Skull Base Approaches for Posterior Circulation Aneurysms

Abstract—With the emergence of skull base surgery, surgical approaches have been developed and redefined, providing surgeons with accessible avenues to difficult lesions of the cranial base. Although the majority of lesions to which these techniques have been applied have been for tumors, we find that these skull base approaches can equally provide access to difficult vascular lesions, especially complex aneurysms of the posterior circulation. In this report, three different skull base approaches were used in four patients for the treatment of posterior circulation aneurysms. A cranio-orbital-zygomatic approach was used for the acute stage of a ruptured basilar tip artery aneurysm and for a giant posterior cerebral artery aneurysm. A petrosal approach was used for a ruptured basilar trunk aneurysm, and the transcondylar approach was used for a vertebral artery aneurysm. Each approach provides a wide field and excellent exposure of vital structures with minimal brain retraction. Neck clipping of the aneurysms was successfully achieved in all cases. We believe that our skull base approaches facilitate the surgical treatment of posterior circulation aneurysms. (*Skull Base Surgery*, 5(4): 251–260, 1995)

With the emergence of skull base surgery, several surgical approaches have been developed and redefined. These approaches provide surgeons with successful avenues to difficult lesions of the cranial base. The majority of lesions in which these skull base techniques have been successfully used have been for tumors. However, we find that with the provision of direct access to basal cisterns from the skull base techniques, complex and giant aneurysms are equally accessible for surgical intervention. In this report, we describe our techniques and results in the use of three different skull base approaches for the surgical management of four different complex posterior circulation aneurysms. The approaches that were used include the cranio-orbital-zygomatic (COZ) approach, the petrosal approach, and the transcondylar approach. Each approach provided a wide field with excellent exposure of vital structures with minimal brain retraction. Clipping of the aneurysm was successfully achieved in all cases.

METHODS

Cranio-Orbital-Zygomatic Approach

The procedure for the COZ approach involves modifications based on the supraorbital approach described by Jane et al.¹ The basic technical aspects of the COZ approach have been previously described.^{2–4} In the COZ approach, a supraorbital-pterional free bone flap is generated that consists of the frontotemporal bone in continuity with the anterior, superior, and lateral rim of the roof of the orbit (Fig. 1). The remainder of the orbital roof is removed as a posterior orbitotomy and reattached to the supraorbital-pterional bone flap (Fig. 2). Oblique osteotomies are placed at either end of the zygoma, and, with the inferior surface of the body of the zygoma attached to the masseter, the zygoma is easily retracted inferiorly,

Figure 1. Illustration of the crano-orbital-zygomatic approach. Outline of the front temporal flap in continuity with the roof and lateral rim of the orbit, with oblique osteotomies along the body of the zygoma. Osteotomy through the roof of the orbit is demonstrated (inset).

thus providing excellent exposure to the floor of the middle fossa. The medial aspects of the sphenoid wing are carefully drilled and removed with unroofing of the superior orbital fissure. The anterior clinoid is carefully skeletonized and removed either extradurally or intradurally. After microscopic opening of the sylvian cistern, multi-directional views and routes are provided, including access to the transsphenoidal, transsylvian, retrochiasmatic (lamina terminalis), subfrontal, and subtemporal areas.

Petrosal Approach

In the petrosal approach, originally described by Al-Mefty et al.,⁴ a single bone flap that incorporates the posterior temporal occipital bone is elevated, exposing the transverse and sigmoid sinuses (Fig. 3). The sigmoid is then skeletonized down to the jugular bulb. A complete mastoidectomy is performed with a high-speed drill, generally removing enough bones to expose sufficiently the

Figure 2. After removal of the supraorbital-pterional bone flap, the remaining portion of the roof and lateral orbital wall are removed as a posterior orbitotomy and reattached to the cranial flap at the end of the procedure.

