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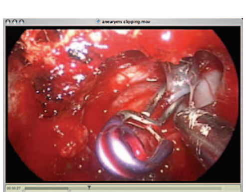
Received, January 9, 2006.
Accepted, February 9, 2006.

ONLINE DIGITAL VIDEO



THE EXPANDED ENDONASAL APPROACH FOR AN ENDOSCOPIC TRANSNASAL CLIPPING AND ANEURYSMORRHAPHY OF A LARGE VERTEBRAL ARTERY ANEURYSM: TECHNICAL CASE REPORT

OBJECTIVE: Aneurysms of the vertebral artery are rare, comprising less than 5% of all aneurysms. They can present with subarachnoid hemorrhage, medullary compression, and cranial neuropathies. In consideration of their surrounding regional anatomy, they present a formidable surgical challenge to the neurosurgeon using traditional techniques. Recent advances in endoscopic transnasal surgery have provided an additional approach for the treatment of these difficult lesions.

CLINICAL PRESENTATION: We present a case of a large vertebral artery aneurysm causing mass effect on the medulla. Initial treatment consisted of endovascular trapping of the aneurysm; however, because of concerns that the remaining aneurysm and intraluminal thrombus was causing mass effect and continued brainstem compression, a decompressive procedure was required.

INTERVENTION: After the endovascular trapping, the patient underwent a completely endoscopic transnasal surgical clipping and aneurysmorrhaphy. After exposure of the aneurysm, distal and proximal clips were applied transnasal, and the aneurysmorrhaphy completed using suction and ultrasonic aspiration.

CONCLUSION: In consideration of their surrounding regional anatomy, aneurysms of the vertebral artery present a formidable surgical challenge to the neurosurgeon. Although endovascular techniques have proven to be extremely valuable for the treatment of these lesions, they are limited when patients have significant mass effect with brainstem compression or cranial neuropathy. Advances in endoscopic transnasal surgery have provided an additional approach for the treatment of these difficult lesions. This case report represents, to our knowledge, the first literature report of a transnasal endoscopic aneurysm clipping and thrombectomy.

KEY WORDS: Aneurysmorrhaphy, Endonasal, Endoscopic neurosurgery, Endovascular coiling, Transsphenoidal, Vertebral artery aneurysm

Neurosurgery 59[ONS Suppl 1]:ONS-162–ONS-165, 2006 DOI: 10.1227/01.NEU.0000220047.25001.F8

Vertebral artery (VA) aneurysms generally represent less than 5% of all aneurysms and can be either saccular or fusiform (6, 10). Most commonly, they present as subarachnoid hemorrhage; however, rarely, they can become large and thrombosed, creating mass effect with subsequent medullary compression as well as cranial neuropathy (8, 9). The consequent mass effect can result in direct compression of the medulla, ischemia of the brainstem from either arterial perforator or venous occlusion, as well as hydrocephalus from fourth ventricular outlet obstruction.

In this report, we describe the multimodality management of a large partially thrombosed fusiform VA aneurysm causing bulbar compression. Treatment initially consisted of endovascular trapping of the aneurysm. However, because of the brainstem compression and mass effect, a decompressive procedure was required. Therefore, after the endovascular trapping, the patient underwent a completely transnasal, fully endoscopic surgical clipping, trapping, and aneurysmorrhaphy to relieve the mass effect. This report describes the relevant anatomy and technical nuances of an expanded endonasal approach (EEA) to the craniocervical junction. To our knowledge, this is the first report in the literature of a transnasal aneurysm clipping and thrombectomy.

CASE HISTORY

A 51-year-old left-handed woman was initially admitted to the hospital in January 2005 with headache and was treated for viral meningitis. After discharge, she began to note progressive clumsiness and weakness, as well as significant headache, neck pain, sensory alterations, incoordination, and vertigo. These symptoms prompted a computed tomographic scan in September 2005 that demonstrated a right VA aneurysm. On her examination, the patient had mild left leg weakness and hemisensory changes. Her past medical history was significant for atrial flutter and a supraventricular tachycardia that did not respond to ablation, but was controlled with medication. She had meningitis as a child.

Diagnostic angiography and magnetic resonance imaging demonstrated a partially thrombosed right VA fusiform aneurysm arising just proximal to the posterior inferior cerebellar artery and compressive of the cervicomedullary junction (*Fig. 1*). Diagnostic angiography showed partial filling of the aneurysm in comparison with the magnetic resonance imaging and computed tomographic angiography. The distal segment of the aneurysmal dilation was proximal to the origin of the posterior inferior cerebellar artery.

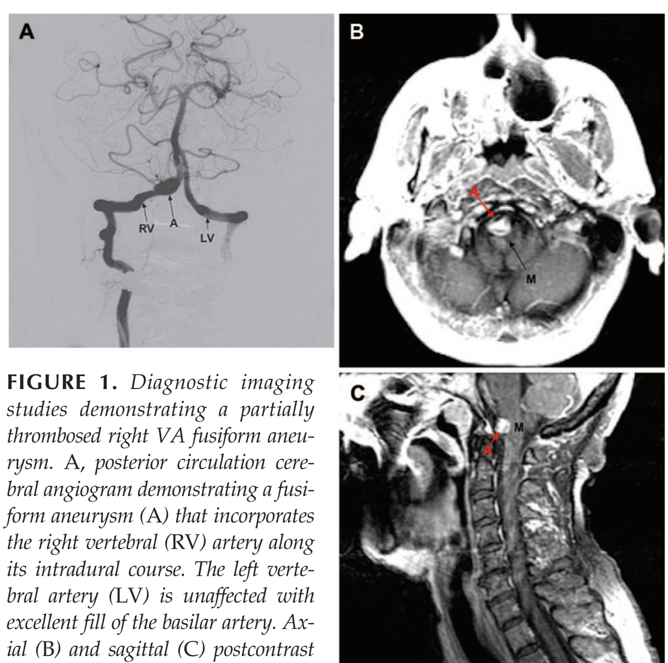


FIGURE 1. *Diagnostic imaging studies demonstrating a partially thrombosed right VA fusiform aneurysm. A, posterior circulation cerebral angiogram demonstrating a fusiform aneurysm (A) that incorporates the right vertebral (RV) artery along its intradural course. The left vertebral artery (LV) is unaffected with excellent fill of the basilar artery. Axial (B) and sagittal (C) postcontrast magnetic resonance imaging scans demonstrating thrombus within the aneurysm (A). Note compression of the medulla (M).*

With use of endovascular techniques, her aneurysm was successfully trapped with coils placed at the level of the intradural VA proximal to the aneurysmal dilation, as well as the distal VA beyond the fusiform dilation and just proximal to the vertebrobasilar junction (see Endovascular Therapy below). However, the mass effect, which was responsible for her progressive long-tract signs, remained. To relieve the mass effect and ensure complete long-term obliteration of the aneurysm, the patient underwent a completely endoscopic and fully transnasal trapping of the aneurysm and aneurysmorrhaphy (see Expanded Endonasal Approach below).

