Maximizing the Petroclival Region Exposure Via a Suboccipital Retrosigmoid Approach: Where Is the Intrapetrous Internal Carotid Artery?

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BACKGROUND: Recent reports have validated the use of retrosigmoid approach extensions to deal with petroclival lesions.

OBJECTIVE: To describe the topographic retrosigmoid anatomy of the intrapetrous internal carotid artery (IICA), providing guidelines for maximizing the petroclival region exposure via this route.

METHODS: The IICA was exposed bilaterally in 6 specimens via a retrosigmoid approach in the semisitting position. Its topographic relationship with pertinent posterolateral cranial base landmarks was quantified with neuronavigation.

RESULTS: Safe exposure of the IICA and the surrounding inframeatal/petroclival regions was accomplished in all specimens. On average, the IICA genu was 15.08 mm anterolateral to the XI nerve in the jugular foramen, 16.18 mm anteroinferolateral to the endolymphatic sac, and 10.63 mm anteroinferolateral to the internal acoustic meatus. On average, the IICA horizontal segment was 9.92 mm inferolateral to the Meckel cave, and its midpoint was 19.96 mm anterolateral to the XI nerve in the jugular foramen. The mean distance from the IICA genu to the cochlea was 1.96 mm. The genu and the midpoint of the horizontal segment of the IICA were exposed at a depth of approximately 14.50 mm from the posterior pyramidal wall with the use of different drilling angles (49.74° vs 39.54°, respectively).

CONCLUSION: Knowledge of the IICA general relationship with these landmarks (combined with a careful assessment of the preoperative imaging and with the use of intraoperative navigation and micro-Doppler) may help to enhance the inframeatal/petroclival region exposure via a retrosigmoid route, maximizing safe inframeatal and suprameatal petrous bone removal while minimizing neurovascular complications.

KEY WORDS: Anterior petrosectomy, Inframeatal region, Intrapetrous internal carotid artery, Microsurgical anatomy, Petroclival region, Retrosigmoid approach

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A variety of complex transtemporal approaches are often used to deal with petrous and petroclival skull base lesions.[1-14] Recent reports propose extensions of the simple and well-known suboccipital retrosigmoid approach to deal with such pathology.[15,16]

No matter which approach is selected, extensive bone removal is necessary to maximize target exposure and to minimize neural injury. Because the intrapetrous internal carotid artery (IICA) straddles the petroclival area, precise knowledge of its topographical anatomy is mandatory if maximum safe bone removal has to be carried out. Although this information is available vis-à-vis lateral transtemporal and anterior transpetrosal approaches, it is sketchy when it comes to posterior retrosigmoid approaches.

The purpose of this work is to describe the topographic retrosigmoid anatomy of the IICA, providing guidelines for maximizing the petroclival region exposure via this surgical route.

ABBREVIATION: IICA, intrapetrous internal carotid artery

METHODS

Six embalmed adult cadaveric heads were used in this study, providing 12 sides for dissection and measurements.

High-resolution computed tomographic scans (slice thickness, 0.6 mm) with bone fiducials were obtained before dissection and used for intraoperative navigation (Stryker Instruments, Kalamazoo, Michigan) according to a previously published protocol.[17] The procedures were performed with standard microsurgical instruments, high-speed drill (Midas Rex, Medtronic, Inc, Minneapolis, Minnesota), a surgical microscope (Moller, Wedel, Germany), a Budde-halo retractor system (Omi Surgical Products, Cincinnati, Ohio), and rigid endoscopes measuring 2.7 mm in outer diameter and 18 cm in length with 0° and 30° lenses (Stryker Instruments). The endoscope video camera was connected to a 19-in high-definition monitor and to the microscope using picture-in-picture technology as previously described.[18] The endoscope was held during the procedure by either the operator or an assistant.

Surgical Procedure

The head was placed in a Mayfield fixation device in the semisitting position with slight anterior flexion. A c-shaped skin incision was executed. It extended from the level of the tip of the ear to the transverse process of the atlas. The skin flap was reflected with the superficial suboccipital muscles. Next, a suboccipital retrosigmoid craniotomy was performed, exposing the inferior and medial edges of the transverse and sigmoid sinuses, respectively. The dura was opened via a c-shaped incision based on the sigmoid sinus. Next, the arachnoid membrane forming the posterior wall of the cerebellomedullary and the cerebellopontine cisterns was opened, identifying the lower cranial nerves, the VII-VIII complex entering the internal auditory canal, and the trigeminal nerve. A retractor was used to support the cerebellum to simulate operative conditions (Figure 1A). Then, after identification of the endolymphatic sac, the dura of the inframeatal portion of the petrous temporal bone was excised, exposing the sigmoid sinus all the way down to the jugular bulb. Drilling of the inframeatal zone was carried out under navigation guidance, exposing an area from the internal acoustic meatus to the lower cranial nerves at the level of the jugular foramen. Petrous bone removal was continued anteriorly, laterally, and inferiorly until the horizontal and the vertical segments of the IICA were exposed. At this stage, the endoscope was used to enhance the microscopic exposure of the inferior-most portion of the inframeatal area, gaining a full exposure of this region (Figure 1B). The suprameatal tubercle was also removed to perform safer drilling of the petrous bone underneath the Meckel cave. During the drilling, the locations of the petrous apex and the IICA were checked with the use of navigation while we kept the cisternal course of the VI nerve under visual control.

