Anatomical and quantitative description of the transcavernous approach to interpeduncular and prepontine cisterns

Technical note

EBERVAL GADELHA FIGUEIREDO, M.D., JOSEPH M. ZABRAMSKI, M.D., PUSHPA DESHMUKH, PH.D., NEIL R. CRAWFORD, PH.D., MARK C. PREUL, M.D., AND ROBERT F. SPETZLER, M.D.

Division of Neurological Surgery, Barrow Neurological Institute, St. Joseph’s Hospital and Medical Center, Phoenix, Arizona

Object. The management of wide-necked, giant, or unsuccessfully coil-treated basilar apex aneurysms requires a wide exposure, for both working area and linear visualization of the basilar artery (BA). Cranial-based approaches, such as the transcavernous approach, have been proposed to deal with such aneurysms; whether abbreviated forms of this approach might provide similar exposure remains controversial. The authors examine this issue quantitatively.

Methods. Four alcohol-preserved cadaveric heads injected with pigmented silicone were prepared for bilateral dissection. After completing an orbitozygomatic craniotomy, the surgeons worked in a reverse direction, performing the transcavernous approach in five steps: 1) posterior clinoidectomy; 2) cavernous sinus opening; 3) anterior clinoidectomy; 4) cutting of the distal dural ring; and 5) cutting of the proximal dural ring.

Performing the complete transcavernous approach significantly increased the working area and linear exposure of the BA compared with abbreviated forms of the approach (p < 0.05). Opening the roof of the cavernous sinus significantly increased the working area compared with posterior clinoidectomy alone (p = 0.014); however, additional gains in exposure required completing the transcavernous approach. Resection of the anterior clinoid process combined with opening of only the distal dural ring did not significantly increase the working area or linear exposure of the BA.

Conclusions. The complete transcavernous approach significantly increases the working area and linear exposure of the BA compared with the more conservative forms of approach.

KEY WORDS • basilar artery • cavernous sinus • microsurgery • quantitative study • transcavernous approach

The management of basilar apex aneurysms remains problematic. Smaller aneurysms with good neck-to-dome ratios can be embolized with coils, but larger lesions with wide necks and those in which coil treatment has failed present a challenge to the microsurgeon who attempts direct clip application.14,22 Surgical exposure is limited by the depth of the target anatomy, the narrow working corridor, and the difficulty of obtaining proximal control of the BA. Obtaining sufficient exposure for safe clip placement may be especially demanding in cases with a low-lying basilar apex.

The classic approach to basilar apex aneurysms has been subtemporal, ptorial, or variants thereof.3,4,6–8,10,11,13,17,18,21,24 These approaches provide widened superficial exposure but cannot enlarge the area of exposure near the lesion. These avenues present drawbacks to surgeons treating low-lying basilar apex aneurysms obscured by the dorsum sellae or clivus.

More “dramatic” skull base approaches to access such aneurysms have been described, including anterior petrosectomy and the transcavernous approach.1,2,5,12,16,20 These alternatives may be considered basal extensions of the subtemporal and ptorial approaches, respectively.

We divided the transcavernous approach, as described by Dolenc and coworkers,2 into five major steps: 1) drilling the anterior clinoid; 2) cutting the distal dural ring; 3) cutting the proximal dural ring; 4) opening the cavernous sinus; and 5) drilling the posterior clinoid process and dorum sellae. Together these steps theoretically provide a wider area of deep anatomical exposure. Some controversies exist over whether each step of the transcavernous approach is actually necessary, or whether a more conservative approach, which avoids some of the steps, could provide the same exposure. Youssef, et al.,26 recently showed that the carotid–oculomotor window can be widened by performing a posterior clinoidectomy and an anterior clinoidectomy. These authors, however, analyzed the “paracavernous approach” and did not include all the steps of the transcavernous approach. Reports by Seoane, et al.,20 and Chanda and Nanda1 showed that the transcavernous approach increases the length and angle of exposure of the BA. However, in no study have the authors assessed each step of the transcavernous approach separately.

Abbreviations used in this paper: AICA = anterior inferior cerebellar artery; BA = basilar artery; ICA = internal carotid artery; PCA = posterior cerebral artery; PICA = posterior inferior cerebellar artery; SCA = superior cerebellar artery.

To determine whether all steps of the trans cavernous approach are essential, or if one or more steps can be eliminated, we evaluated the trans cavernous approach using quantitative and anatomical data. Specifically, we measured the working area and linear exposure of the BA after each major step of the trans cavernous approach was completed. We also “qualitatively” evaluated the anatomical exposure for each step by using a grading system based on the visualization of neurovascular structures.