Figure 3. Illustration of the craniotomy and mastoidectomy required for the petrosal approach. Posterior temporal and suboccipital bone is elevated as a single bone flap exposing the transverse and sigmoid sinuses. The sigmoid is skeletonized to the jugular bulb with complete mastoidectomy to the level of the compact bone, the semicircular canals and bony facial canal (inset).

presigmoid dura, sinodural angle, and superior petrosal sinus. This generally requires careful drilling to the level of the compact bone and the semicircular canals and bony facial canal (Fig. 3). With a presigmoid, retrolabyrinthine route, the temporal dura is incised along the floor of the middle fossa (Fig. 4). The posterior fossa dura anterior to the sigmoid sinus is incised toward the superior petrosal sinus (Fig. 4). To provide adequate exposure for the presigmoid route, the superior petrosal sinus is coagulated and cut with the incision continued through the tentorium along the pyramid through the incisura and behind cranial nerve IV. The opening provided is centered at the anterior, lateral aspect of the pons at the level of a trigeminal root with the exposure extending in a cephalad orientation as high as the cavernous sinus and suprasellar region and as caudal as the foramen magnum.

Transcondylar Approach

The transcondylar approach is useful for both intradural and extradural lesions in the region of the lower clivus, foramen magnum, and cervical spine located ventral in the neural axis. The transcondylar technique relies on the removal of bone in the area of the mastoid process and cranial spinal articulation, which includes the occipital condyle and C1 (Fig. 5). Soft tissue dissection is centered along the lateral masses of C1 and C2, with dissection, control, and mobilization of the horizontal segment of the vertebral artery superior to C1. The lateral aspect of the foramen transversarium of C1 is opened and the vertebral artery is mobilized, thereby providing greater exposure to the occipital condyle and condyle of C1. The occipital bone and mastoid process as well as approximately one half to two thirds of the occipital condyle and condyle C1 are removed. If more of the condyles are

Figure 5. Illustration of the required bone removal for the transcondylar approach. The occipital bone, including the foramen magnum, mastoid process, and up to one half of the occipital condyle and condyle of C1 are removed.

removed as needed for exposure, then unilateral fusion would be required. The generous removal of bone, including the condyles, provides the surgeon with ample anterior exposure from a posterior lateral perspective without retraction.

Figure 4. Artist's enhancement of an operative photograph (case 3), showing the incision of the temporal dura along the floor of the middle fossa (TD). The posterior fossa dura (PFD) anterior to the sigmoid sinus (SS) is incised toward the superior petrosal sinus. Mastoidectomy has been performed to the level of the compact bone of the mastoid (M).

RESULTS

Case 1

In the first case, the COZ was used in the acute stage of a ruptured basilar tip artery aneurysm. A 50-year-old woman presented with an acute grade III subarachnoid hemorrhage. Computed tomographic scans showed diffuse subarachnoid hemorrhage with a large complex basilar tip artery aneurysm on angiogram (Fig. 6). The COZ

approach was directed on the left side. After the zygoma was taken down and the supraorbital-pterional free bone flap removed, the medial aspect of the sphenoid wing was drilled and removed with unroofing of the superior orbital fissure. At least 50% of the anterior clinoid was removed extradurally. A curvilinear incision was then made in the dura, followed by microscopic opening of the arachnoid overlying the sylvian cistern. When the sylvian fissure was opened widely and with the temporal lobe retracted laterally and posteriorly, the transsylvian view was optimized. The edge of the tentorial incisura was readily

Figure 6. Angiogram of patient (case 1) with the large, complex basilar tip artery aneurysm: anteroposterior view (A) and lateral view (B).

Case 2

exposed, centered along the third cranial nerve as it enters underneath the lateral wall of the cavernous sinus. The posterior communicating artery was identified, carefully dissected, and followed back to the posterior cerebral artery (P_1) and then to the large basilar tip artery aneurysm. Careful dissection was performed anterior to the third nerve and the intrapeduncular fossa. The contralateral P_1 and dome of the aneurysm were easily visualized and dissected. Dissection was also continued in a more lateral orientation underneath the third cranial nerve to expose the posterior aspect of the neck of the aneurysm and thalamoperforators. Perforators were identified and dissected, and then the wide neck to the aneurysm was clipped.