On postoperative Day 1, the patient dislodged her nasal packing and deflated the nasal balloon used for reconstruction and, therefore, was returned to the operating room for repacking. The patient was known to have a primary lung mass and developed a postoperative pneumonia requiring antibiotics. Her course was also complicated by a pulmonary embolus needing full systemic anticoagulation as well as cardiac pacemaker for her primary dysrhythmia. The patient was discharged to rehabilitation neurologically intact with an improvement in the preoperative symptoms including the weakness, incoordination, and sensory changes. Postoperative computed tomographic scans and flexion extension views confirmed craniocervical stability with no need for arthrodesis.

METHODS

Endovascular Therapy

Using the Seldinger technique and a 5-French micropuncture set, a 7-French right common femoral sheath was placed. A complete four vessel diagnostic cerebral arteriogram was performed demonstrating no significant posterior communicating arteries, patent bilateral VA, a right posterior inferior cerebellar artery-anterior inferior cerebellar artery variant arising from the basilar artery, and a partially thrombosed 11-mm right VA fusiform aneurysm taking origin from the intradural segment of the right VA (*Fig. 1*). A 0.035-inch hydrophilic exchange wire was advanced into the right VA, the Simmons catheter was removed, and a previously prepared 8.5-mm Meditech balloon occlusion catheter (Boston Scientific Corporation, Natick, MA) was placed into the left VA at the C2 level. The balloon was inflated, arresting anterograde blood flow, and the patient was administered 10,000 units of heparin intravenously. A subsequent activated coagulation time was greater than 300 seconds. Roadmap runs were performed showing the proximal and distal VA, aneurysm, and vertebral confluence. An Echelon 0.014-inch microcatheter (Micro Therapeutics, Inc., Irvine, CA) was advanced over a 0.014-inch Expeedior microwire (Micro Therapeutics, Inc., Irvine, CA) past the aneurysm and placed just proximal to the VA confluence. The VA was occluded distal to the aneurysm using Micro Therapeutics NXT platinum detachable coils. The microcatheter was then drawn proximal to the aneurysm, and proximal arterial occlusion was carried out using the same coils. Having trapped the aneurysm distally and proximally,