As originally described by Dolenc et al., the trans cavernous approach progresses in an anterior-to-posterior direction, beginning with resection of the anterior clinoid process and ending with drilling of the posterior clinoid process. To quantify the individual effects of each trans cavernous approach step and to determine whether any step could be eliminated, we worked in a reverse direction: we began with resection of the posterior clinoid process and ended with mobilization of the ICA.

Materials and Methods

Four embalmed, alcohol-preserved cadaveric heads (eight sides), perfused with colored silicon and without known intracranial diseases, were used in this study. Before undergoing bilateral dissection, each head was rigidly fixed in a Mayfield headholder in a position simulating the actual surgical approach. The procedures were performed using standard microsurgical instruments and a floor-standing surgical microscope. A high-speed drill was used to drill the bone, and osteotomies were made using a reciprocating saw (Midas Rex; Medtronic, Fort Worth, TX). An arcuate scalp incision was started at the base of the zygomatic arch and extended beyond the midline. A standard pterional craniotomy was opened, and an orbitozygomatic osteotomy was performed as described by Zabramski and colleagues. The dura mater was opened in a standard fashion (C-shaped incision based anteriorly), and the sylvian fissure was widely split distally to proximally. The bifurcation of the ICA was visualized, and the adhesions between the oculomotor nerve and uncus were dissected. The Liliequist membrane was opened, and the posterior communicating artery was followed to its junction with the PCA and BA apex.

The main goal of the protocol was to measure the effect of each step of the trans cavernous approach on the amount of BA exposure. Although some of the bone drilling necessitated performing the Dolenc steps out of sequence, we reproduced the trans cavernous approach as much as possible, working in a progressive, reversed, five-step process in the four heads (eight sides): 1) posterior clinoidectomy; 2) opening of the roof of the cavernous sinus medially and parallel to the oculomotor nerve and further drilling of the posterior clinoid and dorsum sellae; 3) anterior clinoidectomy and amplification of Steps 1 and 2, as needed; 4) opening of the distal dural ring; and 5) opening of the proximal dural ring. Further amplification of each previous step was performed to maximize exposure of the BA.

Quantification of the Working Area

The Optotrak 3020 system (Northern Digital, Waterloo, ON, Canada), with a six-marker digitizing probe and accompanying software, was used to quantify the working area of exposure of the BA. We defined five different points to measure the working area after each step of trans cavernous approach. Point 1 was the distal-most point of visualization of the ipsilateral PCA. Point 2 was the distal-most point of visualization of the contralateral PCA. Point 3 was the distal-most point of visualization of the ipsilateral SCA. Point 4 was the distal-most point of visualization of the contralateral SCA. Finally, Point 5 was the most proximal point of visualization of the BA (Fig. 1).

A data point was acquired by touching the tip of the digitizing probe to the anatomical points of interest while the markers on the probe were in view of the camera. The head was fixed rigidly in a three-point headholder to ensure that it remained in the same cartesian coordinate system as the Optotrak. A personal computer connected to the Optotrak system stored data files in the form of x, y, and z coordinates (in mm) of each vertex. The retractor was secured permanently to prevent measurement errors while the points were spatially located. Thus, an area of exposure typically approximating a pentagon was measured for each step without changing the retraction, starting with drilling of the posterior or clinoid process. The working area of exposure was calculated by treating Point 4 (Fig. 1) as the common vertex of three juxtaposed triangles (Triangle 1 formed by Points 2, 3, and 4; Triangle 2 formed by Points 1, 2, and 4; and Triangle 3 formed by Points 1, 4, and 5) and summing the triangular areas. We also measured the linear exposure of the BA from the basilar apex to the most proximal point of visualization (Fig. 2).

Neurovascular structures visible after each step of the approach were identified to describe the approach qualitatively according to a numerical grading system described by Kawashima et al. A value of 0 refers to a structure that is not exposed, whereas a value of 3 indicates that a structure is exposed in 100% of the specimens. Values of 1 and 2 indicate that the structure is exposed in less than 50% or more than 50% of the specimens, respectively. The neural structures were the ipsilateral and contralateral third, fourth, fifth, sixth, and seventh/eighth cranial nerves. The vascular structures were the ipsilateral and contralateral PCAs, SCAs, AICAs, and PICAs.

