery. It is also important not to extend the removal of the nasal septum and the ethmoid too anteriorly, to avoid damaging the olfactory nerve endings. Above the sellar floor, the angle formed by the convergence of the sphenoid planum with the sellar floor is recognized; from the intracranial view, this corresponds to the tuberculum sellae. As the endoscope is moved in an anterior direction, the sphenoid planum becomes visible and laterally delineated by the protuberances of the optic nerves that diverge toward the apices of the orbits. The opening of the planum starts with the removal of the tuberculum sellae, extended bilaterally between the medial OCRs. The upper half of the sellar floor and the posterior portion of the planum sphenoidale are removed first, isolating the tuberculum.

Figure 3



An endoscopic picture showing both the sphenoid sinus cavities. CP, carotid protuberance; DPS, dura of planum sphenoidale; DTS, dura of tuberculum sellae; OCR, lateral opticocarotid recess; OP, optic protuberance; PG, dura covering the pituitary gland.

Figure 4

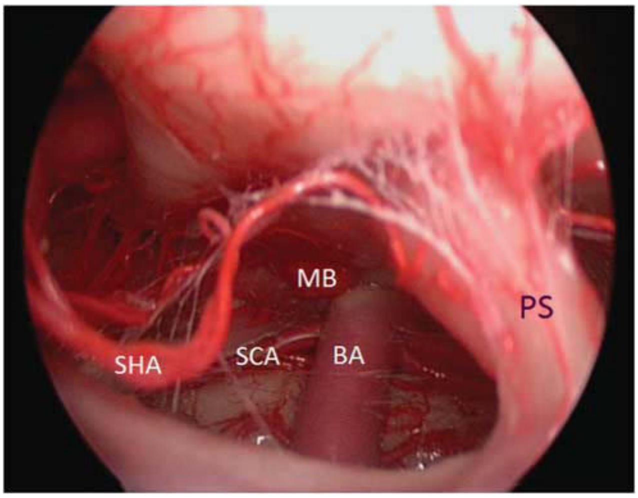


An endoscopic picture after opening the chiasmatic cistern. A2, A2 segment of the internal carotid artery; OC, optic chiasma; ON, optic nerve; PS, pituitary stalk; SHA, superior hypophyseal artery.

Once this has been done, the thinned tuberculum is carefully fractured and dissected from the dura mater, being careful to avoid entering the superior intercavernous sinus. The removal of the sphenoid planum is extended in a posteroanterior direction for 1.5–2 cm, but not beyond the posterior ethmoidal arteries. The lateral extension of the opening is limited by the protuberances of the optic nerves, resulting in a chef-hat window (Fig. 3) [3].

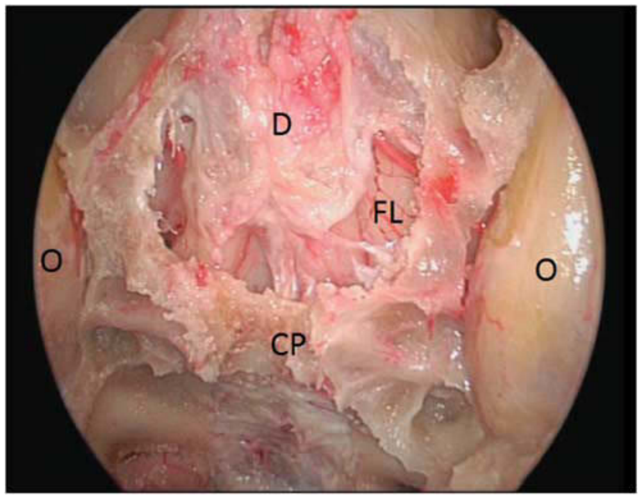
Next, the dura mater above the pituitary gland is opened, allowing visualization of the intracranial structures. The chiasm and the optic nerves are clearly visible. We can consider two endoscopic surgical corridors: one below the chiasm and one above it (Fig. 4). Below the chiasm, the pituitary stalk, the superior hypophyseal artery, and the perforating branches for the inferior surface of the optic chiasm and nerves are apparent (Fig. 5). Laterally, the origin of the ophthalmic artery below the optic nerve is also visible. When the endoscope is advanced below the chiasm, it reveals the ICA, its bifurcation, and the first A1 segment before it reaches the superior surface of the optic chiasm. The superior surface of the pituitary gland and the dorsum sellae are also well visualized (Fig. 6). After opening the Liliequist membrane by directing the endoscope over the dorsum sellae, it is possible to reach the posterior cranial fossa and to expose the upper portion of the brainstem. The basilar artery apex, posterior cerebral arteries, and superior cerebellar arteries, with the third cranial nerves between them, are clearly exposed (Fig. 7). The mammillary bodies and the floor of the third ventricle are also visible. Opening the floor of the ventricle allows access to the ventricle. Advancing the endoscope further provides a panoramic view of the ventricular cavity. The lateral ventricle walls, which are formed by the medial portion of the thalami, are visible, as is the interthalamic commissure. The foramina of Monro are visible superiorly. By advancing the endoscope

