Acoustic Neuroma and Skull Base Surgery

Where is the skull base?

The skull base is the bottom part of the skull. While the sides, front, back, and top of the skull are essentially smooth, thin walls of bone, the skull base is dramatically more complex. The skull base is complex because every nerve in the body that carries signals to and from the brain crosses the skull base. Additionally, the large vessels that carry blood to and from the brain run through the skull base.

Which types of diseases are treated with skull base surgery?

A variety of benign tumors are treated with skull base surgery. These include acoustic neuroma, meningioma, schwannoma, glomus jugulare and vagale, epidermoid, pituitary tumors, and many others. Malignant tumors managed with skull base surgery include squamous cell carcinoma, esthesioneuroblastoma, chondrosarcoma, chordoma, and endolymphatic sac tumors. Occasionally, particularly in the pediatric population, a skull base biopsy may be required in order to diagnose other diseases such as leukemia, lymphoma, plasmacytoma, Langerhans’ cell histiocytosis, rhabdomyosarcoma, osteosarcoma, fibrosarcoma, hemangiopericytoma, malignant fibrous histiocytoma, or metastatic disease. Skull base surgical techniques are also sometimes employed to repair fractures of the skull base, to treat cerebral aneurysms, as well as to remove deep-seated infections of the skull base bone.

What is skull base surgery?

Since tumors of the skull base sit underneath the brain, it can be difficult during surgery to get to the tumor in order to remove it. Traditional techniques used to approach tumors of the brain itself can be used to approach skull base tumors, but these often require significant force to retract the patient’s brain out of the way. This may lead to
unwanted injury to otherwise normal brain tissue.

The basic concept of skull base surgery is to approach the tumor from underneath or from the side by removing specific areas of skull base bone. Thus, the tumor can be exposed with little to no brain retraction. Skull base procedures, for example, may be designed to traverse the bone containing the ear (trans-temporal/trans-petrosal/trans-clival approaches), low on the temple beneath the brain (middle fossa approach), around the eye (trans-orbital/trans-sphenoid approaches), through the nose or paranasal sinuses (trans-sphenoidal/trans-ethmoidal/trans-facial approaches), or from the neck (trans-cervical). Fundamentally, these are minimally-invasive techniques designed to maximize tumor removal while preserving neurological function to the greatest extent possible.

What type of symptoms do patients with skull base tumors have?

Tumors arising within the skull base are rare and usually cause few symptoms until they grow to a size where they begin to affect neurologic function. These symptoms may manifest as double vision, facial pain or twitching, hearing loss, loss of balance or dizziness, hoarseness, or tongue weakness. Occasionally, an asymptomatic tumor may be diagnosed when a middle ear mass is noted during routine examination of the ears.

How is a skull base tumor diagnosed?

An MRI of the brain and/or skull base with and without gadolinium contrast is extremely sensitive at diagnosing these rare tumors with little risk to the patient. A CT scan of the skull base or temporal bone may also be needed to evaluate the condition of the surrounding skull base bone. Occasionally, an MRA or MRV (magnetic resonance angiogram and magnetic resonance venogram) are useful to study how the blood vessels to the brain are affected by the tumor. For large or very vascular tumors, an angiogram with embolization may be performed prior to surgical resection in order to plug the arteries that feed the tumor. This reduces blood loss during surgery.

What technologies are used during skull base surgery?

Microsurgery of skull base tumors is a technologically intensive endeavor. A high-power microscope with a stable, anti-vibratory base mount is important for proper visualization of vital structures. A high powered drill with a wide assortment of burrs is essential, as it is critically important to be able to navigate around each nerve and blood vessel. Delicate microsurgical instruments in a wide variety of sizes and angles, such as hooks, scoops, scissors, and probes, are required. These permit atraumatic microdissection of the tumor off the vital structures.

Cranial nerve monitoring is often used in skull base surgery. A neurophysiologist is present in the operating room throughout the surgery, and tracks the various nerves’ health on a computer system. This optimizes the preservation of cranial nerves by facilitating gentle microdissection of the tumor off of the nerve.

A three-dimensional image guidance navigation system may be required for large tumors that envelop major vascular or neurologic structures. This computer system is programmed to project images of an individual patient’s tumor on a TV for use in the operating room. Using a probe referenced to the patient on the operating table, the surgeon can verify exactly where each vital structure is in relation to the tumor.

What is the success rate of skull base surgery and what other treatment options are available besides surgery?

The goal when managing skull base tumors is to improve patient survival and quality-of-life. Obviously, the best way to treat a skull base tumor is a decision that can only be made after close collaboration between the patient and the physician team. Proper patient selection is critical to good outcomes.

Not all skull base tumors require intervention. Some are so slow growing that they pose only minor risk of more serious problems, especially in older individuals. In such cases, the tumor may simply be monitored by periodic imaging studies. In this situation, because the tumor is predicted not to grow to a size where it will cause disabling symptoms prior to the patient dying of other reasons. Thus, these patients can be treated with the philosophy that they will “take the tumor with them”.

http://med.stanford.edu/ohns/earinstitute/otology-neurotology/resources/skull_base_info.html
Another treatment option that is at times preferable to microsurgery in selected skull base tumors is stereotactic radiation. The goal is to use a computer-guided delivery system to focus the radiation directly on the skull base tumor, while minimizing radiation exposure to the sensitive surrounding structures. While this technique does not remove the tumor, it can reduce or stop the tumor growth in certain situations. There are several different brands of devices that can deliver radiation in a stereotactic fashion, including Gamma Knife, Novalis, Cyberknife, and proton beam. While there are some important differences between them, the ultimate results for many types of tumors are quite similar. That is, the tumor is irradiated and the surrounding normal tissue receives a substantially lower dosage. The Cyberknife was developed at Stanford and we have found it to be a very successful treatment option for skull base tumors.

Success rates of skull base surgery have continued to improve. This is because of the evolution of modern approaches designed to reduce the requirement of brain retraction and sacrifice of normal structures in order to get to the tumor. Our surgical philosophy is based on the concept of removing as much tumor as possible, while maintaining preservation of function. This has led to excellent rates of tumor control, long-term patient survival, as well as in numerous, important quality-of-life measures.
Acoustic Neuroma

What is acoustic neuroma?

