Skull base approaches to the basilar artery

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Posterior circulation lesions constitute approximately 10% of all intracranial aneurysms. Their distribution includes the basilar artery (BA) bifurcation, superior cerebellar artery, posterior inferior cerebellar artery, and anterior inferior cerebellar artery. The specific features of a patient’s aneurysm and superb anatomical knowledge help the surgeon to choose the most appropriate approach and to tailor it to the patient’s situation. The main principle that must be applied is maximization of bone resection. This allows the surgeon to work within a wider corridor, which facilitates the use of surgical instruments and minimizes retraction of the brain.

The management of aneurysms within the posterior circulation requires expertise in skull base and vascular surgery. Endovascular treatments have become increasingly important, but in this paper the authors focus on the surgical management of these difficult aneurysms. The paper is divided into three parts: the first section is a brief review of the anatomy of the BA; the second part is a review of the techniques associated with the management of posterior fossa aneurysms; and in the third section the authors describe the different approaches, their nuances and indications based on the location of the aneurysm, and its relationship to the surrounding bone (especially the clivus, dorsum sellae, and the free edge of the petrous apex).

KEY WORDS • basilar artery aneurysm • skull base approach • far-lateral approach • orbitozygomatic region • middle fossa • transpetrosal approach • revascularization • flow reversal

ANATOMY OF THE BA

The BA begins at the juncture of the VAs at the ponto-medullary sulcus. It ascends anteriorly to the brainstem behind the clivus and terminates when it bifurcates at the interpeduncular cistern. There it gives rise to both PCAs at the pontomesencephalic junction.

The BA gives rise to the arteries that supply the posterior fossa. The SCA, which originates at the pontomesencephalic sulcus, encircles the midbrain to supply the cerebral peduncles before it courses superiorly and medially to supply the tentorial surface of the cerebellum. The AICA sends branches to these nerves and to the choroid plexus before it courses posterolaterally to supply the petrosal surface of the cerebellum.

The length of the BA varies, which determines the position of the bifurcation. It can extend as rostrally as the mammillary bodies and the floor of the third ventricle, or it can be short, with a “low” bifurcation below the pontomesencephalic junction. The BA also can vary in the coronal plane. It can be straight or tortuous with extreme loops on both sides. In addition to this complex intrinsic vascular anatomy, its relationships to bone at each level help determine the suitability of a given approach within the armamentarium to treat these complex lesions.

Conceptually, the BA can be divided into fifths. At its upper two fifths, the main osseous structures that can obscure its visualization are the anterior and posterior clinoid processes and the dorsum sellae (upper clivus). Usually, aneurysms at this level can be reached via an orbitozygomatic approach or a modification thereof. Occasionally, aneurysms are located higher than the petrous edge and lower than the floor of the sella. In such cases a lateral exposure via a subtentorial approach is indicated. The main structures that help decide the approach to midbasilar (middle fifth of the BA) aneurysms are the free edge of the petrous bone and the relationship between the aneurysm and internal auditory canal. The mid-BA can be reached via one of the transpetrosal approaches or via an extended middle fossa approach. Sometimes a retrosigmoid approach is adequate. If the aneurysm is located at the bottom two fifths of the artery (lower BA), the main bone structures of concern are the jugular tubercle and the occipital condyle. Aneurysms at this level can usually be reached via a far-lateral approach or its variants.
SPECIAL TECHNIQUES

Aneurysm Trapping, Flow Reversal, and Revascularization

Although the primary surgical goal in the management of aneurysms is direct clip obliteration with preservation of the parent vessel, not all lesions are amenable to this strategy. Large aneurysms especially can incorporate the parent vessel to such an extent that clip reconstruction is not feasible. The most extreme example would be fusiform vertebro-basilar dolichoectatic aneurysms or dissecting aneurysms, which are common in the posterior fossa. Nevertheless, even large, saccular aneurysms can behave in this fashion. Under these circumstances, the remaining options are trapping of the affected segment or proximal occlusion to alter the flow dynamics in the region of the aneurysm, causing it to regress and thrombose spontaneously (Fig. 1A).10

For mid- and lower basilar lesions, direct trapping may be less desirable because of the potential risk of injuring adjacent perforating vessels. Nevertheless, proximal or even distal BA occlusion can effectively change the flow dynamics, thereby abolishing the aneurysm (Fig. 1B). For large fusiform dolichoectatic aneurysms, proximal occlusion of one or both VAs can accomplish “flow reversal” in a similar fashion. Removing hemodynamic stress from the vessel wall is thought to play an important part in the arrest of growth in these lesions.

