Hearing Preservation Using the Middle Fossa Approach for the Treatment of Vestibular Schwannoma

Joe Walter Kutz, Jr, MD*
Tyler Scoresby, MD*
Brandon Isaacson, MD*
Bruce E. Mickey, MD‡
Christopher J. Madden, MD‡
Samuel L. Barnett, MD‡
Caetano Coimbra, MD§
Linda S. Hynan, PhD||
Peter S. Roland, MD*

*Department of Otolaryngology, University of Texas Southwestern Medical Center, Dallas, Texas; ‡Department of Neurological Surgery, University of Texas Southwestern Medical Center, Dallas, Texas; §Baylor University Medical Center, Dallas, Texas; ||Department of Clinical Sciences (Biostatistics) and Psychiatry, University of Texas Southwestern Medical Center, Dallas, Texas

Correspondence:
Joe Walter Kutz, Jr, MD, FACS,
5323 Harry Hines Blvd.,
Dallas, TX 75390-9035.
E-mail: walter.kutz@utsouthwestern.edu

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BACKGROUND: The incidence of small vestibular schwannomas in patients with serviceable hearing is increasing because of the widespread use of MRI. The middle fossa approach provides the patient with an opportunity for tumor removal with hearing preservation.

OBJECTIVE: To determine the rate of hearing preservation and facial nerve outcomes after removal of a vestibular schwannoma with the use of the middle fossa approach.

METHODS: A retrospective case review at a tertiary, academic medical center was performed identifying patients from 1998 through 2008 that underwent removal of a vestibular schwannoma by the middle fossa approach. Preoperative and postoperative audiograms were compared to determine hearing preservation rates. In addition, facial nerve outcomes at last follow-up were recorded.

RESULTS: Forty-six patients underwent a middle fossa craniotomy for the removal of a vestibular schwannoma. Of the 38 patients that had class A or class B hearing preoperatively, 24 (63.2%) retained class A or B hearing and 29 (76.3%) retained class A, B, or C hearing. When tumors were 10 mm or less in patients with class A or B preoperative hearing, 22 of 30 patients (73.3%) retained class A or B hearing. When the tumor size was greater than 10 mm in patients with class A or B preoperative hearing, 2 of 8 patients (25%) retained class A or B hearing. At most recent follow-up, 76.1% of patients had House-Brackmann grade I facial function, 13.0% had House-Brackmann grade II facial function, and 10.9% had House-Brackmann grade III facial function.

CONCLUSION: Hearing preservation rates are excellent using the middle fossa approach, especially for smaller tumors. No patient experienced long-term facial nerve function worse than House-Brackmann grade III.

KEY WORDS: Acoustic neuroma, Hearing preservation, Middle fossa craniotomy, Vestibular schwannoma

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Small vestibular schwannomas are identified more frequently with the widespread availability of magnetic resonance imaging (MRI).[1,2] The optimal treatment for a small vestibular schwannoma depends on multiple factors including hearing status, age, tumor location and size, and patient preference. Many patients will retain serviceable hearing for a long period of time with observation alone. Other patients with serviceable hearing choose a treatment with the goal of hearing preservation.

Although radiosurgery has been shown to have potential for at least short-term hearing preservation, long-term follow-up is still needed.[3,4] Factors such as the radiation dose to the cochlea, tumor volume, and tumor location affect hearing preservation.[5,6] The middle fossa approach has been the preferred surgical approach at many centers and has the advantage of tumor removal with a high rate of hearing preservation. We are reporting our results with the use of a team approach for the middle fossa removal of vestibular schwannoma.

ABBREVIATIONS: HB, House-Brackmann; **PTA,** pure tone average; **WRS,** word recognition scores

METHODS

Patients

Institutional review board approval was obtained. Patients were identified who underwent a middle fossa craniotomy for removal of a vestibular schwannoma from January 1998 until July 2008. Patient demographics, presenting signs and symptoms, preoperative and postoperative hearing thresholds, and facial nerve outcomes were obtained by retrospective chart review. Tumor size was recorded as the maximum length of the tumor along the plane of the internal auditory canal.