Acoustic neuroma or vestibular schwannoma, is a non-cancerous tumor that may develop from an overproduction of Schwann cells that press on the hearing and balance nerves in the inner ear. Schwann cells are cells that normally wrap around and support nerve fibers. If the tumor becomes large, it can press on the facial nerve or brain structure.

What are the symptoms of acoustic neuroma?

The following are the most common symptoms of acoustic neuroma. However, each individual may experience symptoms differently.

When a neuroma develops, it may cause any/all of the following:

- hearing loss
- tinnitus
- dizziness
- paralysis of a facial nerve
- life-threatening problems in the brain

The symptoms of acoustic neuroma may resemble other conditions or medical problems. Always consult your physician for a diagnosis.

What are the different types of acoustic neuromas?

There are two types of acoustic neuromas:

- Unilateral acoustic neuromas - affect only one ear, and account for 8 percent of all tumors inside the skull. This tumor may develop at any age, but most often occurs between the ages of 30 and 60. Acoustic neurinoma may be the result of gene damage caused by environmental factors.
- Bilateral acoustic neuromas - affect both ears and are hereditary, caused by a genetic disorder called neurofibromatosis-2 (NF2). This tumor develops in the teens or early adulthood.

How are acoustic neuromas diagnosed?

Because symptoms of acoustic neuromas resemble other middle and inner ear conditions, they may be difficult to diagnose. Preliminary diagnostic procedures include ear examination and
hearing test. Computerized tomography (CT) and magnetic resonance imaging (MRI) scans help to determine the location and size of the tumor.

Early diagnosis offers the best opportunity for successful treatment.

**Treatment for acoustic neuroma**

Specific treatment for acoustic neurinoma will be determined by your physician based on:

- your age, overall health, and medical history
- extent of the disease
- your tolerance for specific medications, procedures, or therapies
- expectations for the course of the disease
- your opinion or preference

Treatment may include surgery to remove small acoustic neuromas. Surgery for larger tumors is complicated by the probable damage to hearing, balance, and facial nerves.

Another treatment option is radiosurgery, often called the "gamma knife," using carefully focused radiation to reduce the size or limit the growth of the tumor.
What is an Acoustic Neuroma?

Important Points To Know About an Acoustic Neuroma

- An acoustic neuroma, also called a vestibular schwannoma, is a rare benign tumor of the balance or hearing nerves.
- It is usually slow growing and expands at its site of origin (1.5mm/yr).
- The most common first symptom is hearing loss in the tumor ear.
- The cause is generally unknown, although it may be genetic in some cases.
- If an acoustic tumor becomes large it may push on the surface of the brainstem but not really grow into brain tissue.
- Continued tumor growth that goes untreated may threaten neurological function and even life.
- The treatment options are observation, surgical removal or radiation.

What is an Acoustic Neuroma?

An acoustic neuroma, known as a vestibular schwannoma, is a benign (non-cancerous) growth that arises on the eighth cranial nerve leading from the brain to the inner ear. This nerve has two distinct parts, one part associated with transmitting sound and the
other with sending balance information to the brain from the inner ear. The eighth nerve, along with the facial or seventh cranial nerve, lie adjacent to each other as they pass through a bony canal called the internal auditory canal. This canal is approximately 2 cm (0.8 inches) long. It is generally here that acoustic neuromas originate from the sheath surrounding the eighth nerve. The seventh or facial nerve provides motion to the muscles of facial expression.

A. normal anatomy

B. acoustic neuroma

Acoustic neuromas usually grow slowly over a period of years. They expand in size at their site of origin and when large can displace normal brain tissue. The brain is not invaded by the tumor, but the tumor pushes the brain as it enlarges. The slowly enlarging tumor protrudes from the internal auditory canal into an area behind the temporal bone called the cerebellopontine angle. The tumor now assumes a pear shape with the small end in the internal auditory canal. Larger tumors can press on another nerve in the area (the trigeminal nerve), which is the nerve of facial sensation. Vital functions to sustain life can be threatened when large tumors cause severe pressure on the brainstem and cerebellum. Tumors are typically described as small (less than 1.5 cm), medium (1.5 cm to 2.5 cm) or large (more than 2.5 cm).
Are Acoustic Neuromas hereditary?
Although there is an heritable condition called Neurofibromatosis Type 2 (NF2) which can lead to acoustic neuroma formation in some people, most acoustic neuromas occur spontaneously without any evidence of family history (95%).

How often do Acoustic Neuromas occur?
Most recent publications suggest that the incidence of acoustic neuromas is rising. This is because of advances in MRI scanning both on incidental scans and for patients experiencing symptoms. Studies in Denmark published in 2004 show the incidence is 17.4 per million or close to 2 persons per 100,000. Most acoustic neuromas are diagnosed in patients between the ages of 30 and 60.

Cause or Etiology of Acoustic Neuroma
There is a growing body of evidence that sporadic defects in tumor suppressor genes may give rise to these tumors in some individuals. Other studies have hinted at exposure to loud noise on a consistent basis. One study has shown a relationship of acoustic neuromas to prior exposure to head and neck radiation, and a concomitant history of having had a parathyroid adenoma (tumor found in proximity to the thyroid gland controlling calcium metabolism). There are even controversies on hand held cellular phones. Whether or not the radiofrequency radiation has anything to do with acoustic neuroma formation, remains to be seen. To date, no environmental factor (such as cell phones and diet) has been scientifically proven to cause these tumors. ANA does recommend that frequent cellular phone users use a hands free device to enable
Neurofibromatosis (NF2)

NF2, a genetic disorder, occurs with a frequency of 1 in 30,000 to 1 in 50,000 births. The hallmark of this disorder is bilateral acoustic neuromas (an acoustic neuroma on both sides). This creates the perplexing problem of the possibility of complete deafness if the tumors are left to grow unchecked. Preventing or treating the complete deafness that may befall individuals with NF2 requires complex decision making. The trend at most academic U.S. medical centers is to recommend treatment for the smallest tumor which has the best chance of preserving hearing. If this goal is successful, then treatment can also be offered for the remaining tumor. If hearing is not preserved at the initial treatment, then usually the second tumor, in the only-hearing ear, is just observed. If it shows continued growth and becomes life-threatening, or if the hearing is lost over time as the tumor grows, then treatment is undertaken. This strategy has the highest chance of preserving hearing for the longest time possible.

