Extended Retrosigmoid Approach for Cerebellopontine Angle Meningiomas: Operative Technique and Results—A Series of 28 Patients

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J Neurol Surg B 2018;79:458–465.

Abstract

Keywords

- cerebellopontine angle meningiomas
- extended retrosigmoid approach
- meningiomas
- posterior fossa meningiomas
- sigmoid sinus

Background The purpose of this article is to describe our approach, surgical strategies, and results for resection of meningiomas located at cerebellopontine angle (CPA).

Methods We retrospectively identified 28 patients with CPA meningiomas operated by the extended retrosigmoid approach. This approach incorporates a generous mastoidectomy and the sigmoid sinus exposure.

Results The mean age was 33.8 years, with a follow-up of 12.5 years. Gross total removal (GTR) was achieved in 22 (78.5%) patients with low surgical mortality, acceptable morbidity, and recurrence rate of 7.1% (2 patients).

Conclusion The extended retrosigmoid approach enhances the exposure of the CPA and posterior fossa cisterns and increases the surgical angle of maneuverability. This approach provides adequate access even to extensive CPA meningiomas, enabling, in most of cases, GTR to be safe and effective. The extended retrosigmoid approach used in this group of patients is an alternative to more extensive cranial base approaches.

Introduction

Meningiomas located in the posterior fossa represent 8 to 23% of all intracranial meningiomas. Of posterior fossa meningiomas, those arising from the petroclival region account for 5 to 15%.^{1–6} Though typically benign and slow-growing lesions, they can become quite large before any clinical symptoms are evident or can be found incidentally.^{4,7} Traditionally, CPA meningiomas are being treated through the retrosigmoid approach.^{4–12} While this operative corridor can be sufficient for many cases, they still only provide a limited angle of view for the CPA, petroclival region, and deep midline structures. Additionally, the limited bony exposure can also prevent adequate brain relaxation, as the combination of mass effect and lack of direct access can restrict CSF

egress from the cistern magna and necessitates cerebellar retraction. Compared with the classical retrosigmoid approach, the extended retrosigmoid approach, with additional drilling of the mastoid process and anterior reflection of sigmoid sinus (SS), offers wider exposure of the CPA.^{13–23} The objective of this article is to report on our operative approach and nuances of the surgical technique for removal of CPA meningiomas.

Patients and Methods

Study Design

This study included 28 consecutive patients with CPA meningiomas (histopathologically confirmed) operated between January 1986 and January 2014 (28 years). The main author

received

August 31, 2017

accepted after revision

December 2, 2017

published online

January 18, 2018

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Stuttgart · New York

DOI <https://doi.org/10.1055/s-0037-1620278>.
ISSN 2193-6331.

(J.C.L.) performed majority of the surgeries, between January 1986 and January 2014 (28 years), at the Department of Neurosurgery of the Public Servants Hospital, a tertiary referral academic center and Rede D'Or/São Luiz hospital, a private unit at Rio de Janeiro, Brazil. The medical charts, pre- and postoperative imaging, and pathological reports of the patients were retrospectively reviewed to ascertain the diagnosis of CPA meningiomas, thereby creating a database from which information pertinent to this study was collected. Ethical approval was not required for this study in accordance with the institutional guidelines. The intraoperative videos and/or photos of 22 patients were analyzed for nuances of the microsurgical technique. Computed tomography (CT) and magnetic resonance imaging (MRI) scans were reviewed by the radiology department. In this series, three recently introduced innovations were incorporated: neurophysiological monitoring, endoscopy, and neuronavigation. The Glasgow Outcome Scale (GOS) defined the outcome.

Follow-up

Control postoperative imaging studies were performed within the first 72 hours after surgery to document the extent of resection and postoperative changes. The first clinic visit occurred approximately 15 days after hospital discharge, with subsequent visits at 2 and 6 months. Thereafter, the patients were scheduled for revision at 1-year intervals. They were contacted for imaging studies and clinic visits or interviewed by telephone. The follow-up of this series varied from 3.6 to 29 years with an average of 10.5 years.

