Expanded endonasal approach: the rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum

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Object. Transsphenoidal approaches have been used for a century for the resection of pituitary and other sellar tumors. Recently, however, the standard endonasal approach has been expanded to provide access to other parasellar lesions. With the addition of the endoscope, this expansion has significant potential for the resection of skull base lesions.

Methods. The anatomical landmarks and surgical techniques used in expanded (extended) endoscopic approaches to the clivus and cervicomedullary junction are reviewed and presented, accompanied by case illustrations of each segment (or module) of approach.

The caudal portion of the midline anterior skull base and the cervicomedullary junction is divided into modules of approach: the middle third of the clivus, its lower third, and the cervicomedullary junction. Case illustrations of successful resections of lesions via each module of the approach are presented and discussed.

Conclusions. Endoscopic expanded endonasal approaches to caudally located midline anterior skull base and cervicomedullary lesions are feasible and hold great potential for decreased morbidity. The effectiveness and appropriate use of these techniques must be evaluated by close examination of outcomes as case series expand.

KEY WORDS • endoscopic surgery • skull base • clivus • cervicomedullary junction

In this report we describe our experience over the past 7 years with access to the ventral skull base along a midline sagittal plane by using a fully endoscopic, completely transnasal approach. In the accompanying report¹ we described our system of modular approaches, which was based on specific anatomical corridors to the anterior skull base that extended from the crista galli to the sella turcica. In this report we present the modules outlining the caudal extension from the posterior clinoids to the craniocervical junction. For each of these modules we will outline the key anatomical principles and technical nuances, using illustrative cases to highlight these principles.

ROSTROCAUDAL APPROACH

Middle Third of the Clivus: Exposure of the Superior Portion

The middle third of the clivus can be divided into a superior and inferior portion, each containing key anatomical landmarks. In its superior portion, the rostral extension of the middle third of the clivus is bounded posteriorly by the dorsum sellae in the midline and the posterior clinoids in the paramedian region. We have found that removal of

Abbreviations used in this paper: BA = basilar artery; CA = carotid artery; CSF = cerebrospinal fluid; ICA = internal carotid artery; MR = magnetic resonance; SIS = superior intercavernous sinus; VBJ = vertebrobasilar junction.

these structures provides unparalleled access to the BA and interpeduncular cisterns located directly behind. The dorsum sellae and posterior clinoids can be removed either intradurally via a transsellar approach or extradurally via a subsellar approach by elevating the soft-tissue contents of the pituitary fossa en bloc and allowing for posterior access.

Illustrative Case. This 43-year-old man presented with visual and pituitary function impairment. Admission MR imaging revealed a lesion in the retroinfundibular space (Fig. 1A) behind the chiasm. An initial transplanum approach was performed, as described in the companion paper, and a biopsy specimen was obtained, confirming a granular cell tumor. Because of the patient's visual impairment, we decided to resect the tumor. Based on the retroinfundibular location and the previous procedure it was apparent that an approach to the basilar cistern and midbrain would be required. A complete resection of the tumor was achieved through a posterior clinoidectomy (Fig. 1B). The patient experienced a CSF leak that required revision surgery, but he recovered visual function. This case is presented to demonstrate the technique used for transsellar posterior clinoidectomy to obtain access to the retroinfundibular region.

Transsellar Exposure. The first step is to complete the transtuberculum/transplanum approach as outlined in Part I. The anterior margin of this exposure only needs to reach to the level of the tuberculum/plenum junction and not to the posterior ethmoidal artery (as described in Part I). The

Fig. 1. A: Sagittal and coronal postcontrast MR images demonstrating the retrochiasmatic location of the tumor. Note that the tumor comes to the undersurface of the third ventricle as seen on the coronal image and abuts the BA as seen on the sagittal view. B: Postoperative, postcontrast sagittal MR image (*left*) demonstrating complete removal of the tumor. Postoperative axial computerized tomography scan (*right*) demonstrating removal of the left posterior clinoid that was used for access.

bone over the entire sellar face is completely removed to expose the junction of the sella turcica and clivus, with the SIS above and the inferior intercavernous sinus below.

