Hearing preservation in acoustic neuroma resection: Analysis of petrous bone measurement and intraoperative application

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Abstract

**Background:** There is an increased risk for labyrinthine injury for the resection of acoustic neuromas (AN) on the suboccipital, retrosigmoid approach. Prognostic factors should be analyzed for the postoperative hearing function.

**Methods:** We examined 51 patients with ANs using preoperative intact hearing function. Audiological data were obtained by pure tone audiogram (PTA) and speech audiogram. The preoperative and postoperative anatomical localization of the labyrinth was measured with specific distances regarding the tumor and corresponding anatomy of the posterior fossa by high-resolution magnetic resonance imaging (MRI).

**Results:** Postoperative MRI controls confirmed no injuries to the labyrinth (0%). The postoperative hearing results showed 100% hearing preservation for T1-tumors (<1 ml/<1.1 cm), 50% for T2-tumors (1–4 ml/1.1–1.8 cm), 40% for T3-tumors (4–8 ml/1.8–2.3 cm) and 18% for T4-tumors (>8 ml/>2.3 cm). Postoperative deafness was seen in all cases with ventral tumor extension higher than 5.5 mm. Postoperative loss of hearing was seen in all cases with hearing preservation with 6–8% of speech discrimination and an increase in the hearing threshold of 12 dB in the PTA compared to the preoperative hearing status.

**Conclusion:** Petrous bone measurement by high-resolution MRI data enables safe surgical exposure of the internal acoustic canal with avoidance of injury to the labyrinth and a better postoperative prognosis, especially for intrameatal ANs and for the resection of intrameatal portions of larger neuromas. The prognostic factors enable the patients and the surgeon a better estimation of postoperative results regarding deafness and postoperative hypacusis and support a consolidated treatment planning.

**Key Words:** Acoustic neuroma, hearing preservation, high resolution MRI, petrous bone measurement

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INTRODUCTION

Exposure of the internal acoustic canal (IAC) has significant risks for injury to the labyrinth for the resection of acoustic neuromas (AN) on the suboccipital, retrosigmoid approach. Former studies showed higher incidences of injury for very medially localized semicircular canals of the labyrinth. The insufficient exposure of the IAC is seen as a significant disadvantage of the suboccipital approach. The goal of our prospective clinical study was to develop a safe strategy for the exposure of the IAC in order to avoid injury to the labyrinth by using anatomical data from high-resolution magnetic resonance imaging (MRI). Prognostic factors should be analyzed for the preservation of hearing function from preoperative anatomical findings.

MATERIALS AND METHODS

Clinical data

51 patients (male/female: 42/58%, minimum age: 12, maximum age: 75, mean age: 49) with AN with confirmed and intact preoperative hearing function underwent tumor resection after suboccipital, retrosigmoid craniectomy. One patient (2%) had Type 2 Recklinghausen’s disease. Symptoms such as vertigo, tinnitus, ataxia, preoperative hypacusis, headache, and cranial nerve dysfunctions were documented preoperatively. Inclusion criteria were confirmed hearing function on the side of the tumor (see below audiologic parameters), preoperative and postoperative determination of hearing threshold levels (in dB) and speech discrimination, preoperative high-resolution MRI with measurements of the petrous bone, and postoperative MRI after 3–6 months to look for injury to the labyrinth. Exclusion criteria were recurrent ANs, radiated tumors, and other histological entities such as meningiomas in the cerebellopontine angle (CPA).

Audiologic parameters

Four hearing classes A–D were defined according to the Committee on Hearing and Equilibrium of the AAO-HNSF: A – hearing threshold in audiogram <30 dB and language discrimination score >70% (within 70–100 dB), B – hearing threshold >30 dB and <50 dB and language discrimination >50%, C – hearing threshold >50 dB and language discrimination >50%, D – all hearing threshold values, and language discrimination <50%. Class A represents normal hearing function. Class B represents impaired but useable hearing. In class C, hearing is significantly limited, but useable for the localization of noises and for language comprehension and is amendable by the application of a hearing aid. Hearing in class D is formally verifiable but insufficient because of poor language discrimination below 50%.

