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Petrosal approaches to posterior circulation aneurysms

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Complex posterior circulation aneurysms are formidable lesions with an abysmal natural history. Their management continues to present a challenge to both endovascular and open microsurgical approaches. Affording an expansive, combined supra- and infratentorial exposure, the petrosal approaches are well suited for these challenging lesions when located along the basilar trunk or at a low-lying basilar apex. This report evaluates the evolution and application of petrosal approaches to these lesions. Excluding transsigmoid, infratentorial, or labyrinth-sacrificing approaches, the authors found 23 reports with 61 posterior circulation aneurysms treated via a petrosal approach. Although early morbidity was not negligible, rates of aneurysm occlusion (95% overall) and long-term outcome were quite laudable in light of the challenge posed by these lesions. Moreover, with accumulating experience with petrosal approaches, rates of complications are likely to wane, as neurosurgeons capitalize on the expansive exposure afforded by these indispensable approaches.

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Key Words • **petrosal** • **retrolabyrinthine** • **presigmoid** • **skull base** • **Kawase** • **combined approach** • **aneurysm**

With a notoriously malevolent natural history,[2,39,45,61] complex posterior circulation aneurysms often merit treatment, unless contraindicated by patient age or medical comorbidities. Although endovascular approaches have facilitated safe treatment of narrow-necked aneurysms of the posterior circulation, more complex, larger lesions remain a significant challenge for either endovascular or microsurgical approaches.[14,15,18,44,45,52] Recent enthusiasm for endovascular flow-diverting stents has been curbed by poorly explained delayed aneurysm rupture and even remote lobar hemorrhages.[9,34] Employed as a necessary means to curb thromboembolic complications, requisite dual antiplatelet therapy relatively contraindicates usage of endovascular stent placement in instances of acute subarachnoid hemorrhage.[58,60] In this setting, plagued by the specter of early rerupture, the cerebrovascular neurosurgeon must safely expose these complex aneurysms and adjacent vital perforators while navigating an edematous, "angry" brain.

Minimizing retraction, shortening the trajectory, and affording expansive exposure of complex lesions in the posterior fossa, petrosal approaches are indispensable tools in the armamentarium of any skull base cerebrovascular neurosurgeon.[1,21,26,50,55] Lauded for their usage in the management of complex neoplastic lesions such as meningiomas, schwannomas, and chordomas,[1,10,13,19–21,26,48,50,55] petrosal approaches have also been employed for decades in the management of complex cerebrovascular lesions, particularly posterior circulation aneurysms.[4,11,30,31,37,43,50] In this manuscript, we review the evolutionary application of the standard anterior and posterior petrosal approaches to complex posterior circulation aneurysms.

Historical Perspective

Aneurysms of the basilar trunk were once considered to be in "no man's land;" they have historically posed a remarkable challenge in both exposure and clip reconstruction.[44] Attempted exposure via a subtemporal transtentorial route may place undue traction on the temporal lobe, while a retrosigmoid approach often necessitates excessive retraction of the cerebellum, only to provide a deep, narrow corridor, guarded by the cranial nerves. Reports of transoral, transclival approaches to these lesions from Fox[16] and Sano et al.[49] surfaced in the late 1960s; however, the limited width and extreme depth of this exposure, coupled with prohibitive rates of postoperative CSF leakage and meningitis,[47,62] largely led to the abandonment of this route. Fortunately, at a similar time, Hitselberger and House were cultivating the middle fossa approach[27] as well as a transsigmoid approach with lateral petrosectomy for lesions of the cerebellopontine angle.[25] These early neurotological reports paved the groundwork for modern anterior and posterior petrosal approaches. In experienced hands, the former approach is an ideal choice for low-lying basilar apex and upper basilar trunk aneurysms. Lower basilar trunk aneurysms may be approached by the posterior petrosal approach. A summary of demographic and outcome data for 61 patients with posterior circulation aneurysms treated via a petrosal approach in 23 reports spanning 3 decades is provided in Table 1. This summary excludes studies employing transsigmoid infratentorial approaches[12,17,46] and those with approaches sacrificing all or part of the labyrinth.[5,6,8,14,18,51,52,57]