Once the drilling was completed and the IICA was fully exposed all along the carotid canal (from its entrance into the carotid foramen to the posterior edge of the foramen lacerum; Figure 1C and 1D), we measured using neuronavigation the shortest distance between the genu of the IICA and the XI nerve in the jugular foramen, between the genu of the IICA and the center of the endolymphatic sac, and finally between the IICA genu and the cochlea. Furthermore, the shortest distances between the genu of the IICA and the inferior margin of the internal acoustic meatus, from the horizontal segment of the IICA to the inferior border of the Meckel cave, and between the midpoint of the horizontal portion of the exposed IICA and the XI nerve in the jugular foramen were recorded (Figure 2). Every measurement was taken 5 times, and the mean of the measurements was used for final analysis.

Moreover, at the end of the drilling, we placed the neuronavigator probe at the genu and at the midpoint of the horizontal portion of the exposed IICA, and we measured using the neuronavigation system the distance

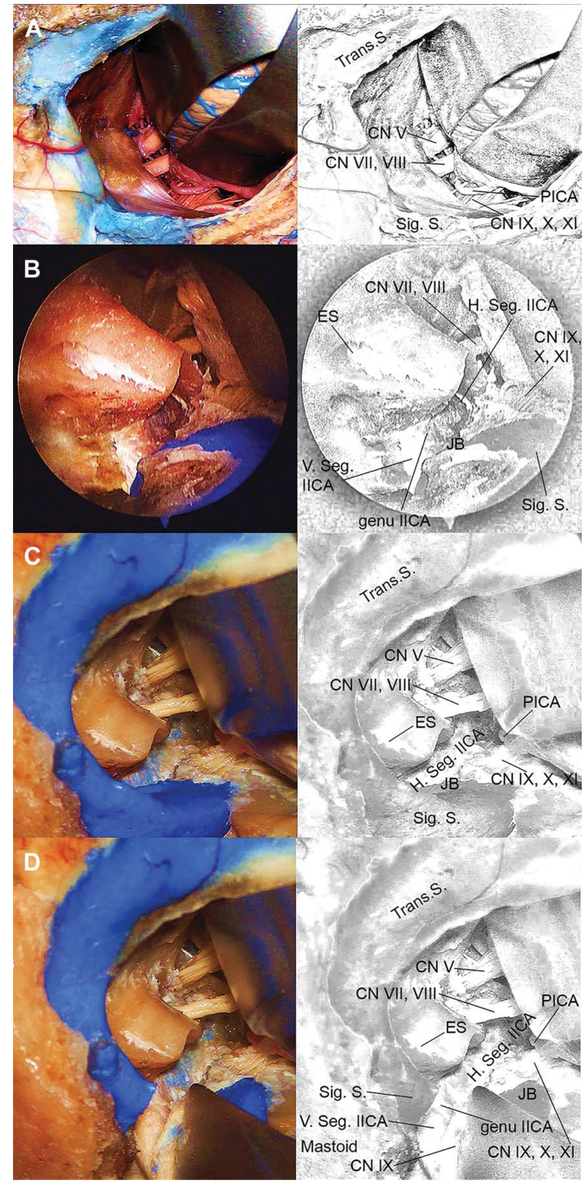

FIGURE 1. *Intradissection photographs and corresponding drawings illustrating the stepwise exposure of the intrapetrous internal carotid artery (IICA) via a suboccipital retrosigmoid approach in a cadaveric specimen.* **A**, *a retrosigmoid exposure of the left cerebellopontine angle has been performed.* **B**, *drilling of the inframeatal and suprameatal petrous bone has been extensively carried out to expose the different segments of the IICA that are easily explored with the endoscope without the transection of the basal sigmoid sinus (Sig. S.).* **C**, *drilling has been continued anteriorly up to the petrous apex to fully expose the entire length of the IICA.* **D**, *at the end of the procedure, the transection of the sigmoid sinus has been performed to gain a better microscopic exposure of the genu and of the vertical segment of the IICA, as well as of their relationship with the lateral half of the jugular foramen, in particular with the IX cranial nerve (CN). ES, endolymphatic sac; H., horizontal; JB, jugular bulb; PICA, posteroinferior cerebellar artery; Seg., segment; V., vertical; trans., transverse.*

