Hearing preservation surgery for vestibular schwannoma: experience with the middle fossa approach

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Object. In the early 1960s William F. House developed the middle fossa approach for the removal of small vestibular schwannomas (VSs) with the preservation of hearing. It is the best approach for tumors that extend laterally to the fundus of the internal auditory canal, although it does have the potential disadvantage of increased facial nerve manipulation, especially for tumors arising from the inferior vestibular nerve. The aim of this study was to monitor the hearing preservation and facial nerve outcomes of this approach.

Methods. A prospective database was constructed, and data were retrospectively reviewed.

Results. Between December 2004 and January 2012, 30 patients with small VSs underwent surgery via a middle fossa approach for hearing preservation. The patients consisted of 13 men and 17 women with a mean age of 46 years. Tumor size ranged from 7 to 19 mm. Gross-total resection was accomplished in 25 of 30 patients. Preoperative hearing was American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) Class A in 21 patients, Class B in 5, Class C in 3, and undocumented in 1. Postoperatively, hearing was graded as AAO-HNS Class A in 15 patients, Class B in 7, Class C in 1, Class D in 2, and undocumented in 5. Facial nerve function was House-Brackmann (HB) Grade I in all patients preoperatively. Postoperatively, facial nerve function was HB Grade I in 28 patients, Grade III in 1, and Grade IV in 1. There were 3 complications: CSF leakage in 1 patient, superficial wound infection in 1, and extradural hematoma (asymptomatic) in 1. The overall hearing preservation rate of at least 73% and HB Grade I facial nerve outcome of 93% in this cohort are in keeping with other contemporary reports.

Conclusions. The middle fossa approach for the resection of small VSs with hearing preservation is a viable and relatively safe option. It should be considered among the various options available for the management of small, growing VSs.

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KEY WORDS • acoustic neuroma • middle fossa approach • hearing preservation • vestibular schwannoma

In the early 1960s William F. House developed the middle fossa approach. It was originally designed to decompress the auditory nerve in cases of far advanced otosclerosis. This procedure was later adapted to VS surgery in 1968. The main indications for the middle fossa approach include the removal of small laterally placed VSs, exposure of the labyrinthine and upper tympanic segments of the facial nerve for decompression, vestibular nerve section, and repair of superior semicircular canal dehiscence. As with all surgical approaches for VS resection, there are both advantages and disadvantages to the middle fossa approach. Advantages include the highest reported hearing preservation rates, a very low incidence of postoperative headache, improved exposure of the lateral IAC as compared with that in the retrosigmoid approach, and the completion of bone removal prior to dural opening. Its disadvantages are limited access to the posterior fossa, a tumor size limitation, and a higher risk of postoperative facial nerve weakness.

Methods

Institutional review board approval was obtained for this study.

Patient Selection

The optimal patient for middle fossa surgery for VS excision and hearing preservation has a tumor that extends 1 cm or less into the cerebellopontine angle, a tumor that involves the distal end of the IAC, hearing loss no greater than 40 dB of pure tone loss with speech discrimination of at least 80% (AAO-HNS Class A and upper Class B hearing), and an age under 65 years since dural elevation becomes more difficult in older patients.

Surgical Techniques and Landmarks

After general endotracheal anesthesia is established, the patient is positioned in a Mayfield headrest with the head turned so that the affected ear is as nearly parallel...
to the floor as possible. Monitoring for facial nerve electromyography and auditory brainstem response is set up.

A variety of skin incisions can be used to access the lateral temporal area for craniotomy to expose the middle fossa. We choose a curvilinear incision, which begins just behind the ear and follows along the hairline to create a posteriorly based 5-cm wide scalp flap held with a self-retaining retractor. A temporalis fascia graft is harvested and set aside for later use. An anteriorly based temporalis muscle flap is then elevated off the calvaria and held with a self-retaining retractor. This arrangement of flaps offsets the incision and is helpful in creating a watertight closure at the end of the procedure.