Anterior Petrosal Approach

An extension of the middle fossa approach,[27] the anterior petrosal approach, originally described by Bochenek and Kukwa in 1975,[7] was initially applied to basilar aneurysms by Kawase in 1985.[31] Prior to the "Kawase approach," low-lying basilar apex and upper basilar trunk aneurysms would often be exposed via a subtemporal-transtentorial approach with added traction placed on the temporal lobe.[31,37,44] This approach provides the addition of an extradural petrous apicectomy.[7,31] A combined supra- and infratentorial exposure is afforded after dividing the tentorium posterior to the entry of the fourth cranial nerve and ligating and dividing the superior petrosal sinus with a perpendicular dural incision. Although some prefer intradural removal of the petrous apex to tailor the amount of bone removed,[23,56] we prefer the traditional extradural petrous apicectomy as it requires less temporal lobe retraction and poses less risk to the temporal bridging veins. In a thoughtful morphometric analysis, MacDonald et al.[37] demonstrated that drilling the petrous apex provided an additional 1–1.5 cm of basilar artery exposure. Another anatomical study demonstrated its caudal extent terminating 18 mm below the floor of the sella at the level of the internal auditory meatus.[4] This reinforces the limited applicability of this approach for lower basilar trunk aneurysms. Nevertheless, the Kawase approach is particularly advantageous for basilar apex and upper basilar trunk aneurysms.

Results of the application of this approach to 27 patients with posterior circulation aneurysms are provided in Table 2.[4,23,28–31,37,38,56,59] This table provides historical perspective on the application of this approach, spanning 3 decades, as some reports are inclusive of earlier reports from the 1980s.[4,30,31] Aneurysm remnants were reported in 3 cases (11%) after treatment. Early morbidity was reported in 18 cases (67%). New cranial nerve deficits were reported in 13 cases (48%), and the CSF leak rate was 4% (1 of 27 cases). The most common new cranial nerve deficit was a sixth cranial nerve palsy (22%). Permanent morbidity was reported in 10 cases (37%), although it was most commonly from perforator infarction (22%); no patient died. There was 1 case (4%) of permanent hearing loss attributed to excessive petrous bone resection in an effort to expose a vertebrobasilar junction aneurysm.[30]

Posterior Petrosal Approach

While the anterior petrosal approach may be limited

TABLE 1: Summary of results for posterior circulation aneurysms treated via a petrosal approach*

Variable	Anterior Petrosal	Posterior Petrosal	Total
no. of patients	27	34	61
no. of studies	9	14	23
mean pt age (yrs)	49.1 ± 10.6	49.2 ± 14.1	49.2 ± 12.6
female sex	13/27 (48)	20/34 (59)	33/61 (54)
unruptured	3/27 (11)	7/34 (21)	10/61 (16)
ruptured†	24/27 (89)	27/34 (79)	51/61 (84)
Grade I†	5/24 (21)	3/22 (14)	8/46 (17)
Grade II†	9/24 (38)	6/22 (27)	15/46 (33)
Grade III†	7/24 (29)	8/22 (36)	15/46 (33)
Grade IV†	2/24 (8)	5/22 (23)	7/46 (15)
Grade V†	1/24 (4)	0/22 (0)	1/46 (2)
location			
basilar apex	9/27 (33)	1/34 (3)	10/61 (16)
basilar trunk	10/27 (37)	19/34 (56)	29/61 (48)
AICA	4/27 (15)	5/34 (15)	9/61 (15)
VBJ	4/27 (15)	8/34 (24)	12/61 (20)
P2	0/27 (0)	1/34 (3)	1/61 (2)
size‡			
small	12/22 (55)	6/23 (26)	18/45 (40)
large	10/22 (45)	11/23 (48)	21/45 (47)
giant	0/22 (0)	6/23 (26)	6/45 (13)
complete occlusion	24/27 (89)	34/34 (100)	58/61 (95)
early morbidity	18/27 (67)	21/34 (62)	39/61 (64)
new CN deficit	13/27 (48)	14/34 (41)	27/61 (44)
CN IV	4/27 (15)	4/34 (12)	8/61 (13)
CN VI	6/27 (22)	8/34 (24)	14/61 (23)
CN VII	3/27 (11)	6/34 (18)	9/61 (15)
hearing loss	2/27 (7)	1/34 (3)	3/61 (5)
CSF leak	1/27 (4)	7/34 (21)	8/61 (13)
permanent morbidity	10/27 (37)	5/34 (15)	15/61 (25)
perforator infarction	6/27 (22)	2/34 (6)	8/61 (13)
new CN deficit	5/27 (19)	4/34 (12)	9/61 (15)
CN IV	1/27 (4)	1/34 (3)	2/61 (3)
CN VI	2/27 (7)	2/34 (6)	4/61 (7)
CN VII	2/27 (7)	3/34 (9)	5/61 (8)
hearing loss	1/27 (4)	0/34 (0)	1/61 (2)
mortality	0/27 (0)	3/34 (9)	3/61 (5)