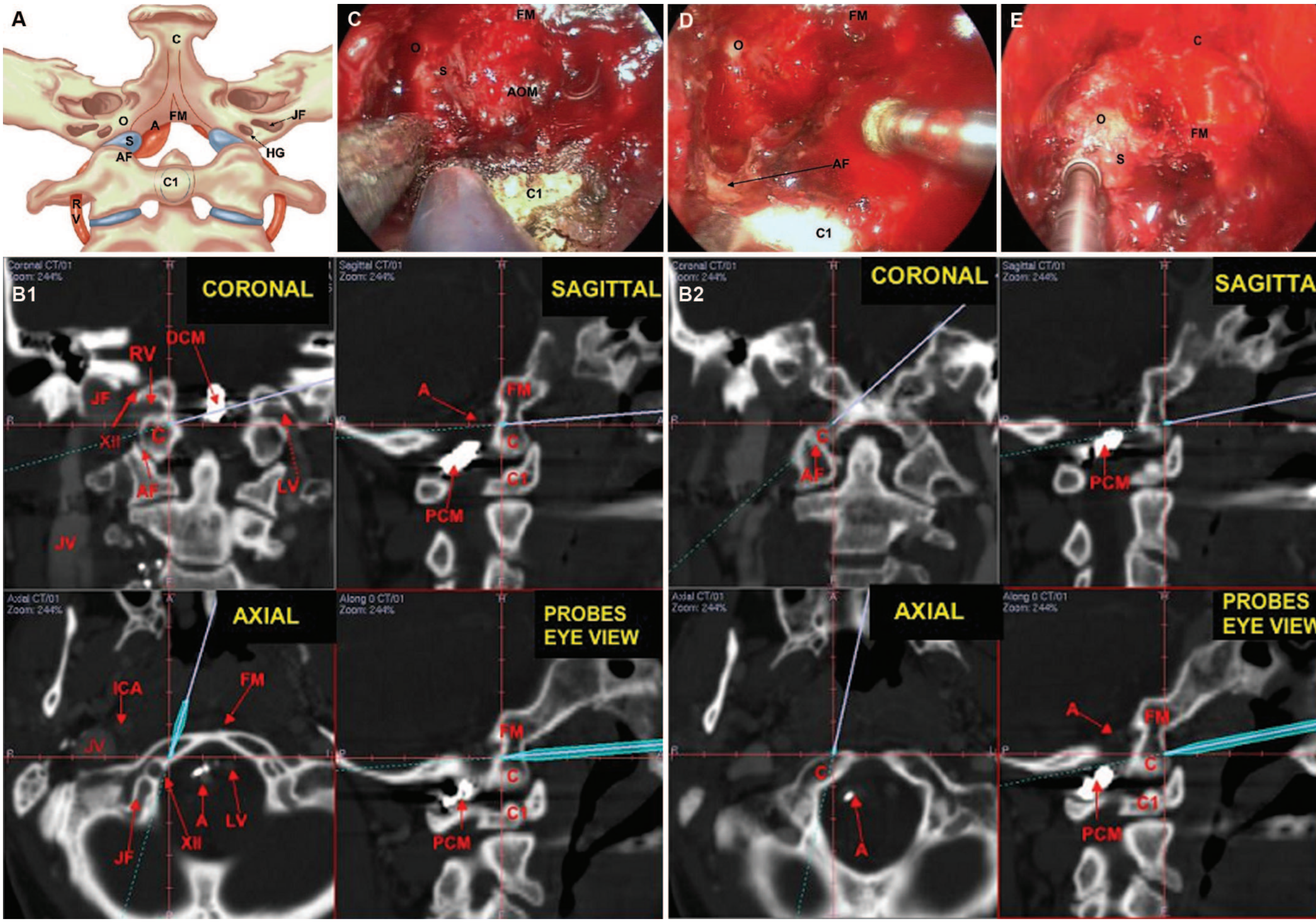


FIGURE 2. *Schematic and intraoperative endonasal views demonstrating the location of the aneurysm, the critical osseous relationships, and the sequence required to achieve paramedian exposure of the craniocervical junction.* A, *schematic view demonstrating critical midline osseous structures. From the caudal to rostral directions, the first cervical vertebrae* (C1)*, foramen magnum* (FM)*, and clivus* (C) *can be seen. The critical paramedian structures represent the medial occipital condyle* (O)*, the superior articular facet* (AF) *of C1, and the intervening synovial joint* (S)*. The location of the aneurysm beneath these structures is schematically represented as the right vertebral artery* (RV) *traverses the foramen transverioum, entering the dura where the fusiform aneurysm* (A) *is located. The RV then continues distally to join the vertebrobasilar junction. Note the location of the aneurysm relative to the hypoglossal canal* (HG) *and the jugular fossa* (JF)*.* B, *correlative intraoperative computed tomographic angiography image-guided views demonstrating the relationship of the foramen magnum* (FM)*, the medial occipital condyle* (C)*, the first cervical vertebrae* (C1)*, the superior articular facet* (AF) *of C1, and the location of the underlying aneurysm. The coronal view best demonstrates the distal coil mass* (DCM) *at the junction of the FM and C. To trap the aneurysm distally, the medial portion of the C and the lateral portion of the FM will need to be removed* (indicated by blue image-guidance system probe)*. The left vertebral artery* (LV) *can be seen in the foramen transversarium, which then courses distally along the C and FM. Similarly, the right vertebral artery* (RV) *can be seen coursing along the C, and lateral exposure will require removal of the FM to the level of the hypoglossal canal* (XII)*. The courses of the jugular vein* (JV)*, jugular fossa* (JF)*, and internal carotid artery* (ICA) *are also shown. Probe's eye view demonstrating the osseous exposure required to gain proximal exposure. The proximal coil mass can be seen within the right VA as it courses in the paracondylar space to enter the dura at the FM. To gain access to this segment for proximal clipping, the medial C as it articulates with the AF will need to be partially removed (indicated by* blue *image-guidance system probe). The bone removal required for proximal trapping is best seen on the coronal view.* C, *correlative coronal intraoperative endoscopic endonasal view demonstrating the key osseous and soft tissue anatomy. Progressing from the caudal to rostral directions, the arch of C1* (C1)*, the atlantoaxial membrane* (AOM)*, and the foramen magnum* (FM) *are seen. To the right of the FM, the occipital condyle* (O) *is visualized with the overlying synovium* (S)*.* D, *intraoperative endoscopic endonasal view demonstrating the paramedian extension required, given the eccentric location of the aneurysm at the craniocervical junction. The C1 and FM are visualized in the midline. The S over the medial portion of the O has been partially removed. The most medial segment of the condyle is removed with a high-speed drill to allow for exposure of the lateral margin of the aneurysm that lies beneath (see* B *and* C*, distal exposure).* E, *intraoperative endoscopic endonasal view demonstrating the proximal inferior lateral extension of exposure. The FM is seen above, and the arch of C1 below, representing the midline. The medial O has been partially resected laterally, and the superior articular facet* (AF) *of C1 has been partially removed, representing the inferior lateral extent of exposure. This represents the osseous bone removal along the craniocervical junction that is required to provide for circumferential exposure of the aneurysm (see* B *and* C*, proximal exposure).*

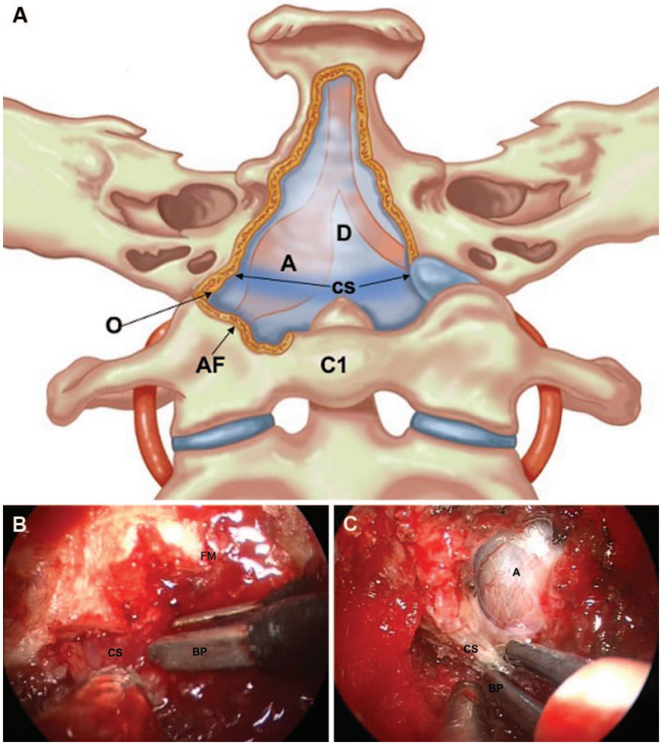


FIGURE 3. *Schematic and intraoperative endonasal views demonstrating the critical soft tissue and neurovascular structures once the overlying osseous structures are removed. The intraoperative views demonstrate the sequence of soft tissue exposure required to isolate the aneurysm.* A, *schematic view demonstrating the removal of the most medial segment of the occipital condyle* (O), *avoiding the hypoglossal canal. The medial portion of the superior articular facet* (AF) *of C1 has been removed, providing access to the proximal VA as it enters the dura. Once the bone has been removed, the underlying dura* (D) *can be seen* (blue). *At the level of the foramen magnum, the dura is thickened* (dark blue), *forming the circular venous sinus* (CS) *guarding the entrance to the ventral intradural contents of the foramen magnum. The aneurysm is depicted in its eccentric position intradurally.* B, *intraoperative endoscopic endonasal view demonstrating the exposure of the circular sinus* (CS) *being coagulated using pistol grip bipolars* (BP) *once the foramen magnum* (FM) *has been partially removed.* C, *intraoperative endoscopic endonasal view after the opening of the distal dura over the clivus. The fusiform aneurysm* (A) *can be seen at the level of the foramen magnum. The dural ring over the foramen magnum containing the circular venous sinus* (CS) *is being coagulated using pistol grip bipolars* (BP) *to provide for proximal exposure.*