Figure 3 illustrates the steps of the procedure. Dissection was initiated by opening the dura mater over the posterior clinoid process and drilling away as much of this clinoid process as possible. The dura behind the resected posterior clinoid process was opened to expose the BA, the ventral surface of the brainstem, and the interpuduncular and preoptic cisterns (Fig. 3B). These neurovascular structures were then identified and measured.

The roof of the cavernous sinus was opened by incising the dura in the oculomotor trigone, medial and parallel to the oculomotor nerve and lateral to the ICA. The dural incision was brought forward to the anterior clinoid process (Fig. 3C). The dorsum sellae and clivus were resected further. The neurovascular structures were again identified and measured. The anterior clinoid process was drilled using an intradural approach, allowing further opening of the cavernous sinus and additional drilling of the clivus (Fig 3D). After exposure data were acquired, the distal dural ring of the ICA was cut. The microscope was relocated to a more craniofacial perspective, and exposure data were again collected. In the same fashion, the proximal dural ring was di-

J. Neurosurg. / Volume 104 / June, 2006
vided to mobilize the ICA, and the final exposure data were collected (Fig. 3E).

**Statistical Analysis**

Friedman repeated measures analysis of variance on ranks followed by the Dunn method was used to evaluate the linear exposure of the BA. A one-way repeated measures analysis of variance followed by the Holm–Sidak method was used to determine significant differences between the exposure areas. All tests were performed using
Results

Linear exposures of the BA obtained after each of the five steps are shown in Table 1. There were statistically significant differences between Step 1 (posterior clinoidectomy) and Step 5 (completed approach) and between Step 2 (posterior clinoidectomy plus opening the cavernous sinus) and Step 5 (p < 0.05). Comparisons of linear exposure between other steps failed to show any statistical differences.

Results for the working area of exposure of the BA are shown in Table 2. Step 5 significantly increased the working area compared with that obtained after each of the other steps (p < 0.001, between Steps 1 and 5; p = 0.013, between Steps 2 and 5; p = 0.05, between Steps 3 and 5; and p = 0.014, between Steps 5 and 4). Steps 2, 3, and 4 significantly improved the working area compared with Step 1 (p = 0.003, p = 0.001, and p = 0.006, respectively). However, there were no statistical differences in the working area of exposure between Steps 2 and 3, Steps 3 and 4, and Steps 2 and 4.

In general, contralateral anatomical structures were visualized better than those ipsilateral to the side of the approach (Table 3). On the contralateral side, the PCA, SCA, AICA, and the third, fourth, and fifth cranial nerves were seen in more than half of the specimens after Step 3, and in all specimens after Step 4. The contralateral seventh cranial nerve could be seen in more than 50% of the specimens after Step 3, but further dissection failed to improve visualization. The fourth, fifth, and seventh cranial nerves were never well visualized on the ipsilateral side. After Step 4, however, visu-
Quantitative description of transcavernous approach

### TABLE 1

**Linear exposure of the BA via the transcavernous approach**

<table>
<thead>
<tr>
<th>Steps of Procedure*</th>
<th>Linear Exposure of the BA (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.07 ± 5.48</td>
</tr>
<tr>
<td>2</td>
<td>13.91 ± 5.16†</td>
</tr>
<tr>
<td>3</td>
<td>14.42 ± 5.11</td>
</tr>
<tr>
<td>4</td>
<td>15.72 ± 4.48</td>
</tr>
<tr>
<td>5</td>
<td>18.87 ± 5.76†</td>
</tr>
</tbody>
</table>

* Step 1, drilling the posterior clinoid process; Step 2, opening the cavernous sinus; Step 3, drilling the anterior clinoid process; Step 4, opening the distal ring; Step 5, opening the proximal ring.
† Significant differences in linear exposure of the BA were found between Steps 1 and 5 and between Steps 2 and 5 (p < 0.05).

### TABLE 2

**Working area of exposure of the BA via the transcavernous approach**

<table>
<thead>
<tr>
<th>Steps of Procedure</th>
<th>Area of Exposure (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>198.43 ± 43.54</td>
</tr>
<tr>
<td>2</td>
<td>292.21 ± 66.71*</td>
</tr>
<tr>
<td>3</td>
<td>293.31 ± 67.80</td>
</tr>
<tr>
<td>4</td>
<td>312.25 ± 139.98</td>
</tr>
<tr>
<td>5</td>
<td>376.60 ± 92.98†</td>
</tr>
</tbody>
</table>

* Step 2 significantly improved the working area compared with Step 1 (p = 0.003). There was no statistical difference in the working area between Steps 2 and 3 (p = 0.524), Steps 3 and 4 (p = 0.547), and Steps 2 and 4 (p = 0.972).
† Step 5 significantly increased the working area compared with each of the other steps (Steps 1 and 5, p < 0.001; Steps 2 and 5, p = 0.013; Steps 3 and 5, p = 0.05; Steps 4 and 5, p = 0.014).