Figure 5



An endoscopic picture after passing the endoscope in the corridor below the optic chiasma. BA, basilar artery; MB, mammillary body; PS, pituitary stalk; SCA, superior cerebellar artery; SHA, superior hypophyseal artery.

Figure 7



An endoscopic picture of the transcribriform approach. CP, cribriform plate; D, dura of the olfactory groove; FL, orbital surface of the frontal lobe; O, orbit.

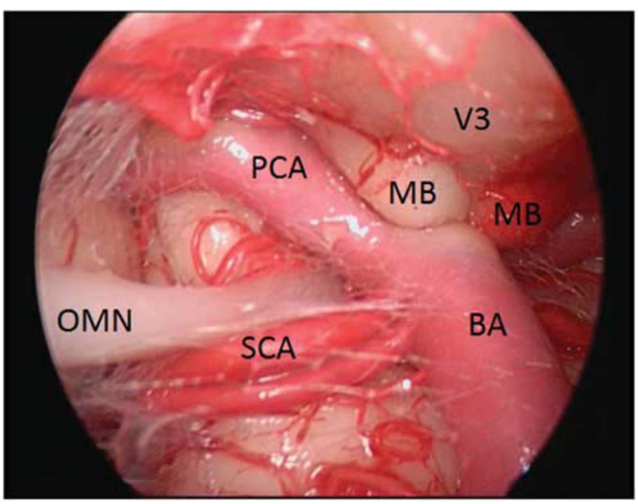
toward the posterior ventricle wall, the pineal and suprapineal recesses, the posterior commissure, the habenular commissure, the habenular trigona, and the beginning of the aqueduct come into view. Once the roof of the third ventricle is opened, the pineal gland and the internal cerebral veins are visible [1].

By angling the endoscope above the chiasm, the A1 segments of both of the anterior cerebral arteries, the anterior communicating artery, the recurrent artery of Heubner, and the A2 segments and gyri recti of the frontal lobes are visible. If the space between the chiasm and the anterior communicating artery is wide, it is possible to observe the lamina terminalis (Fig. 4).

Transcribriform approach

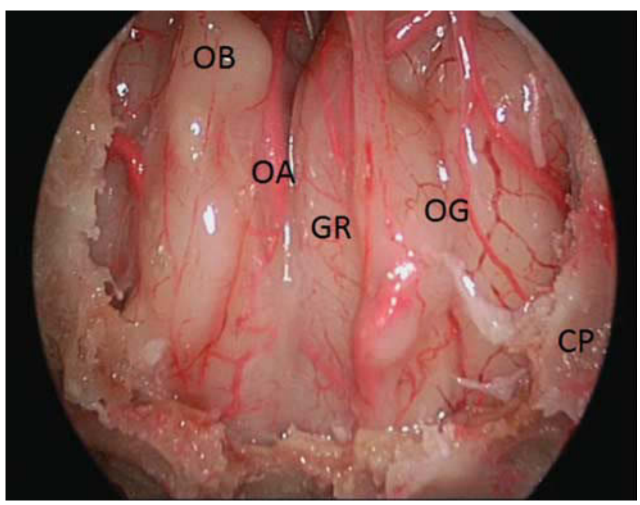
This module expands the rostral extension of the previous approach to the level of the crista galli. The bulla ethmoidalis and the middle and posterior ethmoid cells are opened. The ethmoid septations are drilled flush with the anterior cranial base and lateral to the level of the lamina papyracea, providing for a wide lateral exposure. The superior half of the posterior nasal septum is removed to allow a wide view of the superior portion of the contralateral skull base, without obstruction during insertion of the working instruments. Now the portion of the anterior skull base spanning the distance between the two orbits is exposed. The superior portion of the lamina papyracea is removed, and the anterior and posterior

Figure 6



An endoscopic picture after passing the endoscope in the corridor below the optic chiasma. BA, basilar artery; MB, mamillary body; OMN, oculomotor nerve; PCA, posterior cerebral artery; SCA, superior cerebellar artery; V3, floor of the third ventricle.