The dura mater over the tuberculum, the SIS, and the entire pituitary fossa is exposed. The dura over the prechiasmatic cistern is opened in a cruciate fashion, with the base of the inferior triangle running inferiorly along the SIS, and the dura over the pituitary is opened similarly. The SIS is ligated (clipped or preferably coagulated) with a bipolar cautery and then transected, creating a T-shaped opening vertically through the sella turcica (Fig. 2). The entire pituitary gland is exposed and the diaphragma is cut along the midline at its point of attachment to the sella to expose the stalk. The diaphragma is then cut in a paramedian direction to release the stalk circumferentially (Fig. 2A). The lateral soft tissue extending from the lateral lobes of the pituitary

to the cavernous sinus are sharply cut, avoiding the branches of the superior hypophyseal artery. The dura mater over the posterior clinoid is exposed and the pituitary gland is carefully retracted caudally. With the gland protected, the dura is coagulated and dissected, and venous bleeding is controlled using microfibrillar collagen “sandwiches.” The posterior clinoid is then drilled using a 1-mm diamond bit until it is eggshell thin, and then it is removed with care to avoid injury to the CA and abducent nerve located laterally and directly posteriorly (Fig. 2B, Video 1). The posterior clinoid can be removed bilaterally to provide a direct view into the retrosellar space if required.

Video 1. Posterior clinoidectomy. (Click [here](#) to view with Windows Media Player and a broadband connection, [here](#) to view with a dial-up connection, or [here](#) to view with RealPlayer.)

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If additional bone needs to be removed in the midline, the pituitary gland may have to be transposed. To accomplish this, a 360° sharp dissection of the gland is undertaken, completely freeing it from any soft-tissue attachments. The gland can be elevated, depressed, or lateralized depending on the available space, and it should be covered with a thin coating of fibrin glue to prevent desiccation. In our experience the pituitary gland tolerates these maneuvers remarkably well, provided that the dissection is very gentle and preserves the stalk and vascular supply.

During drilling of these bone elements, significant venous bleeding can be encountered from the rostral portion of the basilar and intercavernous venous plexuses. This can be controlled with meticulous placement and replacement of microfibrillar collagen “sandwiches” (Video 2). After completion of the exposure and before intradural dissection, the microfibrillar collagen is covered with fibrin glue to prevent dislodgement.

Video 2. Controlling bleeding from the basilar venous plexus. (Click [here](#) to view with Windows Media Player and a broadband connection, [here](#) to view with a dial-up connection, or [here](#) to view with RealPlayer.)

Subsellar Extradural Removal of the Posterior Clinoid and Dorsum Sellae. In addition to the transsellar approach just discussed, the posterior clinoid and dorsum sellae can also be removed via a completely extrasellar approach. This is ideal for midline retrosellar lesions such as petroclival meningiomas, that have a predominant caudal as opposed to rostral extension. Transplanum access is not necessary for this approach unless it is needed for specific access to a rostral extension of the tumor. The sellar face is completely removed, then the portion of the middle third of the clivus between the vertical carotid canals and directly under the sella turcica is removed using a 3-mm coarse bit. The pituitary, with dura mater intact, is elevated superiorly and the ICA is identified below and lateral to the sella (Fig. 3). Obviously, great care should be taken to avoid transgressing the carotid canals. The dura mater underlying this bone is exposed and venous bleeding is controlled. The dura over the sella is not opened; however, the bone over the SIS is resected to allow the contents of the pituitary fossa to be mobilized superiorly en bloc. With the pituitary gland elevated, the dorsum sellae and posterior clinoid can be drilled using a 1-mm diamond bit or a rongeur. As the dorsum sellae and posterior clinoid are removed, significant venous bleeding is encountered and this requires meticulous packing with microfibrillar collagen or bone wax.

Intradural Dissection. Once the exposure is completed, providing access to the basilar and interpeduncular cisterns, the intradural dissection proceeds with strict adherence to the endoneurosurgical techniques described previously. The surrounding cisterns contain critical submillimeter-diameter arterial perforating vessels from the posterior circulation along with the third and sixth cranial nerves. Sequential dissection should identify the posterior communicating artery and third cranial nerve laterally before proceeding circumferentially through the basilar cistern and its contents (Fig. 4, Video 3). If the membrane of Liliequist is not violated, then every effort should be made to avoid its transgression because this will prevent subarachnoid spread of blood and reduce the likelihood of persistent CSF leaks after reconstruction.

Fig. 2. A: Endoscopic view obtained following hemoclip (HC) ligation of the SIS. The suprasellar cistern (SC) can be seen above and the diaphragma attachment (DA) to the sellar dura is sharply cut, releasing the stalk. B: Endoscopic view obtained following mobilization of the pituitary gland (P). The right posterior clinoid (PC) is drilled to expose the retrosellar space (RS).

Video 3. Retroinfundibular dissection. (Click [here](#) to view with Windows Media Player and a broadband connection, [here](#) to view with a dial-up connection, or [here](#) to view with RealPlayer.)