Preoperative hearing function

A verifiable hearing function was a prerequisite for inclusion in our study. Forty-seven percent of our patients were assigned to hearing class A, 33% to class B, 10% to class C, and 10% to class D. Figure 1 shows the distribution of the hearing classes to tumoral sizes [Figure 1].

Imaging

All patients underwent high-resolution 1.5 Tesla MR imaging at the Department of Neuroradiology at the University of Erlangen-Nuremberg (Siemens Magnetom, T1w: TR 0.6, TE 20, slice thickness 3 mm, matrix 256 × 256; T2w: TR 2.500, TE 45–90, slice thickness 3 mm, matrix 256 × 256). In high-resolution T2 weighted images, all three semicircular canals of the labyrinth, the utricule, and the cochlea are delineated within the petrous bone in correspondence to the IAC. Especially the posterior semicircular canal (PSCC) can be localized quite medially and directly under the surface of the petrous bone, and therefore, can be prone to injury by exposure of the IAC, as shown in Figure 2.

Principles of petrous bone measurement

The surgeon looks from the dorsolateral aspect of the posterior fossa onto the petrous bone and can see the tumor spreading out of the IAC. For opening of the IAC, a portion of the petrous bone has to be removed without having any safe and clear macroscopic landmarks for the localization of the underlying labyrinth. Therefore, we choose the transversal, highly T2-weighted image slices, which delineate the medially localized portion of the semicircular canals in high resolution, mostly the PSCC. A sagittal line is constructed into this slice, which courses through the fundus of the IAC and tangentially touches the most medial aspect of the semicircular canals [Figure 3]. The extension of this sagittal line to the suboccipital direction results in an intersection point representing the dorsal surface of the petrous bone [see arrow in Figure 3]. The surgeon can measure the distance of this intersection point from the posterior margin of

Figure 1: Distribution of tumoral sizes to hearing classes
the IAC with a ruler. This implies that all bony elements of the petrous bone that lie medially to the intersection point can be removed without injury to the semicircular canals to the fundus of the IAC. The sagittal line must always course strongly sagittally through the fundus of the IAC, and all various elements of the semicircular canals have to lay laterally from this line. This method is oriented to the individual anatomy of the patients and gives exact topographical details, which can be reproduced intraoperatively. We did not use coronal or sagittal slices because the transversal slices reproduce the intraoperative angle of the view of the surgeon. Principally, we measured the distances d1–d8 [Figure 4, see figure legend].

**Calculation of the tumor volume**

a. Extrameatal tumor volume: The extrameatal tumor volume is defined by the volume of a sphere: $V = \frac{4}{3} \pi r^3$. Three diameters, namely, Da, Db, and Dc, from the T1-weighted images in transversal, coronal, and sagittal planes are measured. Note the three diameters Da (parallel to the petrous bone), Db (perpendicular to Db), and Dc (maximal vertical diameter of the tumor from the coronal plane; see Figures 5a-b). $r^3$ arithmetically represents the product of the halves of the three diameters Da, Db, and Dc, such that the extrameatal tumor volume results from the following formula:

$$V = \frac{4}{3} \pi (\frac{Da}{2} \times \frac{Db}{2} \times \frac{Dc}{2})$$

b. Intrameatal tumor volume: The intrameatal tumor volume is defined by the volume of a conus: $V = \frac{1}{3} \pi r^2 h$. r is represented by the half of the previously described distance d6 (see petrous bone measurements, see above), and h is the height of the conus represented by the previously describes distance d2 [Figure 5c].

The total tumor volume results from the sum of the extrameatal and intrameatal tumor volumes:

$$V = \frac{4}{3} \pi (\frac{Da}{2} \times \frac{Db}{2} \times \frac{Dc}{2}) + \frac{1}{3} \pi (\frac{d6}{2})^2 \times \pi \times d2$$

**Definition of tumor classes**

The tumors were defined by four size categories, T1–T4, in order to evaluate possible or not possible prognosis regarding the expecting postoperative hearing preservation or deafness for each tumor class:

- T1: < 1 ml (<1.1 cm diameter)
- T2: 1 ml–4 ml (1.1–1.8 cm diameter)
- T3: 4 ml–8 ml (1.8–2.4 cm diameter)
- T4: >8 ml (>2.4 cm diameter).

