The Challenge of Access to the Pontomesencephalic Junction: An Anatomical Study of Lateral Approach and Exposure

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ABSTRACT

We quantitatively compared relative merits of lateral approaches to the pontomesencephalic junction (PMJ): anterior petrosectomy, subtemporal transtentorial, posterior petrosectomy, and retrosigmoid transtentorial. In dissected cadaveric heads, lengths of exposure were measured anteriorly from CN V along the pontomesencephalic sulcus (PMS); posterosuperiorly along the lateral mesencephalic sulcus (LMS); and posteroinferiorly along the interpeduncular sulcus (IPS). Subtemporal transtentorial approach provided best anterior exposure along the PMS (23.8 ± 4.5 mm). Posterosuperior exposures were comparable for all approaches except anterior petrosectomy (limited). Posteroinferior exposure was most with subtemporal transtentorial approach (13.2 ± 2.8 mm). CN V entry/exit point was identified through all approaches, except for subtemporal transtentorial; shortest surgical depth with posterior petrosectomy was 43.7 ± 5.5 mm. PMS-LMS-IPS convergence point: reached through all approaches, except for anterior petrosectomy (limited); shortest surgical depth with posterior petrosectomy was 40.3 ± 4.3 mm. Anterior petrosectomy provides direct anterolateral views of the pons not afforded by subtemporal approach. Subtemporal transtentorial approach provides optimal posterolateral view to the PMJ and cerebellar peduncles. Retrosigmoid transtentorial approach offers wide exposure of the lateral surface, limited on the posteroinferior PMJ by the cerebellum. The small opening of posterior petrosectomy creates an awkward corridor to anterior PMJ targets but provides a direct and shortest route to the cerebellar peduncles.

KEYWORDS: Petrosal approach, pontomesencephalic junction, retrosigmoid approach, subtemporal approach, surgical-anatomical study

The pontomesencephalic junction (PMJ) is an anatomical area of the brainstem connecting midbrain and pons. Access to this region is limited due to its deep central location and shielding by complex and vital

neurovascular structures. Nonetheless, surgical access to this region is often required (e.g., vascular malformation, tumor).¹⁻³ In other regions of the brain, mass effect from a lesion may widen or improve the surgical

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corridor. In the PMJ a lesion is unlikely to have this effect, thus making an already difficult exposure even tighter and more challenging. Small pathology, however, may cause little disruption to the position and configuration of anatomical structures in the PMJ region. Choosing an appropriate surgical corridor to prevent undesired complications is crucial. Anterior approaches to this region via a frontotemporal craniotomy with or without an orbitozygomatic osteotomy involve a long working distance and are limited by major neurovascular structures that obscure the brainstem. The anterior surface of the PMJ can be explored, but the ability to manipulate instruments is limited. For shorter access, lateral approaches, with multiple corridors of access, may be preferable.

Through standard approaches such as the subtemporal or retrosigmoid avenues, the tentorium or petrous bone may hinder access to the PMJ. Extensions of standard approaches have, therefore, been developed. In the subtemporal transtentorial⁴ and retrosigmoid/supracerebellar transtentorial approaches, the tentorium is cut.^{5,6} In an anterior petrosectomy and posterior petrosectomy (retrolabyrinthine transtentorial approach), the petrous bone is drilled.⁷⁻¹¹ These modifications shorten the distance to lesions while making it easier to manipulate deep structures.

However, not all of these techniques may be appropriate for a given target. Furthermore, the complexity of some of these approaches may increase complications. We, therefore, quantitatively compared exposure of the PMJ through an anterior petrosectomy; subtemporal transtentorial; posterior petrosectomy; and retrosigmoid transtentorial approaches to determine the relative advantages of each approach (Fig. 1). This is an extension of the study we previously published in a more extensive dissection to the lateral surface of the PMJ.¹²

Figure 1 Illustrations showing the approaches compared in this study: AP, anterior petrosectomy; PP, posterior petrosectomy; RT, retrosigmoid transtentorial; SS, sigmoid sinus; STT, subtemporal transtentorial; TS, transverse sinus. *Used with permission from Barrow Neurological Institute.*

MATERIALS AND METHODS

Cadaveric Preparation

Four-colored silicone-injected cadaveric heads were used for bilateral dissection. Before dissections, computed tomography and magnetic resonance imaging were obtained to show navigational trajectories when taking measurements. All surgical approaches were dissected under a standard operating microscope with surgical instruments before measurements were made. The detailed surgical techniques for each approach are described elsewhere.^{4,6-10,13} To quantify all approaches using a single measurement, some modifications to the standard techniques were unavoidable. We accepted minor variances in the extent of bony and venous sinus exposure to demonstrate major differences among approaches.