The root of the zygomatic arch is an external landmark for the IAC and should be in the central portion of the exposure. We then create a 4.5 × 4.5-cm craniotomy. Placement of this craniotomy has been described as extending one-third in front and two-thirds behind the external auditory canal. Exact localization of the craniotomy can be improved by using frameless stereotactic navigation. The use of image guidance ensures that the craniotomy is centered directly over the IAC. The temporal squamous bone is then removed using a high-speed drill and rongeurs to create a flush approach to the floor of the middle cranial fossa. The patient is hyperventilated to a PCO2 of 28 mm Hg, and 0.25 g/kg of mannitol is given. The dura mater is detached from the underside of the calvaria anteriorly and posteriorly, which helps to relax the dura and allows easier elevation of the temporal dura. Under magnification, the dura is elevated off the floor of the temporal fossa beginning posteriorly at the petrous ridge and continuing anteriorly to identify the greater superficial petrosal nerve. The posterior to anterior dissection avoids the risk of dissecting below the greater superficial petrosal nerve and inadvertently avulsing it from the facial hiatus. Venous bleeding is commonly encountered in the region of the foramen spinosum. We avoid coagulation in this location to minimize the risk of both injury to the greater superficial petrosal nerve and interruption of any blood supply to the facial nerve that could arise from the region of the foramen spinosum. Generally, this bleeding is easily managed with gentle tamponading with one of a variety of hemostatic materials. Once the greater superficial petrosal nerve is identified, dural elevation continues to the true petrous ridge. We then place a House-Urban retractor with its edge over the petrous ridge to maintain visualization of the floor of the middle cranial fossa. The superior semicircular canal is positively identified either by direct visualization or by blue-lining of the canal. Typically, the IAC bisects the angle between the course of the greater superficial petrosal nerve and the orientation of the superior semicircular canal. This angle tends to be approximately 60° from the course of the greater superficial petrosal nerve, but the anatomical relationship varies (Fig. 1). Bone anterior and medial to the superior semicircular canal is removed to identify the dura around the porus acusticus. Bone removal continues laterally along the course of the IAC until Bill’s bar, or separation of the facial nerve from the vestibular nerve, comes into view. The cochlea lies just anterior to the lateral IAC, and no attempt is made to expose it. The bone between the labyrinthine facial nerve and the cochlea is less than 1 mm thick.

Bone is removed to expose the IAC and extends both anteriorly and posteriorly along the petrous ridge to create at least a 200°–270° exposure of the internal auditory canal (Fig. 2). This exposure allows greater manipulation of the structures of the IAC in a safe way and is particularly relevant for tumors of inferior vestibular nerve origin. Maximized bone removal improves the ability to mobilize the facial nerve anteriorly and allows a better angle of dissection beneath the facial nerve as viewed from a postero-anterior direction. As the bone removal extends laterally, great care is taken to avoid entry into the cochlea anteriorly or into the labyrinth posteriorly.

Once the bone has been removed, exposing the contents of the IAC, the dura is opened sharply posteriorly to avoid injury to the underlying facial nerve (Fig. 3). Cerebrospinal fluid is allowed to egress. A stimulating dissecting probe is liberally used to identify the facial nerve and separate the facial nerve from the superior vestibular nerve (Fig. 2). At this point it is usually evident whether the tumor is arising from the superior or the inferior vestibular nerve. The distal superior vestibular nerve is divided, allowing greater access to the tumor. In the unusual circumstance that the tumor is in the facial nerve, the nerve is decompressed, and no additional tumor is removed to avoid producing facial paralysis.

Depending on the size and consistency of the tumor, internal debulking is performed with the cup forceps and occasionally the fine tip on the ultrasonic aspirator. Dissection of the IAC is generally more difficult on the right side for a right-handed surgeon because of the “height” of the superior semicircular canal. This bony prominence tends to inhibit dissection of the posterior pole of the tumor and visualization below the facial nerve. The tumor is gently dissected from the posterior edge of the facial nerve and from the underside of the facial nerve. The tumor is progressively dissected posteriorly, allowing identification of the cochlear nerve just inferior to the facial nerve. Tumor dissection is generally performed in a medial to lateral direction to avoid avulsing the auditory nerve from the lamina cribrosa laterally. The inferior vestibular nerve is also divided. The tumor is then gently rolled out of the IAC, and its proximal attachments are divided (Fig. 4). Bipolar cautery within the IAC is avoided, and dissection is generally done under constant irrigation to allow optimal visualization. We believe these techniques are crucial to facial nerve and hearing outcomes.

Following tumor resection a small piece of temporalis muscle is placed over the canal to close off the IAC. Any opened air cells are carefully occluded with bone wax. The middle fossa floor is then covered with the temporalis fascial graft, and a small corner of the bone flap is used to create a bony reconstruction of the middle cranial fossa floor. Careful epidural hemostasis is then achieved with both bipolar cautery and gentle tamponading with hemostatic agents. The self-retaining retractor is removed, and the bone plate is replaced in its anatomical position and rigidly fixed. The temporalis muscle is returned to its anatomical position, and the temporalis fascia is carefully approximated to achieve a watertight closure. The
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**Fig. 1.** Anatomical illustration of the floor of the middle cranial fossa. A line drawn along the course of the greater superficial petrosal nerve (GSPN) creates an approximately 120° angle with a similar line drawn along the orientation of the superior semicircular canal (Sup. SCC). A line bisecting this angle approximates the location of the IAC. The blue arrow points to the opened cochlea, and the green arrow points to the opened vestibule of the labyrinth. The red star indicates the geniculate ganglion. Cistern. Seg. = cisternal segment; CN = cranial nerve; Eust. Tube = Eustachian tube; For. Ovale = foramen ovale; Labyr. Seg. = labyrinthine segment; Lat. SCC = lateral semicircular canal; Meat. Seg. = meatal segment; Mid. Men. A. = middle meningeal artery; Nerv. Interm. = nervus intermedius; Pet. ICA = petrous internal carotid artery; Post. SCC = posterior semicircular canal; Sup. Pet. Sinus = superior petrosal sinus; Sup. Vest. N. = superior vestibular nerve; Tensor Tymp. M. = tensor tympani muscle; Tymp. Seg. = tympanic segment; Trig. Gang. = trigeminal ganglion. Reprinted from *Surgical Neurology*, 71/5, Tanriover et al., Middle fossa approach: microsurgical anatomy and surgical technique from the neurosurgical perspective, pp 586–596, 2009, with permission from Elsevier.