Middle Third of the Clivus: Inferior Portion

It is very rare to need an isolated removal of this segment of the clivus. Removal of this area is usually undertaken as part of a panclival exposure, as described next.

PANCLIVAL APPROACH

General Exposure

To gain progressively more caudal access, several mod-

ifications to the initial bilateral sphenoid exposure are undertaken. First, the nasal septum should be completely detached from the rostrum of the sphenoid, facilitating the removal of an additional 1 to 2 cm posteriorly (Fig. 5). The surgical field now extends from the sphenoid sinus superiorly, to the level of the soft palate caudally, and to the eustachian tubes laterally (Fig. 5B). It is important to perform wide sphenoidotomies because this allows for identification of key anatomical landmarks rostrally (such as the carotid canals, medial pterygoid plates, pterygoid canal, and the vidian nerve) (Fig. 5A). The wide sphenoidotomy

Fig. 3. A: Endoscopic view of a subsellar approach to remove the right posterior clinoid. The bone over the sellar face (S) has been removed and the pituitary is elevated with the overlying dura mater intact. The posterior clinoid (PC) can be seen in the inferior lateral angle formed by the junction of the ICA and the sella. B: Endoscopic view of a posterior clinoid removal accomplished via a subsellar approach on the left side. The sella (S) can be seen above and the ICA on the left. The carotid canal (CA), posterior clinoid (PC) and dorsum sellae have been removed en bloc. The dura mater (D) over the interpeduncular cistern can be seen following removal of this segment of the clivus.

Fig. 4. A: Endoscopic view obtained following resection of the left posterior clinoid. Sequential dissection involves identifying the ICA, the posterior communicating artery (Pcom), and the temporal lobe (TL). The posterior communicating artery can be followed to the junction of the posterior cerebral artery (P₁ and P₂ segments). This leads to the BA apex. The anterior cerebral artery (A₁ segment) can be seen above the optic genu formed by the junction of the optic tract (OT) and optic nerve (ON). The third cranial nerve (III) can be seen as it enters the cavernous sinus with tumor (T) adherent to it. The rostral and posterior exposure can be carried to the level of the mammillary bodies (MB). B: Using the two-suction technique, the tumor is dissected from the third cranial nerve proximally until its origin in the interpeduncular fossa is seen. The third cranial nerve can be seen emerging above the superior cerebral artery (SCA) and under the P₁ segment. The under-surface of the optic recess of the third ventricle (V) can be seen above the BA apex. C: Final view following complete resection. Note the position of the infundibulum (St) and the retroinfundibular exposure provided through this approach.

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also provides for deeper positioning of the endoscope and a direct view caudally, defining the key anatomical boundaries within the fossa of Rosenmüller: the soft palate caudally, the eustachian tubes laterally, the basopharyngeal fascia, the floor of the sphenoid rostrally, and the nasopharyngeal mucosa posteriorly (Fig. 5B, Video 4).

Video 4. Pancrival exposure. (Click [here](#) to view with Windows Media Player and a broadband connection, [here](#) to view with a dial-up connection, or [here](#) to view with RealPlayer.)

The basopharyngeal fascia is completely stripped from the floor of the sphenoid sinus and clival face, and the sphenoid sinus floor is reduced until it is flush with the clivus. The clivus is then drilled using a 3-mm coarse bit. Bleeding from the cancellous bone can be controlled with bone wax applied on a cottonoid once the inner cortex is reached. The inner cortex is removed with a combination of drilling and Kerrison punches. Care should be taken during the removal of the bone located under the horizontal petrous segment of the CA. The vidian nerve and artery represent critical landmarks as they travel in the vidian canal to join the genu of the anterior CA (Fig. 6). When removing the midline clival bone rostral to the level of the vidian nerve, it is imperative to drill only in the midline, between the carotid canals. If the petrous bone inferior and lateral to the anterior CA genu needs to be removed, then the vidian canal is used as a critical landmark. Drilling of this portion of the petrous bone under the horizontal CA should be done from a caudal-to-rostral direction, with the vidian canal representing the superior limit.