Figure 6 shows the distribution of tumor classes in the examined patient population [Figure 6a and b]. Figure 7 shows examples of examined and resected tumors according to the the aforementioned tumor classes.

**Postoperative imaging for evaluation of labyrinth preservation and tumor recurrence**

All patients underwent postoperative MRI 3–6 months after the surgery [Figure 8]. T2-weighted high resolution imaging was performed to delineate the status of the labyrinthine system and T1-weighted images were performed to rule our tumor recurrence. The labyrinthine system is intact when all semicircular canals are delineated and an intact bony lamella can be depicted to
the CPA. Scar tissue also showed contrast enhancement in the T1-weighted images, while the role of postoperative artifacts is also known from literature.\(^{[16]}\)

**Surgical technique**

The suboccipital, retrosigmoid approach was performed in all 51 patients. The patients were positioned with elevation of the ipsilateral shoulder and the head turned horizontally to the contralateral side. Cerebrospinal fluid (CSF) was released after craniectomy from the cisterna magna. After this procedure, one can see the tumor growing out of the IAC. As a next step, intracapsular shrinking of extrameatal tumor portion starts. After the extrameatal tumor shrinkage, the opening of the IAC is delineated with the Crista dorsalis. The distance \(d_1\), which is gained by the preoperative T2-weighted images, is marked on a sterile ruler and transferred to the surgical field that shows the distance from the posterior border of the IAC (Crista dorsalis) to the medial limitation of the labyrinth on the dorsal surface of the petrous bone for secure exposure of the IAC [Figure 9]. The IAC is drilled according to the available length. The tumor is then freed from the facial nerve and prepared into the IAC and the fundus. The complete surgical preparation is performed under electrophysiological monitoring of the cochlear nerve by BERA. The facial nerve is identified by electrical stimulation. After tumor resection, the bony defect is covered with gelitta under the application of fibrin glue and standard closure is done.

**RESULTS**

There was no mortality intra or postoperatively (0.0%). Two out of 51 patients (3.9%) developed transient CSF leak, which was observed conservatively and diminished spontaneously. One patient had immediate postoperative intracerebral hemorrhage (1.96%) within the CPA and underwent emergent revision with good neurological recovery. In 20 of 51 patients (39%), we saw postoperative facial nerve paresis; in 25% of the patients with mild pareses House–Brackmann II°–III° with good remission in follow-up and in 14% of the patients (\(n = 7\)) with House–Brackmann grades IV°–V°. The preservation of the labyrinthine system could be achieved with the method of petrous bone measurement in all 51 patients (100%). A bony lamella of 1–2 mm thickness stayed to the medial border of the semicircular canals in all 51 cases (100%). Tumor recurrences were not seen on the postoperative MRI scans 3–6 months after the surgery (0.0%). Two hearing tests (pure tone audiogram, PTA and speech discrimination score, SDS) were performed within the first two postoperative weeks. In 26 of 51 patients (51%), a useable hearing function was available with 18% with normal hearing function (Class A), in 27% with impaired but useable hearing function (Class B), and 6% of the patients had a significantly limited function but useful for the localization of noises and language comprehension (Class C). In all patients of Class C, the application of a hearing aid supported the hearing function.
because of intact speech discrimination. Postoperative deafness was seen in 25 of 51 patients (49%; Class D). For T1-tumors (<1 ml/<1.1 cm), we saw very good and moderate good hearing function with 36% of T1-tumor patients with Class A and 64% with Class B quality.

In T2-tumors (1–4 ml/1.1–1.8 cm), the success rate was reduced to 50% of not useable hearing function (Class D), 7% to Class C, 29% in Class B, and 14% in Class A. In larger tumors (>8 ml), the success rate was significantly reduced <20% of effective hearing preservation.

For T3-tumors (4–8 ml/1.8–2.3 cm), in 40% of the patients, postoperative hearing function was preserved with 20% Class A quality, 13% Class B, and 7% Class C. For T4-tumors (4–8 ml/>2.3 cm) deafness was seen in 80% of cases (Class D) and 9% moderate to useable hearing function in each Classes A–C. The results of the measured clinical, audiological, and anatomical parameters are shown by Table 1. The distances d5, d2, and d6 have the largest standard deviations of all petrous bone parameters according to the anterior and posterior wall and the width of the IAC. The distances d1 and d4 referring to the localization of the labyrinthine system and the crista dorsalis of the IAC ranged from 4.5–5.9 mm to 12–14 mm. There was no significant, preferred direction of tumor growth to ventral or dorsal direction according to the distances d7 and d8. There was a mean postoperative increase of the hearing threshold in PTA for the postoperative hearing-intact patients with 11.5 dB, and a decrease in the SDS with 6.8 dB. There was no clinically relevant correlation between the preoperative and postoperative hearing function of the acoustic neuromas.