Surgical Technique

Figure 1 illustrates the surgical technique. Continuous seventh nerve and intraoperative auditory brainstem response monitoring were used in all cases. A 5 by 5 cm middle fossa craniotomy is performed with two-thirds of the craniotomy anterior to a line from superior to inferior through the external auditory canal. The dura is elevated from the middle fossa floor in a posterior to anterior direction to prevent injury to a potentially dehiscent geniculate ganglion. The middle meningeal artery is identified and may be sectioned if needed. Next, the arcuate eminence and the greater superficial petrosal nerve are identified. A House-Urban middle fossa retractor is then placed medial to the petrous ridge over the internal auditory canal. The location of the geniculate ganglion is identified. The expected location of the internal auditory canal is the line that bisects the angle between the arcuate eminence and the greater superficial petrosal nerve. Drilling begins near the porus acousticus until the internal auditory canal is identified. The internal auditory canal is followed to the fundus by the use of progressively smaller burrs. Approximately 270° of the internal auditory canal can be exposed near the porus acousticus and will narrow as the dissection extends toward the fundus. The superior semicircular canal serves as the posterior limit of the dissection and may be "blue-lined" to confirm its position. The anterior limit of the internal auditory canal dissection is the cochlea which is adjacent to the labyrinthine facial nerve. A blunt probe is used to determine the remaining bone that can be removed as dissection continues toward the fundus. The vertical crest (Bill's bar) is identified and separates the superior vestibular nerve from the facial nerve. The labyrinthine facial nerve is identified with care not to enter the cochlea. At this point, the dura of the internal auditory canal is opened away from the facial nerve. The facial nerve is identified and tumor dissection is performed from a medial to lateral direction. Once the tumor is removed, a small piece of abdominal fat or temporalis muscle is placed over the internal auditory canal dural defect. The craniotomy bone flap is secured with 3 titanium miniplates and the temporalis muscle is reapproximated. The scalp is closed in 2 layers, and staples are used to close the skin.

Audiology

The pure tone average (PTA) was calculated by averaging the air-conducted thresholds at 500 Hz, 1000 Hz, 2000 Hz, and 3000 Hz. If 3000 Hz was not available, the mean of 2000 Hz and 4000 Hz was used. Patients without a measurable response were recorded with a PTA of 110 dB. Speech discrimination was calculated by using phonetically balanced words from the NU-6 lists at suprathreshold levels to obtain a word recognition score (WRS). In most cases, preoperative audiograms were obtained within a month before surgery. Postoperative audiograms were performed at least a month after surgery.

Facial Nerve Outcomes

Preoperative and postoperative facial nerve outcomes were graded by an attending neurotologist using the House-Brackmann (HB) grading scale.[7] Patients demonstrating any degree of synkinesis were not scored better than grade III. All patients received intraoperative steroids followed by 10 to 14 days of steroids. If a delayed paralysis occurred, steroids were continued for a longer period of time, and antiviral medications were added.

Statistical Analysis

A receiver-operator characteristic analysis was used to determine the most appropriate cutoff point to categorize hearing preservation by tumor size and the accuracy of this cutoff point was tested using a 1-sample proportions test (with Yates correction) against a null hypothesis of guessing (0.50). The comparison between hearing preservation and tumor size was investigated by the use of the Fisher exact test. The relationship between tumor size and facial nerve outcome was investigated by using the Kruskal-Wallis test. A P value of less than .05 was considered significant.

RESULTS

Demographics

Forty-six patients underwent a middle fossa approach for the removal of a vestibular schwannoma. There were 30 female and 16 male patients. The mean age was 49.3 years (range, 30.5-65.4 years). Figure 2 shows the distribution of patients by tumor size. The mean tumor size was 8.3 mm (range, 3-16 mm). Mean follow-up was 1.8 years.

Hearing Outcomes

Hearing results are presented with the use of the standardized reporting guidelines suggested by the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery[8] (Table 1). Preoperative or postoperative audiograms were not available for 4 patients, leaving 42 patients for analysis. Table 2 compares preoperative and postoperative hearing classification. Figure 3 compares preoperative vs postoperative WRS in individual patients. Fifteen patients (35.7%) had a significant decline in WRS. Figure 4 shows preoperative vs postoperative PTAs in individual patients. Seven patients had profound sensorineural hearing loss after surgery. Figures 5 and 6 show the postoperative hearing class for patients with preoperative class A hearing and preoperative class B hearing by using the American Academy of Otolaryngology-Head and Neck Surgery recommendations for reporting hearing outcomes.[8] Of the 38 patients that had class A or class B hearing preoperatively, 24 (63.2%) retained class A or B hearing and 29 (76.3%) retained class A, B, or C hearing. To compare hearing preservation by tumor size, a receiver-operator characteristic analysis determined the optimal cutoff point of $\leq$10 mm and $>$10 mm that resulted in an accuracy of 73.7% (28/38, $z = 2.76$, $P < .006$) predicting postoperative hearing class. When tumors were 10 mm or less in patients with class A or B preoperative hearing, 22 of 30 patients (73.3%) retained class A or B hearing. When the tumor size was greater than 10 mm in patients with class A or B preoperative hearing, 2 of 8 patients (25%) retained class A or B hearing.

