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Treatment of Lateral Skull Base and Posterior Cranial Fossa Lesions Utilizing the Extended Middle Cranial Fossa Approach

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Abstract

Objective—Define the indications and outcomes for subjects undergoing treatment utilizing the extended middle cranial fossa approach (EMCF).

Study design—Retrospective records review.

Setting—University-based tertiary referral center.

Patients—Subjects undergoing treatment of PCF (posterior cranial fossa) lesions.

Intervention(s)—EMCF exposure and treatment of the indicating PCF lesion.

Main outcome measure(s)—Demographic, audiometric, and cranial nerve functioning variables were assessed.

Results—Thirty-five subjects who underwent an EMCF exposure were identified over a 12-year period. The most common indication was meningioma (18; 51%) followed by schwannomas (6, 17%) and vascular lesions (5; 14%). Preoperative cranial nerve complaints were common (32, 94%) as were objective cranial nerve abnormalities on physical exam (21; 60%). Preoperative audiometric data from subjects with hearing demonstrated good functioning including pure tone average (21.7 +/- 15.6 dB HL) and word understanding scores (95.1 +/- 7.4%). Most (34, 97%) subjects had intact facial nerve function. The average length of stay was 11.6 days (median = 9). Cranial neuropathies were common postoperatively with 27 (79%) subjects demonstrating some objective cranial nerve dysfunction, the most common of which was trigeminal nerve hypesthesia (21; 61.7%). Subjects with identifiable pre- and postoperative audiometric data and preoperative hearing demonstrated small declines in the four-tone average (16.2dB) and word recognition scores (22.4%). Two subjects (6%) had new profound hearing loss postoperatively.

Conclusions—The EMCF approach can provide safe and effective exposure of the anterior PCF.

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Introduction

Lesions of the anterior cerebellopontine angle (CPA), prepontine cistern (PPC), cavernous sinus and the surrounding skull base present a formidable challenge to the contemporary skull base surgeon due to the complexity of the regional anatomy. Many surgical techniques have been developed for accessing the anterior CPA and PPC and can be categorized by how each treats the otic capsule. Transcapsular approaches, including the transotic and transcochlear approaches, provide exposure to the CPA and PPC but sacrifice residual hearing and require resection of the external auditory canal (1–3). Retrocapsular approaches include the transcrural, retrolabyrinthine and retrosigmoid approaches and these provide excellent exposure of the lower CPA and can allow for hearing preservation (4,5). However, the angle of approach places cranial nerves (CN) 5–12 between the surgeon and lesion endangering serious risk, requires significant retraction or resection of the lateral lobe of the cerebellum, and places the lateral pons with the corticospinal tracts in surgical jeopardy (6). Supracapsular approaches include the middle fossa (MCF) approach, which when limited to its description by House (7), provides exposure of the internal acoustic canal (IAC) and limited access of the anterior CPA and PPC. Precapsular approaches include the extended middle fossa (EMCF) and subtemporal (ST) techniques. Each of these precapsular approaches afford the possibility of hearing and facial nerve preservation and provide varying degrees of access to the anterior CPA and PPC ventral to the middle and lower CNs.

House's landmark publication in the later half of the 20th century reintroduced exposure of the posterior cranial fossa (PCF) from the MCF approach (7). Since this time, many variations of the MCF approach have been published including the seminal work by Kawase et al (1985) that consisted of an extradural, subtemporal exposure of the central skull base and removal of the anterior petrous apex (APA) (8). This approach has been utilized in the treatment of a wide variety of skull base lesions (8–10). The majority of published articles describing the EMCF approach consists of small series of cases (<6) (6,11,12) or describes the use of the approach in the treatment of one type of lesion (8,10,13,14). Danner and Cueva (2004) describe 16 subjects with an assortment of lesions treated with the EMCF approach and demonstrated excellent results. The current report describes a series of 35 subjects treated at an experienced, tertiary referral center and demonstrates the safety and utility of the EMCF in treating a wide variety of skull base lesions.

Materials and Methods

This study was approved by the University of Iowa Institutional Review Board and was designed as a retrospective case series of subjects undergoing an EMCF approach from 2003 until 2014. This timeframe was chosen to limit the search to cases performed by the 2 senior surgeons. For the purpose of this report, the EMCF approach is defined as exposure and dissection of a region (Kawase's area) bounded on its cranial surface by the IAC or superior semicircular canal posteriorly, the greater superficial petrosal nerve (GSPN) and carotid artery laterally, the trigeminal nerve and Gasserian ganglion anteriorly, and the superior petrosal sinus (SPS) medially (8).

