Evolution of the posterior petrosal approach

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In this article, the authors review the history of the posterior petrosal approach. The early foundation of the retrolabyrinthine lateral petrosectomy has its roots in the otolaryngology literature. These early approaches were limited in exposure by the tentorium superiorly and the sigmoid sinus posteriorly. Although the concept of a transtentorial approach was originally combined with a complete labyrinthectomy, Hakuba and colleagues described the expansive exposure afforded by sectioning the tentorium and superior petrosal sinus and mobilizing a skeletonized sigmoid sinus. This maneuver serves as the key step in allowing for the full, combined supra- and infratentorial exposure that the posterior petrosal approach provides. In contrast to Hakuba et al.’s approach, which used a partial labyrinthectomy, modern approaches often preserve the entire labyrinth (retrolabyrinthine approach). For added exposure, the latter can be combined with the anterior petrosal approach, allowing for the preservation of hearing and an enhanced view of the surgical target. The authors review the evolution of the petrosal approach and highlight its applicability. (http://thejns.org/doi/abs/10.3171/2012.6.FOCUS1233)

Key Words • transpetrosal approach • retrolabyrinthine approach • presigmoid approach • petrosal approach • combined approach • skull base

The posterior petrosal approach has met with considerable success in the management of complex neoplastic and cerebrovascular lesions.1–3,9,13,27,28,30,31,33,34,36 At the mere expense of meticulous bone work to preserve the labyrinth and skeletonize the sigmoid sinus, this approach affords a wide exposure, minimizing operative distance and brain retraction, and affording multiple working angles to the neurosurgical target and adjacent vascular anatomy.1–3,9,13 These advantages are only fully realized by the division of the tentorium and superior petrosal sinus and mobilization of a completely skeletonized sigmoid sinus. This contrasts with early work in the otolaryngology literature in which the exposure was limited superiorly by the tentorium and posteriorly by the sigmoid sinus.12,18,19 To add exposure, some have divided the sigmoid sinus,8,11,17,19,32 however, with meticulous skeletonization and mobilization of the sinus as in the petrosal approach, this potentially dangerous maneuver can be avoided.3,28 In addition, retraction of the dural venous sinuses and temporal lobe is performed in one unit, in contrast to nonpetrosal approaches (such as the combined retrosigmoid-subtemporal approach) that place added traction on the vein of Labbé with retraction.1–20 In this article, we review the history of the posterior petrosal approach, from its predecessors in the early otolaryngology literature through its evolution as a combined supra- and infratentorial exposure with modern extensions and modifications.

Early Work

Early petrous bone work dates back to 1904, when a translabyrinthine approach in combination with a suboccipital craniectomy was performed to expose an acoustic neoplasm.10 Unfortunately, due to excessive blood loss and infection risks this approach was largely abandoned over the ensuing decades, until it was revived in the otolaryngology literature in the 1960s.12,19 Over the ensuing 2 decades, the literature clearly recognized 3 variants of the petrosectomy—a lateral petrosectomy that spared the labyrinth entirely (retrolabyrinthine),12,18 a translabyrinthine approach,12,19 and a complete petrosectomy or transcochlear approach.21 The latter, described by House and Hitselberger in 1976, entailed transposition of the facial nerve with the petrosectomy. This was soon modified by Jenkins and Fisch22 in 1980, who kept the nerve skeletonized in its bony canal without transposition to potentially mitigate the risk of postoperative facial nerve palsy (transotic approach). These approaches are summarized in Table 1.

Early additions to the standard translabyrinthine ap-
The approach included its combination with a suboccipital craniectomy\textsuperscript{10,17} and, importantly, opening of the tentorium, as described by King\textsuperscript{26} in 1970. The latter was a key step in the evolution of the modern petrosal approach, providing an expanded, combined supra- and infratentorial exposure.