we removed the microcatheter from the balloon catheter, and 0.025 inch 5 mm × 3 cm fibered coils (Cook Corporation, Bloomington, IN) were placed in the VA at C2 until contrast injection confirmed arterial occlusion at this level. The balloon was deflated, and the catheter was removed. A diagnostic left VA arteriogram was then performed showing absence of retrograde opacification of the trapped aneurysm. All catheters were removed, and the patient was placed on 800 units of heparin for the next 24 hours and 325 mg of aspirin each day. Neurological examination remained at baseline while the patient was observed in the intensive care unit overnight.

Expanded Endonasal Approach for Clipping and Aneurysmorrhaphy

General Exposure

The patient was positioned supine on the operating table, and general endotracheal anesthesia was induced. Intraoperative monitoring was used, including lower cranial nerve electromyographs. The patient was fixed in Mayfield head pins, and registration with a Stryker image-guidance system (Kalamazoo, MI) was completed. Pledgets soaked in Afrin nasal solution were placed intranasally bilaterally. The pledgets were removed, the nasal cavity was inspected with a 0-degree endoscope (Karl Stortz, Culver City, CA), and a binasal exposure to the sphenoid, as previously described by our group, was initiated. The right middle turbinate was transected and removed. The mucosa over the anterior face of the sphenoid and posterior septum was cauterized. The posterior 1 to 2 cm of the nasal septum was resected to provide additional exposure. This represents the key step in the general EEA exposure and facilitates bimanual binasal dissection, minimizing contamination and visual obscuration of the endoscope by the intervening nasal septum. A high-speed EEA drill (Stryker, Kalamazoo, MI) was used to expose the floor of the sphenoid sinus. This was continued until the sphenoid floor was flush with the clivus to the level of the sphenoclival recess. The lateral sphenoid exposure was continued until both medial pterygoid plates were exposed.

Foramen Magnum Exposure

Once this general exposure was achieved, the caudal extension was pursued. The posterior nasal septum was disarticulated from the rostrum of the sphenoid bone; this allows for a common cavity extending from the sphenoid sinus to the soft palate that is bounded laterally by the eustachian tubes. This maneuver is critical for lower clival and foramen magnum exposures (5). Next a horseshoe-shaped flap was prepared in the nasopharynx, exposing the underlying paraspinal muscles. The midline raphe of these muscles was identified, and the muscles were then stripped away, exposing the underlying arch of C1, foramen magnum, basion, medial occipital condyle, and the superior articular facet of C1 (*Fig.* 2). A detailed step-by-step description of this caudal extension can be found in our previous report describing the EEA module for accessing the odontoid (5).

Paramedian Osseous Craniocervical Exposure

The initial exposure described above provides access to the midline foramen magnum and craniocervical junction (*Fig. 2, A–E*). In considering the eccentric paramedian location of the aneurysm, this exposure was extended laterally (*Fig. 2, A–C*). The lateral extension is initiated by removing the synovial capsule overlying the medial occipital condyle. The most medial portion of the condyle was then drilled away, avoiding the hypoglossal canal laterally (*Fig. 2E*). Next, the medial portion of the superior articular facet of C1 was partially removed (*Fig. 2F*). This provides for access to the inferior lateral portion of the aneurysm and proximal control of the right VA as it enters the dura (*Fig. 2, B* and *C*, proximal exposure).

Soft Tissue and Dural Exposure

Once the overlying bone was removed, the dura under the clivus and at the craniocervical junction was exposed (*Fig. 3A*). The dura was cauterized, and the surface bleeding from the circular sinus was controlled with cautery and Avitene (Ethicon, Somerville, NJ) packing (*Fig. 3B*). The VA containing the coil mass distal to the aneurysm was identified using an image-guidance system. The overlying dura over this distal VA was then resected to expose the distal segment of the aneurysm. The arachnoid membrane, which had been preserved, was sharply dissected, and the large aneurysm sac was visualized (*Fig. 3C*). The dura was opened in a proximal direction, completely isolating the circular sinus and allowing for circumferential cauterization and sectioning (*Fig. 3C*).

Intradural Dissection

After the dural opening, the aneurysm and its relationships to neurovascular structures were systematically identified (*Fig. 4A*). The initial view using a 0-degree scope demonstrated the aneurysm causing compression of the underlying medulla. The distal right VA could be seen with the coil mass within it, and proximally, the hypoglossal (XII) nerve coursing deep to the inferior lateral margin of the aneurysm was identified (*Fig. 4B*). A 45-degree endoscope was then used to identify the structures within the medullary cistern and along the ventral brainstem. Sequentially, the left VA and the distal right VA forming the vertebrobasilar junction were identified. The arachnoid bands forming the medullary cistern were opened using sharp dissection. A single, small perforator originating from the right VA and traveling laterally across the medullary cistern was isolated. The ventral lateral medulla with small vessels overlying it was visualized. The origin of the vagus nerve (X) as it emerged from the vagal trigone and the foramen Luschka was identified (*Fig. 4, C* and *D*). The aneurysm was mobilized medially to more clearly