A wide C-shaped scalp incision was created to expose both the temporal base and infratentorial surface as used for a combined petrosal exposure.¹⁴ The bone was then drilled to incorporate all approaches. For the posterior petrosectomy, a standard mastoidectomy was drilled to preserve all vestibular canals and to expose the presigmoid dura. A wide craniotomy cut was performed involving the retromastoid and temporal regions. The dura was opened anterior to the sigmoid sinus and then reflected anteriorly. The tentorium was cut by dividing the superior petrosal sinus just anterior to the junction of the transverse and sigmoid sinuses. The cut continued medially to the tentorial notch just posterior to the insertion point of the trochlear nerve. The transverse-sigmoid sinus junction and vein of Labbé can be safely retracted posteriorly to increase this surgical corridor. To simulate the actual limited surgical opening associated with a conventional posterior petrosectomy (retrolabyrinthine view), elevation of the temporal base was limited only above the mastoid region.

For the retrosigmoid transtentorial approach, the dura was opened posterior to the sigmoid sinus and inferior to the transverse sinus. Additional bone drilling or tentorial cuts were unnecessary. The small bias from the presigmoid position of the tentorial cut was accepted because the direction of cutting to the tentorial notch was the same. Arguably, this wide craniotomy and excessive venous sinus exposure could be considered an extreme lateral supracerebellar exposure.¹⁵ However, we refer to it as a retrosigmoid transtentorial approach to reflect our use of both the cerebellopontine and supracerebellar corridors.

For the anterior petrosectomy, the temporalis muscle was reflected anteriorly. The zygomatic arch and the temporal base were further flattened by drilling. The temporomandibular joint was not disturbed. The temporal base was exposed from its anterior pole to the junction with the previously performed infratentorial

exposures posteriorly. Next, an extradural anterior petrosectomy was performed to expose the petrous carotid artery, CN V, Meckel's cave, and the CN VII and VIII complex. The depth of drilling was limited by the inferior petrosal sinus, where CN VI entered Dorello's canal anteriorly. The posterior lip of the internal acoustic canal was drilled out with preservation of the vestibular labyrinth. This drilling became contiguous with the posterior petrosal bone work.

A basal incision of the dura was first created in the middle fossa parallel to the superior petrosal sinus. Perpendicular to the first incision, a second incision was extended down to posterior fossa dura. At this point, the superior petrosal sinus was divided. The tentorium was cut approaching the tentorial notch posterior to the insertion site of the trochlear nerve. This cut was connected to the posterior tentorial cut (previously made during the posterior approaches) at the tentorial margin. Hanging sutures were made on tentorial leaflets to expose the PMJ. This approach created the view from below the tentorial notch.

For the subtemporal transtentorial approach, the temporal dura was opened. The temporal lobe was elevated intradurally, using the posterior tentorial cut from the posterior petrosectomy for the exposure. The PMJ was observed from above the tentorial notch.

At this point, two tentorial cuts were created. Both cuts terminated on the tentorial notch just behind the insertion point of the trochlear nerve (Fig. 2). The anterior tentorial cut was used for the anterior petrosectomy. The posterior tentorial cut was used for the posterior petrosectomy, retrosigmoid transtentorial, and the subtemporal transtentorial approaches. During measurements, the appropriate tentorial cut was reapproximated and sutured when it was not part of the approach being measured.

Figure 2 Illustration shows positions of tentorial cuts: A, anterior tentorial cut; P, posterior tentorial cut. Used with permission from Barrow Neurological Institute.