Figure 8



An endoscopic picture of the transcribriform approach. CP, cribriform plate; GR, gyrus rectus; OA, orbital artery; OB, olfactory bulb; OG, orbital gyri.

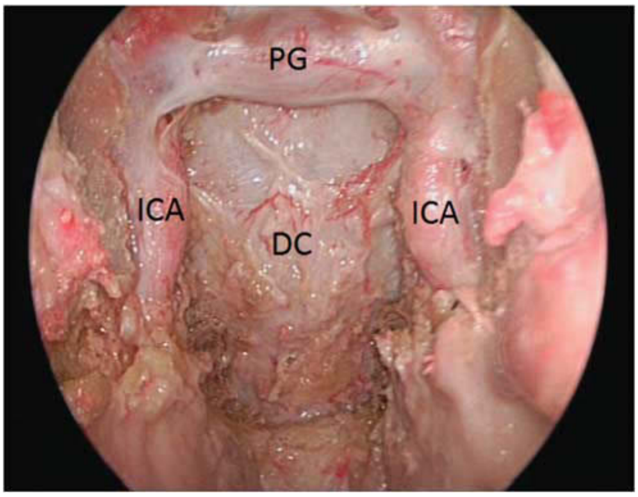
ethmoidal arteries are isolated and ligated on both sides. The bone of the anterior skull base between the orbits is removed (Fig. 7).

The dura mater is opened, allowing exposure of the intracranial contents. The olfactory nerves and the basal surfaces of the frontal lobes are initially visualized (Fig. 8). By retracting the medial surfaces of the frontal lobes, it is possible to expose the two pericallosal arteries in the interhemispheric fissure [1].

Transclival approach

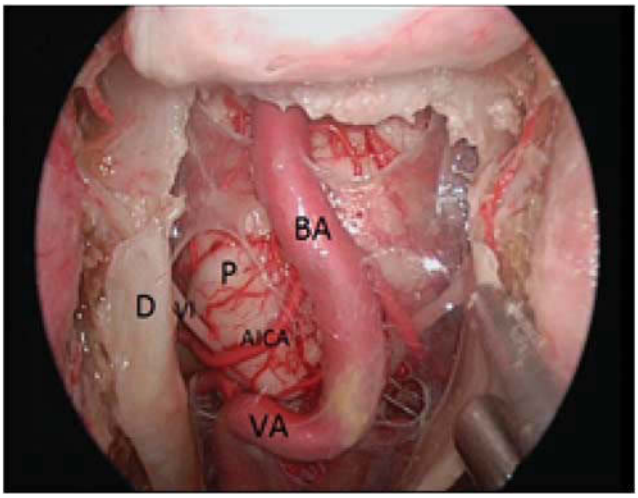
Access to the clivus is achieved through a more caudal trajectory than that necessary for access to the sellar region. Depending on its degree of pneumatization, the sphenoid floor divides the sphenoid portion of the clivus from the rhinopharyngeal segment in variable proportions. The preliminary steps of the procedure include the previously described middle turbinectomy on the right side of the approach, wide anterior sphenoidotomy with removal of all septa, and removal of the posterior portion of the nasal septum to allow a binasal approach. The nasal mucosa is detached from the vomer and along the inferior wall of the sphenoidal sinus. The mucosa is dissected laterally until the vidian nerves are identified; this represents the lateral limits of the surgical corridor. The vomer and the floor of the sphenoidal sinus are completely removed, permitting the union of the sphenoidal and rhinopharyngeal parts of the clivus. The mucosal flap obtained from the dissection of the vomer and the inferior wall of the sphenoidal sinus is cut just medial to the vidian nerves, down to the floor of the nasal cavity inferiorly, thus creating a mucosal flap that can be reflected superiorly, making it available for closure of the surgical defect. At this stage, the clivus is exposed from the level of the pituitary gland down to that of the eustachian tubes. The fascia covering the clivus is extremely tough and adherent and is removed with difficulty. The bone of the clivus is removed, and the limits of the clival fenestration are represented by the sella superiorly and by the paraclival tracts of the ICA laterally (Fig. 9). Inferiorly, below the level of paraclival carotid arteries, there are no relevant vascular structures limiting the lateral bone removal of the clivus, thus allowing a wider exposure of the surgical field. It is important, however, to remain aware of the location of the retropharyngeal carotid arteries, which are deep and variably lateral to the eustachian tubes. Deep to the clivus, there lies the basilar plexus, which is the most extensive series of intercavernous venous connections across the midline. The superior and inferior petrosal sinuses join the basilar plexus. The abducent nerve enters the cavernous sinus by passing through the basilar sinus close to the paraclival tract of the ICA; therefore, particular attention should be paid during bone removal in this area. The course of the dorsal meningeal artery is in close proximity to that of the abducent nerve. After the dura mater is opened, the vertebral artery (VA) and its branches as well as the upper cranial nerves are well visualized in the posterior cranial fossa (Fig. 10) [4].