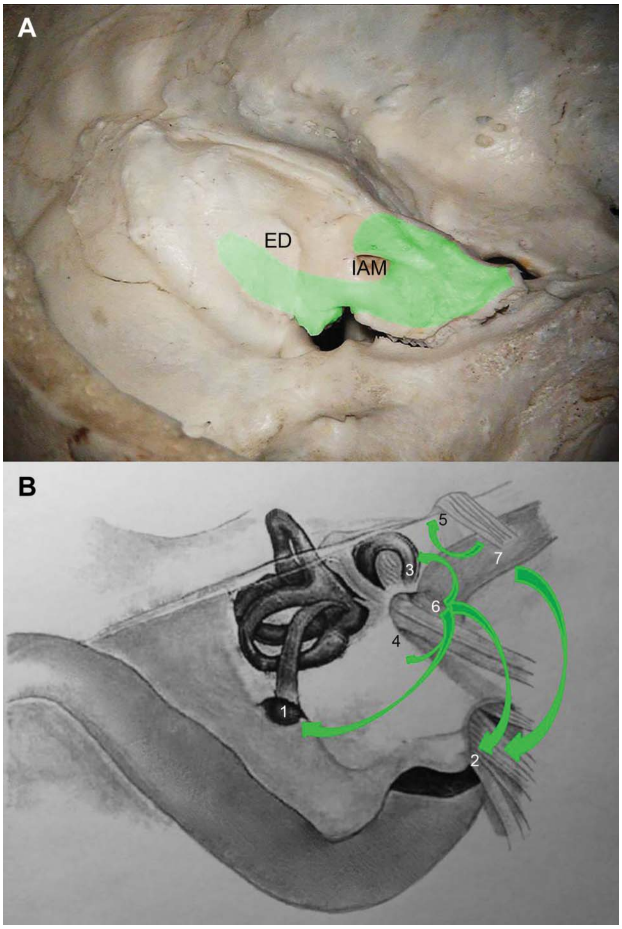

FIGURE 2. **A**, *photograph of a dry skull showing the area of bone drilling in the inframeatal and suprameatal regions.* **B**, *drawing showing the anatomic landmarks we used to localize the intrapetrous internal carotid artery (IICA). Green arrows point to the distances between these landmarks and the IICA. ED, endolymphatic depression; IAM, internal acoustic meatus; 1, endolymphatic sac; 2, XI nerve in the jugular foramen; 3, cochlea; 4, inferior margin of the internal acoustic meatus; 5, inferior border of the Meckel cave; 6, IICA genu; 7, IICA horizontal segment. Adapted from Ammirati et al*[19] *with permission from the American Association of Neurological Surgeons.*

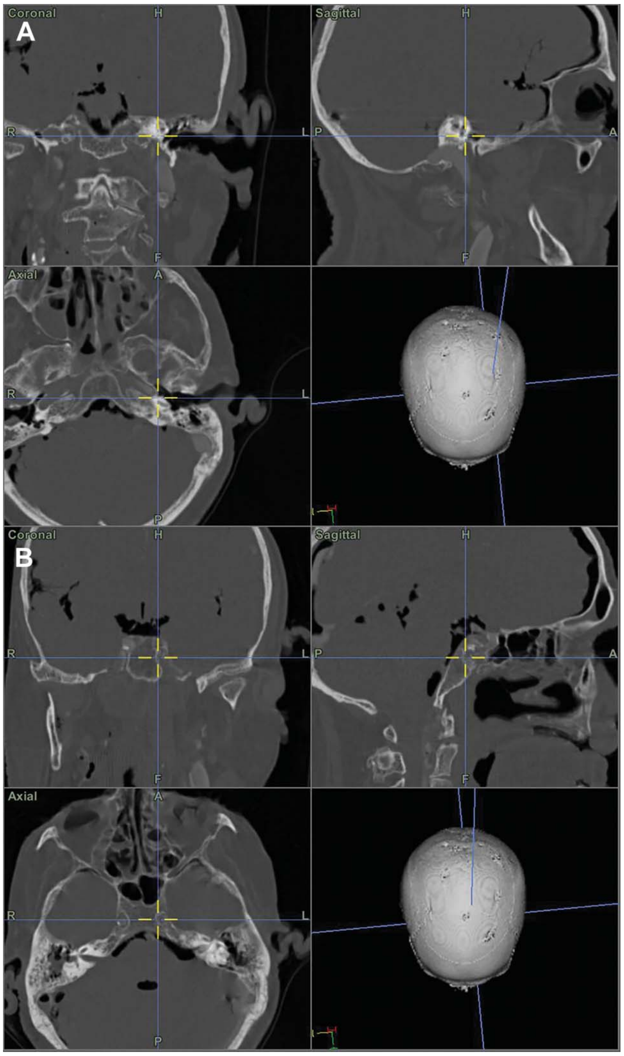

FIGURE 3. **A** *and* **B**, *intraoperative navigation images illustrating the lateral* (**A**) *and anterior* (**B**) *boundaries of the surgical space exposed by the inframeatal and suprameatal extensions of the retrosigmoid approach.*