The Extended Retrosigmoid Approach and Surgical Technique

Patient positioning: Under endotracheal general anesthesia, the patients were placed in a semisitting position, with the head flexed forward, rotated *ipsilateral* approximately 15 degrees and secured in the three-point fixation device. An arterial line and a central venous catheter were placed in all patients. The involved region was shaved, prepped, and draped in a sterile fashion. Routine antibiotics, dexamethasone and mannitol, were used. The patient was secured with a large tape on the operating table with padded cushions under areas vulnerable to nerve compression. These simple maneuvers allowed rotation of the table to the right or left and elevation or depression of the head, and when associated with multiple microscope angulations, enhanced the exposure, expanding the operative field and decreasing the size of the bone removal.

The procedure was initiated with the use of a 2.5× surgical loupe and coaxial lighting for soft tissue incision and bone work.

Skin incision and muscle dissection: A 12-cm vertical linear incision was made 2 to 3 cm medially to the mastoid and centered approximately 2 cm above the mastoid tip (► Fig. 1C). The incision was carried down through the galea and periosteum over the suboccipital bone and the posterior border of the sternocleidomastoid and trapezius muscle, proceeding to the level of C2. Emissary veins that opened during subperiosteal dissection were controlled using bipolar coagulation and waxed immediately, with repeat waxing

Fig. 1 (A) Preoperative contrast-enhanced axial T1-weighted MRI showing a homogeneously enhancing tumor arising from the left petrous pyramid with slight fourth ventricle compression. (B) Preoperative contrast-enhanced sagittal T1-weighted MRI showing the extension of the large meningioma. (C) Operative photograph showing the right straight paramedian incision in a patient positioned in a semisitting position. (D) Operative view revealing the mastectomy and skeletonization of the SS. (E) The dura is opened by a horse-shaped incision and suture to the muscles to draw the SS out of bone margins. (F) Immediate postoperative CT confirming GTR. Observe the extension of the mastectomy creating a flat corridor to CPA (arrow). CT, computed tomography; GTR, gross total resection; MRI, magnetic resonance imaging; SS, sigmoid sinus.

at the end of the surgery. The spinous process of the second cervical vertebra was the palpable bony landmark guide to the position of the foramen magnum (FM) and enabled a safe subperiosteal dissection of the suboccipital region to be carried along the posterior C1 arch. The paravertebral muscles were detached from the suboccipital bone and progressively sectioned with a scalpel. A self-retaining retractor was gradually inserted into the wound, thus exposing the suboccipital triangle and maintaining the paravertebral muscles in the appropriate position. At that point, the posterior arch of C1 was identified.

Craniectomy: The extended retrosigmoid craniectomy was performed unilaterally using a high-speed drill with a cutting burr. The overlying bone was reduced to an eggshell thin, then a burr hole was made just inferior to the junction of transverse (TS) and sigmoid sinus (SS). A regular Leksell rongeur was used to enlarge the craniectomy from the posterior edge of the occipital condyle to the inferior edge of the TS, exposing the lateral edge of SS. The dura mater was

dissected bluntly from the inner surface of suboccipital region; the rongeur crossed the SS and came to within almost a centimeter of the jugular bulb. After the SS had been thoroughly exposed (skeletonizing), the mastoid process was rongeured generously away, permitting a far lateral exposure (—Fig. 1D, 1F, 2C). In case of caudal extension of the tumor to the FM, it will be necessary to open it and the C1 posterior arch unilateral, but preserving the occipital condyle. The vertebral artery is left undisturbed in the arteriosus sulcus. The access achieved, provides a direct, parallel and an unobstructed line of sight of the petrous ridge or to the clivus, providing sufficient midline and lateral exposure of the tumor and multiple working corridors and allow opening of cisterna magna. In older patients, the lateral wall of the sinus may be adherent to the bone and may be damaged if not carefully separated from the bone. The operating microscope was brought into the surgical field and the operation proceeded with magnification ranging from 10 to 20 $\times$.

Opening the dura: The dura mater was opened by a horseshoe-shaped incision with its base toward the midline. Two relaxing incisions were made laterally, one to the TS and other to the SS. The dural edges were *sutured to the muscles and the suture was pulled to draw the margins of the SS out of the bone* and rotated anteriorly with SS. The arachnoid of the cisterna magna was incised and the cerebrospinal fluid (CSF) was allowed to drain spontaneously. The combination of bone removal, dural opening, and CSF drainage provided

excellent visualization of the entire CPA with minimal cerebellar retraction.