Figure 9



An endoscopic picture of the transclival approach. DC, dura behind the clivus; ICA, paraclival part of the internal carotid artery; PG, pituitary gland.

Figure 10

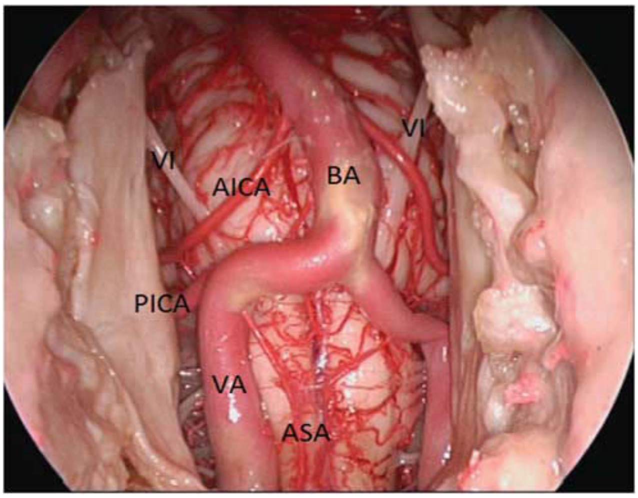


An endoscopic picture of the transclival approach after opening the dura (D). AICA, anterior inferior cerebellar artery; BA, basilar artery; P, pons; VA, vertebral artery; VI, abducent nerve.

Approach to craniovertebral junction and anterior portion of the foramen magnum

This approach can be considered the extreme inferior extension of the previously described endoscopic approach to the clivus. The main difference is in the complete removal of the vomer, extending inferiorly, down to the hard palate. This is done to allow wide exposure of the rhinopharynx and to avoid any conflict among the instruments during the next surgical steps. The lower third of the clivus is removed down to the occipital condyles, and the foramen lacerum on both sides is identified because it represents the lateral limit of the approach. Once a wide surgical corridor has been created, the mucosa of the rhinopharynx is removed and the atlantooccipital membrane, longus capitis and longus colli muscles, the anterior atlas, and axis are exposed. The anterior arch of the atlas is removed, the dens is exposed, and thinned using the microdrill. The dens is then

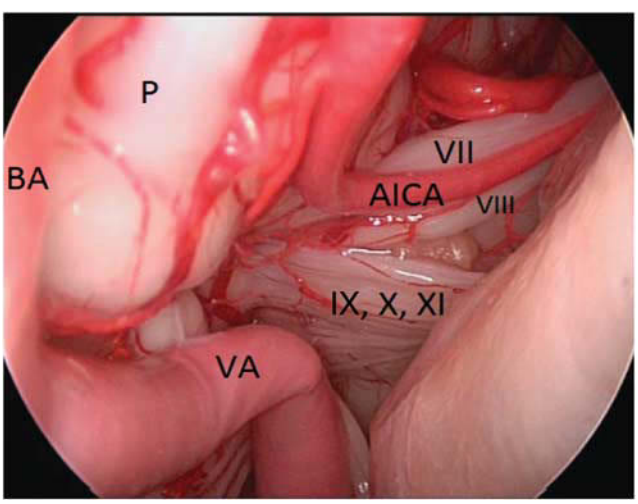
Figure 11



An endoscopic picture of the transclival transcraniovertebral approach after opening the dura (D). AICA, anterior inferior cerebellar artery; ASA, anterior spinal artery; BA, basilar artery; PICA, posterior inferior cerebellar artery; VA, vertebral artery; VI, abducent nerve.

separated from the apical and alar ligaments, dissected from the transverse ligament, and finally removed. At this point, a wide surgical corridor allowing access to the anterior portion of the foramen magnum is created. After the opening of the dura mater, all the neurovascular structures running through the anterior part of the foramen magnum can be visualized. The VAs can be explored from their entrance in the vertebral canal up to the basilar artery (Fig. 11). The two branches of the intradural segment of the VA (the posterior inferior cerebellar artery and the anterior spinal artery) are visible as well. The hypoglossal nerve can be identified as a series of rootlets that converge on the dural orifice of the hypoglossal canal. Below the entrance of the VA, the dentate ligament and the ventral rootlets of the first and second spinal nerves can be visualized in the spinal canal. Passing the endoscope superior and posterior to the VA, the lower cranial nerves and the acoustic–facial bundle (seventh and eighth cranial nerves) are explored along with the anterior inferior cerebellar artery (Fig. 12) [2].