The preoperative speech comprehension correlated more with the postoperative PTA than with the postoperative SDS (P < 0.012). The preoperative hearing function could be seen as a safe prognostic factor for postoperative hearing preservation for the T1-tumors (<1 ml/1.1 cm) and with limitation for T2-tumors (2–4 ml/1.1–1.8 cm). The extrameatal tumor volume correlated significantly with the postoperative hearing preservation (P < 0.01) in contrast to the intrameatal tumor volume. The results of postoperative deafness, increase of hearing threshold in the PTA in case of hearing preservation, and the loss of hearing in speech discrimination in case of hearing preservation are shown by Table 2. The risk for postoperative deafness in ventral tumor growth beyond the crista nasalis of the IAC with more than 5.5 mm was nearly 100%, independent of the tumor size. Especially, the distance d4 with the localization of the labyrinthine system, the depth of the IAC, or the width of the orifice

![Figure 6](image1.png)

**Figure 6:** (a and b) Distribution of tumor classes in the examined patient population (SD: standard deviation, n: number of patients)

![Figure 7](image2.png)

**Figure 7:** Examples of examined and resected tumors according to the defined tumor classes T1-T4. (a) small T1 tumor without contact to the brainstem, 0.42 ml. (b) T2 tumor with contact to the brainstem without significant compression, 3.6 ml. (c) T3 tumor with brainstem compression, 5.6 ml. (d) T4 tumor with compression and dislocation of the brainstem, 13 ml
DISCUSSION

Functional hypacusis after resection of acoustic neuromas, even in anatomically well preserved cochlear nerve is a disappointing event for each surgeon by preparation of the tumor at the cochlear nerve with coagulation of small vessels and subsequent ischemic events and nerval damage by vibration and hyperthermia of the petrous bone during drilling of the posterior elements of the petrous bone and affection of the labyrinthine system. Multiple possibilities were introduced into this field during surgery.\textsuperscript{[8,14,15]} Our prospective, clinical study with 51 patients introduced a new procedure of extension and optimization of the suboccipital, retrosigmoid approach for hearing-preserving resection of ANs. This technique had the goal to deal with the major problems of the retrosigmoid approach such as the injury to the labyrinth during exposure of the IAC with the application of detailed, preoperative petrous bone measurement and intraoperative reproduction of these parameters. Removal of the dorsal wall of the IAC is needed in order to delineate the tumor within the IAC. As described in literature, this region is very variable referring the localization of the labyrinth and the pneumatization

![Figure 8: Postoperative MRI after resection of the AN. (a) T2-weighted image showing the postoperative integrity of labyrinthine system with an intact bony lamella to the CPA. (b) Postoperative enhanced T1 weighted imaging showing scar tissue.](image)

**Table 1: Results of the measured clinical, audiological and anatomical parameters**

| Parameter                                | n   | Minimum | Maximum | Mean     | Standard deviation |
|------------------------------------------|-----|---------|---------|----------|--------------------|
| Patient age                              | 51  | 12.00   | 75.00   | 49.7059  | 14.2538            |
| Preoperative hearing function (dB)       | 51  | 7.50    | 73.00   | 32.4549  | 15.2945            |
| Preoperative Speech discrimination score (dB) | 51  | 0.00    | 100.0   | 74.1176  | 28.0661            |
| Tumor volume, extrameatal                | 51  | 0.03    | 18.80   | 4.7269   | 4.5064             |
| Tumor volume, intrameatal                | 51  | 0.07    | 1.35    | 0.4002   | 0.2648             |
| Distance d1                              | 51  | 5.90    | 14.00   | 9.7039   | 1.9777             |
| Distance d2                              | 51  | 5.00    | 13.00   | 9.2176   | 2.0678             |
| Distance d3                              | 51  | 5.70    | 15.00   | 10.1120  | 1.9331             |
| Distance d4                              | 51  | 4.60    | 12.00   | 7.6804   | 1.6722             |
| Distance d5                              | 51  | 8.10    | 23.00   | 15.0902  | 3.3954             |
| Distance d6                              | 51  | 5.00    | 18.00   | 10.7902  | 3.0475             |
| Distance d7                              | 51  | 0.00    | 14.00   | 4.4176   | 3.9379             |
| Distance d8                              | 51  | 0.00    | 15.00   | 5.5843   | 3.8496             |
| Postoperative hearing function (dB)      | 51  | 7.50    | 100.00  | 65.3863  | 30.9413            |
| Postoperative Speech discrimination score (%) | 51  | 0.00    | 100.00  | 40.8824  | 40.7886            |