At this point it is necessary to establish whether preoperative revascularization is indicated. In general, a nondominant VA can be occluded with impunity, whereas the collateral circulation must be relied on if the artery is dominant. A PCoA with a caliber larger than 1 mm usually represents adequate collateral blood flow.

When collateral flow is inadequate, different techniques for revascularization are available.10 The purpose of using a bypass is to ensure adequate blood flow to the upper basilar territory after the BA trunk has been clipped, unless the caliber of the PCoAs is adequate to provide this flow.10,28 In such cases, the choice of donor and recipient vessels depends on the requirements for blood flow and on the available suitable vessels. The primary arterial donor vessels are the STA and occipital artery, or interposition of a graft from the external carotid artery anastomosed to the PCA or SCA. Use of the nondominant radial artery is recommended because its caliber matches that of the PCA.

A posterior circulation bypass is demanding because of the depth at which the anastomosis must be performed. It is

Fig. 1. Drawings showing lesions that are unsuitable for clip occlusion. A: This giant BA tip aneurysm is unsuitable for direct clip placement because both PCAs are involved with the neck of the lesion. The aneurysm clip is placed below the level of the SCAs in a patient with inadequate collateral flow, with a bypass performed from the STA to the PCA (arrow marked A) or to the SCA (arrow marked B). B: The other aneurysm is located at the level of the mid-BA. The involvement of this giant midbasilar aneurysm with perforating vessels makes it unsuitable for clip occlusion. The flow to the aneurysm is reversed with an aneurysm clip (placed either proximally or distally), and it is revascularized with an STA–PCA bypass. The distal circulation must be bypassed with an anastomosis from the STA or occipital artery into the PCA or SCA. (Reprinted with permission from Barrow Neurological Institute.)
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associated with the general risks of any vascular surgery in the posterior circulation, in addition to the more specific risks of graft failure and secondary ischemia.

Vascular Control

During aneurysm surgery, adequate proximal and distal control must be established. Doing so is particularly challenging in the posterior circulation. For the upper third of the BA, proximal control is obtained by placing a temporary clip below the point where the SCAs emerge. Usually this maneuver softens the aneurysm enough to proceed with the dissection. Typically, adequate control is obtained with a temporary clip on the BA, and it is unnecessary to occlude the PCA or SCA. Alternatives to placement of a temporary clip to obtain adequate proximal control of the upper third of the BA are endovascular balloon occlusion and hypothermic circulatory arrest. Balloon occlusion provides proximal control before dissection of the aneurysm begins, without the inconvenience of a temporary clip that can obstruct visualization of the lesion in a narrow corridor.10

Circulatory arrest collapses the aneurysm, making its dissection from the brainstem feasible. A large, firm sac is converted into a soft, pliable one that allows visualization of the critical anatomy. This procedure makes it easier to differentiate the neck of the aneurysm from adjacent perforating vessels. It eliminates the necessity of obtaining control, which is difficult in the midbasilar trunk. It also facilitates manipulation of the aneurysm clip around the neck of the lesion.21 Furthermore, hypothermia and barbiturate therapy provide cerebral protection.20

The main disadvantages of circulatory arrest are related to the coagulopathy caused by heparinization and platelet trauma when the patient is on the bypass pump.6 Circulatory arrest itself is associated with a risk of cerebral ischemia, which hypothermia and barbiturate drugs counteract to some degree. Meticulous closure is necessary to prevent postoperative hematomas.