**Evolution to the Modern Posterior Petrosal Approach**

In 1977, Hakuba et al.\textsuperscript{16} expanded on the concept of a combined supra- and infratentorial exposure, describing 1 case in a patient with a clival meningioma that was approached via a combined supra- and infratentorial petrosal approach with partial labyrinthectomy. The patient these authors described did well postoperatively without hearing loss. Crucial maneuvers in the description included the meticulous complete skeletonization and mobilization of the sigmoid sinus after division of the tentorium and superior petrosal sinus; these steps serve as the key foundation of the modern posterior petrosal approach. Hakuba's description essentially served as a predecessor to the modern transcrusal (partial labyrinthectomy) approach;\textsuperscript{6,20,35} although hearing is not obligately sacrificed as in the complete labyrinthectomy, hearing loss is seen in up to 42\% of cases.\textsuperscript{6} In contrast, Al-Mefty et al.'s\textsuperscript{5} posterior petrosal approach entails skeletonization of the semicircular canals without sacrifice of the labyrinth. This presigmoid, retrolabyrinthine approach has served as the backbone in the approach to innumerable neoplastic and vascular lesions over the past 3 decades.\textsuperscript{1–3,5,27,28,30,31,33,34,36}

**The Posterior Petrosal Approach**

The posterior petrosal approach is performed with the patient positioned supine, with the head turned 40°–60° after placing a roll under the ipsilateral shoulder. The head is extended to ensure that the petrous bone is the highest point in the field. After fixation in a Mayfield head holder, monitoring leads are placed for somatosensory evoked potentials, brainstem auditory evoked potentials, and select cranial nerves.

An incision is fashioned from the zygoma just anterior to the ear, extending 2 fingerbreadths above the pinna and descending posterior and inferior to the mastoid process. The skin flap is rotated anteriorly and inferiorly, after which the temporalis muscle is released superiorly and reflected inferiorly. Four bur holes are then placed—2 in the posterior fossa and 2 supratentorially, spanning the transverse sinus, after which a combined posterior fossa and middle fossa craniotomy flap is raised. The mastoid cortex is then removed as a single piece and a mastoidectomy is performed to skeletonize the sigmoid sinus down to the jugular bulb (Figs. 1 and 2). The latter maneuver is crucial in allowing for maximal mobilization of the sinus after opening the tentorium. The presigmoid dura mater is then exposed by completing a standard retrolabyrinthine petrosectomy, and then it is opened from the level of the jugular bulb and extended superiorly toward the superior petrosal sinus. An incision is also made in the temporal lobe dura, taking great care to preserve the vein of Labbé. The superior petrosal sinus is then coagulated and cut, and the temporal and presigmoid durotomies are connected. The tentorium is cut parallel to the petrous ridge behind the tentorial entry of the fourth cranial nerve. The

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<th>TABLE 1: Petrosectomy variants*</th>
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<tr>
<td>retrolabyrinthine</td>
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<td>partial labyrinthectomy†</td>
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* CN = cranial nerve.
† Some have referred to this as the transcrusal approach (see Brandt et al. and Horgan et al.).
‡ See Brandt et al. and Sekhar et al.
Posterior petrosal approach

sigmoid sinus is then reflected posteriorly and the temporal lobe gently retracted with the tentorium.3,9,28

The senior author has used the standard posterior petrosal approach in more than 160 cases spanning a period of 3 decades. Although most often used for meningiomas, this approach has been applied to numerous schwannomas, epidermoid lesions, chordomas, craniopharyngiomas, paragangliomas, aneurysms, and brainstem cavernous malformations. Crucial technological elements of this technique include the adjunctive use of neuromonitoring, neuronavigation, and the application of advances in neuroanesthesia.

Although this approach provides an expansive combined supra- and infratentorial exposure, it may be limited in cases in which the lesion crosses the midline, enters the anterior cavernous sinus, or extends below the jugular tubercle. In addition, a high jugular bulb or a prominent sigmoid sinus may significantly restrict the presigmoid corridor. The inability to divide the superior petrosal sinus due to the patient’s venous drainage may also restrict the approach (Fig. 3). To address these limitations, several modifications to the approach, as delineated below, have been cultivated.

