

Original Article

Extended exposure of the petroclival junction: The combined anterior transpetrosal and subtemporal/transcavernous approach

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Abstract

Background: The combined anterior transpetrosal and subtemporal/transcavernous (atsta) approach to the petroclival junction provides a wide exposure facilitating resection of large tumor lesions such as petroclival meningiomas, chondrosarcomas, or chordomas. In this article we provide technical instructions on the approach with anatomical consideration and a literature review of previous applications of this approach.

Methods: The combined approach was performed in two cadaveric specimen and relevant anatomical aspects were studied. Additionally, the authors performed a review of the literature focusing on indications, neurologic outcome, and complications associated with the technique.

Results: A combined atsta approach offers a wide exposure of the crus cerebri, pons, basal temporal lobe, cranial nerves III to VII/VIII, posterior cerebral artery (PCA), superior cerebellar artery (SCA), basilar artery (BA), anterior inferior cerebellar artery (AICA), and posterior communicating artery (Pcom). It has been successfully applied with acceptable morbidity and mortality rates, mainly for (spheno-) petroclival meningiomas.

Conclusion: The combined approach studied here is a useful skull base approach to the petroclival junction and can be applied to treat large or complex pathologies of the region. Detailed anatomical knowledge is essential.

Key Words: Anterior petrosal approach, petroclival junction, subtemporal/transcavernous approach

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INTRODUCTION

The junction between petrous apex and clivus is difficult to expose because of its deep and secluded location. Surgery in this area is complicated by the close proximity of important nervous and vascular structures, such as the basilar artery (BA) and its branching vessels, brainstem, and cranial nerves.^[10,11] In this anatomical region, the following pathologies might arise: chondrosarcomas of the sphenopetroclival junction,^[33] chordomas of clival notochord remnants,^[35] neuroma of the trigeminal nerve,^[1,31] meningiomas of the cavernous sinus, the petroclival junction, the medial tentorial notch or the clivus,^[9,27] and cavernomas of the brainstem.^[12]

In the past, the following approaches have been developed to treat lesions of the petroclival junction: Dolenc's, Hakuba's, and Kawase's interdural approach to the parasellar area, the cavernous sinus, its lateral wall, and Meckel's cave;^[8,13,20] the transsylvian transtentorial approach to the medial incisural space and the pontomesencephalic junction;^[15] the subtemporal approach to the pontomesencephalic junction;^[12] the anterior transpetrosal approach to the antero-lateral pons and the BA/anterior inferior cerebellar artery (AICA) junction,^[18,26,32] as well as the retrosigmoid approach with suprameatal extension to the lateral pons.^[5,6,22]

All these techniques expose only a part of the entire anatomic region, however, in cases requiring a wider exposure a combined technique can be applied: the anterior transpetrosal and subtemporal/transcavernous (atsta) approach.

In this study, we aim to demonstrate the surgical techniques of the "atsta" approach and its anatomic exposure based on dissection on two human cadaver heads. Further we provide a review of published surgical case series applying the combined approach to discuss surgical outcome and possible complication.

MATERIALS AND METHODS

For this study two human cadaver heads were used to demonstrate the surgical anatomy and exposure of the combined "atsta" approach to the petroclival junction. The cadaver specimens were donated by people who had given informed consent for their use for scientific and educational purposes prior to death to the Medical University of Innsbruck, Division of Clinical and Functional Anatomy.^[25] The study was performed according to the local ethics committee's regulations.

The two cadaver heads (one male aged 75 years and one female aged 82 years) showed no gross anatomic distortions, however, the cause of death was unknown to us. Preservation was performed in accordance with

the institute's standard.^[24] Vessels were not injected with colored latex.

We used standard neurosurgical instruments, including bone drill, microinstruments, and microscope. All surgical steps were documented using a digital camera.

RESULTS

The surgical technique outlined in this article consists of a temporal craniotomy with transzygomatic extension and extradural anterior transpetrosal approach, as first described by Kawase *et al.*^[18] To enhance exposure of the petroclival junction the tentorium is incised and the meningeal layer of the temporal dura peeled off the lateral wall of the cavernous sinus.^[19] This combined "atsta" approach was applied on two cadaver heads, on the right and the left side, respectively.

