The Extended Retrosigmoid Approach: An Alternative to Radical Cranial Base Approaches for Posterior Fossa Lesions

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ONLINE DIGITAL VIDEO

OBJECTIVE: The extended retrosigmoid approach is presented as a simple and safe modification of the traditional retrosigmoid approach, with increased exposure resulting from a limited mastoidectomy and skeletonization of the sigmoid sinus.

METHODS: Patients with posterior fossa vascular lesions treated with the extended retrosigmoid approach between 1997 and 2003 were reviewed. A detailed description of the surgical approach, as well as case illustrations, is provided. We present a video narrated by the senior author in which a description of the technique is offered.

RESULTS: Thirty-eight patients underwent this approach to manage 40 lesions, including 15 dural arteriovenous fistulae, 9 arteriovenous malformations, 10 cavernous malformations, and 6 aneurysms. The extended retrosigmoid approach differs from the traditional approach with its C-shaped skin incision, posterior mastoidectomy, and extensive dissection of the sigmoid sinus, craniotomy rather than craniectomy, and anterior mobilization of the sinus with the dural flap.

CONCLUSION: The application of the extended retrosigmoid approach to a series of complex lesions in the posterior fossa demonstrates its applicability as an alternative to radical cranial base approaches. The extended retrosigmoid approach requires a fundamental change in the management of the sigmoid sinus. The neurosurgeon must be familiar with petrous bone anatomy, experienced dissecting through bone using a high-speed drill, and comfortable working directly over a major venous sinus. The technical modifications of the extended retrosigmoid approach can be incorporated into the neurosurgical repertoire and will enhance exposure of the cerebellopontine angle and deep vascular structures, thereby minimizing the need for brain retraction and other transpetrous approaches.

KEY WORDS: Aneurysm, Arteriovenous malformation, Cavernous malformation, Dural arteriovenous fistula, Extended retrosigmoid approach, Microsurgery, Pons

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Since its introduction by Krause in the early 1900s, the retrosigmoid approach has been a popular and dependable approach for dealing with lesions of all types in the posterior fossa (3, 6, 8, 10, 12, 13, 15). Traditionally, the approach involves a linear vertical incision behind the mastoid to expose the asterion where the lambdoidal, parietomastoid, and occipitomastoid sutures converge. This important cranial surface landmark overlies the junction of the transverse and sigmoid sinuses, guiding the burr hole placement for craniotomy or craniectomy (4, 5). This technique exposes the dura of the posterior fossa while avoiding the transverse and sigmoid sinuses and the mastoid air cells. An approach that avoids these structures is appealing because venous sinuses can be a source of significant bleeding complications, and mastoid bone can be a conduit for cerebrospinal fluid (CSF) leakage and postoperative otorrhea or rhinorrhea. This simple, elegant approach has been refined for microvascular decompression operations, with dime-sized craniectomies and minimal patient discomfort (7, 17).

The discipline of cranial base surgery flourished in the 1980s and 1990s when neurosurgeons and neuro-otologists united in multidisciplinary teams to develop radical approaches to posterior fossa and brainstem lesions that removed bone from the cranial base, created wide surgical corridors, and minimized brain retraction (10). This collaborative effort led to the development and application of transpetrosal approaches behind and through the semicircular canals (retro- and translabyrinthine approaches), through and in front of the cochlea (transcochlear and Kawase's approaches), and above the internal auditory canal (middle fossa approach) (1, 2, 9, 11, 14, 16). Transpetrosal approaches were integrated with other craniotomies like the combined supra- and infratentorial approach, and the combined far lateral, supra- and infratentorial approach (combined-combined approach). These radical cranial base approaches provide exquisite exposure, but are lengthy, associated with significant morbidity, and require coordination with surgeons in other disciplines. These disadvantages create the need for an alternative approach that provides adequate exposure, but is faster, less morbid, and simple enough not to require a neuro-otologist. The extended retrosigmoid approach is such an alternative, increasing anterior exposure by drilling through the mastoid air cells and skeletonizing the sigmoid sinus. We present this technique and demonstrate its application in a clinical series of patients with posterior fossa vascular lesions.