Illustrative Case. This 33-year-old woman presented with progressive abducent, glossopharyngeal, and vagal nerve palsy. She was known to have a clival chordoma that had been treated with multiple previous surgeries and radiotherapy. On this occasion she presented with brainstem compression, as evidenced on the preoperative MR images (Fig. 7A). Cerebral angiography demonstrated displacement of the BA (Fig. 7B). A gross-total resection was accomplished via a transclival intradural approach module (Fig. 7C). The patient required revision surgery and ventriculoperitoneal shunt placement to achieve a watertight closure. No new deficits were encountered and an improvement of the abducent nerve palsy was noted. The patient subsequently presented with recurrence after 1 year, and underwent a repeated expanded endonasal transclival approach, which she tolerated well. This case is presented to demonstrate the intradural dissection.

Intradural Dissection. Once the overlying clivus is removed in the midline, the underlying dura mater and its basilar venous plexus are exposed. The basilar dural venous plexus can bleed profusely when it is opened, particularly if it has not been thrombosed by the tumor. In these circumstances, the face of the dura mater is coagulated and segmentally opened in the midline, and microfibrillar collagen “sandwiches” are used to control the bleeding until the sinus thromboses. The lateral dural opening, under the horizontal segment of the petrous CA, is extended until the eustachian tubes are encountered just as they disappear obliquely into the skull base. Lateral opening of the dura mater superior to this segment (at the level of the CA genu) should be performed under direct visualization because the abducent

Fig. 5. A: Endoscopic view showing resection of the posterior nasal septum (PS). The sphenoidal sinus (SS) can be seen above and the nasopharynx (NP) is below. The lateral margins of the exposure extend from the medial pterygoid plate (MP) on the right to the MP on the left. B: Endoscopic view obtained following resection of the posterior nasal septal attachment showing that the sphenoid floor (SF) can be seen. This allows for a pancrival exposure to the level of the nasopharynx. The eustachian tubes (ET) bilaterally mark the lateral border of the exposure.

nerves travel in this space, entering the Dorello canal just medial, superior, and dorsal to the anterior CA genu.

The sequence for intradural dissection in this segment begins with the identification of the vertebral artery, which is then followed to the VBJ. The abducent nerve can be identified at the VBJ bilaterally (Fig. 8, Video 5). The BA can then be followed in a rostral direction to expose the remainder of the posterior circulation, pons, and the fifth through 10th cranial nerves. If exposure of the oculomotor nerve is needed, a posterior clinoidectomy, as described earlier, will have to be completed.

Video 5. Intradural transclival dissection. (Click [here](#) to view with Windows Media Player and a broadband connection, [here](#) to view with a dial-up connection, or [here](#) to view with RealPlayer.)

Fig. 6. Endoscopic view obtained following complete sphenoidotomy and drilling of the sphenoid floor (SF) to the level of the clivus. At the junction of the right medial pterygoid plate (MP) and the sphenoid floor, the vidian canal with the vidian artery (VA) can be seen. Note that drilling of the medial pterygoid plate is undertaken from a caudal-to-rostral direction to avoid the petrous CA. SS = sphenoidal sinus.

DISCUSSION

All of the expanded endonasal approaches described along the rostral caudal axis extending from the crista galli to the foramen magnum represent individual modules that can be combined as mandated by the disease entity and its location. There are few absolute contraindications to the expanded endonasal approach for pathological conditions of the ventral skull base. In principle, however, there are two factors that need to be considered: patient/tumor characteristics and the surgical experience of the operating team.

Video 6. Combined modules. (Click [here](#) to view with Windows Media Player and a broadband connection, [here](#) to view with a dial-up connection, or [here](#) to view with RealPlayer.)

Patient/Tumor Characteristics

Obviously, the patient must be a suitable medical candidate for surgery and anesthesia.

In our experience, the expanded endonasal approach has been used to treat a variety of nonneoplastic and neoplastic conditions of the ventral skull base. The most common nonneoplastic diagnosis that we treat (other than inflammatory sinus disease) is a CSF leak (traumatic, iatrogenic, and spontaneous). The most common benign neoplasms are pituitary adenomas (secreting and nonsecreting), meningiomas, and craniopharyngiomas. In terms of malignant lesions, esthesioneuroblastomas and sinonasal cancers with cranial base involvement are the most common neoplasms treated with the expanded endonasal approach. More recently, other malignancies such as chordomas and chondrosarcomas have been increasingly treated, given their ideal midline position. Although endoscopic techniques have become well established for the treatment of benign extradural and skull base lesions, there are limited data regarding the use of this modality for both benign and malignant intradural tumors. Long-term outcome data will be needed to address this question. In our view, the indications

Fig. 7. A: Preoperative MR images obtained following contrast administration demonstrating recurrent clival chordoma. Note the intradural extension with severe brainstem compression. B: Preoperative cerebral arteriography revealing severe displacement of the BA. C: Postoperative postcontrast MR images demonstrating removal of the tumor with fat packing used for reconstruction.

for surgery are still evolving as surgical techniques and instrumentation continue to improve and our experience increases.