**Fig. 2.** Surgical photograph of middle fossa approach on the left side showing a 270° exposure of the IAC. The dura of the canal has been opened, and the superior vestibular nerve has been separated from the anteriorly located facial nerve. The tumor is visible between the two nerves and has an inferior vestibular nerve origin. SSC = superior semicircular canal; SVN = superior vestibular nerve; T = tumor; VII = facial nerve.

**Fig. 3.** Surgical photograph of middle fossa approach on the left side, featuring the opening of the dura of the IAC. The cleft between the anteriorly located facial nerve (VII) and the superior vestibular nerve (SVN) is faintly visible (arrows). This cleft is developed by dissection with the stimulating dissecting probe.
scalp is returned to its anatomical position, and the galea aponeurotica is closed. The skin edges are approximated and closed with a nonabsorbable nylon suture. A mastoid dressing is applied.

Results

All patients undergoing a middle fossa approach for VS resection with attempted hearing preservation were included in this study extending from December 2004 to January 2012. Thirty patients, 13 men and 17 women, made up the study cohort. The mean patient age was 46 years (range 21–64 years). The mean tumor size was 12 mm, and the median tumor size was 11 mm (range 7–19 mm). Twenty-five of the 30 patients underwent gross-total resection, as determined by intraoperative observation and postoperative MRI (Fig. 5). Three of 30 patients underwent near-total resection in which microscopically visible tumor was left in place for functional reasons. Note that postoperative MRI may or may not have shown the residual lesion. Two patients underwent subtotal resection, and residual tumor was evident on postoperative MRI. Both of these patients had tumors on the right side with an inferior vestibular nerve origin. Superior displacement of the facial nerve and the constricted anatomy did not allow adequate visualization into the anterior portion of the IAC.

Hearing was scored according to the AAO-HNS classification of hearing (Table 1). Twenty-nine of 30 patients had preoperative audiograms available for review. Twenty-one patients had AAO-HNS Class A hearing, 5 had Class B hearing, and 3 had Class C hearing. Postoperative audiograms were available in 25 of the 30 patients. Postoperative hearing was Class A in 15 patients, Class B in 7, and Class C in 1. Two patients had profound hearing loss. Among the 5 patients without postoperative audiograms, 3 probably had Class B hearing since they could use the telephone on the surgically treated side, although this fact could not be definitively documented. Among the 21 patients with Class A hearing preoperatively, that level of hearing remained in 14; hearing diminished to Class B in 4 patients, all hearing was lost in 1, and no postoperative audiograms were available in 2 (Fig. 6). Of the 5 patients with Class B hearing preoperatively, hearing improved to Class A in 1 patient, remained stable (Class B) in 2 patients, and diminished to Class C in 1 patient; a postoperative audiogram was not available in 1 patient (Fig. 7). Among the 3 patients with preoperative Class C hearing, improved to Class B in 1 patient and was lost in 1 patient; 1 patient did not have an audiogram. Twenty-two of 30 patients had Class A or B hearing postoperatively. This result is consistent with a 73% rate of functional hearing preservation.

Of those patients with complete pre- and postoperative data, 11 had Class A or B hearing preoperatively with tumors that were 10 mm or smaller. Nine of these 11 patients remained in hearing Class A or B, and thus an 82% rate of hearing preservation was achieved in this subgroup. Twelve patients with Class A or B hearing preoperatively had tumors larger than 10 mm. All 12 of these patients remained in hearing Class A or B. This finding is consistent with a 100% rate of hearing preservation. There was no significant difference in hearing preservation between groups (p = 0.22, Fisher exact test).

<table>
<thead>
<tr>
<th>Hearing Class</th>
<th>PTA (dB)</th>
<th>SDS (%)</th>
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<tbody>
<tr>
<td>A</td>
<td>≤30</td>
<td>≥70</td>
</tr>
<tr>
<td>B</td>
<td>&gt;30 &amp; ≤50</td>
<td>≥50</td>
</tr>
<tr>
<td>C</td>
<td>&gt;50</td>
<td>≥50</td>
</tr>
<tr>
<td>D</td>
<td>any level</td>
<td>≤50</td>
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* "Serviceable hearing" was defined as Class A or B hearing. Abbreviations: PTA = pure tone average; SDS = speech discrimination score.