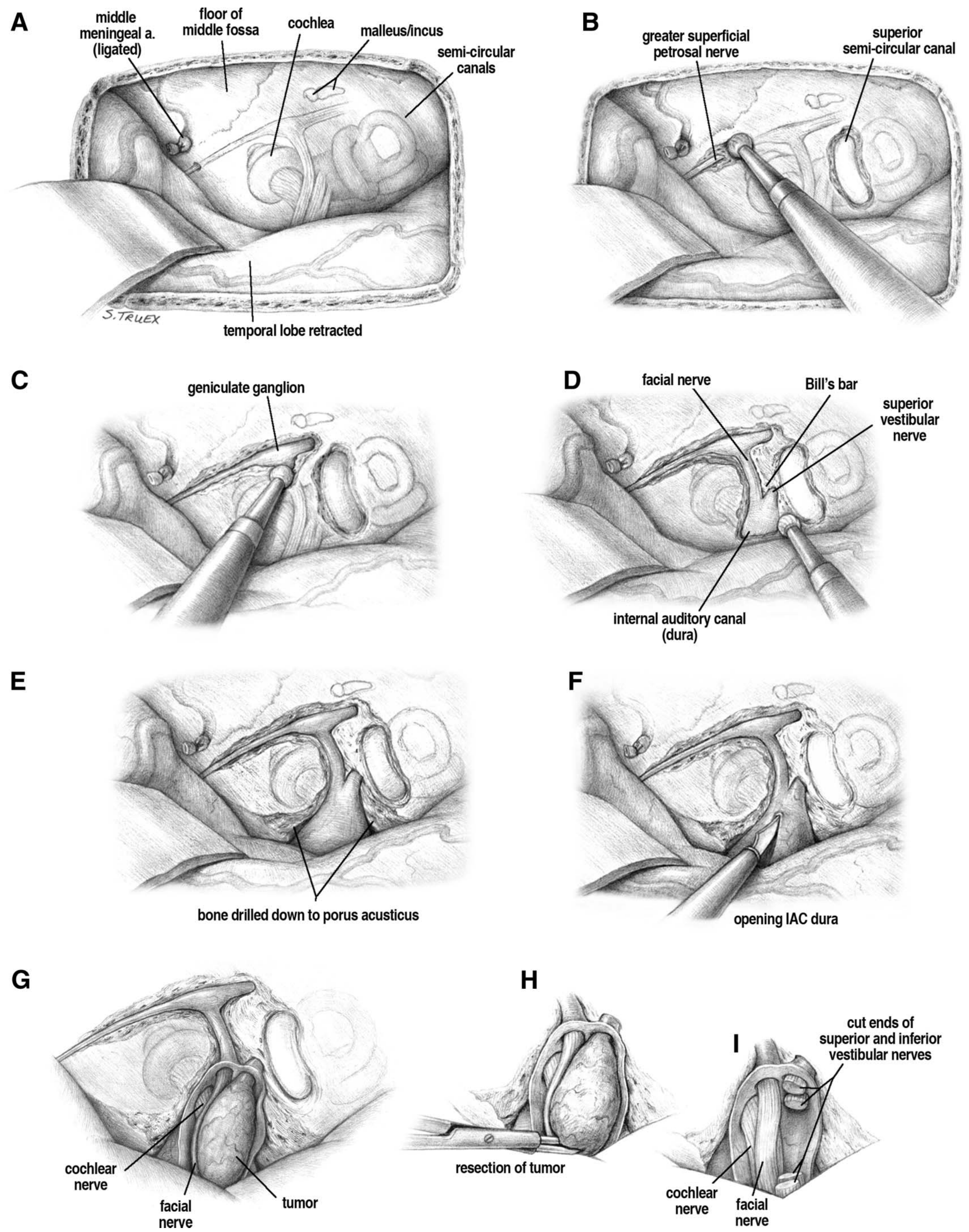

FIGURE 1. *Operative technique.* **A**, *the temporal lobe is retracted, allowing visualization of the floor of the middle fossa.* **B**, *the greater superficial petrosal nerve and arcuate eminence are identified as landmarks for the IAC.* **C**, *the geniculate ganglion is identified by following the greater superficial petrosal nerve posteriorly.* **D**, *the IAC is identified and the facial nerve is followed until the labyrinthine segment is identified. The superior vestibular nerve is identified and followed to the fundus. The vertical crest (Bill's bar) separates the facial and superior vestibular nerves.* **E**, *the IAC is widely exposed by creating superior and inferior troughs.* **F**, *the dura is incised away from the facial nerve.* **G**, *the facial and cochlear nerves are identified.* **H**, *the tumor is dissected away from the facial nerve and removed in a medial to lateral direction to preserve the cochlear nerve.* **I**, *the facial and cochlear nerves are preserved. Meningeal a., meningeal artery; IAC, internal auditory canal.*