### Discussion

Aneurysms of the basilar apex (basilar tip and SCA), which are responsible for more than half of the aneurysms occurring in the posterior circulation, represent a major surgical challenge. The narrow corridor, presence of essential adjacent nerves and vessels, and difficulty in obtaining proximal control all contribute to the difficulty of surgical management. Translateralization of vascular structures was similar both ipsilateral and contralateral to the side of dissection.

### Evolution of Approaches to Basilar Apex Aneurysms

Drake pioneered the development of surgery for basilar apex aneurysms and described a subtentorial route for their treatment. Yasargil reported operative outcomes with basilar apex aneurysms approached via a petrosal–transsylvian anastomotic approach. These approaches provide adequate exposure for placing clips to treat uncomplicated basilar apex aneurysms. However, exposure is inadequate for low-lying basilar apex aneurysms or for giant aneurysms when temporary clip treatment of the proximal BA may be necessary to dissect perforating vessels from the neck of the aneurysm. Additional exposure is also helpful to surgeons treating aneurysms that had been previously occluded with coils.

Dolenc, et al., described the transcavernous approach as a means of obtaining exposure of the BA and its proximal branches as far proximal as the AICAs, with minimal retraction of the brain. They proposed that the transcavernous approach could be used in place of the translival approach to the upper half of the BA. These authors stated, “Removal of dispensable osseous structures affords ample space for manipulation around the lesion and makes preservation of important adjacent nerves and vessels possible.”

Subsequently, Seoane, et al., modified Dolenc’s original technique by performing an orbitozygomatic craniotomy and utilizing a “pretemporal” surgical avenue to the cavernous sinus region. Chanda and Nanda also have used an orbitozygomatic trajectory to perform the transcavernous approach. Nonetheless, the intracranial steps remain unmodified from Dolenc and colleagues’ original description. Whether the anterior clinoid process is removed intra- or extradurally makes no difference in the resulting exposure.

### Assessing the Transcavernous Approach

Although some authors have used the transcavernous approach with excellent results, most neurosurgeons are unfamiliar with this approach. Furthermore, some have questioned its usefulness and have argued whether a complete approach is needed to achieve the desired exposure. Yasargil advocated resection of the posterior clinoid process to improve the area of exposure to retrosellar lesions. Anterior clinoidectomy, with or without opening of the orbital roof and optic canal, has also been proposed as a technique for approaching these aneurysms. Youssef, et al., proposed a paracavernous approach, which consists of drilling the posterior and anterior clinoid processes and mobilizing the ICA (without cutting the proximal dural ring). The aforementioned procedures can be understood as portions of the complete transcavernous approach.

### Quantitative Analysis of the Transcavernous Approach

The goal of the transcavernous approach is to maximize bone resection near the target and thus increase exposure of the BA. It seems intuitive that such an extensive approach would significantly increase both exposure of the BA and the working area in the interpeduncular and preopticine cisterns. However, no quantitative analyses support this assumption. Seoane, et al., and Chanda and Nanda showed that linear exposure can be increased after the transcavernous approach. However, they neither studied the effects on anatomical exposure after each step nor measured the areas of exposure.

By using a quantitative methodology, including a com-
The Transcavernous Approach Significantly Improves Surgical Exposure

In this study, performing the complete transcavernous approach, as outlined by Dolenc, et al., significantly increased the area of surgical exposure and linear exposure of the BA compared with abbreviated forms of the approach. Opening the roof of the cavernous sinus significantly increased the area of exposure when compared with posterior clinoidectomy alone (p = 0.007); however, additional gains in exposure required completing the transcavernous approach. Resection of the anterior clinoid process combined with opening of the distal dural ring, as described by Youssef, et al., did not significantly increase the working area or linear exposure of the BA; it was also necessary to cut the proximal dural ring. Mobilizing the ICA by cutting both distal and proximal dural rings provides the surgeon with a wider field of visualization in the lateral-to-medial and craniocaudal planes (Fig. 4). Mobilizing the ICA early in the approach, as originally described by Dolenc, et al., also allows for safer bone drilling of the posterior clinoid process and clivus.