Measurement Technique

Using the pontomesencephalic sulcus as a major strip on the lateral surface of the PMJ, two reference points that usually can be seen from all approaches were selected: (1) the medial rim of CN V entry/exit site, and (2) the convergence point of the pontomesencephalic sulcus (PMS), lateral mesencephalic sulcus (LMS), and interpeduncular sulcus (IPS). Three extreme directions of exposure were measured for quantification (1) the anterior extension, from CN V along the PMS anteriorly; (2) the posterosuperior extension, from the PMS-LMS-IPS convergence point along the LMS; and (3) the posteroinferior extension, from the PMS-LMS-IPS convergence point along the IPS. All three extensions were measured for each approach (Fig. 3).

In any quantitative cadaveric study, brain retraction is a major concern. In this study, the retractor was maintained but not fixed in the same position, especially during the retrosigmoid transtentorial approach from which a target can be accessed from either the cerebellopontine or supracerebellar space. The obvious differences in the opening needed for each approach made it impossible to establish a uniform distance for retraction. However, the retraction distances in the standard trajectory for each approach were noted for each specimen: from the base of the retractor to the ear canal roof for the subtemporal transtentorial and anterior petrosectomy, from the base of the retractor to the transverse-sigmoid sinus junction for the retrosigmoid transtentorial, and from the base of the retractor to the posterior wall ear canal for the posterior petrosectomy.

The depths of the surgical corridors were measured and compared for each approach. Depth was measured from the midpoint of the retraction distance to two deep targets of interest: CN V and the PMS-LMS-IPS convergence point.

Data Collection and Analysis

The dissected head was fixed rigidly with a three-point head holder mounted with the Stealth TREON Plus Navigation System (Medtronic, Louisville, CO) to retrieve coordinate points from the tip of a navigating probe. All predetermined anatomic points and approach-related points were collected without changing the head position. Navigation images were acquired from the Stealth system to reveal surgical trajectories to the PMJ.

All retrieved coordinate points were entered into a spreadsheet for analysis with a custom-made program (Spherical Area; Microsearch, Bitwise Ideas Inc., Frederickton, NB, Canada). One-way repeated-measures analysis followed by pairwise comparisons with Holm-Sidak correction was used to compare results. All statistical calculations were performed with SigmaStat 3.5 program

Figure 3 Illustration shows a left-sided retrosigmoid approach with measurement of length of exposure from the two reference points, (1) CN V (trigeminal nerve) and (2) PMS-LMS-IPS convergence through an (A) anterior exposure, (B) posterosuperior exposure, and (C) posteroinferior exposure. IPS, interpeduncular sulcus; LMS, lateral mesencephalic sulcus; PMS, pontomesencephalic sulcus; SS, sigmoid sinus; and TS, transverse sinus. *Used with permission from Barrow Neurological Institute.*

(Systat Software, Inc., Point Richmond, CA). Significance was identified when p or the adjusted p value was less than 0.05.

RESULTS

In the supratentorial observations, the vein of Labbé was clearly identified in all specimens. They all terminated on the transverse sinus or lateral tentorium at a mean of 17.1 ± 8.7 mm posterior to the sinodural angle. In two sides of the specimens, the temporal bridging veins from the basal temporal lobe were observed to merge into the superior petrosal sinus and needed to be cut to continue the posterior petrosectomy.

Infratentorially, the superior petrosal veins draining into the superior petrosal sinus were all identified and sacrificed for taking measurements. The mean retraction distance was 29.3 ± 2.9 mm for the anterior petrosectomy, 28.8 ± 2.7 mm for the subtemporal transtentorial, 12.3 ± 3.4 mm for the posterior petrosectomy, and 26.6 ± 1.8 mm for the retrosigmoid transtentorial approach.

The two reference points (CN V and the PMS-LMS-IPS convergence point) were accessible in most specimens via all of the approaches. In the subtemporal transtentorial approach, however, the CN V point was not clearly accessed in any of the 8 sides, and in the anterior petrosectomy, the PMS-LMS-IPS convergence point could not be reached in 6 of the 8 sides.