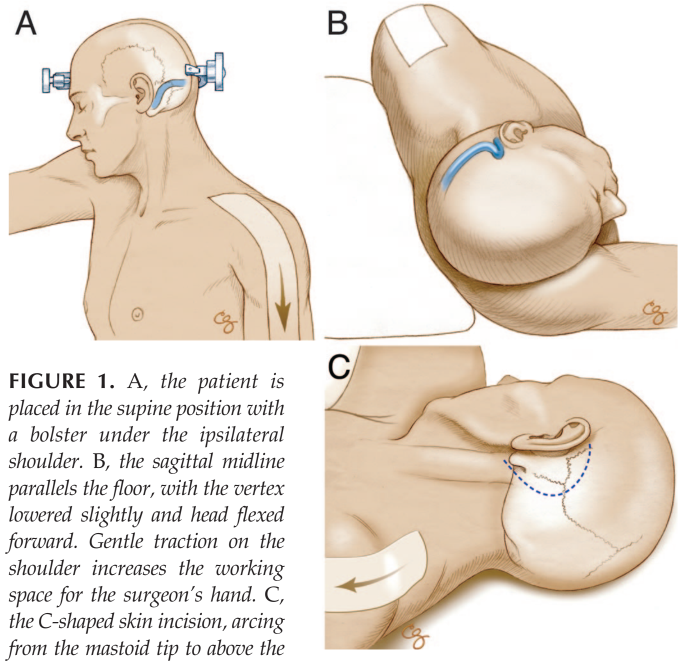

FIGURE 1. A, *the patient is placed in the supine position with a bolster under the ipsilateral shoulder.* B, *the sagittal midline parallels the floor, with the vertex lowered slightly and head flexed forward. Gentle traction on the shoulder increases the working space for the surgeon's hand.* C, *the C-shaped skin incision, arcing from the mastoid tip to above the ear, enables the scalp flap to mobilize anteriorly and easily expose the sigmoid sinus.*

SURGICAL TECHNIQUE

Patient Position and Skin Incision

After induction of general endotracheal tube anesthesia, the patient is positioned supine and bolsters are placed under the ipsilateral shoulder to rotate the shoulders and chest into a semilateral position (*Fig. 1*). The surgeon will work under the microscope from behind the head, so the patient is positioned on that edge of the table to bring the surgeon in close to the surgical field. The head is fixated in the Mayfield clamp with the sagittal midline paralleling the floor, the neck extended laterally to lower the vertex, the head flexed slightly in the anterior-posterior plane to open the angle between the occiput and the neck. The shoulder is pulled down with tape to further open this angle and increase the working space for the surgeon's hand. This position makes the mastoid tip the highest point in the surgical field. Patients with a rigid or stout neck are positioned in the lateral position. Rests are attached to the table to secure the patient and enable the table to be rotated. A lumbar drain is not routinely used.

A C-shaped skin incision begins at mastoid tip, arcs posteriorly, and ends just above the pinna. The scalp flap and the underlying muscles are mobilized anteriorly and retracted with fish hooks and a Leyla bar to flatten the surgical field (*Fig. 2*). These soft tissues are elevated until the depression in the cranium leading to the external auditory canal is appreciated.

Craniotomy

Bone dissection involves a limited posterior mastoidectomy and skeletonization of the sigmoid sinus, from its origin at the transverse-sigmoid sinus junction to the jugular bulb (*Fig. 2*). A high-speed drill with a cutting burr is used to cut through the mastoid process in a vertical line one finger breadth behind the external auditory canal. This initial cut extends from the temporal line (the ridge of bone that continues posteriorly from the zygomatic arch) down to the mastoid tip. This cut is approximately one finger breadth anterior to the asterion. Mastoid air cells are entered and bony trabeculae are removed rapidly. The bone overlying the sigmoid sinus has a solid, compact appearance that can be differentiated from trabeculated mastoid bone. In addition, the thinning bone acquires a blue coloring as the venous sinus is uncovered. This overlying bone is reduced to a layer as thin as an eggshell and the sinus is exposed along its course from transverse sinus to jugular bulb, and from its anterior edge to its border posteriorly, where the dura changes in color from blue to white. The cutting burr is then replaced with a diamond bit, which does not cut soft tissue and allows the remaining bone to be drilled away safely. Time needed to skeletonize the sinus is minimized by performing as much of this bony dissection as possible with the cutting burr. Drilling beyond the junction of the posterior border of the sigmoid sinus and the suboccipital dura reduces the size of the subsequent craniotomy flap and is kept to a minimum.

Emissary veins course from the sigmoid sinus through the occipital bone and produce brisk venous bleeding when encountered. This bleeding is easily controlled with bone wax.