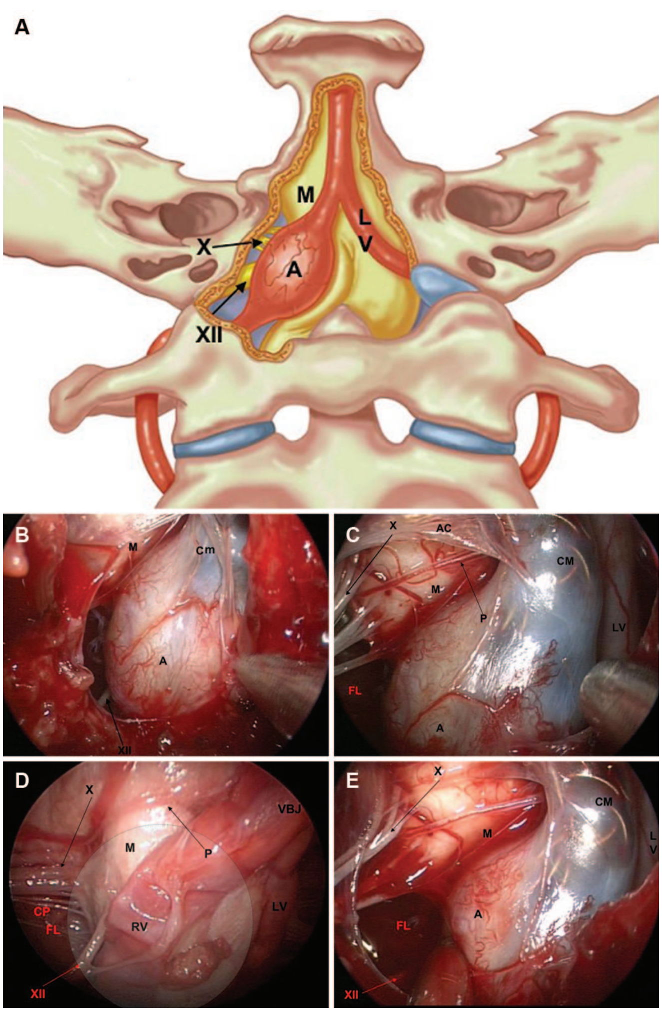


FIGURE 4. *Schematic and intraoperative endoscopic endonasal views demonstrating the intradural anatomy and dissection of the aneurysm.* A, *schematic view after the opening of the dura. The intervening fusiform aneurysm (*A*) is seen as the right vertebral artery enters the dura proximally and travels distally to meet the left vertebral artery (*LV*), forming the vertebrobasilar junction. The aneurysm compresses the medulla (*M*) and lies ventral to the origin of the vagus (*X*) and hypoglossal (*XII*) nerves that then course laterally directly deep to the aneurysm.* B, *intraoperative endoscopic endonasal view demonstrating the initial view after the dural opening. The aneurysm (*A*) can be seen causing compression of the underlying medulla (*M*). The distal portion of the right vertebral artery can be seen with the coil mass (*CM*) within. Proximally, the origin of the hypoglossal nerve (*XII*) can be seen emerging from the medulla. Note the small vasovasorium vessels coursing along the fundus of the aneurysm.* C, *intraoperative endoscopic endonasal view using a 45-degree scope demonstrating the relationships of the aneurysm (*A*) to the critical neurovascular structures. The distal right vertebral artery with the coil mass (*CM*) and the left vertebral artery (*LV*) travel distally to form the vertebrobasilar junction. The aneurysm can be seen compressing the underlying medulla. The small perforator (*P*) emerging from the distal right vertebral artery traveling across the medullary cistern (*AC*) is seen. The origin of vagus nerve (*X*) from the brainstem at the level of outlet of the fourth ventricle and foramen Lushka (*FL*) are located along the lateral border of the aneurysm.* D, *correlative cadaveric endoscopic endonasal view demonstrating the contents of the medullary cistern. The right vertebral artery (*RV*) travels from the proximal to distal directions to join the left vertebral artery (*LV*), forming the vertebrobasilar junction. The location of the fusiform aneurysm seen in the previous image (*C*) is illustrated by the oval shadow. The cadaveric image demonstrates the normal position of the underlying medulla (*M*) when it is not subject to compression by an aneurysm. The same small perforator (*P*) is seen originating from the RV and traveling across the medullary cistern. The origin of the vagus nerve (*X*) can be seen at the level of the Foramen of Lushka (*FL*), and the choroid plexus (*CP*) emerging from fourth ventricle is seen. The origin of the course of the hypoglossal (*XII*) nerve is illustrated along the inferior lateral border of the projected aneurysm.* E, *intraoperative endoscopic endonasal view after mobilization of the aneurysm fundus (*A*) medially. This allows for direct visualization of the outlet of the fourth ventricle (*FL*). The vagus nerve (*X*) above and the hypoglossal nerve (*XII*) below are seen. Note the small vasovasorum vessels traversing the fundus of the aneurysm. The distal vertebral artery with the coil mass (*CM*) joins the contralateral left vertebral artery (*LV*) to form the vertebrobasilar junction. Note the compression of the medulla (*M*) by the fundus of the aneurysm.*

identify the outlet of the fourth ventricle and origin of the XII nerve (*Fig. 4E*).

Aneurysm Trapping and Aneurysmorrhaphy (see video at web site)

After circumferential dissection of the aneurysm, a bayoneted aneurysm clip using a pistol grip applier was placed distal to the fusiform dilation and proximal to the distal coil mass. The first attempt incorporated a small perforator arising from the distal right VA and also failed to completely incorporate the distal right VA. This clip was repositioned more proximally, and the clip blades were rotated clockwise. This was performed under direct visualization with a 0-degree scope; this revised trajectory is illustrated in *Figure 5A*. After clip application, the blades were then examined using a 45-degree scope to ensure the perforator was spared, and complete clipping was achieved (*Fig. 5B*). A gently curved microclip was used to clip the proximal segment of the aneurysmal dilation just distal to the proximal coil mass. The clip blades were applied in a trajectory to avoid the XII nerve that had been previously dissected (*Fig. 5C*).