Exposing the lesion: Exposure was improved after gentle elevation of the cerebellum, which was maintained in position with fixed retractors that also protected the cerebellar cortices from lesions during the inadvertent surgical manipulation. The arachnoid was opened along the ninth nerve near the jugular foramen and the drainage of CSF facilitated the rest of the exposure. The arachnoid attachments along in the cerebellopontine cistern were opened, and the arachnoid membrane enveloping the tumor was incised in the posterior aspect of the exposed area using micro scissors. Then, the arachnoid membrane was gently dissected away from the tumor surface to the sides.

The arachnoid membrane was left intact to protect the brainstem from surgical dissection. At that point, the high magnification provided by the operating microscope proved particularly beneficial. Thorough hemostasis was obtained using bipolar forceps to keep the field bloodless.

Debulking the tumor: After low-current bipolar coagulation under saline irrigation of a few vessels travelling on the tumor surface, the lesion was incised, penetrated, and progressively debulked from within, mobilized, and removed in a piecemeal fashion. Since most of the tumors of this region receive their blood supply through the dura, the coring along the bony attachment devascularize the medial and superior parts of the tumor, making the resection easier. The tumor

Fig. 2 (A) CT scan showing a large tumor with anterior brain stem compression. (B) Sagittal T1-weighted MRI confirming the enhancing tumor. (C) Operative view displaying the left extended retrosigmoid approach and skeletonization of the SS. (D) Postoperative MRI demonstrating near-total tumor resection. The small tumor fragment was left behind because it engulfed the basilar artery and perforating's branches. CT, computed tomography; MRI, magnetic resonance imaging; SS, sigmoid sinus.

can be devascularized by coagulating the meningeal feeders from the petrous bone; these attachments should be thoroughly coagulated. Careful attention was paid to identify and preserve the arachnoid plane at the tumor–brainstem interface, which facilitated complete tumor resection and minimized small vessel and brainstem injury. The use of ultrasonic aspirator speeds up the tumor debulking.

Dissecting the tumor: The surgery proceeded within the space provided by the progressive piecemeal coring of the tumor. In the posterior APC meningioma type, the tumor displaces the seventh and eighth cranial nerves (CNs), superiorly the fifth CN, and inferiorly the LCNs; when dealing with anteriorly located APC meningiomas, the cranial nerves are located posterior in relation to the tumor. The surgeon must work alternatively in the spaces between the CNs. The meningioma is dissected and mobilized away from the facial, acoustic, and trigeminal nerves, the brainstem, and blood vessels by gentle, meticulous microsurgical techniques. As tumor debulking proceeded, the brainstem progressively relaxed and provided additional working space for dissection. When dealing with large lesions that compress and deform the brainstem, these tumors should be dissected from, and not against, the brainstem and CNs. Surgeons should be aware that CNs and vessels could be engulfed by the tumor; these delicate structures should be carefully dissected and spared. GTR is always attempted, but whenever dissection of the tumor from the basilar and its perforating branches, the brainstem, or CNs could entail risk of damage, we leave a thin rim of tumor tissue attached to those structures. Dural attachment of basal meningiomas was removed as extensively as possible. Altered bone was drilled away with the high-speed diamond drill until normal bone was reached. In case of supratentorial tumor extension, the lesion would be resected through the ipsilateral corridor as much as possible. Inspection of the tumor bed with the operating microscope was then performed for verification of the extent of tumor resection. A proper packing of the opened mastoid air cells with bone wax should be routinely done. Before closure, the patient's blood pressure was brought to a normotensive level for at least 10 to 15 minutes and monitored for risk of oozing. The dura was closed primarily or with either a free pericranial graft or an artificial dural substitute. The superficial planes were closed in three layers using interrupted sutures. Postoperatively, all patients were cared for in an intensive care unit before returning to the ward.

Results

Patient Demographics and Clinical Characteristics

This series comprises 28 CPA meningiomas. Many studies have concluded that the clinical symptoms varied among patients depending on tumor location and size of the lesion, ranging from slight CN deficits to severe ataxia, CN dysfunction, and brainstem compression, as we observed in this series (3,4; ► **Table 1**). The location of the meningiomas in relation to IAM was anterior in 7 tumors (25%), posterior in 17 tumors (60.7%), and superior in 4 (14.2%). We considered APC < 2 cm as small. Medium-sized tumor varied between 2 and 4 cm and it was considered large when measured 4 to 6 cm and giant