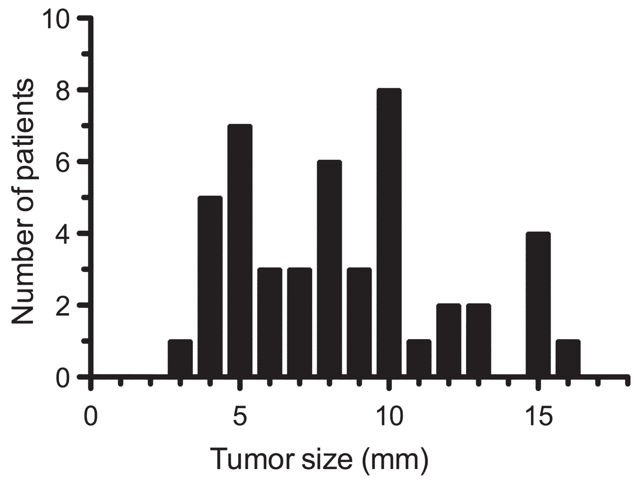

FIGURE 2. *Histogram of patients categorized by tumor size. Tumor size was recorded as the maximum length of the tumor along the plane of the internal auditory canal. The mean tumor size is 8.3 mm.*

Facial Nerve Outcomes

Figure 7 compares immediate postoperative facial grade to the most recent facial grade. Final facial grade was determined at the last postoperative visit recorded in the medical record (range, 2 weeks to 6.4 years). At most recent follow-up, 76.1% of patients were HB grade I, 13.0% were HB grade II, and 10.9% were HB grade III. Three of the 5 patients with HB grade III facial function had HB grade VI function in the immediate postoperative period. One patient developed a delayed facial paralysis on postoperative day 3 and recovered to a HB grade III at 10 months follow-up. No patient had worse than a HB grade III facial function at last follow-up. Figure 8 categorizes facial nerve outcome by tumor size. There was a trend for poorer facial nerve outcomes with larger tumors, but this did not reach significance. (P = .32)

Complications

There were no deaths, seizures, or cerebrovascular accidents. There were no symptomatic temporal lobe injuries. Six patients (13.0%) developed a cerebrospinal fluid leak, and all were successfully treated with a lumber drain for 3 to 5 days. One patient developed postoperative meningitis that was successfully treated with intravenous antibiotics.

TABLE 1. Hearing Classification Using the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology—Head and Neck Surgery Recommendations (1999)[a]

Hearing Class	PTA, dB	WRS, %
A	≤ 30	≥ 70
B	> 30, ≤ 50	≥ 50
C	> 50	≥ 50
D	Any level	< 50

[a]PTA, pure tone average; WRS, word recognition score.

TABLE 2. Preoperative and Postoperative Hearing Classification

Preoperative Hearing Classication	Postoperative Hearing Classication				
	A	B	C	D	Total
A	15	2	1	6	24
B	0	7	4	3	14
C	0	0	0	0	0
D	0	0	0	4	4
Total	15	9	5	13	42

DISCUSSION

Treatment options for a patient with a small vestibular schwannoma include observation with serial MRI scanning, stereotactic radiosurgery, or microsurgical excision. A multitude of factors contribute to the decision-making process, including hearing status, age, tumor location, and tumor size. Much of the decision is based on patient preference after a thorough discussion on the advantages and disadvantages of each treatment option.