Once complete obliteration of the fusiform aneurysm was achieved, the ventral wall with the vasovasorium vessels feeding it were coagulated and opened. Upon opening the aneurysm, wall flashes of arterial blood were encountered, and additional coagulation of the wall and vasovasorium was required. The opening was extended, and the thrombus was seen within. With use of a modified EEA ultrasonic aspirator (Radionics, Boston, MA), a thrombectomy was performed (*Fig. 6*). Once the thrombectomy was completed, clear pulsations of the lateral medulla were seen, confirming decompression and relief of the mass effect. We opted not to resect the back wall of the aneurysm because the goals of surgery were met and we were concerned about adherence to the medulla.

Reconstruction

Adequate hemostasis was achieved, and the dura was reconstructed with an intradural inlay Duragen (Integra Life Sciences, Boston, MA) graft followed by an extradural onlay allograft. Fat autograft was harvested from the abdomen and used to cover the onlay allograft and fill the defect. This was followed by fibrin glue. A Foley catheter balloon was inserted transnasal on the left side and inflated to provide support to the grafts to prevent graft migration. Intranasal silastic splints were sutured in place bilaterally, and a lumbar drain was placed. A more detailed description of the reconstruction technique can be found in our previous report of EEA reconstruction.

The patient dislodged the packing and deflated the balloon on postoperative Day 1. The patient was returned to the operating room, and it was seen that the balloon had been dislodged along with the fat graft and the onlay allograft; these were found floating within the nasopharynx. The grafts were repositioned, a new balloon was inserted, and the patient remained compliant with postoperative instructions. The patient achieved a watertight seal without evidence of cerebrospinal fluid leak and demonstrated excellent healing with granulation tissue at the 6-week follow-up nasal endoscopic examination.

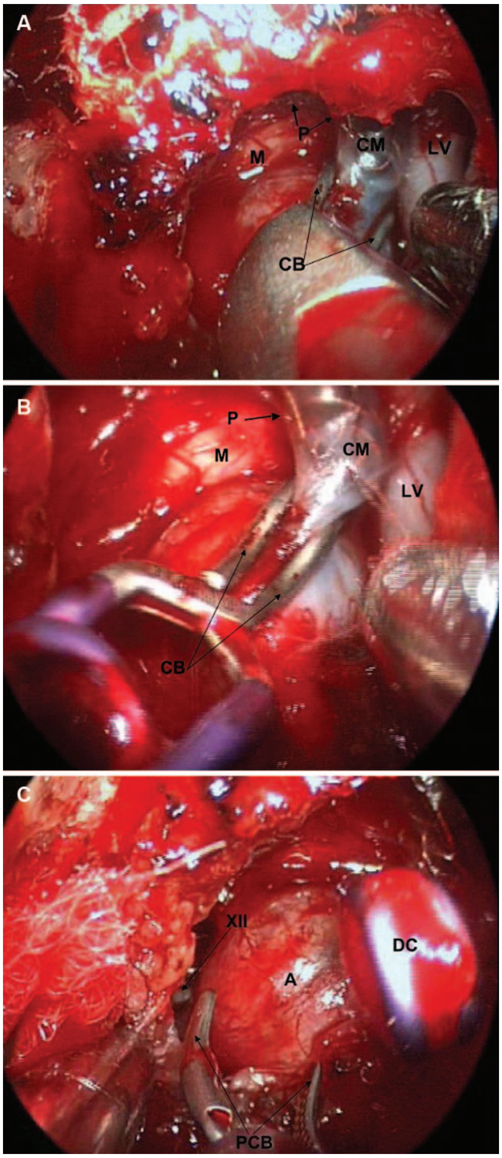


FIGURE 5. *Intraoperative endoscopic endonasal view demonstrating the sequence of aneurysm trapping.* A, *intraoperative endoscopic endonasal view demonstrating clip repositioning. After the initial clipping, the clip blades* (CB) *were rotated clockwise along a more proximal trajectory to avoid the contralateral vertebral artery* (LV) *and small perforator* (P) *arising from the ipsilateral distal vertebral artery. The clip was applied just proximal to the distal coil mass* (CM)*.* B, *intraoperative endoscopic endonasal view using a 45-degree scope to inspect the position of the distal clip blades. Note the perforator origin* (P) *is preserved, and the right blade has completely occluded the distal ipsilateral VA while preserving the contralateral LV.* C, *intraoperative endoscopic endonasal view demonstrating the trajectory of the proximal clip blades* (PCB) *to avoid the hypoglossal nerve* (XII)*. The distal clip* (DC) *is seen to the right.* A, *aneurysm;* M, *medulla.*

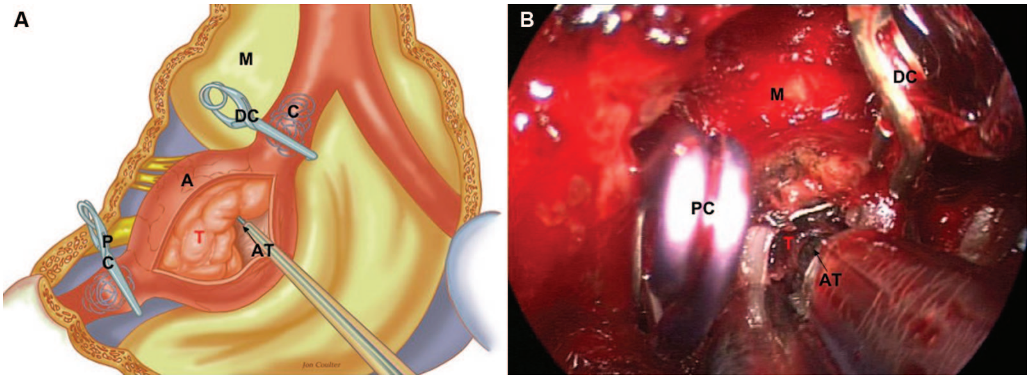


FIGURE 6. *Schematic and intraoperative endoscopic endonasal views demonstrating aneurysm trapping and aneurysmorrhaphy. A, schematic view demonstrating the trapping of the aneurysm with the distal clip (*DC*) applied distal to the aneurysmal dilation and proximal to the coil mass (*C*). Similarly, the proximal clip (*PC*) is applied proximal to the dilation and distal to the proximal coil mass. The aneurysm (*A*) wall has been opened and the aspirator tip (*AT*) can be seen resecting the thrombus (*T*). B, correlative intraoperative endonasal endoscopic view. The aneurysm has been trapped between the distal and proximal clips (*DC *and *PC*, respectively). The aspirator tip (*AT*) can be seen resecting the thrombus (*T*), and the medulla (*M*) is seen in the background.*

DISCUSSION

Because of their location and the surrounding regional anatomy, including cranial nerves, and the brainstem, VA aneurysms present a formidable surgical challenge to the neurosurgeon. The advent of endovascular techniques has proven to be extremely valuable for these lesions, allowing for direct intraluminal therapy in hope of avoiding the approach-related morbidity that results from the conventional techniques (6). However, endovascular therapies are often less effective in dealing with the consequences of mass effect and direct brainstem compression, particularly in the acute setting.