Each specimen was fixed in a head holder, 45° rotation to the contralateral side and moderate head tilt. A question mark skin incision was performed and a two layer skin/galea and muscle flap was elevated. To protect the frontal branches of the facial nerve the superficial temporal fascia was incised posterior to the interfascial fat pad vertically all the way from the superior temporal line until below the zygomatic arch. The superficial fascial layer and interfascial fat pad were dissected off the deep fascial layer and reflected anteriorly. Over the zygomatic arch the superficial temporal fascia is adherent with the bone and has to be peeled off thoroughly to protect the facial nerve branches. An osteotomy of the zygomatic arch is performed using a small side cutting burr and avoiding violation of the temporomandibular joint capsule at the root of the zygoma. After completion of the osteotomy the zygomatic arch remains *in situ* and is not freed from the masseteric muscle attachments at its inferior aspect. The temporalis muscle now is incised parallel to the superior temporal line leaving a small cuff for later re-fixation. Posteriorly the muscle was incised parallel to the course of muscle fibers and finally elevated off the temporal squama in a subperiosteal fashion. Anteriorly sharp dissection is used to detach the muscle insertions from the bone around the frontozygomatic suture. Once the muscle has been mobilized it is reflected inferiorly together with the mobile zygomatic arch. By performing this maneuver the temporalis muscle bulk can be reflected into the gap that was created by the zygomatic arch osteotomy. The downward flexed muscle is now flush with the middle cranial fossa. Now a large temporal craniotomy was performed extending up to the Sylvian fissure. After far downward flexion of the temporalis muscle the craniotomy can be performed all the way anteriorly to the frontozygomatic sutureline and inferiorly to the middle fossa floor. After elevation of the bone flap a high speed diamond drill is used to drill off the remaining few millimeters of the temporal squama

until flush with the middle cranial fossa. At this point the operating microscope is brought into the field.

The dura was now peeled off the middle fossa using a dissector under preservation of the greater superficial petrosal nerve, see Figure 1a. At this point the petrous apex is drilled between the horizontal petrous internal carotid artery (ICA) segment, V3, and internal auditory meatus [see Figure 1b]. After completion of drilling the dura of the posterior fossa is visualized below the superior petrous sinus from the outside. After ligation of the superior petrosal sinus a longitudinal dural incision was placed along the temporal base extending to the deepest point of the Kawase's triangle. Figure 2a shows the final exposure of the anterolateral pons and cranial nerves V, VII/VIII and the AICA.

At this point the subtemporal corridor is further expanded. The dural incision is completed across the tentorium under preservation of the fourth cranial nerve at the level of the tentorial free edge. The tentorium and inner most dural layer is now peeled off the lateral wall of the cavernous sinus under the protection of the entry points of the third and fourth cranial nerves into the cavernous sinus wall (a small piece of tentorium was left in place covering those entry points). Figure 3 outlines the final exposure obtained after this step.

In summary the combined "atsta" approach exposes the areas and structures outlined in Figures 2b and 3 comprising the anterolateral brainstem, cranial nerves III, IV, V, VII, VIII, AICA, middle cerebellar peduncle, supraclinoid ICA, posterior cerebral artery (PCA), superior cerebellar artery (SCA) and cerebral peduncle.

DISCUSSION

The "atsta" approach provides a wide anterolateral exposure of the brainstem, cerebral peduncles and adjacent neurovascular structures from the level of the internal auditory canal caudally to the level of the anterior clinoid process cranially, see Figure 4. The technique has proven useful for resection of large tumor lesions, including petroclival meningiomas and chordomas,^[2,14,17] however, we feel that details of the surgical technique,

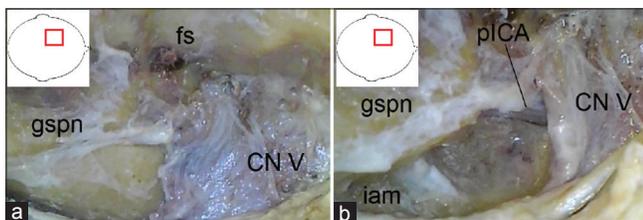


Figure 1: (original): a and b: Left-sided anterior transpetrosal approach, extradural stage: CN V, cranial nerve V; fs, foramen spinosum; gspn, greater superficial petrosal nerve; iam, internal auditory meatus; pICA, petrous segment of the internal carotid artery

surgical anatomy, and final exposure have not been reported in sufficient detail and quality. This study aims at a detailed report of anatomical aspects related to the "atsta" approach.