Figure 4 Results for anterior exposed lengths from CN V ($n = 8$). *All pairwise comparisons were significant (adjusted $p < 0.05$) except between AP and RT. Error bars represent standard deviations. AP, anterior petrosectomy; PP, posterior petrosectomy; RT, retrosigmoid transtentorial; STT, subtemporal transtentorial. *Used with permission from Barrow Neurological Institute.*

Anterior Exposure

The best view for this extension was achieved through the subtemporal transtentorial approach (23.8 ± 4.5 mm). The anterior petrosectomy (16.8 ± 4.7 mm), retrosigmoid transtentorial (14.5 ± 2.2 mm), and posterior petrosectomy (11.2 ± 3.1 mm) were followed. The values for interapproach comparisons were all statistically significant, except for the comparison between the anterior petrosectomy and retrosigmoid transtentorial approaches (Fig. 4).

Posterosuperior Exposure

The mean exposed lengths were calculated for the retrosigmoid transtentorial (7.0 ± 1.3 mm), subtemporal transtentorial (6.3 ± 1.8 mm), and posterior petrosectomy (5.5 ± 2.0 mm) approaches. There were no significant differences between these approaches. The anterior petrosectomy was intentionally excluded from this comparison due to its marked limitation along this extension (Fig. 5).

Posteroinferior Exposure

The subtemporal transtentorial showed the best lengths (13.2 ± 2.8 mm) among the approaches, followed by the posterior petrosectomy (11.3 ± 2.3 mm), anterior petrosectomy (10.5 ± 3.0 mm), and the retrosigmoid transtentorial (8.0 ± 2.6 mm) approaches. The only significant difference was between the subtemporal transtentorial and retrosigmoid transtentorial approaches (Fig. 6).

Surgical Depths

CN V target: The subtemporal transtentorial approach was excluded from the comparison because the CNV

Figure 5 Results for superior exposed lengths along the LMS (lateral mesencephalic sulcus, $n=8$). Error bars represent standard deviations. PP, posterior petrosectomy; RT, retrosigmoid transtentorial; STT, subtemporal transtentorial. Used with permission from Barrow Neurological Institute.

point was not accessible in all specimens. The depth of the surgical corridor was shortest (43.7 ± 5.5 mm) in the posterior petrosectomy and longest (53.7 ± 2.9 mm) in the retrosigmoid approach (Fig. 7).

PMS-LMS-IPS convergence point: The anterior petrosectomy was excluded from the comparison because its poor trajectory to this target made measurement impractical. The depth of the surgical corridor was shortest (40.3 ± 4.3 mm) in the posterior petrosectomy and longest (54.7 ± 5.3 mm) in the subtemporal transtentorial approach (Fig. 8).

DISCUSSION

Ulm et al¹⁶ performed an anatomic study that focused on the perimesencephalic cisterns. They determined that

Figure 6 Results of inferior exposed lengths along IPS (interpeduncular sulcus, $n=8$). *Pairwise comparisons found significance between STT and RT (adjusted $p=0.006$). Error bars represent standard deviations. AP, anterior petrosectomy; PP, posterior petrosectomy; RT, retrosigmoid transtentorial; STT, subtemporal transtentorial. Used with permission from Barrow Neurological Institute.

Figure 7 Results for surgical depth on CN V point ($n=8$). *All pairwise comparisons were significant (adjusted $p<0.05$). Error bars represent standard deviations. AP, anterior petrosectomy; PP, posterior petrosectomy; RT, retrosigmoid transtentorial. Used with permission from Barrow Neurological Institute.

most of the valuable approaches were from supratentorial routes. Our target of interest, the PMJ, is in a lower anatomic position. The PMJ faces the perimesencephalic cisterns, cerebellomesencephalic cistern, and cerebello-pontine cistern. This configuration increases the challenge of gaining access from both supra- and infratentorial approaches.