In the present case, our patient underwent successful endovascular treatment of the partially thrombosed VA aneurysm, but was left with significant medullary compression that resulted in sensory changes and progressive motor changes. An option would have been to wait to see whether the reduction in pulsatility would have resulted in symptomatic relief. However, we were concerned about increased mass effect secondary to stasis and additional thrombus formation, particularly given the limited space available and progressive symptoms. Furthermore, there were concerns of ongoing delayed aneurysm growth secondary to recanalization or feed from the rich vasovasorium (1). On the basis of these concerns, a decision was made to proceed with surgical decompression.

Management options to reduce the bulbar compression included surgical approaches to address mass effect produced by the aneurysm thrombosis. Surgical techniques include proximal ligation and direct microsurgical clip ligation. The conventional surgical approaches using a lateral to medial trajectory include the lateral suboccipital approach, the far lateral approach, and the combined retrolabyrinthine presigmoid approach (2). These have proven to be invaluable in accessing these complex lesions but, at times, can prove to be restrictive. Often, despite extensive osseous and soft-tissue mobilization, the access provided becomes a narrow corridor, leaving the surgeon to navigate between critical structures, particularly the lower cranial nerves.

Crockard and Sen (3) pioneered the early efforts to gain direct ventral surgical access to the intradural craniocervical junction via microsurgical transoral techniques. These failed to gain popularity as a result of the issues related to transgressing the oropharynx, dural reconstruction, and the compromised visualization provided by using the microscopic at a distance along the long transoral corridor. Ogilvy et al. (7) reviewed their experience with the transfacial transclival approaches in a series of five patients. This approach was used for midline posterior circulation aneurysms that were thought to be inaccessible by the lateral approaches. The approach is technically difficult because of the narrow corridor and long reach. Associated morbidities include cerebrospinal fluid leak and meningitis, but this approach avoids the palatal issues in the transoral techniques.

Recent advances in transphenoidal transnasal endoscopic approaches have yielded a series of EEAs that we have described, consisting of modular approaches to the ventral cranial base extending from the crista galli through the craniocervical junction. These represent fully endoscopic, completely transnasal approaches to the intradural space and rely on a medial to lateral trajectory (as demonstrated in this case) and, thereby, may potentially minimize the approach-related morbidity of conventional techniques. Additional potential advantages offered by direct EEAs include avoiding transgressing the oropharynx, thereby potentially decreasing postoperative swallowing dysfunction secondary to mechanical disruption. In addition, dural reconstruction as demonstrated in this case is significantly easier in comparison with transoral approaches. We think this is partially because of the avoidance of oropharyngeal bacterial flora and increased vascularity of the nasopharynx when compared with the oropharynx. Finally, in our opinion, the visualization offered by endoscopic endonasal routes is superior to transoral approaches and is at least comparable with conventional microsurgical approaches, as demonstrated in this case.

The fundamental principle of EEA that supersedes all other considerations is the ability to maintain bimanual dissection, which is of even greater importance in the case of addressing vascular lesions. Critical additional considerations in cerebrovascular surgery include being able to achieve proximal and distal control as well as maintain detailed visualization to preserve neurovascular structures, particularly small perforators. In this report, we have demonstrated the ability to adhere to all of these principles of cerebrovascular structure. Obviously, in this case, the aneurysm was partially secured with endovascular therapy, making the dissection significantly safer. The next concern will be the ability to safely manage an intraoperative rupture from a completely unsecured aneurysm. Although we have successfully managed significant arterial bleeding from intracranial vessels, the ability to manage an aneurysmal rupture remains completely unanswered.

CONCLUSION

Over the past decade, the evolving role of endoscopy within neurosurgery has given rise to the emergence of endoneurosurgery as a field. Increasing technological developments have led to the applications of the endoscope to the cranial base and cerebrovascular surgery (4). In this case, a vertebral aneurysm causing medullary compression that would likely prove to be difficult to access via conventional approaches was accessed via a direct ventral route using the EEA. Although we have reported our previous experience with EEA in achieving arterial hemostasis from intracranial large-vessel bleeding, this report, in and of itself, is limited in addressing the ability to manage an intraoperative aneurismal rupture. Nevertheless, this case is important in establishing the feasibility of the access, the equipment required, and the ability to adhere to the principles of cerebrovascular surgery, including the endonasal application of aneurysm clips.

We think that EEA may have a very specific role for certain well-selected intracranial aneurysms with ventral orientation that are not amenable to endovascular therapy or conventional microsurgical approaches. EEA is unlikely to replace microsurgical techniques for cerebral aneurysm repair, but is more likely to provide an additional tool in the armamentarium of the cerebrovascular surgeon, perhaps, as this case demonstrated, as a part of multimodality therapy. We think it will be most useful for posterior circulation aneurysms located along the midline behind the clivus that are suitable for direct access and that are difficult to reach via conventional approaches. Long-term outcome data addressing safety and efficacy will be needed to definitively establish the role of this technique among the others available.

Finally, it is imperative to stress that the application of EEA for the purposes of aneurysmal repair must be pursued only after significant experience with the procedure has been gained. In our institution, we undertook EEAs for a variety of pathologies for 7 years before using it for aneurysm repair. Complication avoidance is addressed by the incremental acquisition of endoscopic skills and by becoming comfortable with endoscopic anatomy, instrumentation, and, most importantly, team surgery. These principles are critical in the learning curve, and incremental growth should be rigorously adhered to. Before undertaking EEA for an unsecured aneurysm, we opted to do so with a well-suited, partially secured aneurysm to address the feasibility and ensure principles of cerebrovascular surgery could be maintained.