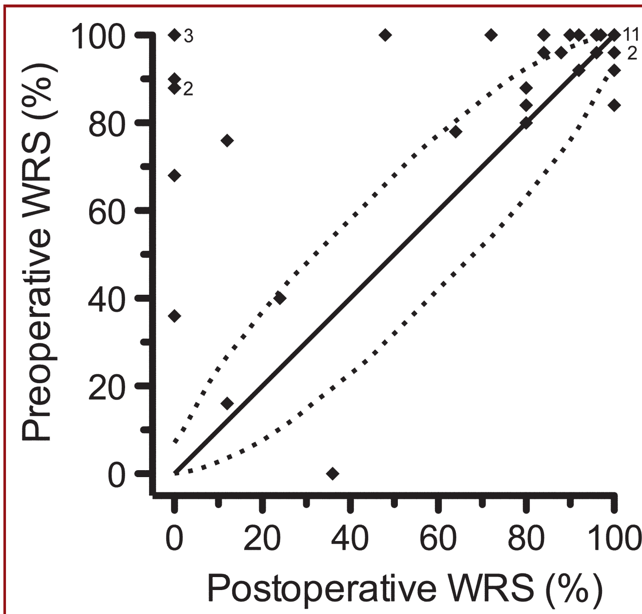

FIGURE 3. *Scatter plot comparing preoperative and postoperative WRS. The dotted lines represent ± 2 standard deviations by using a binomial model for a 50-word speech recognition test.[35] Patients that fall within the dotted lines have no significant change in the WRS. The numbers represent multiple subjects at a coordinate. WRS, word recognition scores.*

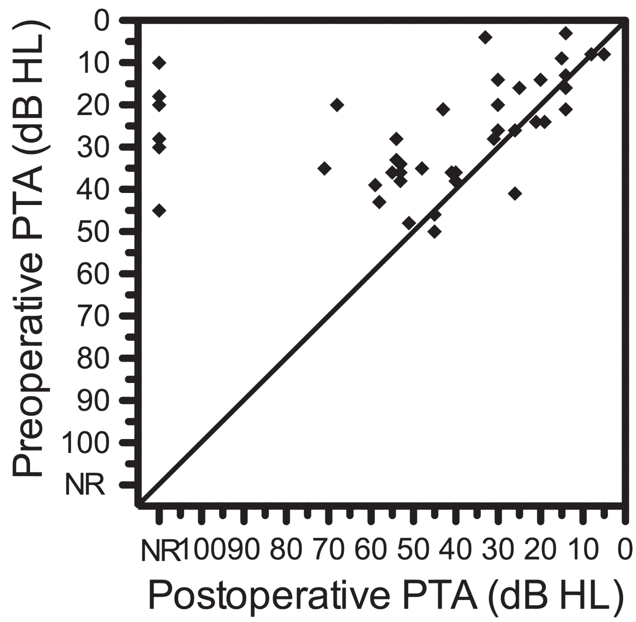

FIGURE 4. *Scatter plot comparing preoperative and postoperative 4-frequency (0.5, 1.0, 2.0, 3.0 Hz) PTA. PTA, pure tone average; HL, hearing level; NR, no response.*

Perhaps the most difficult treatment decision occurs with intracanalicular vestibular schwannomas in patients with serviceable hearing. Early surgery presents not only the potential for hearing preservation, but also the chance of hearing loss when the natural history may have been stable long-term hearing. However, a progressive or sudden hearing loss may occur during the observation period, resulting in nonserviceable hearing and a lost window of opportunity for hearing preservation. A recent study from Denmark demonstrated 49% of patients maintained serviceable hearing over an observation period that averaged 3.9 years.[1] The patient ultimately determines the final decision for treatment, but we advocate early surgical resection if a patient desires hearing preservation.

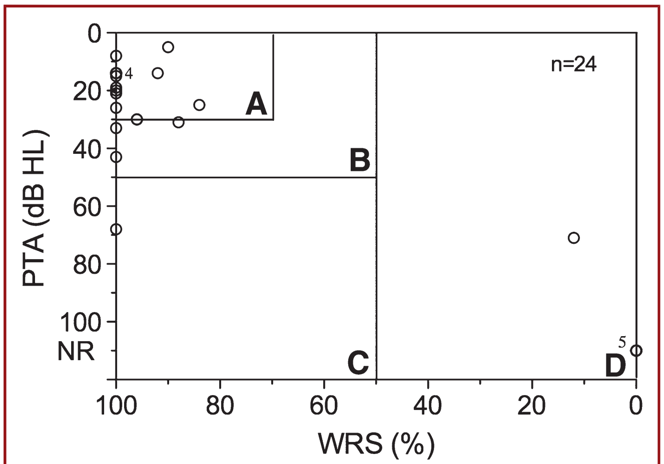

FIGURE 5. *Postoperative PTA and WRS in patients with preoperative class A hearing. The areas on the graph represent the postoperative AAO-HNS hearing class. Numbers represent multiple subjects at a coordinate. PTA, pure tone average; WRS, word recognition scores; HL, hearing level; NR, no response; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery.*