There are now several options to try to rehabilitate deafness in NF2 patients. Implanting the hearing part of the brainstem (Auditory Brainstem Implant) can help restore some sound perception to these patients. Also, cochlear implants can be used if the cochlear nerve is preserved following surgery. Radiosurgery may be an option although stereotactic radiosurgery may not have the effect on the NF2 patient as in patients with unilateral sporadic tumors. There are some centers using radiation therapy for NF2 with mixed results. The risk of malignant transformation after radiation is higher in this group. Recent studies have shown that these individuals may have more tumors that are resistant to radiation, due to the cell type. These cases should be handled in centers with very experienced skull base teams.
Treatment Options Summary

Typical Advantages of Microsurgery over Radiation

1. Surgery removes the tumor for those that want it "out of their body."
2. Some patients have a fear of very rare long-term (many years post-treatment) effects of radiation, such as induced malignancy.
3. Size and/or position of the tumor may make radiation unadvisable, due to post-treatment swelling. Tumors larger than 2.5 to 3 cm in size are not recommended for radiation.
4. Younger age is generally another determining factor for choosing surgery.
5. Subtotal tumor removal may make surgery the best option, followed by radiation.
6. Some physicians do not recommend radiosurgery for large tumors if there has been prior radiation treatment in the same area.
Microsurgical Options - 3 Approaches - Pros and Cons

Translabyrinthine

**Pros:**
- Oldest approach - longest history.
- An option when there is no useful hearing to preserve.
- Approach facilitates identification of facial nerve for preservation.
- Any size tumor can be removed with this approach.

**Con:**
- Results are permanent with complete hearing loss in the AN ear.

Retrosigmoid/Sub-occipital

**Pros:**
- Possible preservation of hearing - 50% chance of this when the tumor is small to medium size.
- Approach provides a good view of the AN in relation to brainstem.
- Possible preservation of facial nerve.
- Any size tumor can be removed with this approach.

**Cons:**
- Hearing preservation decreases if the tumor is large.
- Headaches are a more prevalent post-op side effect.

Middle Fossa

**Pro:**
- Possible preservation of hearing with small tumors in the right location, typically confined to the internal auditory canal.

**Con:**
- Most often used only with small tumors, typically confined to the internal auditory canal.

Typical Advantages of Radiation over Microsurgery

1. Good option for patients in their mid-50's and older or with health issues.
2. Radiation is typically an outpatient procedure, though some patients may stay in the hospital overnight. The radiation session itself is relatively quick. Some procedures are done in one session and others take several sessions.
3. There is usually no need to take time off from work. Some people are treated on their way to or from work when having multiple sessions.
4. There is no recuperation or convalescence time immediately after treatment.
5. There are usually no immediate complications. In the medium term there may occasionally be complications, as radiation takes time to fully present symptoms.
6. The tumor can swell for up to 18 months to two years. Symptoms can be worse during this time and may include acute side effects following radiation treatment. Some of these may be short term while others may last longer and become long term.

Disadvantages of Radiation

1. Long-term success of tumor control is unknown.
2. Long-term risks of radiation to the surrounding brain are not well known.
3. Life-long monitoring is required.
4. Most current data shows that hearing declines over time after radiation.

Radiation Treatment Options

Gamma Knife

- Early use for AN began in late 1980's and early 1990's
- Use of head frame attached by pins attached to the patient's skull
- Local anesthetic is used
- Stereotactic radiosurgery
- Always single session

Linear Accelerator (LINAC)

- Generally for ANs used for FSR (multiple sessions)
- Cyber-Knife is a well-known variation of the LINAC machine which uses a robotic arm guided by X-ray imaging

Typical Advantages of "Watch & Wait" Over Microsurgery or Radiation Treatment

1. Good option for small tumors, especially in older individuals; AN may not grow and may not require treatment.
2. Hearing may be preserved longer in cases where the tumor presents on the only hearing side.
3. All medical treatments, surgical or radiation, carry some risks. As ANs are benign and grow very slowly, many physicians will recommend having a second MRI at least 6 months after the first, to establish the growth rate. If the tumor is not growing, avoiding treatment altogether is a possibility.
4. In time, safer treatments for **acoustic** neuromas, other than surgery or radiation, may be found.

**When to Seek Microsurgical or Radiation Treatment**

- If there is tumor growth.
- If the tumor grows to 2 cm or more, treatment should be considered.
- An increase in symptoms may indicate that the tumor is growing. Symptoms include increased hearing loss, **tinnitus**, increased balance issues and numbness in the face.
Intracanalicular (0 mm)

10 mm

20 mm

30 mm
Translabyrinthine approach

Retrosigmoid approach

Middle Fossa Approach
The Effect of Age on Acoustic Neuroma Surgery Outcomes

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Objectives: To ascertain the effect of age on hearing preservation, facial nerve outcome, and complication rates after acoustic neuroma surgery.

Study Design: Retrospective chart review. Two study arms were used: a comparison of the authors’ oldest patients with their youngest patients (extremes of age arm) and an analysis of all middle fossa surgical procedures (middle fossa arm).

Setting: Tertiary referral center

Patients: Total of 329 patients. For the extremes of age arm, 205 patients were studied in two cohorts with 150 older patients (>60 years) compared with 55 younger patients (<40 years). The approaches included 21 middle fossa (MF), 38 retrosigmoid (RS), and 91 translabyrinthine (TL) procedures in the older group versus 25 MF, 17 RS, and 13 TL in the younger. For the middle fossa arm, there were 170 patients (age range 15–76 years) who underwent the MF approach for an attempt at hearing preservation.