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Fig. 4. Photograph of tumor whose consistency and size made en bloc removal technically possible.

Fig. 5. Preoperative (left) and postoperative (right) axial postcontrast T1-weighted MR images revealing complete resection of a right-sided VS via the middle fossa approach.

Fig. 6. Graph showing postoperative pure tone average (PTA) and word recognition score (WRS) in patients with preoperative AAO-HNS Class A hearing. The letters A, B, C, and D represent the postoperative AAO-HNS hearing class. HL = hearing level; N = number of patients; NR = no response.
Facial nerve function was graded using the HB grading scale. All 30 patients had an HB Grade I level of facial function preoperatively. Postoperatively, 28 (93%) of 30 patients maintained an HB Grade I level of facial function. One patient had facial weakness of HB Grade III, and 1 patient with only 1 week of postoperative follow-up had an HB grade of IV.

Three patients suffered postoperative complications. One patient required reoperation for a CSF leak through a highly aerated temporal bone; the defect was repaired directly with complete resolution. One patient had an asymptomatic but significantly sized extradural hematoma, which was surgically evacuated. Unbeknownst to the surgical team, this patient was a chronic aspirin user. There was 1 superficial wound infection, which resolved with oral antibiotics.

Discussion

Several options exist for the management of small VSs in patients with serviceable hearing. Interestingly, in a recent report, Di Maio et al.6 could not identify a difference in quality of life among the therapeutic options of observation, radiation, or surgery. A commonly used management strategy is careful interval clinical and MRI evaluation without intervention, or the “wait-and-scan” option. In a natural history study from France, Bakkouri et al.2 identified a growth rate of < 1 mm/year in 58.6% of patients. Only 12.2% of patients had a growth rate of > 3 mm/year. Over time, however, many patients will suffer a deterioration in hearing.23 Good high-frequency hearing and speech discrimination at diagnosis are positive predictors of good hearing after several years of observation, although about 15% of patients will have worsened hearing after a year of observation.23 Radiosurgery has assumed a prominent role in the management of patients with small VSs. The short-term tumor growth control rates are in excess of 95%, and long-term control remains in over 85% of patients. Short-term hearing preservation rates are also quite good and range from 60% to 75%;15,16,27 however, long-term results reveal a marked tendency to deteriorate over time. Hearing preservation rates at 5 years postradiosurgery range from 43% to 57%, whereas those at 10 years range from 34% to 45%.5,7,18,27 The middle fossa approach for VSs with attempted hearing preservation has been described by several groups over the years. Data from recent publications reveal the maintenance of postoperative serviceable hearing in 37%–77% of patients (Table 2).1,15–17,19,22,24 These rates are typically superior to hearing preservation outcomes reported for the retrosigmoid approach.20 In contrast to rates in radiosurgical series, the long-term hearing preservation rates following surgical tumor removal typically remain stable over time.8,11,24 Friedman et al.8 reported hearing preservation rates of 70% more than 5 years after surgery, and Hilton et al.11 reported a 10-year hearing preservation rate of 72%. Ninety-six percent of patients in the study by Woodson et al.26 maintained their immediate postoperative hearing levels with > 5 years of follow-up. Thus, despite the inherent variability and selection biases among treatment groups, it seems that microsurgical removal of VSs results in better long-term hearing preservation rates than radiosurgery.

A disadvantage of the middle fossa approach is the need for facial nerve manipulation. Nonetheless, most centers report postoperative HB Grade I and II facial function outcomes in 89%–100% of patients. Facial nerve outcomes have typically been superior in patients undergoing a retrosigmoid approach, with functional outcomes of HB Grades I and II of 90%–100% (Table 3). We chose to report only
those patients with HB Grade I function, and this level of facial nerve function was achieved in 93% of patients.

**Conclusions**

The middle fossa approach for the resection of VSs with hearing preservation is a viable alternative to both a retrosigmoid approach and stereotactic radiosurgery. Hearing preservation rates in excess of 70% can be achieved in well-selected patients. Facial nerve outcomes are typically good despite the need for nerve manipulation.

**Disclosure**

Dr. DeMonte is a yearly lecturer for a Medtronic skull base course.

Author contributions to the study and manuscript preparation include the following. Conception and design: both authors. Acquisition of data: both authors. Analysis and interpretation of data: both authors. Drafting the article: DeMonte. Critically revising the article: both authors. Reviewed submitted version of manuscript: both authors. Approved the final version of the manuscript on behalf of both authors: DeMonte. Statistical analysis: DeMonte. Study supervision: both authors.

**References**


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