between these points and the posterior pyramidal wall. These measurements were taken along the axis of drilling. The drilling angle, ie, the angle between the drill and the posterior pyramidal wall, was also measured. The purpose of these measurements was to give a general topographic framework of the location of different segments of the IICA vis-à-vis readily evident anatomic landmarks present in and around the drilling area to guide the drilling even in the absence of neuronavigation (Figure 2).

All distances were calculated from the 3-dimensional distance formula in which the distance between points (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2) can be defined as follows:

$$d = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2 + (Z_1 - Z_2)^2}$$

RESULTS

We were able to expose the IICA safely in all specimens. In addition, in all specimens, we accomplished a safe and wide exposure of the inframeatal/infralabyrinthine area and of the petroclival region while preserving the neurovascular structures and the labyrinth. Intraoperative navigation screenshots and predissection and postdissection computed tomography images may help to correlate the 2-dimensional radiologic anatomy with the microscopic/endoscopic anatomy shown in Figure 1 while highlighting the limits of the operative exposure (Figures 3 and 4).

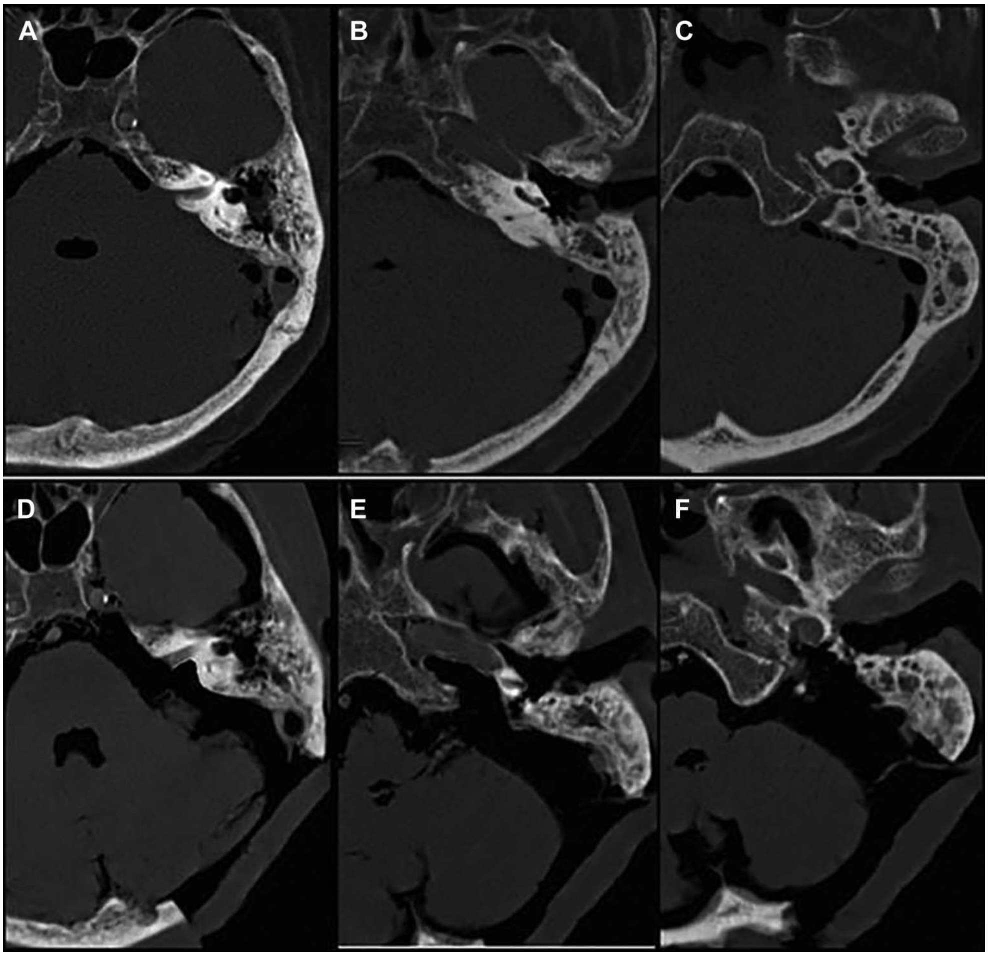

FIGURE 4. *Predissection (**A-C**) and postdissection (**D-F**) axial computed tomography images illustrating the surgical exposure of the inframeatal/infralabyrinthine area and of the petroclival region via a suboccipital retrosigmoid approach. The integrity of the hearing apparatus is maintained.*

The endoscopic view was helpful especially for hard-to-visualize regions such as the inferior-most portion of the inframeatal area and allowed us to fully explore the course of the IICA.