Main Outcome Measures: Hearing preservation was defined as the maintenance of either class A or class B hearing (AAO-HNS class). Good facial nerve outcome was considered the maintenance of either grade 1 or 2 (House-Brackmann scale).

Cerebrospinal fluid leak rates and other postoperative complications were also tabulated.

Results: After adjustment for tumor size and surgical approach using multiple logistic regression analysis, the extremes of age study arm demonstrated that there is a lower chance of preserving good hearing in older patients ($p = 0.048$, odds ratio = 0.30). Age was not associated with a difference in the rate of good facial nerve outcome ($p = 0.2$). There was a trend toward slightly higher rates of cerebrospinal fluid leak in the older patient group ($p = 0.07$) but no difference in the rate of other complications ($p = 0.9$). The middle fossa study arm, after adjustment for tumor size and surgical approach, demonstrated that older patient age is associated with a lower rate of preservation of good hearing ($p = 0.01$, O.R. = 1.044). There was no association between age and good facial outcome ($p = 0.7$).

Conclusions: Older patient age lowers the chance of hearing preservation but does not affect facial outcomes. There is a trend toward a higher rate of cerebrospinal fluid leak in older patients, but no increased risk of other complications.


Acoustic neuromas (AN) in young and middle-aged patients are usually treated surgically. The rates of hearing preservation, facial nerve function, and complications after tumor resection in the general population have been well described by multiple retrospective reviews (1–5). However, because of perceived increases in surgical risk and shorter expected patient life span, the trend in managing these tumors in patients over 60 years old has been toward nonoperative strategies. Consequently, the literature on AN in the elderly tends to focus more on operative versus nonoperative management (6–11). Because the aging baby boomer cohort has improved health and a lengthened life expectancy in comparison with earlier generations (12–14), the role of age in the surgical management of AN needs to be evaluated carefully. Functional outcomes are particularly important in this active and vibrant patient population (15). It is possible, however, that older age may diminish the ability of the cochlear or the facial nerve to tolerate the surgical manipulation necessary to resect an AN. We sought to ascertain the effect of age on hearing preservation, facial nerve outcome, and complication rates after AN surgery.

MATERIALS AND METHODS

Study Design and Patient Population

Our retrospective study of 329 patients included two arms to evaluate for an effect of age on AN surgical outcomes. The first was a comparison of our oldest patients versus our youngest patients (extremes of age study arm). This was because we hypothesized that any major differences in surgical outcomes...
based on age would be most easily detectable using patients at the extremes of age. The second was an analysis of all middle fossa surgery outcomes (middle fossa arm). This study arm was used to evaluate for subtle effects of age on hearing and facial nerve outcomes, because the middle fossa route is our usual approach for hearing conservation surgery.

The extremes of age study arm was a retrospective study comparing older and younger patients (total n = 205). All patients over 60 years of age who underwent surgical excision of an AN were compared with those patients under than 40 years of age. The details of the data are given in Table 1. The extreme patient life span was determined from an actuarial table (16). Tumor size was measured as millimeters in the cerebellopontine angle (CPA). Tumors wholly confined to the internal auditory canal were categorized as intracanalicular (0 mm).

The average tumor size in the patients undergoing the middle fossa approach was much smaller than that in the patients undergoing the retrosigmoid approach. This reflects our philosophy of using the middle fossa approach as our primary strategy toward hearing preservation, while reserving the retrosigmoid approach only for hearing conservation attempts for tumors measuring 15 to 25 mm in the CPA (17). Older patients undergoing the translabyrinthine approach also tended to have larger tumors, because our usual policy for older patients with small tumors and poor hearing is to either monitor them with serial magnetic resonance imaging or treat them with stereotactic radiotherapy. The middle fossa study arm was a retrospective review of all patients who underwent the middle fossa approach for resection of an AN, regardless of age. This included patients at the age extremes as well as those 40 to 60 years old (total n = 170, Table 1). This larger patient population permitted us to study the effect of patient age on hearing preservation with greater power than did the extremes of age study arm. The average patient age was 45 ± 10 years (mean ± SD), and the average tumor size was 5 ± 6 mm (mean ± SD) in the CPA.

Main Outcome Measures

Good hearing preservation was defined as postoperative AAO-HNS class A or B hearing (18). We did not include patients in this analysis who had class C or D hearing preoperatively. We measured postoperative hearing at least 3 months after surgery. Good postoperative facial function was considered House-Brackmann grade 1 or 2 (19). We did not include patients in this analysis who had grade 3 or worse facial function preoperatively. Postoperative facial weakness was not tabulated unless it was present 1 year after surgery.

Postoperative complications were also tabulated. Cerebrospinal fluid (CSF) leaks were identified separately from other complications. This included all postoperative leaks identified, whether they required lumbar subarachnoid drain and/or reoperation. Fewer than 5% of patients with leaks required operative intervention (20). Statistical Analysis

SPSS (version 10.0; SPSS, Inc., Chicago) was used for statistical analysis. All averages are reported as mean ± standard deviation. We used the two-tailed t test to compare continuous variables (patient age and tumor size). Multiple logistic regression analysis was performed to account for confounding variables in the comparison of discrete variables (hearing preservation, good facial function, CSF leak, other complications). This technique was also used for the continuous variables to verify the t test results. A stepwise entry methodology was used. For all analyses, statistical significance was determined if p ≥ 0.05.