In the second case, a 50-year-old man with a giant, partially thrombosed posterior cerebral artery aneurysm presented with the acute onset of confusion but without subarachnoid hemorrhage or cranial nerve deficits (Fig. 7). The COZ approach was used, and the entire anterior clinoid was removed extradurally. After opening of the sylvian cistern, the posterior communicating artery, the posterior cerebral artery, and the posterior cerebral artery aneurysm were well visualized. The dura overlying cranial nerve III as it enters underneath the lateral wall of the cavernous sinus was opened and the posterior clinoid carefully skeletonized and removed (Fig. 8). These two

A

B

C

Figure 7. Giant posterior cerebral artery aneurysm (case 2). Axial T_2 -weighted magnetic resonance image (A). Angiogram anteroposterior view (B) and lateral view (C).

Figure 8. Operative photograph of case 2, which demonstrates the giant posterior cerebral artery aneurysm (A). Carotid artery (CA), posterior clinoid (PC), and cranial nerve III are shown, as well as the posterior cerebral artery (P_2) and perforator.

techniques increased exposure and maneuverability to the aneurysm neck underneath the third cranial nerve and anterior to the third cranial nerve. The neck of the aneurysm was further defined along with P_1 and P_2 , and then the aneurysm was successfully clipped (Fig. 9).

Case 3

In the third case, a petrosal approach was used in the acute stage of a ruptured basilar trunk aneurysm. The

patient was a 30-year-old woman who presented with grade III subarachnoid hemorrhage from a multilobed, fusiform aneurysm located at the basilar trunk (Fig. 10). After the sigmoid sinus was skeletonized down to the jugular bulb, a complete mastoidectomy was performed, removing enough bone to expose sufficiently the presigmoid dura, the sinodural angle, and the superior petrosal sinus (Fig. 4). The superior petrosal sinus was coagulated and then the tentorium was incised along the pyramid through the incisura. With the incision of the tentorium in continuity with incisions in the temporal dura and presig-

Figure 9. Artist's enhancement of an operative photograph of the giant posterior cerebral artery aneurysm after the clip (C) was successfully applied to the neck of the aneurysm (A). The posterior cerebral artery (P_2) and cranial nerve III are shown.

Figure 10. Angiogram of patient (case 3) with a multilobed basilar trunk artery aneurysm, right vertebral injection: anteroposterior view (A) and lateral view (B).

moid posterior fossa dura, the presigmoid space was entirely exposed and centered along the anterolateral aspect of the pons to the level of the seventh and eighth cranial nerve complex. The dome of the multilobed aneurysm was identified and carefully dissected (Fig. 11). Three aneurysmal clips were successfully placed to obliterate the aneurysm and reconstruct the basilar trunk.

Case 4

In the fourth case, a young woman presented with a grade I subarachnoid hemorrhage from a vertebral artery aneurysm with fusiform dilation (Fig. 12A). The patient underwent a transcondylar approach and initially the aneurysm was wrapped with cotton. The postoperative an-

Figure 11. Operative photograph of case 3, which shows the multilobed aneurysm of the basilar trunk.

Figure 12. Vertebral artery aneurysm from case 4. Angiogram, anteroposterior view (A), which shows the fusiform dilation of the aneurysm (arrow). Oblique view of the repeat angiogram (B), 2 weeks after the aneurysm was wrapped with cotton. Intraoperative angiogram (C) from the second operation after the vertebral artery aneurysm was successfully clipped.

angiogram, 2 weeks after surgery, however, demonstrated the presence of a more definable surgical neck (Fig. 12B). The patient was reoperated on, and the surgical clip was successfully applied.