Indeed, the use of the endoscope made possible to expose the entire length of the IICA without the transection of the completely skeletonized basal sigmoid sinus (Figure 1B). Indeed, this transection may allow an effective use of the microscope in manipulating the posterior infratemporal area structures such as the vertical segment and the genu of the IICA, the extradural jugular foramen, the internal jugular vein, and the extracranial lower cranial nerves (Figure 1D).

Intraoperative navigation played a key role. Indeed, it guided the choice of the optimal drilling direction and allowed us to confirm the positions of the endolymphatic sac and various components of the bony labyrinth and to repeatedly assess the amount of the remaining petrous bone covering the IICA. At the end of the procedure, the navigation was used to confirm the boundaries of the surgical exposure (Figure 3).

The drilling of the petrous bone was limited superiorly in a posterior-anterior direction by the internal auditory canal, the cochlea, and the Meckel cave, and inferiorly in a posterior-anterior direction, the jugular bulb, lower cranial nerves, and inferior petrosal sinus limited the drilling. The IICA represented the anterolateral limit.

Our results are shown in Tables 1 and 2. The genu of the IICA was, on average, 15.08 mm anterolateral to the XI nerve in the jugular foramen, 16.18 mm anteroinferolateral to the center of the endolymphatic sac, and 10.63 mm inferolateral to the inferior margin of the internal acoustic meatus. On average, the horizontal segment of the IICA was 9.92 mm inferolateral to the inferior border of the Meckel cave, and the midpoint of the horizontal segment of the IICA was 19.96 mm anterolateral to

TABLE 1. Topographic Anatomy of the Intrapetrous Segment of the Internal Carotid Artery[a]

Distance	Mean, mm	Median, mm	Range, mm
XI–IICA genu	15.08	15.56	11.38-17.18
ES–IICA genu	16.18	16.11	12.42-19.24
IAM–IICA genu	10.63	10.60	7.18-13.60
Cochlea–IICA genu	1.96	2.02	1.00-3.20
PPW–IICA genu[b]	14.63	14.85	12.80-16.30
Meckel cave–IICA horizontal segment	9.92	10.08	7.60-11.64
XI–midpoint IICA horizontal segment	19.96	19.80	15.00-25.80
PPW–midpoint IICA horizontal segment[b]	14.50	14.95	11.70-16.00

[a]Cochlea, basal turn of the cochlea; ES, center of the endolymphatic sac; IAM, inferior margin of the internal acoustic meatus; IICA, intrapetrous internal carotid artery; Meckel cave, inferior border of the Meckel cave; PPW, posterior pyramidal wall; XI, XI nerve in the jugular foramen.
[b]These distances were measured along the axis of drilling.

the XI nerve in the jugular foramen. The mean distance between the genu of the IICA and the cochlea was 1.96 mm.

Moreover, when one considers the axis of drilling, the distance between the posterior pyramidal wall and the genu and midpoint of the horizontal portion of the exposed IICA was, on average, 14.63 and 14.50 mm, respectively. The IICA genu exposure was achieved with a mean drilling angle of 49.74°. A mean drilling angle of 39.54° was used instead to expose the midpoint of the horizontal portion of the IICA.

Table 3 compares our results on the topographic anatomy of the IICA with those reported by previous studies.[20-28]

DISCUSSION

Surgical management of petrous and petroclival skull base lesions is challenging and is usually accomplished through complex and maximally invasive routes.

TABLE 2. Drilling Angle During the Exposure of the Intrapetrous Segment of the Internal Carotid Artery[a]

Drilling Angle[b]	Mean, degrees	Median, degrees	Range, degrees
IICA genu exposure	49.74	49.65	44.30-55.40
Midpoint IICA horizontal segment exposure	39.54	39.53	35.00-47.30

[a]IICA, intrapetrous internal carotid artery.
[b]Drilling angle is the angle between the drill and the posterior pyramidal wall.