**Modifications**

*Extended Posterior Petrosal Approaches*

Additional petrous bone resection via either a partial or complete labyrinthectomy or a complete petrosectomy has been described in combination with the posterior petrosal approach.3,13,16,35,36 Indeed, Hakuba et al.’s16 original approach was essentially a posterior petrosal approach with partial labyrinthectomy, a predecessor to the transcrusal approach in the modern literature.6,28 However, this approach does not preserve hearing at comparable rates to the standard retrolabyrinthine posterior petrosal approach.6,34

In patients without serviceable hearing requiring additional exposure, one may enhance the exposure by performing a complete labyrinthectomy or petrosectomy, if needed.13 We call the former the petrosal translabyrinthine approach to distinguish it from the traditional infratentorial translabyrinthine approach without mobilization of the sinus. These 2 approaches differ significantly in the degree of exposure afforded to the neurosurgeon, and should remain as 2 distinguished entities in neurosurgical parlance. When performing a complete petrosectomy, we advocate skeletonization of the facial nerve in its bony canal rather than complete exposure and transposition (petrosal transotic).13 We often consider these approaches for more expansive lesions with ample medial extent, or in cases with unfavorable venous anatomy such as a high jugular bulb or prominent sigmoid sinus.

*Combined Approaches*

If additional exposure is desired and hearing is not compromised preoperatively, we use the combined petrosal approach. Although the posterior petrosal approach itself has been called the “combined approach” in early literature due to its combined supra- and infratentorial exposure,8,36 modern “combined approaches” have instead combined it with the anterior petrosal (petrous apicectomy) approach in an effort to provide greater exposure without sacrificing the labyrinth (Fig. 4).29 The anterior petrosal approach was originally described by Bochenek and Kukwa5 in 1975. Popularized by Kawase et al.,25 it is sometimes referred to as the Kawase approach. This approach affords posterior fossa access from the middle fossa and permits access to a variety of lesions, including neoplasms, aneurysms, and vascular malformations.4,23–25,29

The concept of combining an anterior and a posterior petrosal approach was originally described by Hakuba et al.13 in 1988. In this original account, these authors combined their posterior petrosal partial labyrinthectomy approach with a petrous apicectomy in the management of 8 clival meningiomas, although hearing was only preserved in 1 of 3 cases with serviceable hearing preoperatively. In an effort to fully preserve hearing, we use a combination of the anterior petrosal approach and the standard
Preservation of the Superior Petrosal Sinus

A meticulous evaluation of the patient’s cerebrovascular anatomy is a crucial component of preoperative planning prior to the performance of the petrosal approach. Knowledge of arterial feeding vessels to a vascular neoplasm should dictate the early avenue of approach to allow for devascularization of the lesion. On the other hand, evaluation of the patient’s venous anatomy is also crucial in any case in which ligation of the superior petrosal sinus is considered. In cases in which the vein of Labbé, important bridging veins, or the sphenoparietal sinus drain into the superior petrosal sinus, it should not be sacrificed (Fig. 3). For such cases, a modification of the traditional approach may be considered. After performing the standard temporooccipital craniotomy and retrolabyrinthine lateral petrosectomy, the superior petrosal sinus is freed from its groove in the petrous ridge and skeletonized by drilling the petrous ridge. The presigmoid dura is then opened and the incision is extended under the superior petrosal sinus to the Meckel cave. The tentorium under the superior petrosal sinus is separated from the Meckel cave and lifted upward, effectively connecting the middle and posterior fossa under the tentorium. This affords an exposure almost comparable to that of the standard posterior petrosal approach while limiting undesirable postoperative venous complications.

Conclusions

The posterior petrosal approach is derived from the retrolabyrinthine exposure described in the early otolaryngology literature in combination with the combined supra- and infratentorial exposure described in Hakuba et al.’s early report. The key feature of this approach is the liberal skeletonization of the sigmoid sinus and subsequent mobilization after division of the tentorium and superior petrosal sinus. A modified posterior petrosal approach can be performed in cases in which the superior petrosal sinus cannot be sacrificed; the sinus is skeletonized and freed, and the dural opening is extended from the presigmoid region under the superior petrosal sinus to the Meckel cave. In lieu of performing a partial or complete labyrinthectomy to sacrifice hearing, one may combine the posterior petrosal approach with an anterior petrosal approach when additional exposure is needed.

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, Al-Mefty. Acquisition of data: Gross, Al-Mefty. 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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