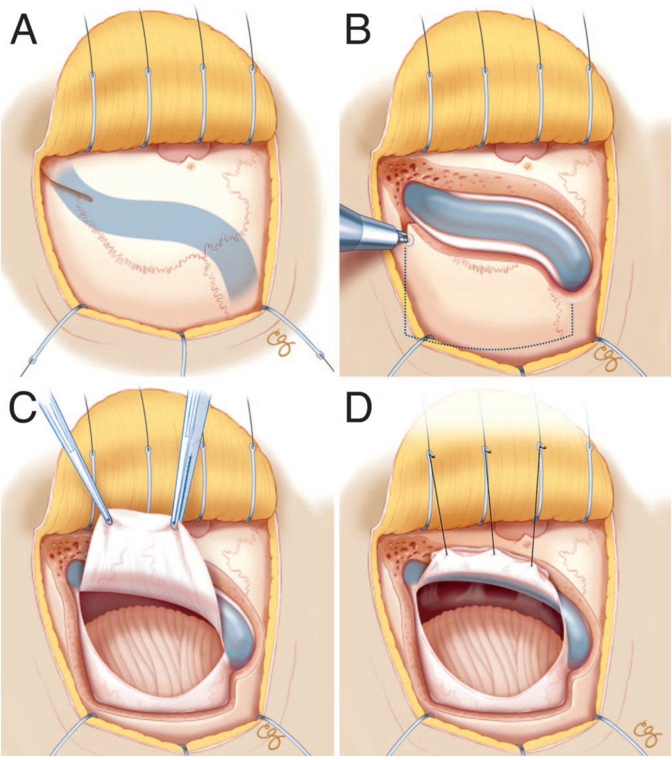

FIGURE 2. A, *the scalp flap and the underlying muscles are mobilized anteriorly and retracted with fish hooks and a Leyla bar to flatten the surgical field.* B, *a limited mastoidectomy extending from anterior to the asterion down to the mastoid process exposes the sigmoid sinus. Bone is removed through the curve into the transverse sinus superiorly, and down to the jugular bulb inferiorly, with careful skeletonization of emissary veins coursing from the sigmoid sinus. By minimizing bone removed along the posterior margin of the sigmoid sinus, the size of the subsequent bone flap is maximized. Dura is dissected from the inner table of suboccipital bone and the craniotomy is cut as far posteriorly as the scalp incision allows.* C, *the dura is opened in a flap based on the sigmoid sinus. The dural opening is performed under the microscope in order to be ready to release CSF from the cisterna magna and relax the cerebellum quickly.* D, *stay sutures placed in the dura pull the sigmoid sinus anteriorly to further open the access into the cerebellopontine angle where the lower cranial nerves and lateral brainstem are recognized.*

The veins are carefully skeletonized along their length, removing the overlying bone circumferentially until the soft pedicle can be coagulated. With some lesions like dural arteriovenous fistulae (DAVF), transmastoid feeding arteries must be controlled with bone wax.

After the sigmoid sinus has been thoroughly exposed, the suboccipital dura is dissected bluntly away from the inner table of occipital bone. Craniotomy, rather than craniectomy, is performed using a side-cutting bit and a foot plate. The craniotomy flap exposes the inferior edge of the transverse sinus, which is easily dissected from the inner table before making these cuts. Additional fishhooks expose the posterior margin of the surgical field. After removing the bone flap, dura leading down to jugular bulb is dissected from the inner table of occipital bone and additional drilling extends the bony exposure to jugular bulb. This maneuver is critical because it provides access to the cisterna magna. Release of CSF from the cisterna magnum is performed immediately after opening dura to relax the cerebellum, and opening this corridor at this stage of the operation facilitates this important step later.

Dural Opening and Microdissection

The dura is opened under the microscope with a semicircular flap based on the sigmoid sinus. The microscope is used here because the cerebellum frequently herniates through the dural opening and CSF must be released from the cisterna magna quickly. Telfa pads are placed over the cerebellar surface, the inferior cerebellum is gently retracted with a suction to visualize the cistern, and the arachnoid is cut with a microscissors. Release of CSF decompresses the posterior fossa and retraction is rarely needed thereafter.

The dural incision is advanced to the posterior edges of the sigmoid sinus and the flap is reflected anteriorly with stay sutures. The pull of these sutures mobilizes the sigmoid sinus anteriorly and opens an unobstructed corridor that is nearly flush with the posterior face of the petrous bone (*Fig. 3*). An additional dural flap based on the transverse sinus can be made if the plane between the cerebellum and tentorium needs to be accessed. The arachnoid in the cerebellopontine angle is opened extensively and the lower cranial nerves are identified. The microsurgical dissection proceeds as the lesions dictates.