Demographic, audiometric, radiographic, histologic, historic, physical exam, surgical, complication and outcomes data were extracted from the medical record and tabulated in a database. Pure tone averages (PTA) were calculated as the mean of the thresholds at 500, 1000, 2000 and 3000 Hertz (Hz). The 3000 Hz pure-tone threshold was not universally available; in these cases, the 3000 Hz threshold was estimated by averaging the thresholds at 2000 and 4000 Hz (15). In subjects with known complete hearing loss and no postoperative study, thresholds were assumed to be at the lower limit of detection or performance. Audiometric data was categorized according Word Recognition Score (WRS) (16), American Academy of Otolaryngology – Head and Neck Surgery Committee on Hearing and Equilibrium (AAO-HNS) 1995 reporting guidelines, and the reporting format described by Gurgel et al, 2012 (17).

Available imaging studies were individually reviewed to determine the anatomic region of the index lesion. Size measurements were taken in the medial-to-lateral (ML) and anterior-to-posterior (AP) dimensions of the cisternal portions of the index lesions. For lesions without a significant cisternal component (e.g., chondrosaroma of foremen lacerum), the maximal ML and AP dimensions were determined without regard temporal bone orientation. Facial nerve function was assessed using the House-Brackmann scale. Symptoms and physical exam findings were dichotomized as present or absent. Length of stay and follow up were determined as the time elapsed between the surgical intervention and the time point of interest. Frequencies and descriptive statistics were calculated using standard methods. Differences between means were tested using the 2-tailed T test for continuous variables. Thresholds for significance were set to 0.05. All statistical calculations were performed in IBM SPSS Statistics 23 (IBM Corporation).

Surgical technique

There are many variations and possible extensions of the EMCF technique and the following description constitutes our basic approach and common variations. A large, anteriorly based incision is made starting in the preauricular region, and a skin flap is elevated over the body of the zygoma and the zygomatic arch. If far medial and inferior exposure of the premeatal CPA and PPC is needed, the zygoma arch is removed with a reciprocating saw. The temporalis muscle is reflected inferiorly. For IAC and CPA lesions, a 5×5cm window centered 1cm above zygomatic process of the temporal bone is created. For petroclival lesions where access to the prepontine cistern is needed, a large frontotemporal craniotomy is made. The dura is carefully elevated from the middle fossa floor and dissection is carried medially to the petrous ridge and the superior petrosal sinus (SPS). The dura is elevated anteriorly to the Gassarian ganglion.

Skull base dissection begins medially and anterior to the approximate location of the IAC and continues with excavation of the APA inferiorly to the level of the inferior petrosal sinus (IPS). The ICA is identified and all bone between the ICA and the SPS is removed. Bone is also removed caudal to expose the entire posterior fossa dura of the petrous apex. Anterior extension can proceed to the level of the clivus. The dura of the anterior petrous apex can be opened to expose the anterior CPA and PPC. In larger lesions that are attached to the tentorium, wider exposure is obtained by dividing the SPS and transecting the tentorium

cerebelli taking care to preserve the fourth CN that becomes a portion of the tentorium in the anterior 1/3. The posterior fossa dura is then opened contiguous with the tentorial cut to open between the middle and posterior fossae. This exposes the entire posterior fossa for access to the primary lesion. In some cases the exposure is expanded by removal of the greater wing of the sphenoid and partial clinoidectomy to provide greater exposure of the gasserian ganglion and cavernous sinus. Removal or treatment of the index lesion now commences.

Results

From 2003 until 2014, 35 cases were identified where the primary surgical exposure was an EMCF approach. All subjects are extensively counseled about the nature of their lesion, when known, and the treatment options available to them including expectant management with serial radiographic evaluations, treatment with stereotactic radiation (when appropriate), and microsurgical removal / debulking. Subjects included in this report had lesions not amenable to radiotherapy (e.g., epidermoids or lesions with brainstem involvement), lesions with documented growth, or cases in which the subject elected to pursue surgical intervention as their preferred treatment option.

Table 1 gives the demographics of the study cohort. Women were almost 3 times as common as men (2.8:1). Four of 35 (11.4%) subjects were initially observed: 2 demonstrated growth of their lesion and 2 elected for treatment without anatomic change in the lesions (1 schwannoma and 1 aneurysm). The time from initial surgical consultation to surgery was just under 1 year. However 2 subjects who were observed for 8 and 15 years, respectively, dominated this time frame. Most subjects were in their 5th decade at the time of surgery though there was a large range. More than half of the index lesions were meningiomas (18, 51%). Supplementary figures 1 and 2 provide representative samples of the lesions in this cohort. Table 2 lists the preoperative clinical characteristics of the cohort. Cranial nerve abnormality on physical examination was found in the majority (21, 60%) of subjects with trigeminal hypesthesia being the most prevalent deficit. Neoplasms were typically moderate to large in size with most being over 1.5 cm in the ML and AP dimensions. Table 3 provides the audiometric and hearing outcomes. Thirty-one subjects had preoperative testing and audiometric function was good overall. When considering just those with serviceable hearing (WRS I-III), the PTA and SDS were both in the normal and good ranges, respectively. Three subjects with pre-operative testing with poor PTA and SDS preoperatively. Two had previously undergone hearing destructive procedures unrelated to their index lesion in this study. The other suffered a bleeding aneurysm with loss of hearing preoperatively.