Table 1 Patient demographics and neurological picture

Age at treatment:
9 to 68 y (mean: 37.9 y)
Gender:
Male: 8 (28.5%)
Female: 20 (71.4%)
Hearing loss: 20 (71.4%)
Cerebellar signs: 17 (60.7%)
Headache: 17 (60.7%)
CN deficits: 15 (53.5%)
ICH: 5 (17.8%)

Abbreviations: CN, cranial nerve; ICH, intracranial hypertension.

when more than 6 cm in the large axis. Two tumors (7.1%) were small, 9 (32.1%) were medium size, 12 large (42.8%), and 5 giant (17.8%; ► **Table 2**). The pathology, as defined by the OMS for the classification of meningiomas, was benign in 25 cases (82.7%) and atypical in 3 (12.2%, ► **Table 1**).

Mortality and Morbidity

We observed a single postoperative mortality (3.5%) due to postoperative hematoma in the surgical field. During the follow-up period, two individuals died due to progression of tumor or recurrence. At the time of the last follow-up, 10 (35.7%) patients were in GOS 5, 12 (42.8%) in GOS 4, 3 (10.7%) in GOS 3, and 3 in GOS 1 (10.7%, ► **Table 3**). Excellent or good outcome was achieved in 78.5% of the patients. The dissection of the adherent capsule from the seventh and eighth CNs led to postoperative facial nerve palsy in 16 patients (57.1%). The long-term facial function (House–Brackmann [HB] 1 and 2) was reported in 62.4% patients and HB 3, 4, and 5 in 37.6% of patients. Three patients were submitted to facial nerve grafting with good results. Hearing deterioration occurred in

Table 2 Tumor characteristics

Size: 2.0–10.5 cm
Small: 2 (7.1%)
Medium: 9 (32.1%)
Large: 12 (42.8%)
Giant: 5 (17.8%)
Grade (WHO):
Grade 1: 26 (92.8%)
Grade 2: 2 (7.1%)
Location in relation to IAM:
Anterior: 7 (25%)
Posterior: 17 (60.7%)
Superior: 4 (14.2%)
Right: 16 (57.1%)
Left: 12 (42.8%)

Abbreviation: WHO, World Health Organization.

Table 3 Surgical outcome and follow-up

Surgical mortality: 1 (3.5%)
Recurrence: 2 (7.1%)
Gross total removal: 22 (78.5%)
GOS 5: 10 (35.7%)
GOS 4: 12 (41.8%)
GOS 3: 3 (10.7%)
GOS 1: 3 (10.7%)
Complications:
CSF leak: 4 (14.2%)
Meningitis: 2 (7.1%)
Wound infection: 2 (7.1%)
Pulmonary complications: 2 (7.1%)
Follow-up: 3.6–28 y (mean, 10.5 y)
Patients lost to follow-up: 2 (7.1%)

Abbreviations: CSF, cerebrospinal fluid; GOS, Glasgow Outcome Scale; GTR, gross total resection.

20 of our patients (71.4%); it can be attributed to purely neural trauma. Complications concerning this approach included two (7.1%) patients with difficulty in swallowing that needed temporary tracheostomy and tube feeding. Minor postoperative complications included wound infection, CSF fistulas occurring in four patients (14.2%). Deep venous thrombosis and pulmonary complications were observed in two (7.1%) patients.

Discussion

Mortality, Morbidity, Extension of Resection, and Recurrence

The best surgical strategy for CPA meningiomas has been debated for a long time. Prior to the advent of the operating