Closure

The dura is closed with running nylon suture and the suture line is reinforced with a sealant, such as Bioglue (Cryolife, Inc., Kennesaw, GA). If the dura cannot be closed watertight, muscle is sutured to any dural defects before applying Bioglue. The mastoid air cells are thoroughly waxed, as they can be a conduit for leaking CSF. The bone flap is replaced

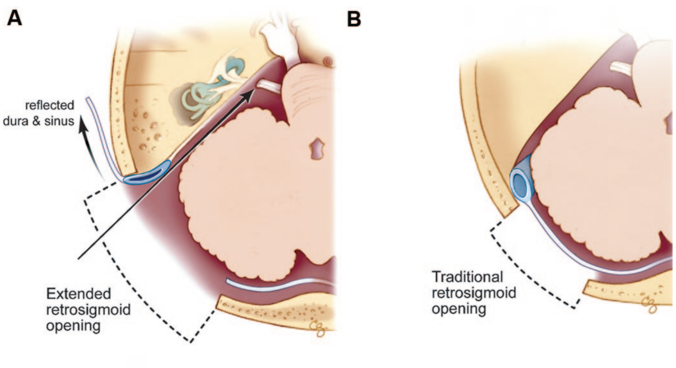

FIGURE 3. A, *skeletonization of the sigmoid sinus and retraction on the dural flap widens the opening into the cerebellopontine angle, creating a trajectory that is flush with the petrous bone.* B, *in comparison, the traditional retrosigmoid craniotomy leaves a ledge of bone over the sigmoid sinus that closes this surgical corridor and necessitates some retraction on the cerebellum.*

with dog-bone plates and screws, and the bony defect overlying the sigmoid sinus is filled with a bone substitute, such as Mimex (Walter Lorenz Surgical, Jacksonville, FL). The overlying muscle and galea are closed in layers, and the skin incision is closed with running nylon suture.

Case Material

Between August 1997 and December 2004, 38 patients with 40 posterior fossa vascular lesions were treated microsurgically by a single neurosurgeon (MTL) using the extended retrosigmoid approach. These lesions included 15 dural arteriovenous fistulae (DAVF), 9 arteriovenous malformations (AVM), 10 cavernous malformations, and 6 aneurysms. Two patients had multiple lesions.

All six aneurysms involved the anterior inferior cerebellar artery (AICA), with three aneurysms located at its origin from the basilar trunk and three aneurysms located distally. DAVFs were located at the transverse-sigmoid sinus junction in six patients, along the superior petrosal sinus in seven patients, at the lateral marginal sinus in two patients, and on the transverse sinus in one patient. AVMs were located in the cerebellum and cerebellopontine angle with the following Spetzler-Martin grades: Grade I, two patients; Grade II, two patients; Grade III, four patients; and Grade IV, one patient. Cavernous malformations were located in the pons in four patients, pontomedullary junction in four patients, midbrain in one patient, and superior cerebellar peduncle in one patient.

Illustrative Case 1: Anterior Inferior Cerebellar Artery Aneurysm

(*see video at web site*)

A 65-year-old woman presented with a transient loss of consciousness. She was neurologically intact at presentation. Diagnostic evaluation with brain MRI and cerebral angiography revealed a 10 mm diameter aneurysm at the origin of the left anterior inferior cerebellar artery, with thrombus within the lumen (*Fig. 4*). Endovascular therapy was considered, but the anteroinferior cerebellar artery originated from the base of the aneurysm and prevented coiling without occlusion of the parent artery.

The aneurysm was exposed through a left extended retrosigmoid craniotomy. The proximal basilar artery was exposed and a temporary clip was applied for 9 minutes with the patient in barbiturate-induced electroencephalogram burst suppression. This softened the aneurysm and facilitated the clip application. The deep portion of the neck was clipped with a straight fenestrated clip and the remaining portion was clipped with a straight clip to close the fenestration. This reconstruction contoured the aneurysm occlusion around the origin of AICA. Flow was confirmed in the basilar artery and AICA with a Doppler probe.

The patient tolerated surgery without complication and her postoperative angiogram demonstrated no residual aneurysm and a competent AICA. She was discharged home without neurological deficit on the third postoperative day.

Illustrative Case 2: Cavernous Malformation

A 31-year-old man presented with sudden headache, nausea, vomiting, right hemibody paresthesias, and vertigo. He had a posterior fossa cavernous malformation that was subtotally resected 10 years before this presentation, with subsequent cranial neuropathy in the right abducens, facial, and vestibulocochlear nerves. On neurological examination, the patient had a right VIth cranial nerve palsy, complete right facial palsy, no hearing in the right ear, and right hemiatrophy of the tongue with rightward deviation. Head computed tomographic scans and brain demonstrated a 3-cm cavernous malformation in the right cerebellopontine angle (*Fig. 5, A and B*). The MRI scans also demonstrated encephalomalacia in the right cerebellar hemisphere from retraction during the previous operation.

The cavernous malformation was exposed and resected completely through a right extended retrosigmoid craniectomy. The original retrosigmoid craniectomy had left a significant amount of bone over the sigmoid sinus, which explained the need for cerebellar retraction then and the encephalomalacia seen on MRI scans. Additional bone was removed until the sigmoid sinus was completely skeletonized. This additional bone resection provided wide exposure of the cranial nerves and enabled a complete resection of the lesion (*Fig. 5, C–E*).