* Values represent numbers of cases (%) unless otherwise indicated. Means are presented ± SD. Abbreviations: AICA = anterior inferior cerebellar artery; CN = cranial nerve; P2 = P2 segment of posterior cerebral artery; pt = patient; VBJ = vertebrobasilar junction.

† Hunt and Hess Grade; not specified for all patients. Percentages for each grade reflect percentage of patients with ruptured aneurysms at each grade.

‡ Not specified for all patients.

TABLE 2: Posterior circulation aneurysms treated via an anterior petrosal approach*

Authors & Year	Pt Age (yrs), Sex	HH Grade	Aneurysm Size† & Location	Approach Notes	Results
Harsh & Sekhar, 1992		II	basilar apex		worse from perforator infarct
		V	basilar apex		improved, no complications
Inoue et al., 1992	41, F	II	small AICA		transient CN V & VII deficits, intact at 8 mos
Mizoi et al., 1994	40, M	II	large basilar trunk	adjunct TBO	excellent
Kato et al., 1996	46, M	I	large VBJ	circ arrest	CN VI & VII deficits, HP
	41, M	I	large VBJ	circ arrest, residual	transient CN VI deficit
Kawase et al., 1996‡	46, F	I	small basilar trunk		excellent
	58, M	I	small basilar trunk		excellent
	43, F	III	large AICA		transient bilat CN V & VI deficits—intact at 3 mos
	64, M	I	small AICA	residual	excellent
	49, F	II	small VBJ	added bone resection	CSF leak, hearing loss, partial CN VI & VII deficits at 3 mos
	53, F	II	large VBJ		hearing loss, transient CN VI deficit
	58, M	III	large basilar trunk		brainstem stroke—HP
	67, F	II	large basilar trunk		brainstem stroke—severely disabled
MacDonald et al., 1998	42, F	III	basilar apex		worsened CN III deficit
	37, F	II	large basilar apex		mild CN IV deficit
	45, M	III	basilar apex		excellent
Aziz et al., 1999	40, M	II	large basilar apex		excellent
	41, M	III	small basilar apex		transient CN IV & V deficits
	45, F	II	large basilar apex		meningitis, good recovery
	43, M	0, ASx	small basilar trunk		transient CN IV deficit
	51, M	0, HP	small basilar apex		brainstem stroke—severely disabled
	54, M	0, ASx	small basilar trunk		transient CN III & V deficits
	61, F	III	small basilar trunk		transient CN IV deficit, permanent HP
Terasaka et al., 2002	62, F	III	basilar trunk	ECA-PCA bypass	transient CN VI deficit, delayed infarct causing HP at 2 mos
Steiger et al., 2006	29, F	IV	small basilar trunk		improved
	73, F	IV	small AICA	residual	improved

* ASx = asymptomatic; circ = circulatory; ECA-PCA = external carotid artery–posterior cerebral artery; HH = Hunt and Hess; HP = hemiparesis; TBO = transient balloon occlusion.
† Not specified for all patients.
‡ Includes results from Kawase et al.[31] (study published in 1985) and data that Kawase subsequently provided for Aziz et al.[4] (study published in 1999).