RESULTS

Extremes of Age Study Arm

This first arm was designed to compare patients at the extremes of age for each of the three surgical approaches to identify major differences that might be associated with patient age. The main outcome measures are presented in Table 2. The rate of hearing preservation was lower in the older patient group than in the younger patient group for both the middle fossa (29% vs. 60%) and the retrosigmoid (8% vs. 15%) approaches. Multiple logistic regression analysis was performed to identify an effect of age on hearing preservation, while accounting for surgical approach and tumor size. This demonstrated that patients older than 60 years were less likely to have

<table>
<thead>
<tr>
<th>Surgical approach</th>
<th>Group</th>
<th>Age (yr)</th>
<th>Expected lifespan (yr)</th>
<th>Tumor sizea (mm in CPA)</th>
<th>Study arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle fossa</td>
<td>&lt;40 yr</td>
<td>25 32 ± 7</td>
<td>46 ± 6</td>
<td>5 ± 6</td>
<td>Extremes of age, middle fossa</td>
</tr>
<tr>
<td></td>
<td>40–60 yr</td>
<td>124 51 ± 5</td>
<td>[41–59] 30 ± 2</td>
<td>5 ± 6</td>
<td>Middle fossa</td>
</tr>
<tr>
<td></td>
<td>&gt;60 yr</td>
<td>21 66 ± 4</td>
<td>[60–76] 17 ± 3</td>
<td>7 ± 5</td>
<td>Extremes of age, middle fossa</td>
</tr>
<tr>
<td>Retrosigmoid</td>
<td>&lt;40 yr</td>
<td>17 32 ± 6</td>
<td>46 ± 6</td>
<td>21 ± 3</td>
<td>Extremes of age</td>
</tr>
<tr>
<td></td>
<td>&gt;60 yr</td>
<td>31 68 ± 6</td>
<td>[60–89] 16 ± 4</td>
<td>21 ± 11</td>
<td>Extremes of age</td>
</tr>
<tr>
<td>Translabyrinthine</td>
<td>&lt;40 yr</td>
<td>16 33 ± 6</td>
<td>45 ± 5</td>
<td>22 ± 15</td>
<td>Extremes of age</td>
</tr>
<tr>
<td></td>
<td>&gt;60 yr</td>
<td>68 68 ± 6</td>
<td>[60–86] 16 ± 4</td>
<td>20 ± 12</td>
<td>Extremes of age</td>
</tr>
</tbody>
</table>

All values are mean ± standard deviation. The range is in brackets. Expected lifespan was calculated from actuarial data (25).

*Intracanalicular tumors recorded as 0 mm in the cerebellopontine angle.
preserved good hearing than those younger than 40 years ($p = 0.048$, odds ratio = 0.30).

The rate of good postoperative facial function did not seem to be dramatically different between the older and the younger age groups for any of the surgical approaches (87–100%). Multiple logistic regression analysis accounting for surgical approach and tumor size demonstrated that there was no effect of age on facial outcomes ($p = 0.2$). There was a trend toward slightly higher rates of CSF leak (0–15%) in the older patient group ($p = 0.07$), but there was no statistically significant difference in the rate of other complications (0–7%, $p = 0.8$) between the age extremes.

**Middle Fossa Study Arm**

This second arm was a review of all patients who underwent the middle fossa approach. It was designed to identify subtle associations of age with hearing and facial nerve outcomes in our primary hearing preservation approach. First, we compared the average patient age and tumor size for patients in whom we were and were not able to preserve hearing and maintain good facial nerve function (Fig. 1.). Patients in whom hearing was preserved were younger than those in whom hearing was not preserved (A, preserved: 48 ± 11 years, $n = 75$ vs. not preserved: 52 ± 9 years, $n = 88$, $p = 0.01$). Additionally, there was a trend toward patients with a smaller tumor size having an improved rate of hearing preservation (B, preserved: 4 ± 5 mm, $n = 74$ vs. not preserved: 6 ± 6 mm, $n = 88$, $p = 0.08$). Neither younger patient age (C, good facial function: 50 ± 10 years, $n = 155$ vs. poor facial function: 51 ± 7 years, $n = 10$, $p = 0.8$) nor tumor size (D, good facial function: 5 ± 6 mm, $n = 154$ vs. poor facial function: 6 ± 5 mm, $n = 10$, $p = 0.7$) were correlated with good facial function.

Because larger tumor size can be associated with lower hearing preservation rates and worse facial nerve outcomes, it is important to distinguish between the effects of patient age and the effects of tumor size. Multiple logistic regression analysis was then performed to account for tumor size as a confounding variable. This revealed that older age was associated with poorer rates of hearing preservation ($p = 0.01$; odds ratio = 1.044). This means that the odds of hearing preservation decreases by 4.4% per year. However, older age was not an independent predictor of poor facial function ($p = 0.7$).

**DISCUSSION**

Both arms of the study demonstrate that older patients have a decreased rate of hearing preservation when tumor size was controlled for. Additionally, there was also a trend toward higher CSF leak rates in older patients, but there was no statistically significant effect of age on other complications or facial nerve function. However, our facial function results may be biased toward better preservation rates in older patients because we typically are less aggressive in trying to achieve total tumor removal in this population. We may leave a small bit of tumor on the facial nerve to reduce trauma and subsequent morbidity. A near-total resection means leaving a larger piece. It is likely that without our altered surgical technique for older patients, there would have been a significantly reduced rate of good postoperative facial

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**TABLE 2. Outcome measures stratified by surgical approach and age group**

<table>
<thead>
<tr>
<th>Surgical approach</th>
<th>Group</th>
<th>Good hearing (%)</th>
<th>Good facial function (%)</th>
<th>CSF leak (%)</th>
<th>Rate of other complications (%)</th>
<th>Other complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle fossa</td>
<td>&lt;40 yr</td>
<td>15/25 (60)</td>
<td>24/25 (96)</td>
<td>4/25 (16)</td>
<td>0/25 (0)</td>
<td>Deep venous thrombosis, treated with inferior vena cava filter (1)</td>
</tr>
<tr>
<td></td>
<td>40–60 yr</td>
<td>55/121 (46)</td>
<td>115/124 (93)</td>
<td>12/124 (10)</td>
<td>1/124 (0)</td>
<td></td>
</tr>
<tr>
<td>Retrosigmoid</td>
<td>&gt;60 yr</td>
<td>5/17 (29)</td>
<td>16/16 (100)</td>
<td>5/21 (24)</td>
<td>0/21 (0)</td>
<td>Postoperative communicating hydrocephalus that resolved spontaneously (1)</td>
</tr>
<tr>
<td></td>
<td>&lt;40 yr</td>
<td>2/13 (15)</td>
<td>16/16 (100)</td>
<td>1/16 (6)</td>
<td>0/16 (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;60 yr</td>
<td>1/12 (8)</td>
<td>25/28 (89)</td>
<td>6/38 (16)</td>
<td>1/38 (3)</td>
<td></td>
</tr>
<tr>
<td>Translabyrinthine</td>
<td>&lt;40 yr</td>
<td>n/a</td>
<td>12/13 (92)</td>
<td>0/13 (0)</td>
<td>0/16 (0)</td>
<td>Wound infections that resolved with local wound care and antibiotics (3), non-communicating hydrocephalus secondary to intraventricular hemorrhage that required ventriculoperitoneal shunt (1), diplopia (1), postoperative myocardial infarction with good recovery (1)</td>
</tr>
<tr>
<td></td>
<td>&gt;60 yr</td>
<td>n/a</td>
<td>64/74 (87)</td>
<td>14/91 (15)</td>
<td>6/91 (7)</td>
<td></td>
</tr>
</tbody>
</table>