**Table 2: Results of postoperative deafness, increase of hearing threshold in the PTA in state of hearing preservation and the loss of hearing in speech discrimination in case of hearing preservation**

| Parameter                                | T1-tumors <1ml (≤1.1 cm) | T2-tumors 1-4ml (1.1-1.8 cm) | T3-tumors 4-8ml (1.8-2.4 cm) | T4-tumors >8ml (>2.4 cm) |
|------------------------------------------|---------------------------|-------------------------------|-------------------------------|---------------------------|
| Frequency of postoperative surditas      | <20%                       | 20-40%                        | 40-70%                        | >70%                       |
| Increase of hearing threshold in PTA     | +12 dB                     | +11.5dB                       | Not defined                   | Not defined               |
| Decrease of hearing in speech discrimination | −6.5%                     | −7.7%                         | Not defined                   | Not defined               |

![Figure 9: Microsurgical view onto the CPA with depiction of the distances d1 and d6. (a) d1: Distance from Crista dorsalis – dorsal margin – of the IAC to the intersection point of the medial limitation of the labyrinth with the dorsal surface of the petrous bone. (b) d6: Distance from the Crista nasalis to the Crista dorsalis of the IAC.](image)
below the surface of the petrous bone.\cite{11} Studies by Matthies et al. showed injury to the posterior semicircular canals with a frequency of 20% and of the lateral semicircular canal with 10% in cases of very medially localized labyrinthine systems.\cite{11} In studies of Tatagiba et al., a so-called “sinus-fundus-line” was introduced and described to measure the risk for opening of the labyrinth, which was marked in the preoperative CT scan as the line from the sigmoid sinus to the fundus of the IAC.\cite{13} In studies of Yokoyama et al., 25% of labyrinthine elements were on the described sinus-fundus-line or even coursed medially to this line, and therefore, on the surgical route for opening of the IAC.\cite{19} A significant relation between a reduced postoperative hearing capacity and increased fenestration of the semicircular system of these patients could be shown.\cite{11,19} Low et al. introduced the projection of landmarks with the operating microscope onto the petrous bone, where a border of maximum 3 mm for the opening of the IAC to laterally was maintained.\cite{10} In our study, the distance d4, which is similar to this landmark, was never smaller than 4 mm but 9 mm in the mean. Therefore, Low et al. introduced and described the technique of endoscopic visualization of the lateral IAC.\cite{10} Some studies prefer the middle fossa approach for the resection of small, intrameatal tumors up to a diameter of 2 mm. Staecker et al. showed a frequency of 47% of postoperative hearing preservation for the retrosigmoid approach versus 57% for the middle fossa approach with a dominance of the retrosigmoid approach for the large and extrameatal tumors.\cite{17} There might be the hypothesis that the cause for worsening hearing function for the retrosigmoid approach is possibly based on frequent and unrecognized injuries to the labyrinth. Matthies et al. showed an increased rate of intraoperative injuries to the posterior and lateral semicircular canals in very medially localized labyrinthine systems, so that fenestration of one semicircular canal reduces the success rate of hearing preservation.\cite{11} For small, intrameatal tumors there should be an improvement of the rate of hearing preservation because of the good preoperative hearing function. Referring to the middle fossa approach, a complete intrameatal tumor resection is partially based on a blind dissection. Discroll et al. showed in a CT-based study that the inferior compartment with the facial nerve is covered by the transverse crest at a frequency of 25%.\cite{15} This might be the reason for the higher incidence of facial nerve lesions for the middle fossa approach.\cite{17} Our considerations to solve the problem of labyrinthine system injury was based on the anatomical documentation of the localization of the labyrinth in the preoperative imaging in relation to the IAC and the implementation of the preoperatively acquired anatomical data to the intraoperative surgical domain with exact measurement values, which could be reproduced intraoperatively in all 51 patients. The sinus-fundus-line has the disadvantage that a very medially localized semicircular canal, especially the PSCC, cannot be exclusively seen as a safe line for the surgeon for the preservation of the labyrinth [Figure 10]. Our presented method deals with the anatomical localization of the labyrinthine system itself and always was localized medially to the labyrinthine system. With our introduced method, we think that we have found a safe retrosigmoid approach to the fundus of the IAC. In the postoperative MRI scans, we could not find any injuries (0%) to the labyrinthine system in all 51 patients. Even in very medially localized posterior semicircular canals, a sufficient bony lamella of 1–2 mm was seen. Therefore, we could achieve similarly good postoperative hearing results such as the middle fossa approach. This corresponds to our results for the small T1-tumors with postoperative hearing preservation >90%, which corresponds to the best postoperative results for intracanalicular tumors via the middle fossa approach of 95%, as described by Kumon et al.\cite{19} There is a rate of 51% (n = 25) for the preservation of a useable hearing function independent of the tumor sizes. Former studies also describe a rate of hearing preservation of 31% to 59%.\cite{14,7,13} The chance for postoperative useable hearing function is higher because the tumor sizes are smaller and the preoperative hearing function is better.\cite{14,7,13} Tumors larger than 2–3 cm show a hearing preservation rate of 0% in general, corresponding to our tumor class T4 with 18% hearing preservation. As a possible cause we see the exclusion of labyrinthine injury during the exposure of the IAC with the described method of petrous bone measurement. The postoperative deafness for tumors larger than 4 ml (>1.8 cm) with more than 50% in our series is a very unsatisfactory result. Comey et al. suggested a two-staged surgery for large tumors; they described the advantage of this staged procedure in the reduction of mortality and cranial nerve morbidity.\cite{4} As a cause they reported that there is a devascularization of the