Postoperatively, the patient experienced hiccups, which were treated with baclofen. He had no new cranial nerve deficits and was discharged home on the third postoperative day.

Illustrative Case 3: Dural Arteriovenous Fistula

A 49-year-old woman presented with a history of pulsatile tinnitus and chronic headaches. MRI scans revealed a vascular lesion in the cerebellopontine angle (*Fig. 6A*), and angiography demonstrated a dural arteriovenous fistula involving the left superior petrosal sinus. The DAVF was supplied by the tentorial, middle meningeal, and occipital arteries, and drained retrograde into cortical veins adjacent to the occluded transverse and sigmoid sinuses (*Fig. 6, B* and *C*). Two stages of transarterial embolization reduced flow through the fistula, but failed to obliterate it. The patient, therefore, underwent a left extended retrosigmoid craniotomy to occlude the fistula (*Fig. 6D*). A large, arterialized varix was identified in the angle between the tentorium and the posterior petrous bone, with multiple arterialized veins coursing from the varix over the cerebellar surface (*Fig. 6E*). The fistula was occluded by gathering the varix between the blades of an aneurysm clip, then coagulating and dividing the distal varix (*Fig. 6F*). The cerebellar veins darkened immediately, and no other venous outflow was identified. Her postoperative angiogram showed complete elimination of the fistula (*Fig. 6G*).

DISCUSSION

The extended retrosigmoid approach is a simple, quick, and safe surgical approach that can be used in the surgical management of a variety of challenging vascular lesions in the posterior fossa as described in this report. The technical steps that adapt a traditional retrosigmoid approach into the extended retrosigmoid approach are not dramatic, but require a fundamental change in management of the sigmoid sinus. With the traditional method, the sigmoid sinus and associated bleeding complications are meticulously avoided. The initial burr hole is placed behind the transverse-sigmoid junction at the asterion and bone is removed anteriorly until the posterior edge of the sinus is encountered. This limited exposure of the sigmoid sinus leaves a ledge of bone overlying the entry into the corridor to the cerebellopontine angle, which compromises the surgical exposure and necessitates cerebellar retraction.