The majority of non-vascular lesions underwent a gross total (19, 59%) or near total (8, 25%) resection. Intraoperative placement of a lumbar CSF drain was performed in 13 (37%) of cases. Use of a lumbar drain was not associated with the size of the lesion on preoperative imaging (data not shown). Table 4 and supplemental table 1 give the postoperative outcomes. Three subjects were found to have postoperative CSF leakage including in one case where a lumbar CSF drain had been placed intraoperatively. Two of these resolved while one required a petrous apicectomy and Eustachian tube obliteration. The length of stay

on average was just over 11 days with a considerable range. The presence of a postoperative complication was associated with longer admission duration: those having a complication stayed just over 19 days and those without a complication stayed just over 7 days ($p < 0.02$). Three (8.8%) of 34 available subjects had a decline in facial nerve function from HB I to HB II function at 1 years time from surgery. Additional surgical interventions were required in 4 subjects, 2 of who have NF2 and needed other skull base lesions addressed. When considering postoperative CN function, 32 subjects had at least one CN deficit versus 21 subjects with at least one CN dysfunction preoperatively. The most common pre- and postoperative deficit involved the trigeminal nerve, typically hypesthesia. There were a considerable number of CN deficits that resolved after surgery: 13 deficits involving CNs 3, 4, and/or 6 and 11 deficits involving CN 5 resolved (Supplemental Table 1).

Hearing outcomes were generally good (Table 3). Of the 21 subjects with postoperative testing, 15 had serviceable hearing via WRS scoring and 11 had serviceable hearing via AAO-HNS classification. The majority (26, 74%) had some evidence of hearing postoperatively. On average, the PTA was in the moderate hearing loss range and SDS scores were adequate. When considering subjects with serviceable hearing (WRS I-III) preoperatively, both PTA and SDS performances were better than the overall cohort. The mean change in PTA was a 16.2dB nHL elevation while the mean change in SDS score was a 22.4% decline. In those with WRS class I hearing, these metrics were slightly better. Figure 1 provides the preoperative and postoperative audiometric data presented in scattergram format.

The mean follow up time was 113.4 months with a standard deviation of just over 7 years and a range of greater than 10 years. Table 5 documents the major complications. Overall 13 (37%) subjects had a complicated postoperative course including 1 perioperative death not directly attributable to the surgical intervention. The majority (8, 61%) resolved completely. Three subjects required admission to a rehabilitation facility; all were discharged with a final disposition to their previous living situation without further care indicated. Postoperative radiation was utilized in 5 subjects: 3 with chondrosarcoma and 2 for persistent meningiomas involving eloquent skull base regions that demonstrated growth on postoperative surveillance imaging.

Discussion

Though the first description of a middle fossa exposure of PCF structures occurred over 110 years ago, it would be another than half a century before the groundbreaking work by House popularized the middle fossa approach (7). Since the reintroduction of the middle fossa exposure in 1961, numerous “extended” variations have been described including the introduction of the subtemporal anterior petrousectomy by Kawase (8). This combination of extradural, subtemporal exposure and removal of the anterior petrous pyramided allows for expanded exposure of the CPA and PPC while limiting temporal lobe retraction. Additionally, many authors report the use of the EMCF approach in combination with other petrosal approaches (18–24). The exposure provided by the EMCF approach gives access to the IAC, APA, upper and anterior CPA to the level of the 7th and 8th CNs, PPC to the level of the IPS, Meckel’s cave, the ventrolateral pons, the lateral bony skull base, and upper two-

thirds of the clivus (6,9,10,12). Common to most descriptions is a large temporal craniotomy and thorough dissection of the petrous apex to the level of the IPS. The SPS can be divided as can the tentorium cerebelli for more exposure to the PPC.

The EMCF approach has several advantages over other approaches to the anterior CPA and PPC. The largely extradural dissection protects the temporal lobe. The angle of approach provides improved cisternal windows between the 4th and 5th CNs and between the 5th, 7th and 8th CNs (10,14). Additionally, several authors have advocated enhanced surgical freedom due to the conical shape of the bony exposure (10,14). Lastly, as the approach does not require violation of the otic capsule, preservation of hearing, balance and facial nerve function is possible and has been demonstrated in several publications (9,14).