The implementation of cardiac standstill is complex. It requires the close cooperation of an organized team, including cardiac surgeons, and the expertise of both cardiac and neuroanesthesia personnel. Therefore, the technique must be used judiciously only in selected cases. In the senior author’s experience with more than 50 procedures in which hypothermic cardiac arrest was used, the mortality rate was almost 10%. This rate reflects the complex premorbid status of the patients more than use of the technique itself.26

For lower BA aneurysms, proximal control is easily obtained by placing a temporary clip across the VA. Distal control is harder to obtain, even when endovascular techniques are used.20

**SURGICAL APPROACHES**

Orbitozygomatic Approach

The pterional approach is a traditional and versatile one that allows access to aneurysms in the anterior circulation. This is the basis for the orbitozygomatic approach (Fig. 2), which combines the pterional approach with different osteotomies that remove the superior and lateral walls of the ipsilateral orbit and zygomatic arch. This extra bone resection is grounded in the skull base surgical principle of maximizing bone resection to minimize brain retraction (Fig. 3).18

 Yaşargil popularized the use of the pterional approach for the treatment of anterior and posterior circulation aneurysms. The main advantages of this approach are the ability to attack the aneurysm from its neck, with a good perspective on the interpeduncular cistern and the ability to establish different surgical corridors. These corridors are established based on the local anatomy: through the optico-carotid triangle, laterally between the ICA and third cranial nerve, and the window between the A1, M1, and optic tract can be used as well (Fig. 4). A wide opening of the sylvian fissure limits the need to retract the brain.21

The relationship between the aneurysm and upper clivus (posterior clinoid process) is key. Aneurysms located within 5 mm of the dorsum sellae are considered normal. If they occur higher or lower than that point, they are considered high-lying or low-lying, respectively.11

To reach normal or high-lying aneurysms, we prefer the orbitozygomatic approach, which allows good exposure of the interpeduncular and preopticine cisterns. There are three osseous obstacles to the BA apex: the anterior clinoid process, posterior clinoid process, and dorsum sellae.29 Resection of these three obstacles makes the extended orbitozygomatic approach especially useful for low-lying aneurysms.

Preoperative preparation includes placing a femoral radionucent sheath for intraoperative angiography and an electrode to record the electroencephalographic and somatosensory evoked potential responses. The patient’s head is placed in a radiolucent Mayfield headholder, slightly extended, and rotated 10 to 15° to the contralateral side. Specific details about the approach are reported elsewhere.42 The carotid cistern is opened wide, and the PCoA is followed posteriorly to the junction between P1 and P2. The Liliequist membrane is then opened. The exposure should allow the identification of both PCAs and both SCAs. Sometimes the lamina terminalis is opened. Decreasing the degree of rotation of the head helps to bring the contralateral side into view. Sometimes it is necessary to sacrifice the PCoA to create more space21 to ease the manipulation of instruments and the placement of temporary and permanent aneurysm clips.

**Pretemporal Transcavernous Approach**

A variation of the orbitozygomatic approach includes an extension into the upper wall of the cavernous sinus to increase access to the anterior incisura. This modification was initially described by Dolenc, et al.5 It has been used for low-lying aneurysms and facilitates access to the interpeduncular cistern from the carotid–oculomotor triangle. Seoane, et al.,17 illustrated this procedure, which consists of an orbitozygomatic approach with extradural drilling of the anterior clinoid process (Fig. 5A).18 The clinoid segment of the ICA is exposed and released from its distal and proximal dural rings. Once the ICA is free, the posterior clinoid process (Fig. 5B)44 is drilled and the upper clivus (dorsum sellae) is removed. The main disadvantage of this approach is the almost inevitable postoperative palsy of the third cranial nerve.11

Subtemporal Approach

This approach was popularized by Drake,7 who has published many papers relating his vast experience with treating posterior fossa aneurysms. Compared with the pterion-
al and orbitozygomatic approaches, its main advantage is better visualization of the perforating arteries of the thalamus (Fig. 6). It is also feasible to establish proximal and distal control via the subtemporal approach. Its main disadvantages are the intrinsic need to retract the temporal lobe and the potential for injury to the third and fourth cranial nerves during manipulation of the tentorium.