PMJ is an anatomical area that curves along the PMS. Because the anatomical boundary of this region is vague and involves both midbrain and pons, we used the term *upper neurovascular complex*, as described by Rhoton,¹⁷ to refer to this region. Its lower limit is defined

Figure 8 Results of surgical depth on PMS-LMS-IPS convergence point ($n=8$). *All pairwise comparisons were significant (adjusted $p<0.05$). Error bars represent standard deviations. IPS, interpeduncular sulcus; LMS, lateral mesencephalic sulcus; PMS, pontomesencephalic sulcus; PP, posterior petrosectomy; RT, retrosigmoid transtentorial; STT, subtemporal transtentorial. Used with permission from Barrow Neurological Institute.

by the CN V level anteriorly, curving posteriorly to the middle and superior cerebellar peduncles. Its upper limit is the lower margin of CN III anteriorly and curving along the temporal base to the posterior cerebral artery (PCA, P2a) in the crural cistern, laterally. The high-riding position of the posterior portion of the PCA (P2p) in the ambient cistern, hindered by the temporal base, makes it undesirable to use the PCA as the upper limit posteriorly. The PMJ merges with the collicular plate posteriorly where CN IV exits the brainstem.

Approach-Related Exposure

ANTERIOR PETROSECTOMY

This approach provides the second best anterior exposure along the PMS. Our measurements were intentionally limited to viewing infratentorial structures (limited by the reflected tentorial edge and trochlear nerve). In surgery, the subtemporal view is usually combined with this view to the infratentorial structures. The anterolateral pons and CN V, VII, and VIII are easily exposed in the center of the surgical field (Fig. 9A). CN IV needs to be identified before the tentorium is cut. CN VI and the inferior petrosal sinus are at the anteroinferior limits of petrous drilling. The upper to midbasilar artery and the origin of the anterior inferior cerebellar artery are accessible at the anterior limit of the pons. Compared with the standard subtemporal approach,¹⁸ the anterior petrosectomy provides proximal exposure of the basilar artery for an additional 1 to 1.5 cm. Compared with the transcavernous approach,¹⁹ it provides an additional 1 cm of exposure.

To approach the posterior half of the PMJ (Fig. 9B), the superior petrosal vein draining into the superior petrosal sinus must be sacrificed in all cases. Posterosuperior exposure along the LMS is almost impossible from this angle of approach as is exposure of the PMS-LMS-IPS convergence point. In our dissections the latter point could be identified only in 2 of the 8 sides.

A fairly good posteroinferior view to the cerebellar peduncles can be achieved. To appreciate this view, the posterior lip of the internal acoustic canal must be drilled flat. Doing so, however, risks injury to the vestibular labyrinth. This view also requires a more anterior-to-posterior trajectory. A wide temporal craniotomy that exposes the temporal pole must be prepared.

SUBTEMPORAL TRANSTENTORIAL

This approach provides the best anterior exposure along the PMS. However, the tentorium and the petrous bone hinder access to the structures located inferiorly such as CN IV, CN V, the anterolateral part of pons, and the upper to midbasilar artery. In fact, the tentorial cut is not required to increase the length of the anterior exposure

along the PMS. This exposure can be obtained with a standard subtemporal approach. Supratentorial lesions that involve the anterolateral part of the PMJ can be resected by a standard subtemporal approach. With wide access along the temporal base, the lateral view of CN III, basilar artery tip, and proximal PCA are clearly in view (Fig. 9C). This observation correlates well with the clinical experience for exposure of PCA aneurysms.²⁰

The posterosuperior exposure and the ability to follow the posterior portions of PCA (P2p, P3) are similar to the other approaches in this study. This limitation is mainly influenced by the temporal base, parahippocampal gyrus, and position of the vein of Labbé. The subtemporal transtentorial modification facilitates achieving a vertical view posterior to the point where the tentorium is incised. When surgery proceeds along the cerebellomesencephalic fissure to direct the view to the dorsolateral upper brainstem and cerebellar peduncles, this route seems to be valuable.^{4,21} In our dissection, however, the CN V entry/exit site could not be clearly exposed. In our opinion, this limitation is caused by the location of the posterior tentorial cut, which is necessarily posterior to the trochlear nerve and petrous ridge (Fig. 9D).