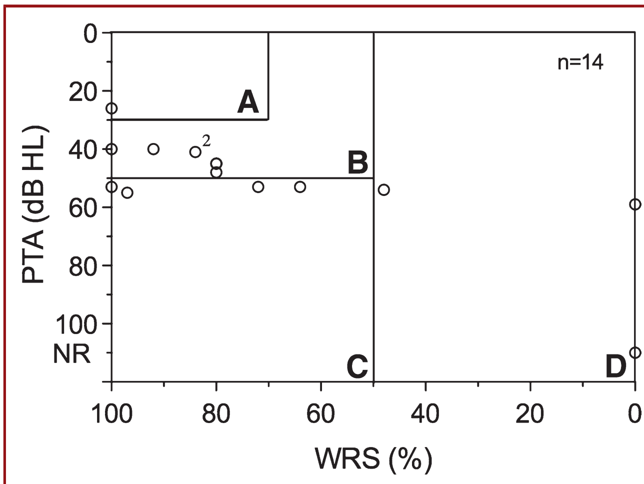

FIGURE 6. *Postoperative PTA and WRS in patients with preoperative class B hearing. The areas on the graph represent the postoperative AAO-HNS hearing class. Numbers represent multiple subjects at a coordinate. PTA, pure tone average; WRS, word recognition scores; HL, hearing level; NR, no response; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery.*

Radiosurgery is a viable treatment modality for patients with a vestibular schwannoma. Successful treatment defined by the avoidance of surgical treatment is greater than 90% in most series by using 12 to 13 Gy with a follow-up time of 8 to 10 years.[9-13] Radiosurgery has the potential for hearing preservation. Yang et al[14] recently published a systematic review of hearing preservation after radiosurgery for vestibular schwannoma. A total of

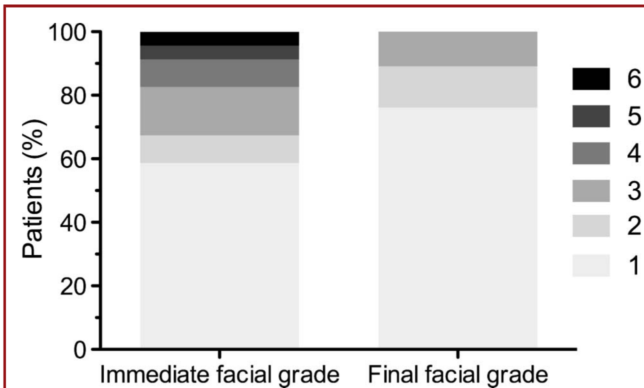

FIGURE 7. *Immediate and last follow-up facial nerve grade. Facial grading was determined by using the House-Brackmann facial grading scale.*

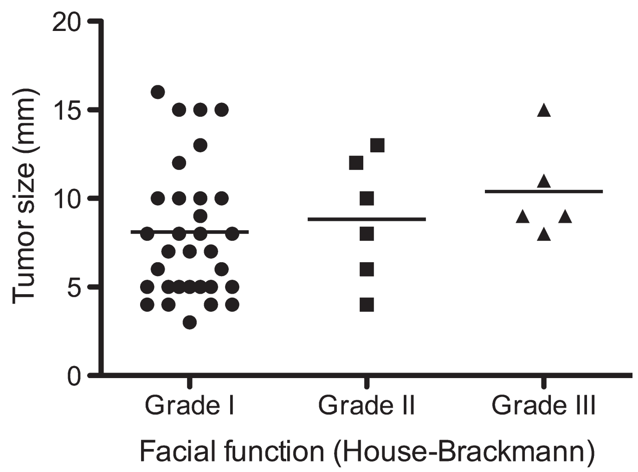

FIGURE 8. *Dot-plot showing tumor size in relationship to facial nerve outcome at last follow-up. The mean tumor size for grade 1, grade 2, and grade 3 facial function was 8.1 mm (SD 3.6), 8.8 mm (SD 3.5), and 10.4 (SD 2.8), respectively. Although there was a trend for worse facial nerve outcome with larger tumors, this did not reach statistical significance (P = .32). SD, standard deviation.*

5825 patients were identified from 74 articles and concluded a 59% hearing preservation rate (maintaining American Academy of Otolaryngology-Head and Neck Surgery class A or B hearing or Gardner-Robertson grade I or II hearing) with doses equal to or less than 12.5 Gy as the marginal dose. The average time of follow-up was 41.2 months. However, detrimental radiation effects on hearing may occur many years after treatment and may result in hearing loss in the majority of patients after radiosurgery.[10,15] Chopra et al[10] evaluated long-term hearing preservation in 106 patients who underwent Gamma Knife radiosurgery for a unilateral vestibular schwannoma with the use of a marginal tumor dose of 12 to 13 Gy. The 10-year actuarial hearing preservation rate was 44.5%. The authors conclude continued hearing loss with time is likely through a number of mechanisms, including direct radiation effects, vascular effects, and changes in tumor remnants. More studies with longer follow-up periods are needed to assess the durability of hearing preservation after radiosurgery.