At the University of Iowa, lesions requiring surgery involving the cisterns of the anterior CPA and PPC, the cavernous sinus, upper clivus and petrous apex are preferentially exposed via the EMCF approach. Similar to the work by Danner and Cueva (2004), the majority of the lesions were meningiomas (9). This explains the high proportion of females in the cohort. Most of lesions were located primarily in or involving the petroclival region including the anterior CPA, PPC, and MC. This provides an explanation for the majority of our findings including preoperative symptoms and postoperative outcomes. The majority of lesions involved the region of the trigeminal nerve making preoperative facial pain / numbness an expected finding, though the rate reported herein is higher than in previously reports (18–29% vs. 48% in the present study) (9,14). Hearing loss was the next most prevalent complaint and is not surprising given that the lesions were on average moderately large and located near the 8th nerve. However, the objective audiometric data revealed that most subjects had quite good hearing, consistent with the results published by Shen et al (2004) (14). This was especially true of subjects with serviceable hearing (WRS III or better). When the 3 subjects with preoperative WRS class IV hearing are excluded, the pure tone thresholds and word recognition scores were essentially normal. This is not unexpected when considering the location of the index lesions were anatomically far from the cisternal portions of the 8th CN and thus can attain considerable size before hearing is impacted. Preoperative facial nerve function was normal in 34 of 35 subjects and preoperatively paralyzed in one subject, consistent with other reports (9,14).

Gross total resection was the most common extent of resection though ~46% underwent a near total or subtotal resection in an attempt to minimize morbidity. This is consistent with most recent literature as early series demonstrated high gross total resections rate but concomitant high morbidity rates (25–28). Contemporary reports advocate near total or subtotal resection in an effort to preserve CN function (14,29).

Three subjects developed facial nerve weakness that stabilized to a HB II at 1 year postoperatively, a slightly lower rate than previously reported (14). New CN deficits were found in 19 (~55%) of subjects. While high, this number is in line with a survey of the literature regarding the treatment of petroclival meningiomas (range 26–91%) (9,19,21,23,27,28,30–33). The most common persistent CN deficit was trigeminal dysfunction. This not surprising given the typical location of the lesions in this cohort. The most common preoperative cranial neuropathy to improve was than of CNs 3, 4, or 6 in

which 13 subjects had documented resolution of a gaze weakness or paresis (supplemental table 1). One explanation could be that removal or debulking of the index lesion allowed for resolution of pressure or traction on the nerves in the cavernous sinus.

Hearing outcomes were overall good (Table 3 and Figure 1). Unfortunately, only 21 subjects had postoperative audiometric results available. When looking at the WRS scores from before and after surgery on available tests, 89% were WRS I before surgery as opposed to 72% after surgery. Inspection of Figure 1c reveals that only 2 subjects were at the extreme of the scattergram. Thus, most subjects preserved a significant amount of useful hearing. Most subjects (26, 76%) had clinical evidence of postoperative hearing, consistent previous results (9).

Cerebrospinal fluid leakage occurred in 3 subjects for a rate of 8.5%, which is slightly higher than our CSF leak rate in the treatment of vestibular schwannoma but within the range of other reports (6,14,34). Complications occurred in 13 (37%) subjects including one perioperative death (~3%); the majority resolved and most improved over time. The rate of complications is slightly higher than the reports by Shen et al (2004) (15%) and Danner and Cueva (2004) (22%) but inline with other reports documenting treatment of petroclival lesions using a variety of approaches (16–59%) (26–28,31,33).

A detailed review of these complications revealed only 4 subjects (11.4%) with complications that can be considered approach specific: one isolated seizure and 3 cases of cerebral edema. Retraction of the temporal lobe is a known risk factor for both of these types of complications and may have been avoided with an alternative posterior fossa approach. These risks are always discussed with subjects in detail during the surgical decision making process. In all 4 of these subjects, at the time of their most recent follow-up, there was no evidence of persistent symptoms. Meningitis is a known risk factor for any craniotomy and is not necessarily avoided with alternative surgical approaches. Similarly, tension pneumocephalus is a risk with any procedure that results in a skull base defect. Regardless of the approach taken, risks associated with removal of large cisternal skull base lesions include stroke, hematomas and injury to the brainstem. The CPA hematoma occurred after removal of a hemangioblastoma from a subject with von Hippel-Lindau disease constituting a vascular complication from a vascular lesion. The cases of contralateral hemiparesis all resulted in subjects with large lesions compressing the brainstem. In each instance, dissection on the lateral and ventrolateral brainstem was required and would not be obviated with selection of a different approach. The case of complete renal failure occurred in a subject with advanced chronic renal insufficiency that was exacerbated by postoperative meningitis. Other postoperative complications including pneumonia and requirement for prolonged mechanical (with attendant comorbidities) are known risks of surgery of petroclival and anterior clival lesions. The 1 perioperative death in this series was attributed to the sequelae of the presenting subarachnoid hemorrhage. Thus, while we have presented all complications in this series, when considering complications that likely to be specific to the EMCF approach, the risk profile is consistent with the reports by Danner and Cueva and Shen et al (9,14). Minimizing retraction, both overall retraction time and focal points of retraction, can help minimize the risk of cerebral edema. Seizure is uncommon but risks can be further reduced by vigilant protection of any exposed neocortex and possible use of

perioperative antiepileptics. Lastly, hearing preservation should be abandoned if risks to the brainstem or posterior fossa vasculature become elevated during lesion removal.