POSTERIOR PETROSECTOMY

This approach is limited anteriorly by the vestibular canals, superiorly by the temporal base, inferiorly by the jugular bulb, and posteriorly by the sigmoid sinus. As in other reports,^{22,23} there was considerable variation in this space even though it is small. The mean horizontal distance from the posterior canal to the retractor on the sigmoid sinus was 12.3 ± 3.4 mm. This distance does not include the vertical variations created by the position of jugular bulb. We intentionally disregarded this variation because our PMJ target was high lying. The surgical corridor was centered on the cerebellopontine angle. The petrosal surface of the cerebellum was easily retracted posteriorly to expose the cerebellar peduncles (Fig. 9E).

The anterior view from the posterior petrosal approach is limited by obstruction from the vestibular canals. The posterior petrosal approach improves anterior exposure by significant posterior retraction of the sigmoid sinus or by aggressive drilling with partial or complete (translabyrinth/transotic/transcochlear) removal of the vestibular labyrinth.^{14,24} The only exception is tumor growth that distorts the brainstem when the primary goal of surgery is brainstem decompression. We did not include these more aggressive procedures other than posterior petrosectomy in this study because it seems unreasonable to compare a procedure with a high risk of hearing loss with lower risk procedures.

In this approach the ability to elevate the temporal base is advantageous compared with the more restrictive position of the transverse sinus in the retrosigmoid

Anterior View

Posterior View

Figure 9 All right side dissections. (A,B) Exposure provided by anterior petrosectomy. (C) Exposure provided by standard subtemporal approach. (D) Exposure provided by subtemporal transtentorial. (E,F) Exposure provided by posterior petrosectomy. (G,H). Exposure provided by retrosigmoid/supracerebellar transtentorial. AICA, anterior inferior cerebellar artery; BA, basilar artery; GSPN, greater superficial petrosal nerve; ICA, internal carotid artery; Inf.PS, inferior petrosal sinus; IPS, interpeduncular sulcus; LMS, lateral mesencephalic sulcus; PCA, posterior cerebral artery; PMS, pontomesencephalic sulcus; SCA, superior cerebellar artery; SPV, superior petrosal vein; SS, sigmoid sinus; SSC, superior semicircular canal; VC, vestibular canals. *Used with permission from Barrow Neurological Institute.*

approach. However, this effect cannot be seen clearly with the posterosuperior exposure either due to the relatively small opening or the curvature of the temporal base.

This approach provided the second best exposure to the posteroinferior target without placing the vein of Labbé at risk. With the small opening, the corridor is already directed to the cerebellopontine cistern through shortest surgical corridor (i.e., mean of 40.3 ± 4.3 mm to PMS-LMS-IPS convergence point). Compared with the retrosigmoid approach, the opening is more anterior. Therefore, the cerebellar peduncles are directly in view with minimal retraction applied to the cerebellar surface (Fig. 9F).

RETROSIGMOID TRANSTENTORIAL APPROACH

The retrosigmoid approach uses a more posterior-to-anterior trajectory compared with the posterior petrosectomy. This trajectory improves anterior exposure (without obstruction by the vestibular canals as in the posterior petrosectomy) but entails a deeper surgical corridor (mean surgical depth at CN V point: retrosigmoid 53.7 ± 2.9 mm versus posterior petrosectomy 43.7 ± 5.5 mm, adjusted $p < 0.001$) (Figs. 7, 9G, and 10). However, the working area provided by the retrosigmoid approach when targeting brainstem pathology is greater than that available when confronted with petroclival pathology.²⁵ Using both the supracerebellar and cerebellopontine routes, the entire cisternal part of the CN V can easily be exposed. The suprameatal petrous ridge that we removed via anterior petrosectomy is a concern. This structure obstructs deeper petrous structures (i.e., upper petroclival area, Meckel's cave) through a standard retrosigmoid exposure^{26,27} but not at the brainstem site.²⁸ In some cases, however, the horizontal angle of approach to the anterolateral PMJ is limited by this structure.¹²

Although the posterosuperior exposure provides a slightly better view than the other approaches, the difference was not significant. In the retrosigmoid/supracerebellar approach, the tentorial incision may not offer a significant additional rostral advantage on the brainstem side. In this study, the mean superior extension with a tentorial incision was almost the same (7.0 ± 1.3 mm) as in our previous anatomical study, which did not include a tentorial incision (7.3 ± 2.0 mm).¹² This similarity is based on the dome-shaped curvature of the tentorium. The rostral view is obtained without cutting the tentorium. Doing so, however, is essential when approaching the medial temporal region.⁶