microscope, operative mortality for removal of CPA meningiomas ranged from 27 to 57%. Death rates have declined since then.^{3,4,6,11,12,18,20} The operative mortality in this series was 3.5% (one patient). Yasargil et al,¹¹ Samii et al,¹² Malis,¹⁸ and others^{3–5} advocate that the ideal management of CPA meningiomas is GTR. In literature, GTR rates range from 27.5 to 86.1%.^{3,6–8,12,17,18,20,24} In the current series, we achieved GTR in 22 individuals (78.5%; ►Fig. 1F, 2C, 3B; ►Table 3). On diagnosis, many lesions are already large or giant. Several authors reported increasing tumor size to portend higher rates of incomplete resection, higher rates of surgical morbidity, and an increased risk of recurrent disease.^{5,12,20,25} In this sample, 60.7% of the lesions were large or giant. In this situation, GTR could be dangerous due to adherence or even encasement of vital structures by the tumor. If the surgeon persists with any attempt to remove every last residual piece of tumor to cure the patient, it could result in an unwarranted CN or arterial injury, thus increasing mortality and morbidity. Consequently, GTR is not always a reasonable goal to achieve, especially in elderly patients and in large lesions.^{6,17,18,24–29} On the other hand, when tumors are removed incompletely, they tend to regrow after varying periods of time. Secondary operations undertaken after incomplete first attempt are even more problematic since reoperation is, therefore, less likely to achieve GTR and will carry a higher mortality and morbidity.^{18,24,25} As some of the CPA meningiomas can behave indolently, the risk of potential complications of GTR should be well-weighed against the benefits. Other authors advocate a safer STR followed by radio-surgery.^{30–32} The recurrence rate in this sample was 7.1% (two cases, ►Table 3). Our surgical objective was always GTR, but in tumors encasing the basilar artery and perforating vessels or adhering to CNs, a STR could represent a very acceptable goal.

In literature, postoperative facial nerve paralysis varies from 2 to 35%.^{3–5,7,8,12,25} In our work, we achieved good facial function (HB 1 and 2) in 62.4% of the patients, and HB 3, 4, and 5 in 37.6% of patients. To preserve the function of the seventh and eighth nerves, we took several careful steps during the surgery: (1) Increase the microscopic magnification during nerve

Fig. 3 (A) CT scan showing a large petrous ridge meningioma with brain stem compression and contra lateral shift. (B) Operative microphotograph after GTR. We can clearly identify the preserved seventh and eighth CNs in the lower quadrant, the fifth CN, the Basilar artery, and decompressed brain stem. (C) Postoperative CT scan confirming the GTR. CT, computed tomography; CN, cranial nerve; GTR, gross total resection.

manipulation to 20×. (2) The preservation of the auditory artery branch is requisite if the hearing is to be maintained. (3) Sharp dissection with micro scissors is used for the dissection of the tumor from the nerves, the use of bipolar coagulation is kept to a minimal necessary, and when used, the coagulation is done in small segments between the forceps tips under a stream of normal saline, with a low current, to prevent heating damage. (4) The aspiration is regulated in the soft module, and the suction tip can be used without fear of damaging a nerve or vascular structures. (5) The dissection of the meningioma from the seventh and eighth nerves should be performed from medial to lateral, avoiding traction under the fragile cochlear nerve in the meatus. (6) After the removal of the lesion, if there is slight ooze under the facial nerve, a hemostatic agent should be used instead of the bipolar coagulation. (7) Drilling the posterior wall of the IAC to remove intracanalicular fragments is performed with a 2.5-mm burr under continuous irrigation, without damaging the neural structures.

In this series, adjuvant RT was daily applied, five times a week for 6 weeks in two postoperative patients. With recent advances in neuroendoscopic techniques, reports of endoscopic-assisted and purely endoscopic removal of CPA tumors have emerged.^{33,34} In this sample, the endoscopic-assisted techniques were employed on only two occasions. The expanded endoscopic endonasal approach in the management of ventral posterior fossa meningiomas is still restricted due to limited surgical indications. It can be used for the rare cases of meningiomas with most part of its dural base at the midline clival region.³⁵

The Extended Retrosigmoid Approach

In this study, we explored the efficacy of the extended retrosigmoid approach for surgical removal of meningiomas located in the APC. These meningiomas present a unique operative challenge in the setting of significant mass effect and limited visualization, mainly for large or giant lesions. Even a modest CPA meningioma can occupy a significant proportion of the posterior fossa, severely restricting surgical maneuverability, placing cranial nerves on stretch, and increasing the risk of injuring the cerebellum or its vascular supply during resection. Additionally, the limited bony exposure can also prevent adequate brain relaxation, as the combination of mass effect and lack of direct access can restrict CSF egress from the cistern magna.^{24,25,36,37} Traditionally, CPA meningiomas have been resected through a retrosigmoid approach.^{4–12} While this operative corridor can be sufficient in many lesions, it only provides a limited angle of view for the CPA. Resecting large CPA meningiomas through the classical retrosigmoid approach can be technically challenging.^{3,5,7,12,15–17,20}