The number of patients in each category may be less than the total number of patients studied. Only patients with preoperative AAO-HNS class A or B hearing or preoperative House-Brackmann grade 1 or 2 facial function were included in the analysis.

This middle age group of patients was not used for the extremes of age study arm, but was included in the middle fossa study arm.

CSF, cerebrospinal fluid; n/a, not applicable.
function (as there was with the rate of hearing preservation). We did not have enough patients to perform a quantitative analysis of the effect of the completeness of surgical resection on hearing and facial nerve function.

Our hearing and facial nerve preservation findings concur with and expand on those of other investigators. Brackmann et al. (3) found that the average age of patients who lost hearing postoperatively with the middle fossa approach was slightly higher than in patients who did not, although the difference was not significant. Ramsay and Luxford (6) found similar postoperative facial nerve function in patients older than 70 years and younger than 70 years of age, all of whom were treated with the translabyrinthine approach.

Certainly, there is a generalized increased risk of surgical complications in older patients in all types of surgery. This is predominantly due to the steady decline in organ system functioning during aging (21). One might reasonably suspect that complications during AN surgery should occur more frequently in older patients. However, older patient age has not been shown to be associated with increased complications in AN surgery (22,23). Our data support these studies, in that we saw no effect of older age on complication rates. The middle fossa approach is thought to be more technically challenging in older patients because of thinning and adhesions of the dura. Indeed, patient age greater than 60 years has been suggested as a relative contraindication to the middle fossa approach (24,25). Our philosophy has been to base our surgical approach on tumor size, location, and residual hearing, and we do not believe that older patient age is a contraindication to the middle fossa approach. Meticulous surgical technique in raising the craniectomy bone flap, suture repair of any dural tears, and careful bipolar cautery of any bleeding vessels is critical to the successful prevention of technical complications. Also larger tumor size is probably not associated with an increased rate of CSF leak (20).

The dilemma in treating older patients is whether to remove a small AN to preserve potential hearing loss in the years to come. Our philosophy on the management of AN in patients older than 60 years is to treat with either surgery or stereotactic radiation only if the patient has a large tumor with substantial brainstem compression, has progressive worsening of symptoms (particularly failing balance), or demonstrates tumor growth at a rate that will eventually lead to serious brainstem compression within the patient’s predicted life span. By far the majority of older patients with tumors smaller than 2 cm in the CPA undergo a period of observation with serial magnetic resonance imaging to determine tumor growth rate, before intervention strategies are decided on. The risk of tumor progression and hearing loss (with either no treatment or stereotactic radiation) and the risk of the development of a radiation-induced malignancy (with stereotactic radiation) during an expected life span of 15 to 20 years should be weighed against the risks and benefits of tumor removal in consultation with the patient.

**FIG. 1.** The effect of patient age and tumor size on surgical outcomes with the middle fossa approach. Patients in whom hearing (A, B) or good facial nerve function (C, D) were able to be preserved were compared with those in whom they could not be preserved. The box and whisker plots demonstrate the 25th and 75th percentiles of the samples (bottom and top of the boxes), the medians (line in the middle of the boxes), and the extent of the sample (whiskers above and below the boxes). Outliers more than 1.5 times the interquartile range away from the top or bottom of the box are identified (o). Younger patient age (A, 48 ± 11 years, n = 75, vs. 52 ± 9 years, n = 88, p = 0.01) was correlated with hearing preservation. There was a trend toward hearing preservation in patients with smaller tumors (B, 4 ± 5 mm, n = 74, vs. 6 ± 6 mm, n = 88, p = 0.08). The number of patients is less than the total number of patients studied because only patients with preoperative AAO-HNS class A or B hearing were analyzed. Neither younger patient age (C, 50 ± 10 years, n = 155, vs. 51 ± 7 years, n = 10, p = 0.8) nor tumor size (D, 5 ± 6 mm, n = 154, vs. 6 ± 5 mm, n = 10, p = 0.7) was correlated with good facial function.

(C, 50 ± 10 years, n = 155, vs. 51 ± 7 years, n = 10, p = 0.8) nor tumor size (D, 5 ± 6 mm, n = 154, vs. 6 ± 5 mm, n = 10, p = 0.7) was correlated with good facial function.
REFERENCES


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The fate of the tumor remnant after less-than-complete acoustic neuroma resection

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San Francisco, California

OBJECTIVES: We sought to determine the recurrence rate after near-total and subtotal resection of acoustic neuroma.

STUDY DESIGN, SETTING, AND PATIENTS: We conducted a retrospective chart review of a total of 79 patients: 50 with near-total resections (remnant \(< 25 \text{ mm}^2\) and \(< 2 \text{ mm thick})\) and 29 with subtotal resections (any larger remnant). Surgical approach included 5 middle fossa, 17 retrosigmoid, and 57 translabyrinthine.

MAIN OUTCOME MEASURES: Recurrence was defined as documented tumor growth by serial imaging or the recommendation for further treatment after a single scan. No recurrence was defined as no visible tumor on imaging for a minimum follow-up time of 3 years or tumor remnants that remained unchanged on serial scans (mean, 5-year follow-up).