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COMMENTS

This interesting and novel article by Kassam et al. reports their experience with a case in which a vertebral artery aneurysm causing brainstem mass effect was trapped endovascularly. The patient was taken to the operating room where the aneurysm was secured with clips and debulked through an endoscopic endonasal transclival-transcondylar-transatlantal technique.

The essential issue is whether or not this novel approach was necessary. The alternative "traditional" approaches to this lesion are restrictive. However, they do provide access to the same region. An aneurysm like this one could have been addressed by one or more of the conventional approaches. As the authors observe, conservative management after coiling for an aneurysm this size would have been another reasonable option. However, the technique represents a technical tour de force. It is yet another milestone in the progression of endoscope controlled transnasal cranial base surgery, which Kassam et al. have pioneered. The trajectory the authors chose is preferable to any of the lateral to medial routes for this lesion. Its routine use has been hampered by the anatomical limitations that make open attempts technically difficult, by the morbidity associated with the major transfacial approaches that provide good access, and by the difficulty of managing infections and spinal fluid.

The senior author overcame these limitations using a relatively minimally invasive transnasal approach. To reach this point, however, he has polished many key skills and specialized techniques, and he has obtained a wealth of knowledge without which this kind of surgery would be impossible. Whether this approach can be duplicated by others without the same long and arduous practice remains to be seen. This single operation may be seen as an impressive validation of proof of concept. However, its value and place in cerebrovascular practice will be defined only after a statistically meaningful number of cases have been performed.

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Kassam et al. continue to push the endonasal endoscopic "envelope," as is shown in the case of a woman with a vertebral artery aneurysm initially treated by endovascular coiling, and then treated further by a transclival endoscopic thrombus removal to alleviate mass effect upon the medulla. The authors note that this is the first report of a fully endoscopic aneurysm clipping and thrombectomy. Although it is somewhat debatable whether the mass effect from the aneurysm postcoiling still needed further decompression, the treatment rationale was reasonable and the outcome was favorable. Furthermore, the transclival approach makes anatomical sense in that midline pathology was approached from a midline trajectory, minimizing manipulation of the brainstem and cranial nerves. Ultimately, the future use of such transsphenoidal transclival approaches by a fully endoscopic or endoscope assisted method to treat ruptured posterior circulation aneurysms is likely to be limited given the ever increasing scope of endovascular treatment techniques. Finally, this case highlights the ongoing challenge of all extended transsphenoidal approaches of achieving effective closure of the cranial base bony and dural defect.

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The authors report the surgical trapping and aneurysm decompression of a previously endovascularly trapped vertebral aneurysm by a purely transnasal endoscopic technique. It is critical to note that the authors have developed their endoscopic protocol through years of careful experience. Their first aneurysm was selected for an endoscopic attack in which proximal and distal control already were secured. In this particular case, the use of angled scopes and intraoperative surgical navigation techniques enabled a very precise transnasal approach with an elegant means of visualizing the surgical anatomy.

Many readers would look at the pretreatment images and note that a far lateral microsurgical approach would be feasible for trapping, decompression, and revascularization of the posteroinferior cerebellar artery if necessary. Endovascular neurosurgeons would also suggest that endovascular trapping of the lesion likely would be sufficient in the long term, despite the known incidence of occasional aneurysm distention during the thrombotic process. Nevertheless, this report is a beautiful illustration of the use of new technology to expand surgical possibilities.

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Kassam et al. have reported a case of a large thrombosed vertebral artery aneurysm treated by the expanded endonasal approach (EEA). This is the first report of application of EEA to aneurysm surgery located on the ventral surface of the brainstem. Precise operative procedures are described well in this article. In terms of feasibility, EEA will provide a possible choice to the neurosurgeon. However, we think the indication of EEA should be limited to the midline ventral lesions of the brainstem. In the presented case, the far lateral approach is a useful alternative because the lesion is extended laterally. The authors drilled out the medial portion of the condyle and the superior articular facet of C1 to secure the proximal end of the aneurysm. Such a destructive maneuver is not necessary in the lateral approach. From this point of view, basilar trunk aneurysms may be one of the suitable candidates of EEA. Managing massive bleeding due to aneurismal rupture remains a problem. The operative field is deep with a small entry in the anterior approach to the ventral lesion of the brainstem. It is difficult to control and manage massive bleeding in a deep and narrow operative field, especially under an endoscope.

Regardless of the limits of this approach, endoscopy assisted microneurosurgery illuminates the area where the light of microscope cannot reach. The advancement of neuroendoscopic technique is noteworthy. We think that it will play an important role in the multimodality treatment in the future neurosurgery.

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This well-written and illustrated manuscript is the first report of a vascular brain lesion fully managed through an extended endoscopic endonasal approach. Such technique has been used by the authors to treat a partially thrombosed fusiform vertebral artery aneurysm causing symptomatic bulbar compression and embolization.

The authors are not the first to anticipate future applications of the endoscopic endonasal approach, and the present report is another example of their pioneering work. In recent years, the endoscopic endonasal approach gradually has substituted the anterior microsurgical approaches, which often require wide facial skin incision, maxillotomy, etc., for the treatment of most extradural lesions of the clival area. The idea to extend such endoscopic approach to intradural lesion might be considered too risky because different authors previously have attempted to manage intradural lesions through anterior microsurgical approaches. They had to face several problems, such as lack of adequate exposure and postoperative complications as cerebrospinal fluid leak and/or meningitis. Today, the endoscope improve some problems of the anterior approaches for intradural lesions.

If we consider that vertebral artery aneurysms represent a surgical challenge for the neurosurgeon, the use of the approach is rationale in selected cases. Furthermore, it helps surgeons appreciate the advantages of the endoscopic endonasal technique for intradural lesions at the level of the clival and craniovertebral junction. In fact, the possibility of having a close-up, wide view of the ventral brain stem surface without any skin incision or brain retraction should not be minimized.

Obviously, prudence and adequate skill are needed when proposing this procedure as an alternative to other well-established techniques. We rely on the integrity of the authors, as well as on others involved in extended endonasal approaches, in developing such promising techniques.

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