Postoperative radiation was utilized for subjects with malignancies and those with persistent and growing lesions. Radiotherapy offers a nonsurgical treatment option for subjects with persistent / recurrent disease, those medically unable to tolerate surgical intervention, and lesions not readily accessible to surgical intervention without significant morbidity. In the context of the EMCF approach, this would include lesions of the lower clivus and foremen magnum and those with advanced age. We prefer to observe benign lesions until radiographic demonstration of growth so as to ensure that radiotherapy is indicated.

The main limitations of this study are its retrospective design, lack of postoperative testing in all subjects, and sample size. These shortcomings limit the ability to generalize the findings. Over a 12-year period, only 35 procedures were performed at a tertiary skull base surgery center with a robust referral pattern. Additionally, while the approach is familiar to most skull base surgeons, significant technical experience is required to perform the procedure at a high level. Lastly, one of the benefits of the EMCF approach is the potential for preservation of inner ear function. The lack of comprehensive pre- and postoperative testing may have resulted in an overestimation of the ability of the EMCF approach to preserve inner ear function. However, despite these limitations, this report demonstrates that the EMCF approach can be a useful approach in appropriately selected patients and can provide satisfactory outcomes for both patient and surgeons.

Conclusions

The EMCF approach to the anterior CPA and PPC is a valuable tool in the treatment of skull base lesions and demonstrates a favorable safety profile.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Bibliography

1. House WF, Hitselberger WE. The transcochlear approach to the skull base. *Arch Otolaryngol* 1976;102:334–42. [PubMed: 1084148]
2. Gantz BJ, Fisch U. Modified transotic approach to the cerebellopontine angle. *Arch Otolaryngol* 1983;109:252–6. [PubMed: 6600926]
3. Jenkins HA, Fisch U. The transotic approach to resection of difficult acoustic tumors of the cerebellopontine angle. *Am J Otol* 1980;2:70–6. [PubMed: 6971060]
4. Horgan MA, Delashaw JB, Schwartz MS et al. Transcrural approach to the petroclival region with hearing preservation. Technical note and illustrative cases. *J Neurosurg* 2001;94:660–6. [PubMed: 11302672]