Anatomical data from this study showed that more anatomical structures can be visualized as the approach progresses from Steps 1 to 4 and that contralateral anatomical targets were visualized better than ipsilateral ones. The anteromedial route of the transcavernous approach may explain the superior visualization of contralateral anatomical structures.

Clinical Considerations

At our institution, this approach is reserved for the management of large or low-lying aneurysms of the upper BA. For giant aneurysms involving the basilar apex, we prefer to use hypothermic circulatory arrest, which allows complete collapse of the aneurysm during final dissection and clip occlusion.

An orbitozygomatic craniotomy and initial exposure of the aneurysm are completed before performing any of the steps of the transcavernous approach. For many aneurysms, removal of the posterior clinoid process provides sufficient exposure to allow proximal control and clip application. Proximal control for temporary vessel occlusion is particularly critical in large, posteriorly projecting aneurysms, as it softens the aneurysm dome, allowing it to be safely manipulated during dissection and clip placement in the aneurysm neck. This step is critical to ensure that none of the vital perforating branches supplying the brainstem and thalamus in this region are trapped in the clip blades. If exposure remains inadequate, we open the dura of the cavernous sinus parallel to the medial border of the oculomotor nerve and lateral to the ICA, which allows additional bone resection of the dorsum sellae and clivus, thus improving access. Beyond this step, significant additional exposure can be gained only by completing all remaining steps of the transcavernous approach. Completing the transcavernous approach requires resection of the anterior clinoid process and opening of the proximal and distal dural rings. With the carotid artery mobilized, additional drilling of the clivus and dorsum sellae is possible.

The opening of the dura over the posterior roof of the cavernous sinus and drilling of the posterior clinoid process and clivus require an intimate understanding of the anatomical relationship of these structures to the cavernous portion of the carotid artery, which lies very near these structures. Appreciation of these details can be gained only by careful dissection in a cadaver laboratory.

Manipulation of the third cranial nerve, inherent in this approach, results in near-universal oculomotor paresis; however, in most patients this resolves in 6 to 12 weeks. Injury to the cavernous portion of the carotid artery and to the second and fourth cranial nerves is also a potential complication of this approach. In light of these risks, endovascular management should be considered for all low-lying and posteriorly projecting aneurysms with suitable vascular anatomy and favorable neck-to-dome ratios. The best approach includes a neurovascular team with experienced mi-
crosurgical and endovascular specialists meeting to discuss each case on a patient-by-patient basis. Factors that should be considered are patient age, medical risk factors, history (ruptured or unruptured), and the size and projection of the aneurysm. For the microsurgeon, clip application is much more difficult for aneurysms that project posteriorly. Endovascular therapy should be considered first for these lesions. On the other hand, endovascular therapy of large aneurysms and those with unfavorable neck-to-dome ratios is associated with high rates of recurrence. Aneurysms that recur after endovascular therapy are difficult to treat surgically because the coil mass may prevent the clip blades from closing across the aneurysm neck. For basilar apex aneurysms, successful clip occlusion may then require hypothermic circulatory arrest, opening of the aneurysm, and removal or mobilization of coils to provide a suitable neck for obliteration.

Limitations of the Study

Cadaveric tissues, such as the heads used in this study, possess inherent limitations. Properties of formalin-fixed tissues differ from those of living tissue in terms of the firmness of the brain and other structures. Such factors can affect the results through retraction or shrinkage of structures. Nevertheless, quantitative studies on cadaveric tissues provide an important source of data for evaluating the role of specific surgical approaches, particularly technically difficult approaches such as the transcavernous approach. Furthermore, this quantitative and anatomical study does not address the clinical risks of the transcavernous approach.

Conclusions

The anatomical and quantitative data from this study demonstrate that the complete transcavernous approach significantly increases the working area and linear exposure of the BA compared with abbreviated forms of the approach. The area of exposure provided by posterior clinoidectomy may be improved significantly by opening the cavernous sinus and increasing bone removal. However, additional increases in exposure require performing the complete transcavernous approach.

Despite its technical difficulty, the transcavernous approach should be considered for the surgical management of low-lying basilar apex and SCA aneurysms, and for giant or recurrent BA aneurysms in which proximal vascular control would be helpful during dissection and clip placement.

References


Manuscript received March 7, 2005. Accepted in final form January 11, 2006. Address reprint requests to: Joseph M. Zabramski, M.D., c/o Neuroscience Publications, Barrow Neurological Institute, 350 West Thomas Road, Phoenix, Arizona 85013. email: neuropub@chw.edu.