The approach was developed from the right side with mobilization of the vertebral artery laterally and inferiorly. The mastoid bone and suboccipital bone, including the foramen magnum, were removed. Bony removal was extended far laterally to include one half of the occipital condyle. The posterior fossa dura was then incised longitudinally, with the incision in the dura continued anteriorly around the vertebral artery as it enters the foramen magnum. Cranial nerves XI and XII as well as the ninth and tenth nerve complex and the medulla were visualized. The vertebral artery was identified and followed proximally. The cotton gauze that was previously placed over the aneurysm was removed and the vertebral artery aneurysm was carefully dissected around the cranial nerve XII. The aneurysm clip was applied and

the intraoperative angiogram demonstrated complete obliteration of the aneurysm (Fig. 12C). The patient's postoperative deficits include a mild cranial nerve 12 palsy.

DISCUSSION

The COZ approach is one of the more versatile of the skull base approaches, minimizing brain retraction by removing bone and gaining access under the frontal and temporal lobes, thus shortening the distance to the targeted lesion. The position and size of the flap can be tailored specifically to the targeted lesion, with increased access to the floor of the middle fossa extending to the cavernous sinus and upper clivus. With the wide transsylvian dissection, exposure is provided anywhere along the carotid artery, along the anterior and middle cerebral arteries, and in the interpeduncular cistern.

The fundamental exposure to the interpeduncular cistern for clipping of basilar apex artery aneurysms have traditionally been either the lateral subtemporal approach or the pterional or transsylvian approach. The lateral subtemporal exposure, originally pioneered by Drake,^{5,6} has the advantage of exposure to the posterior aspect of the aneurysm neck and thalamoperforators along the back wall. Aggressive temporal lobe protraction is required, often eliminating the exposure to superiorly located basilar apex artery aneurysms, and exposure to the contralateral P₁ is poor. Application of the transsylvian approaches for basilar artery aneurysms, originally promoted by Yasargil et al⁷ provides wide access to the medial and lateral carotid artery, with anterior and superior access to the basilar apex and with good exposure to the contralateral P₁. However, exposure to the back wall of the aneurysm and posterior perforators is limited. Additionally, the "half-and-half,"⁶ which is a modification of the pterional approach, removes additional temporal squamous bone, which results in more extensive sylvian fissure dissection and exposure to the tentorial edge.

All three approaches have been used successfully for clipping basilar tip artery aneurysms. The subtemporal approach is superior to the anterior approach for posterior and inferiorly located apex aneurysms, and the anterior approach is favored for large superiorly located aneurysms. With some of the aneurysms, however, neither of the approaches is sufficient alone and both anterior and lateral orientations are required for successful dissection and clipping. The COZ approach, on the other hand, incorporates a wide arc for both transsylvian and subtemporal exposures, shorting the distance to the targeted lesion and increasing the number of viewing angles to the aneurysm. After extensive bony removal, opening of the dura, and wide transsylvian dissection, the frontal and temporal poles readily open under the weight of gravity without retraction, decreasing the distance to the circle of Willis. With the temporal lobe retracted laterally and posteriorly, the lateral and medial carotid cisterns and incisural edge of the tentorium, including the lateral wall of the cavernous sinus, are widely exposed. The exposure of the lateral wall of the cavernous sinus is centered at the level of the third cranial nerve as it enters the ocular motor foramen. With dissection guided by the third cranial nerve, the back wall of the aneurysm can be dissected, laterally and underneath the third cranial nerve, or the superior aspect of the aneurysm dissected with exposure provided anterior to the third cranial nerve. In essence, both "transsylvian and subtemporal" routes are provided with the COZ approach. Anterior or lateral exposures may be increased by untethering the third nerve and opening the oculomotor foramen and by skeletonizing the posterior clinoid. The more anterior or more lateral exposures can be exaggerated by rotating the operating table. Also with the temporalis muscle reflected posteriorly and inferiorly over the zygoma, the surgical field is flattened. Osteotomy of the zygoma with retraction inferiorly im-

proves the access to the floor of the middle fossa, minimizing temporal lobe retraction; not only does removal of the superior and lateral rims of the orbits aid in the opening of the frontal and temporal poles, but transsylvian dissection can be extended superiorly.