Each approach has associated advantages and disadvantages, and the choice has to be made on a case-by-case basis. The anterior transpetrosal approaches offer a wide exposure of the petroclival region, but they are known to be associated with approach-related morbidity that is proportional to the extent of bony removal and vascular manipulations. The translabyrinthine approach, its transcochlear extension, and the Fisch infratemporal routes make available different degrees of petroclival region exposure, but they result in inevitable hearing loss and are often associated with facial nerve malfunction owing to its rerouting. The presigmoid approaches may also be suitable for these tumors, but they entail the risk of temporal lobe vascular injuries and require a massive mastoidectomy, jeopardizing hearing and endangering the facial nerve.[1-14]

There have been recent reports of using extensions of the simple and well-known suboccipital retrosigmoid approach to petroclival lesions with variable bone invasion. Samii et al[15] reported gaining satisfactory access to the inframeatal/infralabyrinthine/petrous apex regions by drilling the petrous pyramid while respecting the integrity of the labyrinth and of the different neurovascular structures. In addition, the suprameatal extension of the retrosigmoid approach has been used to deal with petroclival lesions extending in the lateral incisural and parasellar areas.[16]

Retrosigmoid approaches have been associated with a higher incidence of postoperative headaches than lateral transtemporal routes. This has been related to fibrous adhesions formed between the dura mater and suboccipital muscles and to the potentially irritating bone dust created by petrous pyramid drilling after opening of the dura. In this regard, cranioplasty to seal the bony defect may largely lessen the incidence of postoperative headaches. It has been pointed out that large tumors may restrict the bone particles to the surgical cavity so as to stop their dissemination. Moreover, large tumors usually present a variable degree of erosion/invasion of the petrous pyramid, thus decreasing the amount of bone drilling. In addition, the semisitting position may protect against bone dust collection compared with the supine position.[29-34]

However, both the inframeatal and suprameatal extensions of the retrosigmoid approach rely on extensive bony removal in an area that is traversed by the IICA. This drilling may be challenging because it is executed in narrow corridors, ie, between the trigeminal nerve, the VII-VIII complex, and the lower cranial nerves, and in close proximity to important vascular structures. Nonetheless, the retrosigmoid route allows an earlier visualization of cranial nerves compared with the complex lateral transtemporal/infratemporal or presigmoid approaches, thus reducing the risk of their injury. However, scant information is available on how to execute this drilling from a retrosigmoid avenue while protecting the IICA.

The IICA is divided into 3 parts: a vertical portion, a bend (genu or posterior loop of the IICA), and a horizontal portion.[35] The vertical segment begins where the IICA enters into the carotid canal at the skull base and ends at the genu where the artery turns sharply anteromedially. It is located anterior to the jugular foramen fossa and bulb and anteromedial to the styloid process.

TABLE 3. Topographic Anatomy of the Intrapetrous Segment of the Internal Carotid Artery: Comparison Between Our Results and Literature Data[a]

	Distance, Mean (Range), mm							
Reference	XI–IICA Genu	ES–IICA Genu	IAM–IICA Genu	Cochlea–IICA Genu	PPW–IICA Genu[b]	Meckel Cave–IICA Horizontal Segment	XI–Midpoint IICA Horizontal Segment	PPW–Midpoint IICA Horizontal Segment[b]
Present study	15.08 (11.38-17.18)	16.18 (12.42-19.24)	10.63 (7.18-13.60)	1.96 (1.00-3.20)	14.63 (12.80-16.30)	9.92 (7.60-11.64)	19.96 (15.00-25.80)	14.50 (11.70-16.00)
Paullus et al[20]	NE	NE	6.60 (4.00-10.00)	2.10 (0.60-10.00)	NE	NE	NE	NE
Villavicencio et al[21]	10.10 (4.00-14.70)	NE	NE	2.60 (1.80-4.30)	NE	NE	NE	NE
Osawa et al[22]	NE	NE	NE	2.20 (0.40-4.80)	NE	NE	NE	NE
Leonetti et al[23]	NE	NE	NE	1.68 (0.67-4.24)	NE	NE	NE	NE
Mortini et al[24]	NE	NE	NE	3.00 (2.00-5.50)	NE	NE	NE	NE
Zhen et al[25]	NE	NE	NE	2.00 (0.90-5.00)	NE	NE	NE	NE
Day et al[26]	NE	NE	NE	2.80 (1.00-4.50)	NE	NE	NE	NE
Dew et al[27]	NE	NE	NE	4.30 (3.00-6.00)	NE	NE	NE	NE
Young et al[28]	NE	NE	NE	1.15 (0.20-5.00)	NE	NE	NE	NE

[a]Cochlea, basal turn of the cochlea; ES, center of the endolymphatic sac; IAM, inferior margin of the internal acoustic meatus; IICA, intrapetrous internal carotid artery; Meckel cave, inferior border of the Meckel cave; NE, not evaluated; PPW, posterior pyramidal wall; XI, XI nerve in the jugular foramen.
[b]These distances were measured along the axis of drilling.