With the patient positioned laterally, a craniotomy is per-
formed in front of the ear. It is usually performed from the right side unless there are special circumstances such as the projection of the aneurysm, compromise of the third cranial nerve, or right hemiparesis. Once the craniotomy is completed, the floor of the middle fossa must be flush with the zygomatic arch. All of the squamous bone is resected, and the temporal lobe is retracted (the temporal vein should be preserved if possible). The surgical corridor is established perpendicular to the axis of the head (Fig. 7). A combined subtemporal–orbitozygomatic approach can be obtained by performing a wide craniotomy and drilling the floor of the middle fossa, then the microscope can be swiveled back and forth to obtain the visual advantages of each approach. Once the tentorium is reached, it can be retracted with one suture stitch and pulled or cut to obtain proximal control. The temporary clip is placed below the SCA because this area is relatively free of circumflex perforating vessels. Exposing the tentorium provides access to the fourth cranial nerve. The arachnoid is opened and then the Liliequist membrane is opened, exposing the SCAs and PCAs. This approach should be reserved for cases in which the CA is short, the PComA is dominant, and the BA bifurcation is below the dorsum sellae and above the internal auditory canal.

Extended Middle Fossa or Kawase Approach

The middle fossa approach was developed by House and Crabtree to treat lesions of the seventh and eighth cranial nerves in the internal auditory canal.

Conceptually, the floor of the middle fossa has been divided into two triangular areas, the posterosleral and posterosmedial triangles. The posterosleral triangle (Fig. 8) is the bone surface defined by the foramen spinosum, cochlea, and mandibular nerve near its intersection with the greater superficial petrosal nerve. This area was originally defined by Glasscock. It is a key landmark for exposure of the horizontal intrapetrous segment of the ICA. The posterosmedial triangle was named by Fukushima after its description by Kanzaki and colleagues. The cochlea, trigeminal groove, and horizontal intrapetrous ICA delimit this area of bone. It defines a shallow volume of petrous apex that can be resected with impunity because no structures are present to establish a surgical corridor into the posterior fossa from the middle fossa. The advantage of this approach is that most of the exposure is achieved through resection of extradural bone; hence, brain retraction is minimized.

The middle fossa approach is a useful route for resection of intracanalicular vestibular schwannomas. This corridor was initially used to resect large tumors of this type. Later, the same approach was used to treat aneurysms of the mid-BA. Detailed morphometric analysis of the local bone anatomy (dorsum sellae, internal auditory canal, jugular tubercle) has been proposed to identify an aneurysm’s location and to determine the feasibility of using this approach for access to it.

Transpetrosal Approach

The retro labyrinthine, translabyrinthine, and transcochlear approaches, which constitute the transpetrosal approaches, are typically used to treat lesions located in front of the brainstem, such as tumors or midbasilar aneurysms, following the principle of removing bone rather than retracting neural tissue. The difference between these approaches is the gradually increasing amount of resection of the mastoid process. Progressive drilling of the petrous bone exposes the anterior aspect of the brainstem, minimizing retraction and leaving the surgeon closer to the target.

Transpetrosal approaches are described in more detail elsewhere in this issue. The patient is placed supine, with the head rotated to the contralateral side, parallel to the floor, and declined slightly. The head is held in three-pin Mayfield fixation. A soft shoulder roll is placed under the ipsilateral shoulder to facilitate rotation. The head should be flexed slightly. The shoulder is taped caudally to increase the surgeon’s working room. If the patient’s habitus precludes adequate depression of the shoulder, the park bench position is used. The skin incision begins 1 cm anterior to the ear and continues in a gentle curve around the ear to just below the mastoid tip in a C-shaped fashion.

The retro labyrinthine approach only compromises the bone anterior to the sigmoid sinus and posterior to the semicircular canals (Fig. 9). To preserve hearing, the latter are skeletonized but not opened. Ligation and division of the sigmoid sinus provide additional exposure by opening a wider angle between the cerebellum and petrous bone. The translabyrinthine approach involves drilling the entire otic capsule, providing a progressively more anterior view of the brainstem; however, hearing is sacrificed. An intermediate step is the partial labyrinthectomy, which opens only the common crus. The theoretical advantage in this approach is preservation of hearing.

The transcochlear approach involves further resection of the petrous bone. The external auditory canal is closed. The otic capsule is drilled completely. The facial nerve is transected, and the cochlea is drilled. The chorda tympani and the greater petrosal superficial nerve are cut. The transotic approach is a variant of the transcochlear, in which the facial nerve is not mobilized, and therefore is highly preserved. The result is a wide avenue with the straightest pos-
possible trajectory (widest angle) to the pons and mid-BA. As bone is resected more aggressively, the risk of complications (primarily cerebrospinal fluid leaks, transitory or definitive facial nerve paralysis, and deafness) increases.