in its caudal exposure for lower basilar trunk aneurysms, retrosigmoid approaches are limited by a deep, narrow operative field often requiring cerebellar retraction and encumbered by the middle cranial nerves. These limitations led to the development of presigmoid approaches to basilar trunk aneurysms in the latter half of the 1980s.[17] Early applications of presigmoid exposures to posterior circulation aneurysms were based on transsigmoid, infratentorial approaches.[17,46] These exposures are limited superiorly by the tentorium and rely on the feasibility and safety of dividing the sigmoid sinus. In our experience, dividing the sigmoid sinus is unnecessary, as it can be preserved and mobilized instead with the modern posterior petrosal approach.[1,13]

The modern posterior petrosal approach is based on a combined supra- and infratentorial exposure.[1] The concept of performing a temporooccipital craniotomy and mobilizing a skeletonized sigmoid sinus after dividing the superior petrosal sinus and tentorium, the crucial maneuver of this approach, was originally devised by Hakuba in 1977.[21] In this original account, Hakuba performed a partial labyrinthectomy prior to the division of the sinus and tentorium in an approach serving as the early predecessor to the modern transcrusal approach.[8,26] Although hearing is not ubiquitously sacrificed, it is now well known that this approach does pose a significant threat to postoperative hearing function.[9,52] In contrast, the modern posterior petrosal approach entails a presigmoid retrolabyrinthine exposure with exceedingly high rates of preservation of postoperative hearing, as demonstrated in this report and many others.[1,33,48,50]

In comparison with the anterior petrosal approach, an anatomical study revealed that the posterior petrosal approach afforded an additional 6 mm of caudal exposure below the floor of the sella, essentially to the level of the upper jugular tubercle.[4] In the context of posterior circulation aneurysms, such an approach affords better proximal exposure and control along the basilar trunk.[43] Capitalizing on bone removal in lieu of retraction, these approaches are particularly advantageous in the context of a swollen brain after subarachnoid hemorrhage. In addition, the perforators are more easily visualized,[40] and most importantly, the working distance to the target is lessened.

Cerebrovascular applications of the posterior petrosal approach were largely popularized by the report of Spetzler et al. in 1992.[55] In addition to evaluating applications to neoplastic lesions, this report illustrated the successful usage of petrosal approaches to aneurysms, arteriovenous malformations, and cavernous malformations.[55] In our review of the literature, we found 34 cases of posterior circulation aneurysms treated via the standard retrolabyrinthine posterior petrosal approach reported in 14 studies over the course of 2 decades (Table 3).[3,6,11,12,14,22,24,32,40,42,43,50,54,56] All aneurysms were completely occluded. In addition, although early morbidity was high (62%; 41% in the form of cranial nerve deficits), it was often transient. Specifically, permanent morbidity was seen in 15% of patients, with 12% suffering permanent cranial nerve deficits. The mortality rate was 9%. Of particular note, no patient suffered permanent hearing loss from this approach. Interestingly, the CSF leak rate from this approach was 21%. Although this may be reflective of an increased tendency to develop CSF leaks in patients with subarachnoid hemorrhage, it does contrast with most recent literature describing markedly lower rates,[1,33,35,41] likely reflective of a learning curve with this approach and encouraging continued cultivation

TABLE 3: Posterior circulation aneurysms treated via the posterior petrosal retrolabyrinthine approach*