Surgical options with hearing preservation as a goal include the retrosigmoid approach and the middle fossa approach. The retrosigmoid approach has the advantage of a more familiar approach for most neurosurgeons, panoramic view of the posterior fossa, and no temporal lobe retraction. The disadvantages include limited exposure of the fundus of the internal auditory canal, late exposure of the facial nerve, and a higher incidence of headaches.[16] Hearing preservation is often the goal of removing a vestibular schwannoma with the use of a retrosigmoid approach, with hearing preservation ranging from 21 to 71%.[17-21] However, many studies do not separate hearing results based on the size of the tumor, and hearing preservation may be higher for smaller tumors. Grade I or II postoperative facial nerve function after a retrosigmoid approach for small and medium tumors is between 72 and 100%.[17,18,22,23] It is difficult to compare facial nerve outcomes between the retrosigmoid and middle fossa approaches because the retrosigmoid approach usually includes larger tumors.

Published rates of hearing preservation with the middle fossa approach are 50% to 69%.[24-27] Our hearing results compare favorably with previous studies with an overall hearing preservation rate defined as having a postoperative class of A or B of 63.2%. Hearing preservation improved to 73.3% in our study when the tumors were 10 mm or less. The size of the tumor has been shown in multiple reports to affect hearing preservation.[28,29] Several other factors have been shown to predict hearing preservation including tumor location, involved nerve, and preoperative hearing.[29-31] Tumors impacting the fundus of the internal auditory canal are especially challenging because of the close association to the labyrinth and cochlear aperture. Also, extension under the transverse crest may prevent full tumor visualization.[32] Inferior vestibular nerve schwannomas have a lower rate of hearing preservation because of the close relationship to the cochlear nerve and the greater potential of tumor extension under the transverse crest.[29] Long-term hearing preservation has been demonstrated in most patients after successful hearing preservation surgery. Friedman et al monitored 23 patients with serviceable hearing for more than 5 years after middle fossa removal of a vestibular schwannoma. Seventy percent of the patients maintained serviceable hearing, and 2 patients improved to serviceable hearing during the follow-up period. The authors also demonstrated no significant change in PTA or speech discrimination score when comparing the immediate postoperative audiogram with the most recent audiogram.[33] Additional studies are needed to confirm the durability of hearing after hearing preservation surgery.

It should be noted 4 patients in our series had preoperative class D hearing and underwent a middle fossa approach. None of these patients developed postoperative serviceable hearing. Gantz et al[24] has described improvement in hearing from Class D to Class A or B in 6 of 30 patients. We generally do not recommend a middle fossa in patients without serviceable hearing, but we do allow the patient to choose treatment after counseling.

All patients in our series had HB grade I to III facial nerve function at last follow-up; 89.1% of patients had good to excellent facial function (HB grade I or II). This is consistent with previous reports.[25,26,29,34] The 3 patients that had a HB grade VI in the postoperative period had HB grade III facial function at last follow-up. One patient developed a delayed facial paralysis 3 days after surgery and had partially recovered to a grade III with mild synkinesis at 10 months follow-up. Tumor size did not significantly affect facial nerve outcomes in our series.

CONCLUSION

The middle fossa approach for the removal of a vestibular schwannoma has a high rate of hearing preservation with relatively low risk of morbidity. Hearing preservation is better in patients with smaller tumors. Facial nerve results are good to excellent with all patients having at least a grade III HB function at last follow-up.

Disclosure

Joe Walter Kutz, Jr, is a consultant for Medtronic. Brandon Isaacson is a consultant and an instructor for Medtronic. The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

The authors report their experience with hearing preservation in small vestibular schwannomas treated surgically via the middle fossa approach. Their results are consistent with previous reports and my own experience. I think that there are several important points to be stressed when considering this treatment. The majority of patients choosing this treatment at present express the preference to have the tumor removed, rather than to have radiosurgery. Whether this is rational, given the results of radiosurgery, is difficult to debate with the patient who is fixated on tumor removal. A second reason is to optimize their chances of long-term hearing preservation. Tumors confined to the canal, and especially those that are not impacted into the fundus, in experienced hands can expect a hearing preservation rate of about 70%. More importantly, it has been demonstrated that hearing preservation is durable in these patients. The same durability has not been demonstrated in radiosurgery patients.