The senior author’s preference is to obtain as much exposure as possible from the orbitozygomatic or retrosigmoid approach. A far-lateral exposure is used to access the lower portions of the BA as much as possible. The mid-basilar region is accessed from a retrosigmoid craniotomy when possible. Because of their associated morbidity, use of the transpetrosal approaches is limited to selected cases of large and giant midbasilar trunk aneurysms. Furthermore, the angle of attack exposes the dome of the aneurysm rather than its neck. The neck can be exposed using a contralateral approach, but more complex clip placement techniques, including the use of fenestrated clips, become necessary. Consequently, the potential for injury to perforating vessels increases. In contrast, the orbitozygomatic or far-lateral approach exposes the aneurysm’s neck in an almost parallel trajectory with the parent vessel.
Retrosigmoid Approach

The retrosigmoid craniotomy provides a narrow opening with an angle that parallels the petrous bone. Exposure of the lateral or anterior medulla is limited. The craniotomy must be extended as laterally as possible. The sigmoid sinus is outlined so that it can be retracted to gain a couple more millimeters of exposure (Fig. 10). This approach is most often used during the resection of posterior fossa tumors, in the rare cases of aneurysms involving the AICA where it emerges from the BA,14 or for midbasilar trunk aneurysms. When a more anterior or inferior exposure is required to reach the lower two fifths of the BA, the far-lateral approach with its variants is the procedure of choice. Sometimes the retrosigmoid craniotomy is combined with an orbitozygomatic osteotomy provide the advantages associated with each approach. (Reprinted with permission from Barrow Neurological Institute.)

Far-Lateral Approach

The far-lateral approach and its variants consist of a low suboccipital craniotomy and removal of part of the ipsilat-
eral posterior arch of C-1. This combination provides a simultaneously oblique and inferior trajectory that facilitates exposure of the anterior rim of the foramen magnum, odontoid process, anterior and lateral aspects of the medulla, and the VA without the need to retract the cerebellum. This approach offers unique access to the anterior brainstem and provides excellent proximal control of the ipsilateral VA.

Multiple variations of this approach have been described and summarized by Salas, et al. Exposure of the occipital condyle ranges from nonresection during the retrocondylar approach (without drilling the occipital condyle), to progressive removal of the condyle (transcondylar approach), to the extreme-lateral transjugular approach in which the exposure includes extradural resection of the jugular tubercle above the occipital condyle (supracondylar approach). In cases of a high-riding vertebrobasilar junction, the jugular tubercle must be exposed, usually in an extradural fashion, because this bone prominence blocks access to the midclival region. Rarely, this exposure is required to access a normal vertebrobasilar junction.

The patient is placed laterally in a modified park bench position with the side to be treated facing up, and the head is placed in a three-pin Mayfield frame. The patient’s dependent arm is allowed to drop off the edge of the table and is carefully cradled in foam. A foam axillary roll is placed at the edge of the table. With the patient in this position, the ipsilateral mastoid process is the highest point in the operative field. The upper shoulder is taped, pulling it downward toward the feet and increasing the working space for the surgeon.

An inverted hockey stick incision is started at the mastoid prominence and proceeds under the superior nuchal line to the midline (Fig. 11). From there, it follows the midline down to the C-3 or C-4 spinous process. A 1-cm border of nuchal fascia and muscle is left at the edge of the upper incision to permit anatomical closure of the wound. The myocutaneous flap is retracted inferiorly and laterally with fish-hooks attached to a Leyla bar. Alternatively, a linear lateral incision can achieve the same exposure without a bulky myocutaneous flap. This type of incision, however, is associated with a higher risk of injury to the VA at the inferior aspect of the incision.