RESULTS: Fifty-two patients were included in the study group. Recurrences were seen in 1 (3%) of 33 patients who had a near-total resection compared with 6 (32%) of 19 patients who had a subtotal resection. After adjustment for follow-up time and large tumor size, the odds ratio for recurrence was 12 times larger for subtotal than for near-total resections (P = 0.033). All recurrences were seen following the translabyrinthine approach in the midcerebellopontine angle. None were encountered in the internal auditory canal. The mean time interval from surgery to the detection of a recurrence was 3 years (range, 1 to 5 years).

CONCLUSIONS: The recurrence rate when performing a near-total resection is low but is substantially higher with a subtotal resection. Recurrences can be detected within the first 5 postoperative years. We recommend near-total resection in any patient if needed to preserve neural integrity. Subtotal resection is best avoided whenever possible; however, adjunctive treatment with stereotactic radiotherapy may be considered. (Otolaryngol Head Neck Surg 2004;130:104-12.)

The goals of acoustic neuroma (AN) surgery are tumor control and preservation of cranial nerves, including the facial nerve and at times the auditory nerve. Balancing the priority of these goals is influenced by other considerations such as patient age and life expectancy, overall health and comorbidities, and tumor adherence and size. Microsurgical gross total tumor removal is by far the most common result of AN surgery. Less-than-complete resection most commonly involves an intraoperative decision to leave tumor remnants behind as a concession to neural integrity. Elderly or debilitated patients may have a subtotal removal planned preoperatively to minimize the morbidity and mortality associated with a more extensive and lengthy procedure. The aim of the present study was to determine the risk of tumor recurrence with incomplete AN resection.

METHODS

Seventy-nine patients with incomplete AN resections from 1978 to 1999 were identified, accounting for less than 10% of the patients who underwent AN surgery at our institution. At the University of California–San Francisco (UCSF), a team composed of a neurotologist and a neurosurgeon perform the procedure. A retrospective chart review was performed from records kept by both departments and entered into a computerized database. The study protocol was approved by the UCSF Committee on Human Research.

Clinical parameters, including patient age, gender, symptoms, surgical approach, and postopera-
tive complications, were recorded. Tumor size, based on the greatest dimension within the cerebellopontine angle (CPA), was obtained from preoperative imaging data. The surgeons’ notes were examined to ascertain the indication for performing an incomplete resection whenever possible. As opposed to defining residual tumor as a percentage of the original tumor, near-total resections were defined by tumor remnants no greater than 25 mm² and 2 mm thick; subtotal resections included anything larger (Fig 1). Facial nerve outcomes with a minimum of 1-year follow-up were recorded, based on the House-Brackmann (HB) grading system.

Our routine protocol for postoperative tumor surveillance consists of imaging at 1 and 3 years for tumors that have been totally removed. Incompletely resected tumors are followed annually with a gradual lengthening of the time between scans when there is no evidence of recurrence. Because UCSF is a tertiary referral center, some patients receiving longitudinal follow-up care at other institutions had different imaging regimens. The modality most com-
commonly used was magnetic resonance imaging (MRI), although a few patients early in the study period had computed tomography (CT). All patients, except for 1, had an MRI study at some point in their follow-up.

The results of all postoperative follow-up imaging were recorded to identify residual and/or recurrent tumor. No tumor recurrence was defined by the absence of visible tumor on imaging after a minimum follow-up of 3 years or if stable residual tumor was present. Stable residual tumor was defined as a tumor remnant that remained unchanged on serial imaging. Recurrent tumor was defined as tumor growth on serial imaging. Additionally, tumor recurrence was defined as when the patient underwent additional treatment (either stereotactic radiation or repeat surgery) after only a single scan because of the large tumor size.

### Statistical Analysis

Stata (version 7.0; Stata Corp, College Station, TX), SPSS (version 10.0; SPSS, Inc, Chicago, IL), and StatXact (version 3.0; Cytel Software, Cambridge, MA) were used for statistical analysis. Fisher exact test and 2-sided t test were used to evaluate bivariate relationships. Logistic regression was performed on recurrence and good facial nerve function (HB I or II) to assess the influence of subtotal versus near-total resection, age, large tumor size (≥25 mm), and other predictors. Odds ratios were calculated and statistical significance was determined if $P < 0.05$. Logistic regression was followed by statistical analyses using exact stratified contingency table analysis to check the stability of the logistic regression results.

### RESULTS

#### Patient Population

There were 50 patients (63%) with near-total resections and 29 patients (37%) with subtotal resections (Table 1). The mean age was 59 years (range, 21 to 81 years). Patients who underwent subtotal resections tended to be older than the near-total group (mean, 62 versus 57 years; $P < 0.05$). The mean tumor size was significantly greater in the subtotal resection group than in the near-total resection group (31 mm versus 24 mm, $P = 0.005$). The predominant approach used in this group of patients was the translabyrinthine (TL), accounting for 72% of the operations. The average tumor size was greatest for the TL approach (26 mm) followed by the retrolabyrinthine (RS) (22 mm) and the middle fossa (MF) (7 mm) approaches. A comparison between the near-total and subtotal groups showed no significant difference in terms of gender, approach, and follow-up period.