Figure 10: Comparison of the “sinus-fundus-line” (1) to the sagittal fundus-line (2). Note that very medially localized labyrinthine systems are not contained by the sinus-fundus-line but by the sagittal fundus-line.
residual tumor and “self decompression” of the brainstem and the root entry zones of the cranial nerves after the first surgery. As a second step, a complication-reduced resection of the residual tumor is possible. It should be discussed if tumors above 2 cm in size should be operated in this two-staged procedure regarding the results of postoperative hearing preservation; during the first surgery, a primary volume reduction is obtained, which is oriented to the acoustic evoked potentials, and residual tumor resection on the brainstem and intrameatal with the second surgery.

We saw a significant relationship between preoperative hearing function and postoperative hearing result for all tumor sizes in our series (P < 0.05) for the pre and postoperative PTA and the speech audiogram for the T1-tumors (<1 ml/<1 cm). If the tumor is localized primarily intrameatal, the postoperative hearing preservation is nearly equal to the preoperative hearing level with a frequency of more than 80% (80–85%). If the tumor is small and primarily extending extrameatally, the postoperative hearing quality is reduced for one hearing class (in our series Class B). For patients with larger tumors (T3 and T4: >4 ml/>2.3 cm), there is no relationship between preoperative hearing function and postoperative hearing result. Obviously, there are other factors, e.g., intrapetrous bone measurement by high-resolution MRI data enables the safe surgical exposure of the IAC with avoidance of injury to the labyrinthine system along with the root entry zones of the cranial nerves after the craniotomy approach for acoustic neuromas and the resection of intrameatal portions of larger neuromas. The prognostic factors enable the patients and the surgeon a better estimation of postoperative results regarding deafness and postoperative hypacusis and support a consolidated treatment planning.