5. Kaylie DM, Horgan MA, Delashaw JB et al. Hearing preservation with the transcranial approach to the petroclival region. *Otol Neurotol* 2004;25:594–8; discussion 8. [PubMed: 15241240]
6. Slater PW, Welling DB, Goodman JH et al. Middle fossa transpetrosal approach for petroclival and brainstem tumors. *Laryngoscope* 1998;108:1408–12. [PubMed: 9738768]
7. House WF. Surgical exposure of the internal auditory canal and its contents through the middle, cranial fossa. *Laryngoscope* 1961;71:1363–85. [PubMed: 14036379]
8. Kawase T, Toya S, Shiobara R et al. Transpetrosal approach for aneurysms of the lower basilar artery. *J Neurosurg* 1985;63:857–61. [PubMed: 4056899]
9. Danner C, Cueva RA. Extended middle fossa approach to the petroclival junction and anterior cerebellopontine angle. *Otol Neurotol* 2004;25:762–8. [PubMed: 15354008]
10. Friedman RA, Pensak ML, Tauber M et al. Anterior petrosectomy approach to infraclinoid basilar artery aneurysms: the emerging role of the neuro-otologist in multidisciplinary management of basilar artery aneurysms. *Laryngoscope* 1997;107:977–83. [PubMed: 9217142]
11. Goel A. Extended middle fossa approach for petroclival lesions. *Acta Neurochir (Wien)* 1995;135:78–83. [PubMed: 8748796]
12. House WF, Hitselberger WE, Horn KL. The middle fossa transpetrosal approach to the anterior-superior cerebellopontine angle. *Am J Otol* 1986;7:1–4. [PubMed: 3484905]
13. Kawase T, Shiobara R, Toya S. Middle fossa transpetrosal-transstentorial approaches for petroclival meningiomas. Selective pyramid resection and radicality. *Acta Neurochir (Wien)* 1994;129:113–20. [PubMed: 7847150]
14. Shen T, Friedman RA, Brackmann DE et al. The evolution of surgical approaches for posterior fossa meningiomas. *Otol Neurotol* 2004;25:394–7. [PubMed: 15129123]
15. Gurgel RK, Popelka GR, Oghalai JS et al. Is it valid to calculate the 3-kilohertz threshold by averaging 2 and 4 kilohertz? *Otolaryngol Head Neck Surg* 2012;147:102–4. [PubMed: 22301102]
16. Meyer TA, Carty PA, Wilkinson EP et al. Small acoustic neuromas: surgical outcomes versus observation or radiation. *Otol Neurotol* 2006;27:380–92. [PubMed: 16639278]
17. Gurgel RK, Jackler RK, Dobie RA et al. A new standardized format for reporting hearing outcome in clinical trials. *Otolaryngol Head Neck Surg* 2012;147:803–7. [PubMed: 22931898]
18. Blevins NH, Jackler RK, Kaplan MJ et al. Combined transpetrosal-subtemporal craniotomy for clival tumors with extension into the posterior fossa. *Laryngoscope* 1995;105:975–82. [PubMed: 7666734]
19. Al-Mefty O, Fox JL, Smith RR. Petrosal approach for petroclival meningiomas. *Neurosurgery* 1988;22:510–7. [PubMed: 3362317]
20. Sekhar LN, Jannetta PJ, Burkhart LE et al. Meningiomas involving the clivus: a six-year experience with 41 patients. *Neurosurgery* 1990;27:764–81; discussion 81. [PubMed: 2259407]
21. Zentner J, Meyer B, Vieweg U et al. Petroclival meningiomas: is radical resection always the best option? *J Neurol Neurosurg Psychiatry* 1997;62:341–5. [PubMed: 9120445]
22. Erkmén K, Pravdenkova S, Al-Mefty O. Surgical management of petroclival meningiomas: factors determining the choice of approach. *Neurosurg Focus* 2005;19:E7.
23. Spetzler RF, Dasgupta CP, Pappas CT. The combined supra- and infratentorial approach for lesions of the petrous and clival regions: experience with 46 cases. *J Neurosurg* 1992;76:588–99. [PubMed: 1545251]
24. Megerian CA, Chiocca EA, McKenna MJ et al. The subtemporal-transpetrosal approach for excision of petroclival tumors. *Am J Otol* 1996;17:773–9. [PubMed: 8892575]
25. Hakuba A, Nishimura S, Tanaka K et al. Clivus meningioma: six cases of total removal. *Neurol Med Chir (Tokyo)* 1977;17:63–77.
26. Mayberg MR, Symon L. Meningiomas of the clivus and apical petrous bone. Report of 35 cases. *J Neurosurg* 1986;65:160–7. [PubMed: 3723172]
27. Bricolo AP, Turazzi S, Talacchi A et al. Microsurgical removal of petroclival meningiomas: a report of 33 patients. *Neurosurgery* 1992;31:813–28; discussion 28. [PubMed: 1436406]
28. Nishimura S, Hakuba A, Jang BJ et al. Clivus and apicopetroclivus meningiomas--report of 24 cases. *Neurol Med Chir (Tokyo)* 1989;29:1004–11. [PubMed: 2483855]

29. Natarajan SK, Sekhar LN, Schessel D et al. Petroclival meningiomas: multimodality treatment and outcomes at long-term follow-up. *Neurosurgery* 2007;60:965–79; discussion 79–81. [PubMed: 17538370]
30. Abdel Aziz KM, Sanan A, van Loveren HR et al. Petroclival meningiomas: predictive parameters for transpetrosal approaches. *Neurosurgery* 2000;47:139–50; discussion 50–2. [PubMed: 10917357]
31. Jung HW, Yoo H, Paek SH et al. Long-term outcome and growth rate of subtotally resected petroclival meningiomas: experience with 38 cases. *Neurosurgery* 2000;46:567–74; discussion 74–5. [PubMed: 10719852]
32. Couldwell WT, Fukushima T, Giannotta SL et al. Petroclival meningiomas: surgical experience in 109 cases. *J Neurosurg* 1996;84:20–8. [PubMed: 8613831]
33. Samii M, Ammirati M, Mahran A et al. Surgery of petroclival meningiomas: report of 24 cases. *Neurosurgery* 1989;24:12–7. [PubMed: 2927589]
34. Weber PC, Gantz BJ. Results and complications from acoustic neuroma excision via middle cranial fossa approach. *Am J Otol* 1996;17:669–75. [PubMed: 8841719]

Figure 1:

Audiometric characteristics of subjects with cerebellopontine angle masses. Not all subjects had data available at each time-point nor all testing types performed when data was available. A) Preoperative audiometric characteristics of subjects with available results. B) Postoperative audiometric characteristics of the subjects with available results. C) Changes in pure-tone averages and word recognition scores for subjects with both available preoperative and postoperative audiometric testing results. Subjects with known non-functional hearing pre-operatively were excluded as these would be plotted as not having had a change in hearing status.

Table 1.

Demographics of the Subjects.