Heros initially described the concept of a posterolateral approach to the anterior aspect of the craniovertebral junction.³⁸ George et al described an anterolateral approach.³⁹ In the extended retrosigmoid approach, described by Malis^{13,14,18} and by others,^{15–17,19–23,37} the SS is fully skeletonized, moved laterally and superiorly by a dural tend suture, expanding the operative field to CPA and deep vascular structures. A generous drilling of the mastoid air cells and skeletonizing the SS markedly increase the anterior exposure,

decrease the amount of cerebellum retraction, consequently reducing the incidence of venous infarction, edema, and contusion. It also allows for greater visualization of the operative space within the posterior fossa and a wider operative field with the possibility of employing several operative microscopy angulations and multiple surgical corridors, that is particularly important in cases of large or giant type of APC tumors. Shifting the surgical microscope axis from lateral to medial, the tumors can be reached through a tangential view, besides the usual posterior lateral angulation. For two tumors presented with small expansion toward the Meckel cave, we used the intradural suprameatal approach as described by Samii et al.¹² GTR was obtained in both meningiomas. Three meningiomas extended to the FM; they were removed with expansion of FM and C1 removal. In one case, the tumor extended to the incisural notch, the lesion was subtotally removed. In five patients, the IAC drilling was needed to achieve a more complete resection.

One of the potentiated benefits of this approach adopted is the avoidance of temporal lobe retraction.^{5,12,16,36} But, a clear contraindication is occlusion of the contralateral SS.^{20,36,40} In the posterior CPA meningioma type, the tumor displaces forward the seventh and eighth CNs, superiorly the fifth CN, and inferiorly the LCNs. Thereafter, the meningioma can be relatively easily dissected from neural structures. When dealing with anteriorly located APC meningiomas, the facial and cochlear nerves are displaced posteriorly in relation to the tumor. The surgeon must cautiously work alternatively in the spaces between the CNs or between the tentorium and trigeminal nerve.^{4,5,10,12,36,41} Compared with the classical retrosigmoid approach, the extended retrosigmoid craniotomy allows for greater visualization of the posterior fossa. It is relatively simple, safe, and diminishes bone removal in comparison to the extreme lateral approach. The drilling of the jugular tubercle and occipital condyle or vertebral transposition is not necessary, avoiding the possibility of craniovertebral instability.^{13–23} Ceylan et al,¹⁹ in a cadaveric study, concluded that the extended retrosigmoid approach offered to neurosurgeons approximately 50% larger angle of view and shorter working distance than the traditional approach. Abolfotoh et al²⁰ stated that the mean working distance for the transmastoid approach was 23.06 mm, whereas the working distance in the traditional approach was 46.44 mm. The mean increase in the angle of work after drilling of the mastoid was 25.39 degrees. There is a worry that the SS can be squeezed against the occipital bone and produce venous congestion and cerebral edema. If this happens, it will be necessary to relieve the traction on the SS.^{15,16} This complication has not been observed in our case series.

The extended retrosigmoid approach is also suitable for treatment of petroclival meningioma if the main part of the tumor is located in the cerebellopontine angle, and only a minor part of the tumor extends to the posterior wall of the cavernous sinus. Al-Mefty et al²⁵ and others^{18,20,36,37} advocate that the petrosal approach should be reserved for large petroclival meningiomas that extend both supratentorially and infratentorially. The guiding principle of these complex

skull base surgical routes has been extensive bone removal to minimize brain retraction and bring the surgeon close to the target. Although these approaches have proved useful, they are associated with significant built-in morbidity and potential complications.^{18,20,24–26,37,40,41} *As this article describes a retrospective study, it has inherent biases and drawbacks and only a prospective study can overcome these weaknesses.*

Conclusion

In the extended retrocondylar approach, a generous drilling of the mastoid air cells and skeletonizing the SS markedly increase the anterior exposure, decrease the amount of cerebellum retraction, allowing for greater visualization of the operative space within the posterior fossa. This technical modification over the standard retrosigmoid approach may provide useful advantages to neurosurgeons dealing with these complex lesions. The extended retrosigmoid approach is a versatile approach to this area and allows GTR even to giant CPA meningiomas.

The extended retrosigmoid approach can be a valid alternative to more extensive cranial base approaches. This surgical approach is safe and effective, but our results should be interpreted with caution due to the small sample size and lack of a control group.

Acknowledgment

The authors would like to thank Dr. Leonard I Malis, MD (in memoriam), for his valuable intellectual and creative inputs.

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