CONCLUSION

Petrous bone measurement by high-resolution MRI data enables the safe surgical exposure of the IAC with avoidance of injury to the labyrinthine system along with the postoperative hearing preservation, especially in small, intrameatal tumors. Of course, gammaknife radiosurgery is an excellent alternative with excellent risk profile and outcome statistics in comparison to our work. With our study we were able to give a prognostic of postoperative hearing preservation, which contributed to patient and physician relationship as well as patient consultation.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. American Academy of Otolaryngology-Head and Neck Surgery Foundation INC: Committee on Hearing and Equilibrium guidelines for the evaluation of hearing preservation in acoustic neuroma (vestibular schwannoma). Otolaryngol Head Neck Surg 1995;113:179-80.
2. Brackmann DE, House JR 3rd, Hiteselberger WE, Technical modifications to the middle fossa craniotomy approach in removal of acoustic neuromas. Am J Otol 1994;15:614-9.
3. Cohen NL, Ransohoff J. Hearing preservation: Posterior fossa approach. Otolaryngol Head Neck Surg 1984;92:176-83.
4. Comey CH, Jannetta PJ, Sheptak PE, Joh HD, Burkhardt LE. Staged removal of acoustic tumors: Techniques and lessons learned from a series of 83 patients. Neurosurgery 1995;37:915-20.
5. Discroll CL, Jackler RK, Pitts LH, Bantista V. Is the entire fundus of the internal auditory canal visible during the middle fossa approach for acoustic neuroma? Am J Otol 2000;21:382-8.
6. Fischer G, Fischer C, Remond J. Hearing preservation in acoustic neuroma surgery. J Neurosurgery 1992;76:910-7.
7. Gardner G, Robertson JH. Hearing preservation in unilateral acoustic neuroma surgery. Ann Otol Rhinol Laryngol 1988;97:55-66.
8. Koos WT, Day JD, Matula C, Levy DL. Neurotopographic considerations in the microsurgical treatment of small. J Neurosurgery 1998;88:506-12.
9. Kumon Y, Sakaki S, Kohno K, Ohta S, Nakagawa K, Ohue S. Selection of surgical approaches for small acoustic neuromas. Surg Neurol 2000;53:52-9.

10. Low WK. Enhancing hearing preservation in endoscopic-assisted excision of acoustic neuroma via the retrosigmoid approach. J Laryngol Otol 1999;113:973-7.

11. Matthies C, Samii M, Krebs S. Management of vestibular schwannomas (acoustic neuromas): Radiological features in 202 cases—their value for diagnosis and their predictive importance. Neurosurgery 1997;40:469-81.

12. Pollock BE, Lunsford LD, Kondziolka D, Flickinger JC, Bissonette DJ, Kelsey SF. Outcome analysis of acoustic neuroma management: A comparison of microsurgery and stereotactic radiosurgery. Neurosurgery 1995;36:215-24.

13. Post KD, Eisenberg MB, Catalano PJ. Hearing preservation in vestibular schwannoma surgery: What factors influence outcome? J Neurosurg 1995;83:191-6.

14. Samii M, Matthies C. Management of 1000 vestibular schwannomas (acoustic neuromas): Surgical management and results with an emphasis on complications and how to avoid them. Neurosurgery 1997;40:1-23.

15. Sampath P, Rini D, Long DM. Microanatomical variations in the cerebellopontine angle associated with vestibular schwannomas (acoustic neuromas): A retrospective study of 1006 consecutive cases. J Neurosurg 2000;92:70-8.

16. Sridhar K, Ramamurthi R, Vasudevan MC, Ramamurti B. Magnetic resonance imaging artifact following acoustic neurofibroma surgery—Case report. Neurol Med Chir 1999;39:938-40.

17. Staecker H, Nadol JB Jr, Ojemann R, Ronner S, McKenna MJ. Hearing preservation in acoustic neuroma surgery: Middle fossa versus retrosigmoidal approach. Am J Otol 2000;21:399-404.

18. Tatagiba M, Samii M, Matthies C, al Azm M, Schönmayr R. The significance for postoperative hearing of preserving the labyrinth in acoustic neurinoma surgery. J Neurosurg 1992;77:677-84.

19. Yokoyama T, Uemura K, Ryu H, Hinokuma K, Nishizawa S, Yamamoto S, et al. Surgical approach to the internal auditory meatus in acoustic neuroma surgery: Significance of preoperative high-resolution computed tomography. Neurosurgery 1996;39:965-70.