Gender	Male	Female
	9	26
Ear	Right	Left
	17	18
Lesion		Subtype
Meningioma	18	
Schwannoma	6	Schwannoma Locations
		Trigeminal 3
		Vestibular 3
Epidermoid Cyst	2	
Vascular lesions	5	Vascular lesions type
		Cavernoma 2
		Aneurysm ^a 2
		Hemangioblastoma 1
Chondrosarcoma	3	
Neurofibroma	1	
Location ^b		
CPA	7	
PC/CPA	1	
PC	18	
PC/MC	5	
Prepontine	3	
Pons	1	
Mean age at surgery	46.7 +/- 14.6 years	
Range	13-72 years	

^aIncludes one aneurysm of the superior cerebellar artery and one aneurysm of the basilar artery.

^bCPA = cerebellopontine angle; PC = petroclivus; MC = Meckel's cave; Prepontine = prepontine cistern; Pons = within the parenchyma of the ventral pons.

Table 2.**Preoperative Symptoms and Findings**

Symptom	Number ^a	% ^a
Headache	9	25.7
Visual Disturbance ^b	8	22.8
Facial pain /numbness	17	48.6
Hearing loss	11	31.4
Tinnitus	5	14.3
Vestibular Symptoms	7	20.0
Clinical Exam findings	Number ^a	% ^a
Any cranial nerve deficit	21	60.0
CN ^c II	1	2.9
CN's III,IV,VI	5	14.3
CN V	11	31.4
CN VII	1	2.9
CN IX, X, XI, XII	2	5.7
Average Lesion Size ^d	M-L ^d	A-P ^d
Meningiomas	24.6±11.2	19.6±9.5
Schwannomas	31.7±18.2	21.3±10.3
Epidermoids	42.5±15.6	18.0±8.0
Chondrosarcoma / Neurofibroma	29.3±9.2	19.0±4.2

^a. Numbers and percentages sum to greater than 35 and 100%, respectively, due to multiple symptoms being present in numerous subjects.

^b. Change in visual acuity, diplopia or both.

^c. CN = Cranial Nerve.

^d. Determined as maximal medial-to-lateral and anterior-to-posterior dimensions for space occupying lesions in millimeters. M-L = maximal medial-to-lateral dimension; A-P = maximal anterior-to-posterior dimension. There were 31 lesions with images and meaningful sizes to measure.

Table 3.

Audiometric result for patients undergoing extended middle fossa approach to posterior cranial fossa and skull base lesions.^m

Preoperative Audiometry					
<u>Overall Cohort</u>			WRS Class ^d	AAO-HNS Class ^e	Any Hearing ^f
PTA ^a	SDS ^b	SRT ^c	1 = 26	A = 22	29 (82.8%)
29.4 ± 27.1 (N=31)	85.2 ± 30.2 (N=29)	29.3 ± 30.3 (N=30)	2 = 0	B = 1	
			3 = 0	C = 3	
			4 = 3	D = 3	
<u>Subjects with Serviceable hearing^g</u>		N=26	CNT ^h = 2	CNT ^h = 2	
PTA ^a	SDS ^b	SRT ^c			
21.7 ± 15.6	95.1 ± 7.4	19.6 ± 13.5			
Postoperative Audiometry					
<u>Overall Cohort</u>			WRS Class ^d	AAO-HNS Class ^e	Any Hearing ^f
PTA ^a	SDS ^b	SRT ^c	1 = 15	A = 9	26 (76.4%)
48.7 ± 40.8 (N=23) ^j	62.6 ± 45.4 (N=21) ^j	47.5 ± 41 (N=20) ^k	2 = 0	B = 2	
			3 = 1	C = 4	
			4 = 5	D = 6	
<u>Subjects with Preoperative Serviceable Hearing^g</u>			CNT ^h = 2	CNT ^h = 2	
PTA ^a	SDS ^b	SRT ^c			
39.7 ± 35.6 (N=20)	73 ± 40.3 (N=18)	36.5 ± 33.7 (N=18)			
Change in Hearing Class					
		Numbers of Classes decreased	WRS ^d N=20	AAO-HNS ^e N=20	
		0	17	16	
		1	0	0	
		2	1	1	
		3	2	3	
Changes in Audiometry in those with Serviceable Hearing preoperatively^l					
PTA change overall	SDS change overall	PTA in Maintained WRS I hearing	SDS in Maintained WRS I hearing		
+16.2±31(N=20)	-22.4%±40.1(N=18)	+15.6±18.4 (N=15)	-12.9±31.7(N=15)		

^a Pure tone average, determined from the arithmetic mean of thresholds from 0.5, 1, 2, & 3 kHz; if the 3 kHz thresholds were not available, these were calculated from the mean of the 2 & 4 kHz thresholds as described in the methods section.

^b Speech discrimination score as percentage of correctly repeated words from a W-22 word list.

^c Speech reception threshold using spondaic words.