Authors & Year	Pt Age (yrs), Sex	HH Grade	Aneurysm Size & Location	Approach Notes	Results
Solomon et al., 1991	49, F	I	giant basilar trunk	circ arrest	excellent outcome
Spetzler et al., 1992	58, M	III	giant basilar trunk		no complications
King et al., 1993	58, M	SAH	small AICA		transient CN VI & VII deficits, permanent CN IX & X deficits
	68, M	SAH	AICA		transient CN VI deficit
	56, F	0	basilar apex		transient CN VI deficit & HP
	58, M	SAH	VBJ		transient CN VI deficit
Origitano et al., 1993	53, M	IV	giant AICA	trapped	brainstem infarct
	58, F	III	VBJ		transient CN IX & X deficits
Collice et al., 1997	60, F	III	VBJ		excellent
	53, F	IV	VBJ		transient CN IV & X deficits, permanent CN VII deficit
	61, F	IV	VBJ		no surgical complications, death from sepsis
Day et al., 1997	79, F	SAH	large basilar trunk		excellent
Arai et al., 1998	56, F	SAH	basilar trunk		mild CN VII deficit
Motoyama et al., 2000	53, F	0	large basilar trunk		transient CN VI deficit
Ng & Yeo, 2000	7, F	0	large P2	trapped	transient CN IV deficit
Seifert et al., 2003	47, M	I	small basilar trunk		transient hearing loss, CSF leak, transient CN VII deficit
	40, M	II	large basilar trunk		transient CN VII deficit, CSF leak
	42, M	0	giant VBJ		CSF leak
	42, M	IV	basilar trunk		brainstem infarct, death
	19, F	III	small basilar trunk		excellent
	66, M	II	large basilar trunk		CSF leak, CN VI & VII paresis, poor outcome
	46, F	II	large VBJ		excellent
	56, M	0	giant basilar trunk		CSF leak
	30, M	IV	large basilar trunk		no complications
	42, M	II	small VBJ		excellent
	25, F	III	large basilar trunk		no complications
	44, F	III	large basilar trunk		CSF leak
	45, F	III	small basilar trunk		excellent
	49, F	I	large basilar trunk		transient CN VI deficit
	41, F	II	basilar trunk		excellent
Evans et al., 2004	62, F	0	giant basilar trunk		graft spasm & return to OR, death from sepsis
Hamel et al., 2005	44, M	III	basilar perforator		tension pneumocephalus & CSF leak
Bambakidis et al., 2009	58, F	0	large AICA		transient CN VI & VII deficits
Higa et al., 2009	48, F	II	small AICA		good recovery

* OR = operating room; SAH = subarachnoid hemorrhage.

and experience with it. Indeed, this point was underscored by the largest study we reviewed, which showed a learning curve and gradual diminution in CSF leak rates with time.[50]

Sparse reports of extended posterior petrosal approaches to posterior circulation aneurysms, sacrificing all or part of the labyrinth, are present in the literature.[5,6,8,14,18,51,52,57] Approach-related morbidity in the form of cranial nerve deficits was seen in nearly all cases, even in cases of partial labyrinthectomy.[14,52] In addition, most patients treated with complete petrosectomy suffered long-term facial nerve palsies.[6,18] These results reinforce the intuitive point that labyrinth-sacrificing approaches are less germane in cerebrovascular applications of the petrosal approaches, given the near-ubiquitous presence of serviceable preoperative hearing. Originally conceptualized by Hakuba,[21] a combined posterior petrosal and anterior petrosal approach may be used instead.[10,13] The combined approach is particularly advantageous in the context of aneurysm clip reconstruction, as the line of sight need not be obstructed by the clip applier during placement of the clip. Instead, the surgeon's line of sight may be in one working corridor (for example, the posterior petrosal corridor, visualizing basilar perforators), while the working angle of clip application may be in the other (for example, the anterior petrosal corridor).

Looking Forward

Complex posterior circulation aneurysms are formidable targets that require management by highly experienced endovascular and open microsurgical neurosurgeons. Despite the preponderance of endovascular approaches to these lesions,[15,36,45,53,58] some may remain refractory to safe endovascular management. In several cases we reviewed endovascular treatment had previously been attempted without success.[11] In a recent report describing 7 posterior circulation aneurysms treated with flow-diverting stents, 4 patients were dead at follow-up (2 from de novo aneurysm rupture) and an additional patient was severely disabled.[53] Combined with delayed in-stent stenosis and thrombosis,[36] these complications may accrue with time, though they will hopefully be mitigated with advances in endovascular technology and technique.

Although our review of petrosal approaches to posterior circulation aneurysms demonstrated high rates of aneurysm occlusion, early morbidity was seen in 64% of cases, and the long-term morbidity and mortality rates were 25% and 5%, respectively (Table 1). These early rates encourage the continued cultivation of skull base techniques in the management of posterior circulation aneurysms at highly experienced centers. Specifically, just as the observed CSF leak rate for the posterior petrosal approach seen in our review seems inconsistent with the modern literature,[1,33,35,41] these early results illustrate a potential learning curve to follow toward improved outcomes with open microsurgical techniques in the management of these challenging lesions.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Dunn, Gross, Du, Al-Mefty. Acquisition of data: Gross. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Dunn. Study supervision: Dunn, Du, Al-Mefty.

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