The middle ear cavity is mostly posterolateral to the genu and vertical segment.[20,22] The genu of the IICA lies posterior to the entrance of the Eustachian tube into the middle ear and has a consistent relationship with the cochlea, which lies mostly posterosuperiorly.[20] The greater superficial petrosal nerve originating from the anterior aspect of the geniculate ganglion usually travels anteromedial above the genu and the horizontal segment of the IICA.[20] Paullus et al[20] measured an average length of the vertical segment of 10.50 mm (range, 6.00-15.00 mm), in close agreement with other reports.[22,23] Villavicencio et al[21] radiographically studied 15 patients using 3-dimensional computed tomography angiography and reported extremely variable lengths of the ascending portion of the IICA, ranging from 1.70 to 13.80 mm.

The horizontal segment runs anteromedially along the long axis of the petrous pyramid, posteromedial to the tensor tympani muscle, the Eustachian tube, and the foramina spinosum and ovale, and terminates below the trigeminal nerve and ganglion at the posterior edge of the foramen lacerum. Paullus et al[20] noted an average length of the horizontal segment of 20.10 mm (range, 15.00-25.10 mm). Other authors reported similar data[23]; others, shorter lengths[22,24,25]; and others, longer lengths.[21]

The diameter of the IICA was constant in all of its 3 segments, being measured at 5.20 mm (range, 4.00-8.00 mm).[20] Other authors reported similar data.[21,23,24]

Since the seminal studies of Glasscock and Paullus, numerous studies have dealt with the surgical management of skull base lesions involving the IICA via the middle fossa approach or its variants. The complex anatomy of this area led to the definition of geometrical landmarks such as the Glasscock triangle and the middle fossa rhomboid for guiding the approach to these lesions while minimizing possible neurovascular complications.[3-5,7-11,20,24,26,27,36-39]

However, only scant information may be gathered from these studies on the topographic anatomy of the IICA through a suboccipital retrosigmoid approach; its deep position inside the petrous pyramid and the great variability in size and orientation of the petrous pyramid itself make its location challenging. In addition, IICA anatomy may be distorted by the pathology.

Clearly, in a clinical setting, the location and the extension of the tumor dictate the area that needs to be exposed/drilled and whether the sacrifice of the sigmoid sinus/jugular bulb is necessary. However, an extensive petrous pyramid drilling may be required to gain satisfactory exposure of the petroclival region via a retrosigmoid route. Because the IICA represents the anterolateral limit of this drilling, we reasoned that it would be worthwhile to define a general topographic framework of the location of different segments of the IICA itself.

Obviously, accurate preoperative planning is mandatory and the use of neuronavigation is extremely useful for performing such surgeries owing to the anatomic individual variability and the distortion of the petrous bone anatomy produced by the tumor. Nonetheless, the information presented in this anatomic prosection in normal specimens may be helpful in guiding the exposure in pathological situations.

Indeed, our study focuses on consistent anatomic landmarks encountered during a retrosigmoid approach that may be used to identify the area where the IICA is located, thereby allowing safe and maximal bone removal around it even in the absence of neuronavigation. We selected landmarks that are readily evident in the retrosigmoid approach. Some of these landmarks such as the center of the endolymphatic sac and the inferior border of the Meckel cave have not been previously reported.

Our results on the topographic retrosigmoid anatomy of the IICA are largely in agreement with, but in part differ from, those reported by previous studies, highlighting again the great variability in size and orientation of the petrous pyramid itself.[20-28]

The close anatomic relationship between the cochlea and the IICA has considerable importance in a clinical setting. Indeed, it varies widely among patients and requires an accurate preoperative evaluation representing an actual surgical hazard during operative procedures in this region.[28]

The drilling angle, ie, the angle between the drill and the posterior pyramidal wall, is surgically relevant because it is correlated with the cerebellar retraction. It has been estimated that a drilling angle no greater than 60° is safe in clinical situations.[40-42] We accomplished the IICA exposure by using a mean drilling angle of 49.74° for the genu and 39.54° for the horizontal portion. Moreover, as above mentioned, in a clinical setting, large tumors may displace the different neurovascular complexes and present various degrees of temporal bone invasion/destruction, widening the working spaces and in a way showing the best path to their own removal.