Aoyagi *et al.* applied the technique on seven patients with tumor lesions of the petroclival junctional area.^[2] Gross total resection was achieved in four of seven patients, >80% resection was achieved in another two patients. The Karnofsky Performance Index did not worsen in any patient, however, transient third nerve palsy was observed in three patients. Harsh and Sekhar utilized the "atsta" approach to treat four patients with tumor lesions.^[14] They achieved gross total resection in all patients, palsy of either third or fourth cranial nerve was observed in two patients. In another series by Kawase *et al.* applying the "atsta" approach on 10 patients with meningiomas they achieved gross total resection in 7 out of 10 patients.^[17]

Pathology-specific considerations

Meningiomas are frequent neoplasms that can be found in 3% of autopsies in patients >60 years and comprise 15% of intracranial neoplasms.^[23] Of all meningiomas 5–10% arise in the petroclival region.^[4] A common problem in clinical practice is that these lesions can reach considerable size until they cause clinical symptoms. The natural history of these lesions is often poor, since 76% of patients progress radiologically and 63% deteriorate clinically after a mean of 82 months.^[34]

Complete surgical resection, unlike radiosurgery relieves mass effects on adjacent structures and offers the possibility of long-term cure. It is well established that a complete resection leads to a significantly lower recurrence rate of 3–4% compared to a recurrence rate of 10–25% in case of subtotal resection. However, surgery of such lesions frequently can carry considerable risks. In a large systematic review including 1000 patients with petroclival meningiomas undergoing surgical treatment the rate of

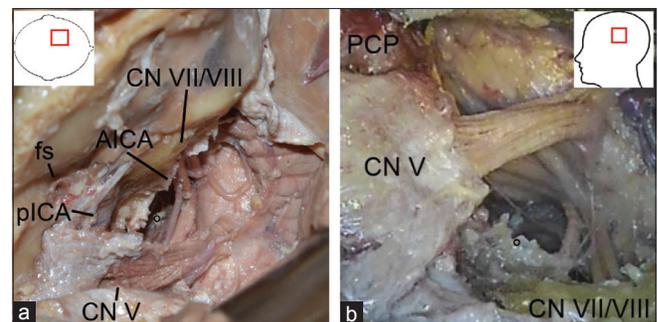


Figure 2: (original) a: Left-sided anterior transpetrosal approach, intradural stage with final exposure of the paramedian brainstem and surrounding structures: AICA, anterior inferior cerebellar artery; CN V and VII/VIII, cranial nerve V and VII/VIII; fs, foramen spinosum; pICA, petrous segment of the internal carotid artery. **b:** Left-sided anterior transpetrosal approach with transtentorial/transcavernous extension, intradural stage with final exposure of the median brainstem: CN V and VII/VIII, cranial nerve V and VII/VIII; PCP, posterior clinoid process

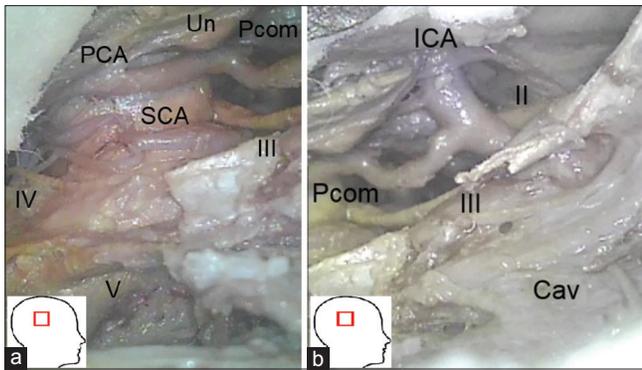


Figure 3: (original): a and b: Right-sided subtemporal/transcavernous/transientorial exposure of the petroclival junction: CN III, IV, V, cranial nerves III, IV, and V; Cav, lateral wall of the cavernous sinus; PCA, posterior cerebral artery; Pcom, posterior communicating artery; SCA, superior cerebral artery; Un, uncus