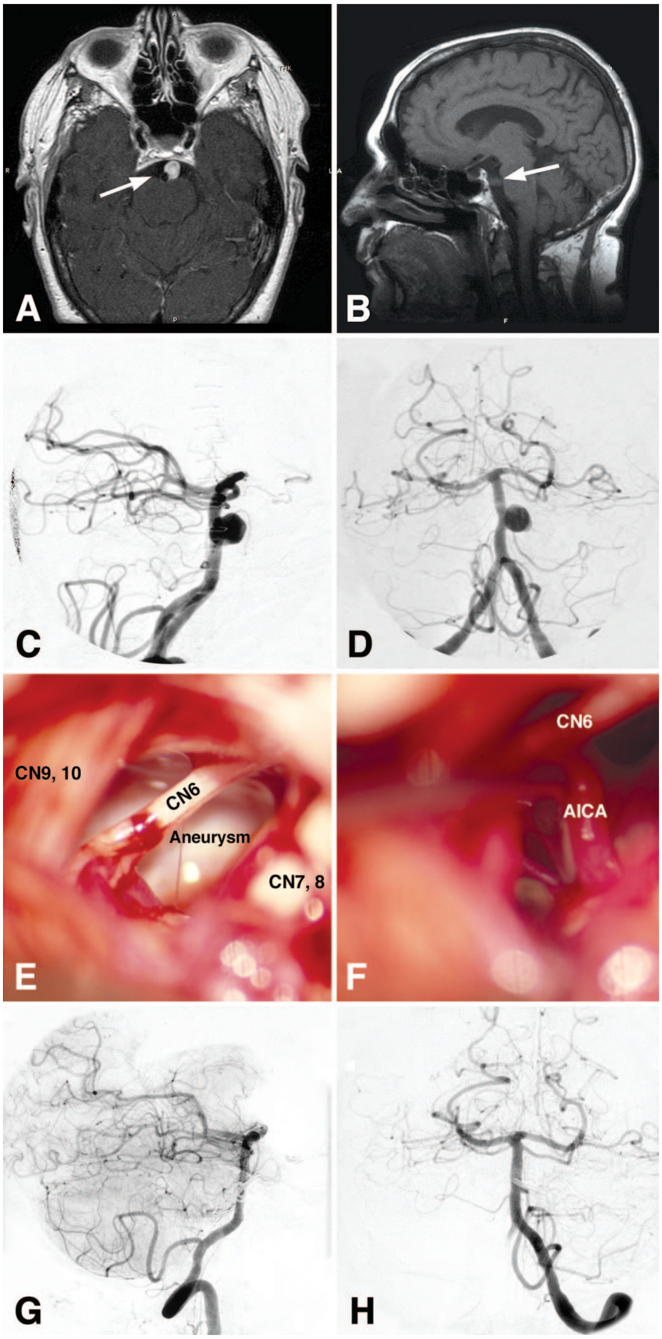

FIGURE 4. *Preoperative T1-weighted MRI scans in the axial with contrast* (A) *and sagittal without contrast* (B) *planes demonstrate a 10 mm saccular aneurysm* (arrows) *along the basilar artery anterior to the pons. Digital subtraction angiography with injection of contrast in the right vertebral artery shows an aneurysm at the origin of the left AICA* (C, *lateral view;* D, *anterior-posterior view*). E, *intraoperative photographs show the important cranial nerves involved around the aneurysm as well as the aneurysm in view through the exposed window.* F, *intraoperative photographs show that the involvement of the AICA, as well as the course of the 6th cranial nerve* (CN6). G *and* H, *postoperative angiography in the lateral and anterior-posterior views demonstrating successful clipping of the aneurysm, with preservation of blood flow in anterior inferior cerebellar artery.*

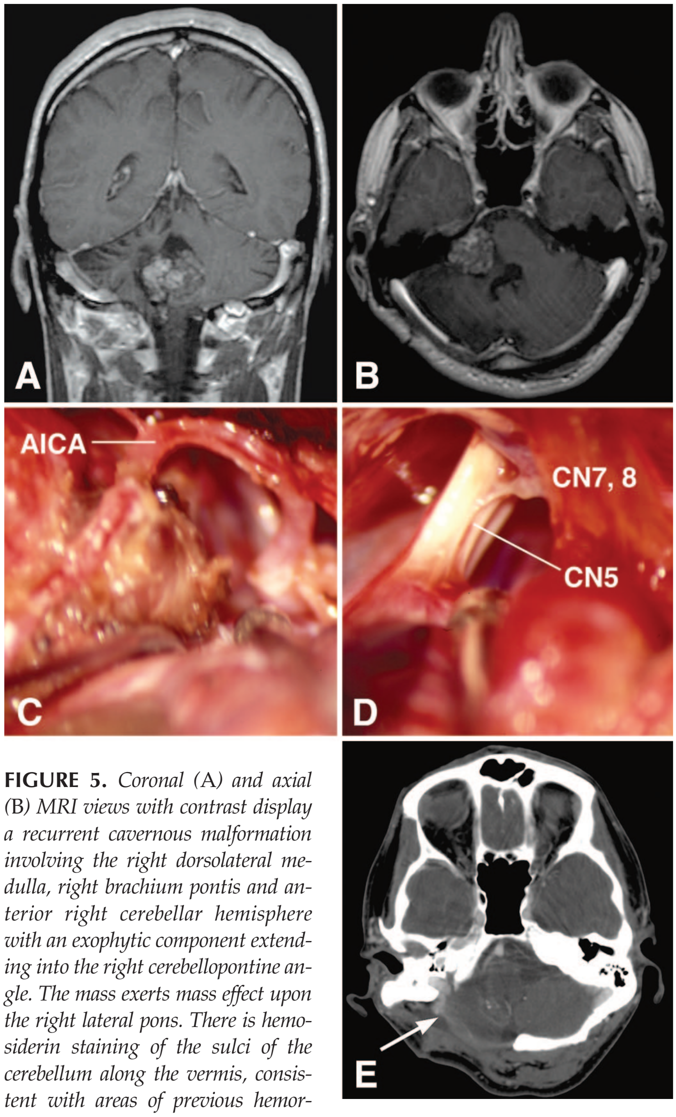

FIGURE 5. *Coronal* (A) *and axial* (B) *MRI views with contrast display a recurrent cavernous malformation involving the right dorsolateral medulla, right brachium pontis and anterior right cerebellar hemisphere with an exophytic component extending into the right cerebellopontine angle. The mass exerts mass effect upon the right lateral pons. There is hemosiderin staining of the sulci of the cerebellum along the vermis, consistent with areas of previous hemorrhage.* C *and* D, *intraoperative photographs demonstrating the course of the AICA, as well as the course of the trigeminal nerve* (CN5) *and the VIIth and VIIIth cranial nerves.* E, *postoperative computed tomographic scan showing the "extended" craniectomy boundaries after total resection of the lesion* (arrow).