The lateral mass of C-1 and the VA are exposed, from the

Fig. 8. Photographs of a cadaveric dissection showing the right middle fossa. A: The exposure shows the Kawase area (K) after the petrous apex has been drilled. This area represents the “door” to the posterior fossa from the middle fossa. B: Once the door to the posterior fossa has been opened, the midbasilar trunk is exposed. Note the close relationship between the AICA and abducent nerve (CN VI). CN VII = facial nerve; FS = foramen spinosum; GG = geniculate ganglion; GSPN = greater superficial petrosal nerve; V1 = ophthalmic branch of the trigeminal nerve; V2 = maxillary branch of the trigeminal nerve; V3 = mandibular branch of the trigeminal nerve.

Fig. 9. Drawing showing presigmoid retrolabyrinthine craniectomy with complete skeletonization of the sigmoidal sinus, which can be transected if adequate drainage is present contralaterally on the preoperative angiogram or after pressure within the sinus has been determined before and after its temporary occlusion. CN V = trigeminal nerve; CN VI = abducent nerve; CN VIII = vestibulocochlear nerve; CN IX = glossopharyngeal nerve; CN X = vagus nerve. (Reprinted with permission from Barrow Neurological Institute.)
sulcus arteriosus of C-1 to its point of dural entry at the posterior fossa (Fig. 12A). Bleeding from the venous plexus surrounding the VA is controlled with small pieces of hemostatic material. A C-1 hemilaminectomy is performed medial to the sulcus arteriosus (Fig. 12B).

A limited suboccipital retrosigmoid craniotomy is performed (Fig. 13A). The opening extends from the margin of the foramen magnum just beyond midline as far laterally as possible and inferiorly to the foramen magnum just medial to the level at which the VA enters the dura mater. The height of the craniotomy can extend to the level of the transverse sinus as needed (combined retrosigmoid–far lateral approach), depending on the location and size of the lesion.

The lateral rim of the foramen magnum is removed with a bone rongeur or a pneumatic drill. The occipital condyle and superior lateral mass and facet of C-1 are removed with a high-speed drill (Fig. 13B). During drilling the surgeon must pay special attention to identify cortical bone first, followed by cancellous bone, and again by cortical bone as the hypoglossal canal is approached. Additional removal threatens the hypoglossal canal situated in the anterior medial third of the occipital condyle and may destabilize the condylar joint. Progressive drilling of the occipital condyle widens the surgical exposure, increases anterior access to the brainstem, and increases the angle of exposure by 30 and 40% if the occipital condyle is resected 25 or 50%, respectively, compared with a retrocondylar exposure. The stability of the craniovertebral junction is based on the integrity of articular capsules and ligaments. The ligaments insert at the occipital condyle, especially the alar ligament. Therefore, progressive removal of the condyle (> 50%) usually involves sectioning of the ligament and will cause instability. Occipitocervical fusion then becomes necessary.

Bleeding from condylar vessels can be readily controlled with bone wax and hemostatic agents. The jugular tubercle can be drilled extradurally because its presence obscures the vertebrobasilar junction (Fig. 14A).

The dura mater is opened in a curvilinear fashion with its base hinged laterally and pulled tight against the lateral aspect of the craniotomy with sutures (Fig. 14B). The extensive extradural bone removal and dural retraction allow visualization of the anteroinferior brainstem without retraction, as far rostrally as the pontomedullary junction (Fig. 14C).

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**Fig. 10.** Drawing showing a retrosigmoid craniotomy with complete exposure of the sigmoid sinus. Opening the dura mater as close as possible to the sinus allows it to be pulled and the sinus to be retracted to maximize use of this approach. The BA is located deep at the bottom of the approach. (Reprinted with permission from Barrow Neurological Institute.)

**Fig. 11.** Illustration showing two different types of skin incisions. A: A straight-line incision minimizes operative time but it is harder to maintain orientation during the procedure. The VA can be accessed quickly but is at risk during dissection of the muscle. B: A hockey stick incision typically includes a short limb that starts at the mastoid process and a longer limb that extends toward the midline up to C-3 or C-4. (From Baldwin HZ, Miller CG, van Loveren HR, et al: The far lateral/combined supra- and infratentorial approach. A human cadaveric prostatection model for routes of access to the petroclival region and ventral brain stem. J Neurosurg 81:60–68, 1994.)
Combined Supratentorial and Infratentorial Approach