new cranial nerve deficits was 34% after surgery.^[7] The combined “atsta” approach has been successfully applied in cases of petroclival meningiomas and proved useful especially because of its wide exposure.^[2,14,17] The combined petrosal approach is a different technique, that has been applied, which however gives a slightly different exposure of the posterior fossa extending more caudally compared to the combined approach in this article and requires extensive temporal bone drilling. In a series of 46 patients undergoing a combined petrosal approach to treat petroclival meningiomas gross total resection was achieved in 91%, however, new cranial nerve palsies were shown in 32% of patients, facial nerve palsy being the most frequent (87%).^[29] Interestingly, it was found that tumor size does negatively affect the rate of gross tumor resection, however, there is no effect on postoperative new cranial nerve deficits. The only factors associated with postoperative cranial nerve deficits are previous radiotherapy, prior resection, fibrous tumor consistence, and tumor adherence to its surroundings.^[21] Radiosurgery is an alternative to open surgery in selected cases by controlling tumor size in case of smaller tumor lesions. In a large series by Starke *et al.* of 254 patients undergoing stereotactic radiosurgery for petroclival meningiomas only 9% showed tumor growth and the progression-free survival was 80% at 12 years.^[30] It was noted that tumor control was worse for lesions >8 cc.

For the rare clival chordomas and sphenopetroclival chondrosarcomas (incidence 0.02/100 000 per year) the effect of “extend of resection” on “progression-free survival” and “overall survival” are not well established.^[3,33] However, gross total resection is attempted whenever possible.

Potential Complications of the “atsta” approach

Temporal lobe retraction carries the risk of brain contusion. It has been shown that the temporal upward retraction in subtemporal approaches is more complication prone than a postero-lateral retraction, as

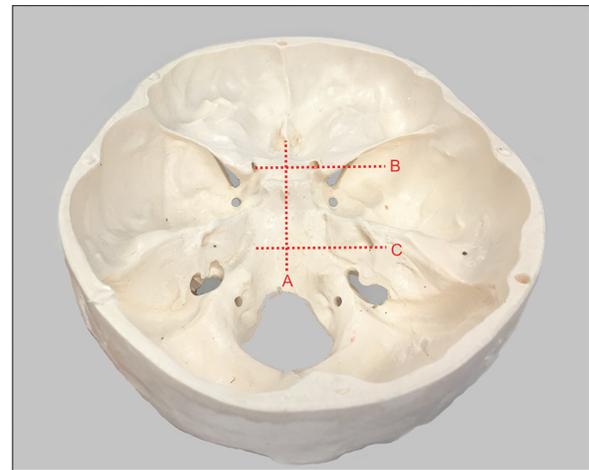


Figure 4: (original): Exposure achieved by the “atsta” approach. Borders of exposure are: A: midline clivus, B: anterior clinoid process, C: internal auditory meatus

applied with a pretemporal approach.^[36] The addition of a zygomatic osteotomy however spares temporal lobe retraction and is believed to lower the risk of temporal lobe retraction injury. However, in published series on patients undergoing tumor removal via the “atsta” approach,^[2,14,17] temporal contusion has not been reported, even though signs of temporal lobe edema have been present in 2 out of 7 patients in the study by Aoyagi *et al.*^[2] Another possible complication is that of a vein of Labbe infarction. The vein usually empties into the transverse sinus near the inflow of the superior petrosal sinus, but in some cases it might drain into the superior petrosal sinus.^[16] Damage can result from temporal lobe retraction or direct injury.

A further potential complication can occur depending on the course of the superficial Sylvian vein. In some individuals this major vein runs along the base of the temporal lobe, rather than draining into the sphenoparietal sinus.^[28] In cases of a subtemporal course of a dominant, poorly collateralized superficial Sylvian vein coursing along the base of the temporal lobe, an anterior transpetrosal approach with a subtemporal dural incision, might have a deleterious result on venous outflow.

The third and fourth cranial nerves are at particular risk during this combined “atsta” approach. Separating the dura from the lateral cavernous sinus wall poses a risk for postoperative dysfunction of the third and fourth cranial nerve.

CONCLUSION

The combined “atsta” approach studied in this article is a useful skull base approach to the petroclival junction and can be applied to treat large or complex pathologies such as sphenopetroclival meningiomas, chordomas, or

chondrosarcomas. The technique enables the surgeon to achieve gross total resection in a significant proportion of patients. Even though cranial nerve deficits (especially cranial nerves III and IV) can be potential complications, the literature shows that these are temporary in a substantial proportion of patients.

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Abbreviations

AICA anterior inferior cerebellar artery

atsta anterior transpetrosal and subtemporal/transcavernous

BA basilar artery

PCA posterior cerebral artery

Pcom posterior communicating artery

SCA superior cerebellar artery

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Nil.

Conflicts of interest

There are no conflicts of interest.

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