The view along the cerebellar peduncles is significantly smaller compared with that associated with the subtemporal transtentorial approach. When the approach is from the supracerebellar space, the dome-shaped cerebellar hemisphere obstructs the cerebellar peduncles to some degree (Fig. 9H). When the approach is from the cerebellopontine space, the trajectory cannot provide an

Figure 10 Navigation captures showing trajectory views to the most anterior PMJ via a (A) posterior petrosectomy and a (B) retrosigmoid/supracerebellar approach. Used with permission from Barrow Neurological Institute.

adequate view posterior to the middle cerebellar peduncle¹² unlike when a posterior petrosectomy is used. However, this approach eliminates all risks to the vein of Labbé.

Tentorial Cut

Both supra- and infra-tentorial approaches have been developed to approach the PMJ. In these approaches, the

tentorium is the primary concern. Many tentorial cut techniques have been reported to overcome this problem. We found that most techniques use a posterior tentorial cut.^{5,6,29} The lateral extension of this cut can vary in relation to the type of approach. The directions of cutting, however, are almost the same, involving a parallel cut to the petrous ridge reaching the tentorial notch posterior to insertion site of the trochlear nerve. The anterior tentorial cut, which is used in the anterior petrosectomy,^{7,8,11,18} can only be performed when the petrous apex has been removed and the superior petrosal sinus has been divided. The tentorial cut may provide no additional exposure in the retrosigmoid/ supracerebellar route to the PMJ.

Combination of Approaches

A combination of approaches such as the combined petrosal or transsinus approach^{14,30} may provide a wider corridor than any single approach. This strategy should be considered when access from multiple angles is desired, especially when lesions involve both the supra- and infra-tentorial space.³¹ However, the views provided by individual trajectories, as presented here, can help surgeons devise a preoperative plan to minimize the exposure needed to access a specific target. Such careful planning can decrease operative time and the risk of complications and can prevent unnecessary bone drilling.

Venous Drainage

In all our specimens the vein of Labbé was located posterior to the sinodural junction. In two specimens the temporal bridging veins had to be sacrificed to perform the posterior petrosectomy. Injury to the vein of Labbé and temporal bridging veins plays a major role in postoperative outcomes. This consideration is critical when performing petrosal or subtemporal approaches.^{32,33} The retrosigmoid route seems to be the safest approach to avoid this problem.

The superior petrosal veins drain infratentorial parenchymal structures. Resection of these veins may sometimes cause adverse clinical effects.³⁴ Another surgical concern, the location of this vein entering the superior petrosal sinus, was not considered in this study. The selection of approach with respect to this vein is discussed elsewhere.³⁵

Study Limitations

The response of formalin-fixed cadaveric tissue does not duplicate the response of living tissue. The advantage of gravity in altering head position, cerebrospinal fluid drainage, venous congestion, and brain tissue elasticity cannot be reproduced. Unfortunately, the effects of a tumor mass causing an anatomical shift is difficult to recreate in fixed

cadaver tissue, although we have previously attempted to do so.³⁶ The position of draining veins in the temporal lobe plays a major role in surgical selection and may vary from specimen to specimen. This natural variation could affect results. Extensive bone removal, as performed in this study, admittedly affects surgical exposure. However, we believe that these relatively small variations can be tolerated to define the main differences in exposure between the approaches. Overall, we believe that the view in this study is reasonably representative of gaining access to the PMJ in a clinical situation.

CONCLUSION

A small vascular malformation or tumor can be located within the PMJ without causing significant brain shift, just as a large lesion outside the PMJ can significantly disrupt or narrow a corridor. The precise direction of approach must be determined to reach a target. Each surgical corridor provides different surgical benefits for approaching the PMJ. The tentorium plays a major role in limiting the approach in this region. Venous sinus and bridging veins also limit the exposure. Selecting an appropriate approach based on these measurements will help surgeons to obtain optimal access while minimizing brain retraction or bone drilling. These findings can help surgeons to minimize the surgical opening while still obtaining the desired exposure to the lateral PMJ.

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