I have found that the influence of tumor size and location in relation to the fundus is extremely important. Tumors that are impacted in the fundus, whether arising from the inferior or superior vestibular nerve, present a difficult challenge. The cochlear nerve splits into many fascicles as it enters the modiolus; these fascicles are very fragile and more susceptible to stretch and tension than the entire nerve bundle. Even with gentle medial to lateral dissection, the chance of avulsing these fascicles is high in this circumstance. Even a small gap between the tumor and the fundus is helpful. A second factor related to size was demonstrated in the authors' data in terms of whether the tumor extended into the cerebellopontine angle or remained intracanalicular. I have had similar results when the tumor is large enough to extend into the angle, ie, a grade 2 tumor. I believe that the reason for the drop in hearing preservation of approximately 50% is due to the cochlear nerve having a thinned, fanned-out configuration over the tumor at the internal meatus. This leaves the nerve more vulnerable to dissection than if it is preserved as a more cohesive bundle.

The facial nerve results were also consistent with previous series. The expected incidence of a House-Brackman grade 3 or worse is approximately 10%. Certainly, even though a good facial result is approximately 90%, this does not match the results obtained with stereotactic radiosurgery. I have also found in my experience that tumor size influences the result even in these small tumors. The dividing point in my experience has been between purely intracanalicular tumors vs those with extension into the cerebellopontine angle. Tumors that are larger than 10 mm tend to require a more difficult facial nerve dissection, because a longer segment of the nerve must be dissected from tumor. More manipulation of the nerve generally translates to greater morbidity.

Based on the available data, patients with tumors larger than 10 mm, with extension into the cerebellopontine angle, do not fare as well as those with small, purely intracanalicular tumors. Hearing preservation in these patients is significantly lower overall, and the risk of facial nerve weakness is higher. Therefore, in general, I discourage a patient with a tumor larger than 10 mm with extension into the cerebellopontine angle from surgery via the middle fossa approach. Nevertheless, there will be individual cases where it might be reasonable to offer this if the anatomic situation is favorable (ie, gap between fundus and the tumor, limited expansion of tumor at the internal meatus, grade A hearing, etc). I currently offer both microsurgery or radiosurgery to younger patients who have intracanalicular tumors with good hearing. I stress the good chance (72% in my series) of durable hearing preservation with microsurgery, but at the added risk of about 10% of grade 3 or worse facial nerve weakness. Patients with tumors larger than 10% are considered case-by-case based on age, position in the canal, hearing grade, and other patient-related factors. Generally, these patients are mostly treated by radiosurgery in my practice. A balanced, unbiased approach to decision making in vestibular schwannoma patients will yield the highest patient satisfaction and quality of life. I commend these authors for offering a reasonable alternative to these patients to help them meet their treatment goals.

John Diaz Day
Little Rock, Arkansas

The authors report their experience with a small series of intracanalicular vestibular schwannoma (VS) operated on through a middle fossa approach over a 10-year period. The report mainly deals with the rate of postoperative hearing preservation and facial nerve function. Of the 38 patients who had class A and B hearing preoperatively, 63% retained it. This hearing preservation rate improved to 77% when only cases with tumors less than 10 mm were considered. Excellent facial nerve function (HB grade I and II) was preserved in nearly 90% of cases. The results are as expected. Not many large series with small tumors are available today because of the other options like radiosurgery and observation. Whereas reasonably good results have been achieved by the authors, is it good enough for the patient? Nearly 40% patients had worse hearing postoperatively. Would their hearing been better off for at least a time if they were not operated on? As discussed by the authors, there is a risk of progressive or sudden hearing loss while under observation, and, hence, the authors advocate early surgical resection if a patient desires hearing preservation. However, sudden hearing loss is rare, and early surgery can be advocated to the patient once progressive loss of hearing is documented. Hence, we advise a period of observation for intracanalicular VS patients and advise microsurgery only when progressive hearing loss or growth of tumor is documented. There is little to offer by intervention in another group of patients, patients with intracanalicular VS who are deaf. The series has 4 such patients. Unless affected by disabling vestibular dysfunction, we would just counsel and observe such patients and not offer microsurgery or radiosurgery until the tumor shows growth.

The postoperative facial function reported in this series after intracanalicular VS surgery seems to be worse than that reported after retrosigmoid approach.[1] This, in our opinion, is a significant point in favor of a retrosigmoid approach. The authors are to be complemented for the detailed reporting of the facial function and hearing of patients over a long period of time in this retrospective series. The value of this report is, however, somewhat reduced because of the absence of follow-up imaging data. The total excision rate, evaluated by contrast MRI images, would have added significant value to this article.

Basant Kumar Misra
Mumbai, India

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