^d Word Recognition Score (WRS) as reported in Meyer et al, 2005.

e. American Academy of Otolaryngology- Head and Neck Surgery Committee on Hearing and Equilibrium classification system, 1995.

f. Any evidence of hearing (WRS I, II, or III; AAO-HNS A, B, or C; any clinical notation of hearing prior to surgical intervention.

g. This was defined as WRS III or better.

h. Could not test; this was due to a language barrier between the tester and the subject.

i. There were 21 tests performed and 2 subjects with known total hearing loss whose post-operative thresholds were estimated as described previously.

j. There were 2 subjects where speech audiometry could not be tested due to a language barrier between the tester and the subject.

k. There were 2 subjects where speech audiometry could not be tested due to a language barrier between the tester and the subject and 1 subject where SRT was not documented.

l. Preoperative hearing was defined as any measureable audiometric data.

m. Numbers and percentages may not sum to the total number of subjects for each calculation as not every subject had data both pre- and postoperative audiometric data. Additionally, not every metric was collected or could be collected (e.g., language barrier) when testing was accomplished.

Table 4.

Postoperative Course.

Intraoperative Complications: None		Facial Nerve Outcomes		
		HB ^e Grade	Preoperative	Postoperative
<u>Length of stay^a</u>		I	34	30
Mean	11.6 days	II	0	3
Median	9 days	III	0	0
Mode	9 days	IV	0	0
Range	4 – 52 days	V	0	0
		VI	1	1
<u>New Cranial Nerve Deficit (N=34)</u>			N=35	N=34
19 (55.8%)				
<u>Cranial Nerve Deficit^b</u>				
CN II	0 (0%)			
CN's III, IV, VI	15 (44.1%)	<u>Postoperative CSF Leak:</u>		3 (8.6%)
CN V	21 (61.7%)	<u>Intraoperative LD use:</u>		13 (37.1%)
CN IX, X, XI, XII	2 (5.8%)			
		<u>More Surgery</u>	4 (11.7%)	
<u>Extent of Surgery^c</u>		Schwannoma	2 ^f	
Total	19 (59.3%)	Meningioma	1	
Near Total	8 (25%)	Chondrosarcoma	1	
Subtotal	5 (15.6%)			
		<u>Follow up</u>	Mean	113.4
<u>Post-operative complications^d: 13 (37.1%), N=35</u>		(months)	Median	67
Mortality	1		StdDev ^g	95.2
			Range	9 – 314
		<u>Use of XRT^h</u>	5 (14.3%)	
		Indication	Meningioma	2
			Chondrosarcoma	3

^a. Measured in total admission days from the index surgery including the day of the surgical intervention.

^b. Numbers and percentage total more than 35 and 100% as several subjects had multiple new CN deficits.

^c. There were 32 lesions where resection extent was meaningful.

^d. Table 5 provides details regarding post-operative complications.

^e. HB = House- Brackmann Facial nerve grading Scale.

^f. Both subjects had clinical Neurofibromatosis type 2 and required additional interventions for other lesions.

^g. StdDev = Standard Deviation.

^h. Use of postoperative radiation therapy.

Table 5.

Complications.

Subject #	Index lesion ^a	Complication(s)	Outcome ^d	Comment
3	MN	Seizure	R	
5	S	Cerebral edema	R	
6	MN	Contralateral hemiparesis	R	
7	MN	Prolonged mechanical ventilation due to attenuated arousal state, pneumonia, tracheotomy, gastrostomy tube	R	
10	MN	Prolonged mechanical ventilation, tracheotomy, pneumonia	P	Significant improvement: distal lower extremity weakness persists
14	S	Meningitis, aphasia, acute kidney injury in the setting of long standing chronic renal insufficiency	P	Progressed to renal transplant; all other issues resolved
20	MN	Tension pneumocephalus	R	
22	CS	Cerebral edema	R	
28	EC	Attenuated arousal state, pneumonia, death	P	Presented with SAH and attenuated arousal state; death attributed to SAH ^e
29	MN	Mild contralateral hemiparesis	R	
32	EC	Stroke with contralateral hemiparesis, meningitis, hydrocephalus	P	Required VP ^d shunt due to persistent mass effect of the index lesion.
33	V ^b	CPA ^d hematoma, tracheotomy, gastrostomy tube placement, contralateral hemiparesis	P	Significantly improved but persistent hemiparesis; tracheotomy and gastrostomy tubes removed
35	V ^c	Cerebral edema	R	

^a MN = meningioma; S = Schwannoma, CS = Chondrosarcoma; EC = Epidermoid Cyst; V = Vascular lesion; CPA = cerebellopontine angle; VP = ventriculoperitoneal

^b Hemangioblastoma

^c Aneurism

^d R = Resolved; P = Persistent. A complication was considered resolved if at the time of last follow up, no residual sequelae were present. If any portion of the original complication was present in any form, the complication was considered to be persistent. All in indwelling tubes had been removed and sites healed, if applicable.

^e Subarachnoid hemorrhage