CONCLUSION

From a practical point of view, we have found it useful to start the drilling in an area immediately inferior to the internal acoustic meatus and then to continue forward in the direction of the petrous apex because this part of the temporal bone is devoid of important structures. Moreover, our measurements give a general idea of how deep the IICA is from the posterior pyramidal wall. Indeed, when the drilling is begun in this area, the genu and the midpoint of the horizontal segment of the IICA may be exposed at a depth of approximately 14.50 mm from the posterior pyramidal wall using obviously different drilling angles, greater for the genu (49.74°) than for the horizontal segment of the IICA (39.54°). The IICA represents the anterolateral limit of this drilling; hence, knowledge of the general relationship of the IICA with the anatomic landmarks we describe, combined with a careful assessment of the preoperative imaging, the use of intraoperative navigation, and, in a clinical setting, the use of the micro-Doppler, maximizes safe inframeatal and suprameatal petrous bone removal via a retrosigmoid approach while minimizing facial nerve and hearing injuries and possible neurovascular complications. As a result of this extensive pericarotid bony removal, a wide window into the petroclival region is created.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

"Maximizing the Petroclival Region Exposure Via a Suboccipital Retrosigmoid Approach: Where Is the Intrapetrous Internal Carotid Artery?" is an anatomic study exploring the feasibility of exposing the intrapetrous carotid artery (IICA) from a retrosigmoid craniotomy. The study is well done and delineates very elegantly the anatomic landmarks to identify the IICA from this route. Although in a static model this is feasible, it is difficult to compare to a live situation.

The time-honored approach to petroclival lesions is the graded transpetrous system. It provides the widest exposure of the medial cerebellopontine angle, full control of the IICA in case of vessel damage, and a wide corridor lateral to the nerves and vessels. The loss of hearing is an acceptable price to pay compared with the rate of true hearing preservation when a restrosigmoid approach is used for petroclival lesions.

When a transpetrous approach is performed, all the drilling is extradural, preventing bone dust from collecting in the posterior fossa, which can contribute to postoperative headaches. More important, the dura serves as a protective barrier to the cerebellum, lower cranial nerves, and mid neurovascular complex circulation during drilling. When drilling the IICA from a retrosigmoid approach, the surgeon works in a narrow space between the cranial nerves with no protective barriers for these critical structures.

Full exposure of the vertical segment and the first genu of the IICA from a retrosigmoid approach requires either transection of the jugular bulb for visualization or endoscopic visualization and angled drilling. Given the narrow corridor during live surgery, one can conceive a significant risk for jugular bulb injury with the latter. With a transpetrous approach, the entire IICA can be easily exposed without disturbing the jugular bulb and with direct visualization of the vessel, minimizing any potential for injury. Jugular bulb sacrifice with the transpetrous approach is dictated solely by tumor characteristics.

The exposure provided through the retrosigmoid approach seems most appropriate for intradural lesions abutting the IICA. When the lesion itself is mostly extradural or transdural, I cannot conceive a reason to manage the lesion from a retrosigmoid approach (ie, from intradural to extradural). Furthermore, when the IICA is encased by tumor, the transpetrous exposure allows the safest dissection with proximal and distal control of the vessel.

Although clinical applications of this approach at present seem limited, the work presented complements and expand our anatomic knowledge of the IICA. The authors should be commended for an excellent anatomic study.

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This is a detailed discussion of the course of the petrous internal carotid artery (ICA) from the strictly retrosigmoid approach. The authors provide a detailed anatomic discussion based on cadaveric dissection and aided by image-guided frameless navigation. They provide some measurements of the location of the intrapetrous ICA from several posterior fossa landmarks. They emphasize the importance of knowing the relationship of the intrapetrous ICA to avoid injuring it when drilling the petrous temporal bone.

I have to admit, I have never given much thought to the ICA when working in the petrous bone from a retrosigmoid approach. I am extremely fortunate to work with 3 outstanding neuro-otologists. We not uncommonly will remove the suprameatal tubercle, above the internal auditory canal, and a significant portion of the petrous apex through the retrosigmoid approach when dealing with certain petroclival meningiomas but have never actually exposed the ICA when doing so. We have become very impressed with the exposure of the Meckel cave that we can get with this approach, for instance. Less commonly, we remove the jugular tubercle also to increase exposure but not to the extent that it would expose or put the ICA at risk. I think for any pathology for which the approach described in this article might be used such as paraganglioma or chondrosarcoma of the temporal bone, we would much prefer to work in the presigmoid space, transmastoid. We are just much more familiar with the anatomy, could combine it with a retrosigmoid approach if necessary, and would have both better visualization and access to the ICA should it be injured. I look forward to the authors' series of clinical cases using this approach in the future.

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The authors provide an anatomic study focusing on the anatomic landmarks that help identify the petrous carotid artery from a retrosigmoid approach. The study is well done and delineates nicely how one may expose the petrous ICA via a retrosigmoid approach by drilling in the described areas. The study is a cadaveric anatomic study, and no clinical example is provided. The value of this article is in the general description and details on the topographical relationships of the ICA to the cranial nerves and various faces of the petrous bone as visualized during a retrosigmoid craniotomy. From a purely clinical standpoint, I find it dubious that this approach can be safely executed, given the required angle of drilling and the narrow confines delimited by critical structures. Regardless, the anatomic information is quite valuable in terms of optimizing exposure of the petroclival region with approaches commonly used in the clinical setting.

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