Thus, the traditional technique shies away from the sigmoid sinus and leaves the surgeon guessing as to its exact course. In contrast, the extended technique begins with aggressive sigmoid sinus exposure. The sigmoid sinus is unlike other dural venous sinuses because it cannot be crossed with a craniotome and uncovered with a simple bone flap. The sigmoid sinus is deeply notched in the bone and the petrous pyramid prevents the drill's footplate from crossing it. Therefore, its exposure requires techniques borrowed from the neuro-otologists, with which neurosurgeons may be less comfortable. Furthermore, the anatomy of mastoid bone and middle ear are also less familiar to neurosurgeons, which makes drilling into the petrous bone more unsettling. The extended retrosigmoid ap-

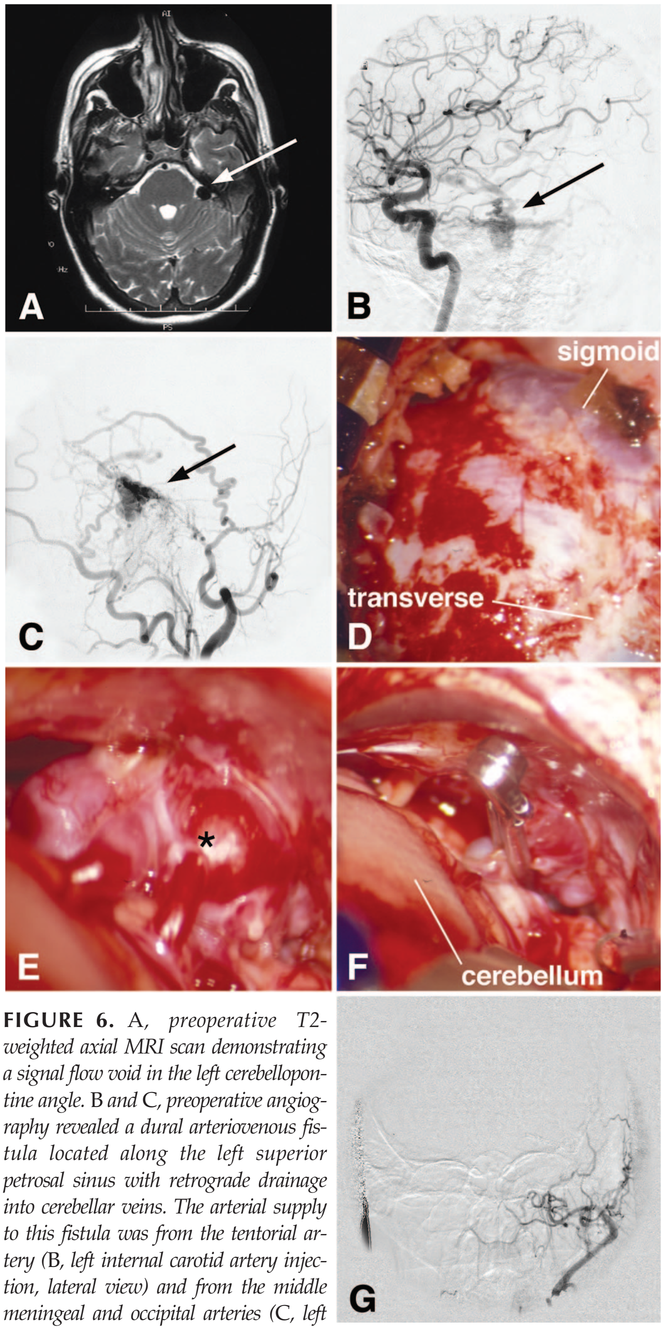

FIGURE 6. A, *preoperative T2-weighted axial MRI scan demonstrating a signal flow void in the left cerebellopontine angle.* B and C, *preoperative angiography revealed a dural arteriovenous fistula located along the left superior petrosal sinus with retrograde drainage into cerebellar veins. The arterial supply to this fistula was from the tentorial artery* (B, *left internal carotid artery injection, lateral view) and from the middle meningeal and occipital arteries* (C, *left external carotid artery injection).* D, *the extended retrosigmoid approach exposed the transverse and sigmoid sinuses and the lateral posterior fossa dura.* E, *the arterialized varix draining the fistula was identified in the angle between the tentorium and posterior petrous bone, and multiple arterialized veins originating from the varix coursed over the cerebellar surface* (asterisk). F, *the DAVF was occluded with an aneurysm clip placed across the varix, which was then coagulated and divided.* G, *postoperative angiogram showed complete elimination of the fistula (left external carotid artery injection, anterior-posterior view).*

proach therefore requires the demystification of petrous bone anatomy, experience dissecting through bone with a high-speed drill, and comfort working directly over a major venous sinus. This combination of prerequisites makes the extended retrosigmoid approach more of a leap from the traditional approach than the procedural differences would suggest.