The exposure of the BA provided by the transpetrosal approach can be dramatically enhanced when combined with a supratentorial approach. This combined supra- and infratentorial surgical approach can provide exposure that extends from the petrous ridge and cavernous sinus to the foramen magnum. The key elements needed for this approach are variable amounts of mastoidectomy in conjunction with a supratentorial craniotomy. Finally, the tentorium is divided to connect the supra- and infratentorial compartments. These maneuvers allow extensive exposure of the clivus, medial petrous region, and associated neural and vascular structures with minimal brain retraction. Variations of this combined approach have been described for many years.\textsuperscript{17,30,32}

A number of authors have presented their experience with variations of the combined infratentorial and posterior

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**Fig. 12.** A: Illustration showing the VA at its horizontal portion and its dural entrance. Between C-1 and C-2, the VA is under the root of C-2. During surgery this landmark can be used to localize the artery. A pneumatic drill is used to perform the laminectomy. B: Once the posterior arch of C-1 is removed, the VA is exposed. If further exposure is required, the foramen transversarium of C-1 can be drilled with a diamond drill. The VA is then mobilized medially to provide access to the occipito-C1 joint. PCEV = posterior condylar emissary vein. (From Baldwin HZ, Miller CG, van Loveren HR, et al: The far lateral/combined supra- and infratentorial approach. A human cadaveric prosection model for routes of access to the Petroclival region and ventral brain stem. \textit{J Neurosurg} \textbf{81}:60–68, 1994.)

**Fig. 13.** A: Illustration of the exposure obtained through the far-lateral retrocondylar approach. The VA is exposed from the occipital condyle to its entrance into the dura mater of the posterior fossa. To begin the craniotomy, the drill is used with a foot plate. B: Illustration showing the craniotomy, including removal of the ipsilateral posterior arch of C-1 and exposure of the dura mater. The VA is protected while the occipital condyle is drilled. When the occipital condyle is drilled, cortical bone is encountered first, followed by cancellous bone, and then cortical bone again as the hypoglossal canal is approached. (From Baldwin HZ, Miller CG, van Loveren HR, et al: The far lateral/combined supra- and infratentorial approach. A human cadaveric prosection model for routes of access to the Petroclival region and ventral brain stem. \textit{J Neurosurg} \textbf{81}:60–68, 1994.)
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Occasionally, an extensive lateral exposure of the clivus is required to treat giant aneurysms of the midbasilar or lower BA. Such an exposure can be achieved by combining the far-lateral and combined supra- and infratentorial approaches. This so-called combined–combined approach uses the same principles previously outlined for each individual procedure. The anterior and lateral aspect of the brainstem can be exposed with this complicated technique. This approach is rarely used to treat BA aneurysms; the technique has been detailed elsewhere. The combined approaches are explained in detail elsewhere in this issue.

CONCLUSIONS

Posterior fossa aneurysms are challenging lesions that require expertise in vascular and skull base surgery for their treatment. The choice of approach is based on the specific features of each aneurysm. Multiple trajectories and angles of approach are available and should be tailored on a case-by-case basis. The preferred method is to work with an angle that runs parallel to the parent vessel (that is, orbitozygomatic and far-lateral approaches). The transpetrosal and retrosigmoid approaches are limited to selected cases.

The traditional principles of skull base surgery in terms of maximizing bone resection to minimize brain retraction and to facilitate instrument manipulation apply. In aneurysm surgery, the ultimate goal is to clip the aneurysm and to exclude it from the circulation. If these goals cannot be achieved, the aneurysm can be trapped or the flow dynamics changed. It is crucial to identify preoperatively whether revascularization is indicated.

Hypothermic cardiac arrest facilitates dissection of an aneurysm from perforating arteries. The aneurysm is deflated and transmural pressure is minimal. The technique eliminates the risk of rupture and the hypothermia induced with barbiturate therapy protects the brain. Nevertheless, this complex technique is associated with high mortality and morbidity rates and should be reserved for selected patients treated only at specialized centers.

References

38. Spetzler RF, Daspit CP, Pappas CT: The combined supra-and infratentorial approach for lesions of the petrous and clival regions: experience with 46 cases. J Neurosurg 76:588–599, 1992

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