In terms of the evolving use of these procedures, an ideal application for expanded endonasal approaches is for the purposes of obtaining a tissue diagnosis. Currently, endoscopic techniques allow biopsy sampling with minimal morbidity and often in an outpatient setting. Before their advent, it was often difficult to obtain tissue for diagnosis in specific anatomical regions, such as midline lesions, and

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biopsy procedures were often undertaken at the same time as the extirpative surgery. In addition, obtaining a tissue diagnosis could result in an extensive surgical approach for conditions better treated nonsurgically (for example, plasmacytoma, lymphomas, and infection).

In our experience, tumor volume has not been a limiting factor in appropriately selected cases. The expanded endonasal approach can yield the same resection margins as traditional open approaches for skull base lesions that are suited for these ventral approaches. This is predicated on the surgeon's experience, which is best gained in clearly defined increments. If an orbital exenteration or resection of external tissues is necessary, then the expanded endonasal approach may offer no advantage over an open approach. Dural involvement and brain invasion of the tumor represent the same limitation as they would for any open approach. In appropriately selected patients, we have been able to achieve a degree of resection that is comparable to that achieved with an open approach. Similarly, we have not found that tumor type or vascularity represents an additional limitation when considering the appropriateness of an expanded endonasal approach as opposed to an open approach.

The most important tumor characteristic in selecting an open compared with an expanded endonasal approach is the exact relationship of the lesion to critical neurovascular structures. Simply put, if the neurovascular structures are ventral to the tumor, they will be encountered before it and will need to be retracted and manipulated when using the ventrally oriented expanded endonasal approaches. In this circumstance it is preferable to use an alternative approach. The expanded endonasal approach is an ideal one for lesions in which the critical neurovascular structures are on the perimeter of the tumor, thus allowing direct access to the lesion with minimal manipulation of normal neurovascular structures. Currently, the expanded endonasal ap-

proach is also contraindicated when resection or reconstruction of a major vessel is needed.

In summary, in our experience the degree of resection has been determined based on a combination of several key predetermined factors that define the goals of surgery: patient age, premorbid conditions, symptoms, and natural history of the lesions. These are the same factors that determine the goals of surgery whether an expanded endonasal or an open approach is being considered. Specifically, the approach should not and does not determine the degree of resection, but rather the same factors that determine the goals of open surgery are the primary issues when considering the degree of resection to be performed using endoscopic techniques.

Experience of the Surgical Team

When selecting the approach, the experience of the surgical team is as important as the aforementioned patient and tumor characteristics. There may be institutional barriers to selecting the expanded endonasal approach, such as availability of equipment or personnel to form the necessary team. The critical factor relating to surgical experience stems from the modular nature of the expanded endonasal approach, with increasing experience required for each approach and location (extradural/intradural). The primary contraindication to an expanded endonasal approach is the lack of progressive experience that is gained from each module and disease type before advancing to the next. We encourage all practitioners to follow a methodical progression through each anatomical module. Each level will provide increasing experience with endoscopic skills, anatomy, and instrumentation as well as establishing the necessary teamwork and coordination. This will provide the background needed to proceed to the next level, thus minimizing the risk of catastrophic events.

CONCLUSIONS

The goal of this report was to demonstrate the feasibility of the endoscopic approaches to the midline rostrocaudal axis, extending caudally from the posterior clinoids to the foramen magnum and odontoid. Addressing the anatomy extending from the anterior skull base in a caudal direction, this second paper in our series expands on our modular approach. In this report we have outlined the key anatomical nuances and detailed the endoneurosurgical techniques for addressing lesions from the middle and lower third of the clivus to the cervicomedullary junction. Having established the feasibility of the approach, the important outcome studies are underway to determine the clinical efficacy of this work.

Reference

1. Kassam A, Snyderman CH, Mintz A, et al: Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. **Neurosurg Focus** 19(1):E3, 2005

Manuscript received May 31, 2005.

Accepted in final form June 28, 2005.

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Fig. 8. Endoscopic view obtained following a complete clivectomy and intradural tumor removal. The right and left vertebral arteries (VA) can be seen forming the VBJ. The BA can be seen extending distally. Small perforating vessels (PV) supplying the pons (P) and medulla (M) are also apparent. The abducent nerve (VI) can be seen emerging from the brainstem at the level of the VBJ.