This experience demonstrated that working so intimately with the sigmoid sinus is safe. There were no sinus injuries, hemorrhagic complications, or occlusions. Bleeding from emissary veins was controlled with bipolar cautery, and bleeding from the sinus itself, when it occurred, was easily controlled with Nu-knit packing and gentle pressure. With the sigmoid sinus skeletonized and pulled forward by the dural flap, the neurosurgeon is rewarded with markedly enhanced access to the cerebellopontine angle, the cranial nerves, and the deep vascular structures. Mobilization of the sigmoid sinus can occlude or compromise it, and the stay sutures should be loosened if the cerebellum remains swollen after CSF has been released from the cisterna magna. Although not encountered in this experience, venous outflow obstruction may be relevant in patients with venous occlusion on the contralateral side.

Dissection with a high-speed drill is practiced best in an anatomy lab. The speed of the procedure increases as one becomes comfortable working around the sigmoid sinus with a cutting burr. Dissection with a diamond drill bit is slower but safer, because diamond bits do not cut soft tissues. With practice, the conversion to a diamond drill bit comes later in the dissection. In addition to practice, intraoperative navigation with computed tomographic images can be useful in identifying the underlying venous anatomy during the bony dissection.

We described our experience with the extended retrosigmoid approach for vascular lesions of the posterior fossa, but have also applied it to tumors, cysts, and vascular compression syndromes. We highlight the extended retrosigmoid approach because it represents a simple, safe alternative to more radical transpetrous approaches that can be easily incorporated into the repertoire of most neurosurgeons, without the need for a multidisciplinary cranial base team and without the associated complexities and complications of these more extensive operations.

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Acknowledgments

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COMMENTS

The authors describe the operative technique of the extended retrosigmoid approach (standard retrosigmoid approach with complete skeletonization of sigmoid sinus to jugular bulb) in 38 patients with vascular disease. A video is also provided. No complications were encountered. The authors conclude that this approach is a safe and effective alternative to more invasive transpetrosal procedures. The authors, however, provide no follow-up data to further substantiate their zero rate of morbidity. We believe that this approach is associated with a higher risk of cerebrospinal fluid leakage and venous sinus thrombosis. Therefore, the risk-benefit ratio needs to be determined when this approach is compared with a standard retrosigmoid approach. In our more recent experience with cerebellopontine angle vascular and tumor pathology, the standard retrosigmoid approach has proven fully sufficient in terms of exposure and working room. We have rarely needed to use more invasive transpetrosal approaches to access this region.

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As we near the end of the "push the envelope" era in open cranial base strategies, inevitably some regression back to more moderate alternatives is appropriate. All too frequently, the biology or consistency of the pathology foils the ultimate goal of the procedure, irrespective of the expertise with which the approach was accomplished. With the advent of adjunctive radiosurgery, less aggressive tumor strategies can result in long-term control minus the associated cranial nerve or vascular morbidity associated with long and arduous exposures. The authors have added relatively subtle maneuvers to the traditional retrosigmoid approach to enhance exposure for complex vascular lesions. We described this strategy for acoustic tumors in *Operative Techniques in Neurosurgery* in 1999. It is our approach of choice for most complex vascular and neoplastic lesions in the posterior fossa. The authors' presentation is accurate and cogent, and the illustrations are helpful. This is an important tool for the neurosurgeon.

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The conventional lateral suboccipital approach has been offered as a tangent surgical field to the brainstem, and one of the disadvantages might be over-retraction of the cerebellum in a lesion located deeply in the cerebellopontine angle. The disadvantage has been improved by the presigmoid approach. However, neurosurgeons need their expert skill for preservation of labyrinth, and it is not uncommon to ask for the cooperation of ear, nose and throat personnel in surgery. The extended retrosigmoid approach could offer a similar advantage for direct vision to the cerebellopontine angle, reducing retraction to the cerebellum.

However, the operator is required to have the skill to expose the sigmoid sinus completely and to know how to manage time in sinus rupture, experience which cannot be gained by cadaver dissection. It must additionally be noted that this technique is necessary for observation of the brain not the cranial nerves or the internal auditory canal.

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This paper is excellent, both in its simplicity and the clarity of the illustrations. Essentially, this approach allows the surgeon to have an even more direct view into the cerebellopontine angle by allowing displacement and distraction of the venous sinuses without their sacrifice. One must be careful, however, in making sure that the sinus lumen is not compromised by the dural traction because venous pressure may increase and lead to parenchymal swelling or hemorrhage or to delayed sinus thrombosis. The technique is one that many cranial base surgeons have been using variations of for years. It is easily transferable to all surgeons familiar with posterior fossa approaches, and its broader dissemination will only serve to enhance patient safety for lesions approachable through the traditional suboccipital approach.

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