Because of the wide exposure to the interpeduncular cistern with multiple viewing angles, excellent exposure is provided anywhere on top of the basilar artery and along the carotid artery, posterior communicating artery, and posterior cerebral artery. In case 2 (posterior cerebral artery aneurysm), dissection for the perforators and neck of the aneurysm was facilitated by working completely around the third cranial nerve. Maneuverability was also increased by untethering cranial nerve III and drilling off the posterior clinoid.

The petrosal approach provides wide exposure from the cavernous sinus to the foramen magnum. Regarding the posterior circulation, the petrosal approach is ideal for aneurysms of the midbasilar trunk and branches. After skeletonization of the sigmoid sinus, mastoid bone is carefully removed to provide sufficient exposure of the presigmoid space while preserving facial and hearing nerve functions. Dural openings are anterior to the cerebellum, thus minimizing cerebellar retraction; opening of the tentorium increases the exposure in the presigmoid space with an anterolateral view of the brainstem, which facilitates multidirectional viewing and clip placement. The petrosal approach was ideal for the midbasilar artery aneurysm described in case 3. The aneurysm was located far superiorly for exposure provided from a traditional suboccipital retrosigmoid approach or from either a lateral suboccipital approach⁸ or an extreme lateral transcondylar approach.^{9,10} The aneurysm was located far too inferiorly for exposure from the subtemporal, pterional, or COZ approaches; the inferior extent of exposure of the COZ was limited just above the internal acoustic meatus. With the retrolabyrinthine presigmoid route provided from the petrosal approach, a wide corridor to the anterior lateral aspect of the pons, dome of the aneurysm, and fusiform neck was achieved.

A modification of the unilateral suboccipital approach has been described by Heros⁸ as the lateral suboccipital approach for vertebral and vertebral artery lesions. The emphasis is removal of bone, including the rim of the foramen magnum toward the condylar fossa and posterior lateral removal of the arch of the atlas. Retraction of the tonsil is minimal with no retraction of the medulla. The extreme transcondylar approach, popularized by Sen and Sekhar^{9,10} especially for the treatment of intradural tumors anteriorly located in the cranial cervical region and foramen magnum, takes bone removal one step further with removal of the occipital condyle and C1, with opening of the foramen transversarium with mobilization and control of the vertebral artery. We find the transcondylar approach ideally suited for aneurysms involving the lower third of the basilar trunk and vertebral arteries. With the extradural exposure of the vertebral

artery, proximal control of the other vertebral arteries is achieved before the dura is opened. The mastoid tip is carefully removed while preserving facial and hearing nerve function to improve the exposure of the occipital condyle and C1. Removing condyles of the occiput and C2 places the surgeon anterior to the lower pons and medulla. After dural opening, both vertebral arteries and basilar trunk with perforators are exposed.

Skull base techniques are continuing to develop and their utility is constantly being defined and confirmed. The approaches are generally well-tolerated by patients and have been widely used for tumors of the base of the skull. Moreover, the skull base techniques minimize brain retraction and improve exposure with access to the basal cisterns, which can enhance the surgeon's ability to dissect and expose complex vascular lesions, including aneurysms. The advantages of skull base approaches for aneurysms of the anterior circulation have been well described by Smith et al.¹¹ At our institutions, we continue to use skull base techniques for anterior circulation aneurysms and vascular lesions; however, we find that the posterior lateral skull base approaches also provide superb access to difficult placed aneurysms in the posterior circulation. In the cases described, direct access was provided for four different complex aneurysms in the posterior circulation. All aneurysms were successfully clipped and the procedures were well-tolerated.

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