Figure 12



An endoscopic picture of the transclival approach after opening the dura (D). AICA, anterior inferior cerebellar artery; BA, basilar artery; P, pons; VA, vertebral artery; VII, facial nerve; VIII, vestibulocochlear nerve; IX, X, XI, glossopharyngeal, vagus, and accessory nerves.

Discussion

The midline skull base is commonly divided into three parts: (a) the anterior cranial base, which covers the upper nasal cavity and the sphenoidal sinus, and is composed of the crista galli, the cribriform plate of the ethmoid bone, and the planum sphenoidale; (b) the middle cranial base, which is formed by the tuberculum sellae, the pituitary fossa, the anterior and posterior clinoid processes, and the dorsum sellae; and (c) the posterior cranial base, which extends from the dorsum sellae to the anterior border of the foramen magnum and is formed of the clivus with its two constituents: basisphenoid and basiocciput.

The extended endoscopic endonasal route offers the possibility of exposing the entire midline skull base from below, with the advantage of passing through a less delicate structure (the nasal cavity) to reach a more noble one (the brain with its neurovascular structures). Through different trajectories, the endoscope allows full access to the skull base and the cisternal spaces it encloses, yielding complete visualization of the carotid and vertebrobasilar arterial systems and of all 12 cranial nerves safely and effectively. In addition, the constant improvements in diagnostic imaging techniques and the increasing use of image guidance systems during endoscopic endonasal procedures have provided increasing accuracy and safety for this approach, allowing improved, constant surgical orientation in an anatomically complex area. Furthermore, it provides a direct anatomical route to the lesion without traversing any major neurovascular structures, obviating brain retraction. Many tumors grow in a medial-to-lateral direction, displacing structures laterally as they expand, creating natural corridors for their resection through an endonasal approach. The disadvantages of the approach include the relatively restricted working space and the danger of an inadequate dural repair with cerebrospinal fluid leakage and the potential occurrence of meningitis. However, the surgical corridors for the extended approaches are widened by the removal of the middle turbinate on one side (usually the right one), lateralization of the middle turbinate in the other nasal cavity, and removal of the posterior portion of the nasal septum. This variation will allow the use of both nostrils for access, with three instruments inserted in addition to the endoscope, which needs to be continuously moved to expose and reach all the possible areas and to provide a sense of depth and perspective. Cerebrospinal fluid leaks have remarkably reduced with the use of nasoseptal flaps and effective buttresses to hold the implant in place. Bleeding from intercavernous and basilar sinuses can be controlled by avitene and warm saline irrigation, and arterial bleeds with bipolar cautery.

The endoscope always provides a focused panoramic view with bright illumination, incremental magnification, and angled visualization allowing visualization around the corners. The limitations of the endoscopic technique are the lack of depth (two-dimensional), possibility of obtaining a distorted image (barrel effect), and the frequent need for irrigation of the lens.

The extended endoscopic endonasal approach allows experienced surgeons to deal with a diverse array of intradural and extradural ventral midline skull base lesions with reduced operative time and decreased intraoperative blood loss, less morbidity, and short hospitalization time. Among these lesions are olfactory groove meningiomas, planum sphenoidale and tuberculum sellae meningiomas, extrasellar pituitary adenomas, Rathke's pouch cysts, craniopharyngioma, chordoma, and epidermoid cysts.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Cavallo LM, de Divitiis O, Aydin S, Messina A, Esposito F, Iaconetta G, *et al.* Extended endoscopic endonasal transsphenoidal approach to the suprasellar area: anatomic considerations – part 1. Neurosurgery 2007; 61 (3 Suppl): 24–33, discussion 33–34.

2 Cavallo LM, Messina A, Cappabianca P, Esposito F, de Divitiis E, Gardner P, *et al.* Endoscopic endonasal surgery of the midline skull base: anatomical study and clinical considerations. Neurosurg Focus 2005; 19:E2.

3 Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. Neurosurg Focus 2005; 19:E3.

4 Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. Neurosurg Focus 2005; 19:E4.