Postoperative complications are presented in Table 2. The cerebellar peduncular infarcts

### Table 1. Patient populations

<table>
<thead>
<tr>
<th></th>
<th>Near-total (n = 50; 63%)</th>
<th>Subtotal (n = 29; 37%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>Female</td>
<td>27</td>
<td>14</td>
</tr>
<tr>
<td>Tumor size in CPA, $^*$</td>
<td>24 ± 10 (range, 0 to 45)</td>
<td>31 ± 12 (range, 7 to 65)</td>
</tr>
<tr>
<td>Surgical approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Translabyrinthine</td>
<td>34 (68%)</td>
<td>23 (79%)</td>
</tr>
<tr>
<td>Mean (mm)</td>
<td>26 (range, 12 to 45)</td>
<td>31 (range, 7 to 65)</td>
</tr>
<tr>
<td>Retrolabyrinthine</td>
<td>12 (24%)</td>
<td>5 (17%)</td>
</tr>
<tr>
<td>Mean (mm)</td>
<td>22 (range, 0 to 37)</td>
<td>33 (range, 18 to 45)</td>
</tr>
<tr>
<td>Middle fossa</td>
<td>4 (8%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Mean (mm)</td>
<td>7 (range, 0 to 12)</td>
<td>15</td>
</tr>
<tr>
<td>Age</td>
<td>57 ± 13 (range, 21 to 78)</td>
<td>62 ± 13 (range, 34 to 81)</td>
</tr>
</tbody>
</table>

$^*$Largest diameter dimension in the CPA. Intracanalicular tumors recorded as 0 mm.

CPA, Cerebellopontine angle.
were areas of distal anterior inferior cerebellar artery ischemia (with minimal symptomatology), not major strokes.2 There were no known tumor-related deaths, but there were 4 unrelated deaths seen on long-term follow-up.

**Indications for Incomplete Resection**

Although all patients had an incomplete resection to preserve facial nerve integrity, there were additional indications for this technique in a few patients. One patient had a near-total resection after experiencing bradyarrhythmias during dissection of the tumor from the brain stem. Four patients had planned incomplete resections for other reasons, including advanced age and medical comorbidities. Finally, 4 patients had subtotal sections after initial treatment with stereotactic radiotherapy failed. Of these, 3 patients had a ventriculoperitoneal shunt placed preoperatively to treat hydrocephalus and subsequently underwent a planned subtotal resection for brain stem decompression. The time interval between failed radiotherapy and operative intervention was from 3 to 17 months. Three of 4 of these patients had no evidence of recurrence at 3 years (the fourth patient was lost to follow-up).

**Facial Nerve Outcomes**

Good facial nerve function at 1 year postoperatively, defined as HB grade I or II, was seen in 57 (81%) of the 65 patients (Table 3). There were no detectable associations between good facial nerve function and tumor size \( (P = 0.98) \), age \( (P = 0.41) \), or approach \( (P = 0.66) \). Logistic regression analysis demonstrated no statistically significant difference in good facial nerve function between the near-total and subtotal groups when controlling for age, tumor size, and operative approach \( (P > 0.1) \).

**Radiographic Imaging**

Sixty-four patients had imaging available for at least 1 year postoperatively, with a mean radiographic follow-up period of 4.3 years (range, 1 to 13 years). Imaging revealed the residual tumor in approximately 20% of patients in the near-total group and 80% of patients in the subtotal group (Figs 2 and 3). The proportion of scans at each year that revealed tumor remained relatively stable over the study period.

**Recurrence Risk**

The risk of developing a tumor recurrence was determined in a subgroup of 52 patients who met the criteria for adequate follow-up, as described in Methods. The mean follow-up time for these patients was 5 years (maximum, 13 years). Recurrences were seen in 1 (3%) of 33 patients who had a near-total resection compared with 6 (32%) of 19 patients who had a subtotal resection. Multiple logistic regression analysis was then performed to adjust for differences in follow-up time and large tumor size (≥25 mm). From this analysis, the odds ratio for recurrence was found to be 12 times larger for subtotal than for near-total resections \( (P = 0.033) \) (Fig 4).

Seven patients had recurrent tumors (Table 4). All recurrences were seen following the TL approach (Fig 5). The locations of the recurrences were in the mid-CPA, and none were encountered in the internal auditory canal. The recurrent tumors were all large at the initial operation (mean, 37 mm; \( P = 0.001 \)); however, large size as a risk factor for recurrence was not significant when controlling for subtotal resections \( (P = 0.32) \). There was no association between patient age and recurrence risk \( (P = 0.19) \). The mean time interval from surgery to the detection of a recurrence was 3 years (range, 1 to 5 years). Stereotactic radiation treatment was recommended in 5 patients. The remaining 2 patients underwent a repeat incomplete resection with the RS approach (1 NT and 1 ST).

**DISCUSSION**

The rationale for using an incomplete tumor dissection technique is dictated by the risk/benefit ratio for the patient. Our data suggest that the risk of tumor recurrence after a near-total resection is
quite low. Although we did not perform a randomized controlled trial to determine the degree of improvement in facial nerve outcomes, it seems logical to conclude that any further tumor removal would have compromised facial nerve function. Every patient in our study was selected because of a particularly high level of tumor adherence. Comparisons with stratified control patients who underwent a complete tumor resection would be inherently flawed, because these patients did not have tumors that were as difficult to dissect.

In our experience, substantial adherence of the tumor to the facial nerve has a high risk of a poor facial nerve outcome. Near-total resection involves leaving a small rind of tumor to better preserve the facial nerve. Incomplete resection is helpful in preserving facial nerve integrity because as the tumor enlarges, it compresses the facial nerve and the tumor–arachnoid mater plane is lost. Difficulty in identifying a plane between the tumor and the facial nerve most commonly occurred just medial to the porus acusticus (Fig 1). The facial nerve, which follows the shape of the tumor, often becomes splayed and thinned in this region, possibly accounting for the adherence.

Subtotal resection, in contrast, leads to a 12-time higher risk of recurrence. This may be explained merely by the larger initial tumor size in the subtotal group compared with the near-total group \((P = 0.005)\), resulting in a more tenuous and adherent facial nerve. However, another explanation may be distinct variations in AN biological behavior. Although most tumors are slow growing (approximately 2 mm per year), a small subset demonstrate rapid growth. One patient illustrating an aggressive variant had a subtotal resection for a 25-mm tumor. She subsequently had 2 large symptomatic cystic recurrences after a 2- to 3-year interval. We use the subtotal resection technique with large tumors that have a large area of tumor stuck to the facial nerve and/or brain stem or to minimize other complications, particularly in elderly or debilitated patients. Rarely, an intraoperative event is the indication for a subtotal resection. We favor a conservative approach

<table>
<thead>
<tr>
<th>House-Brackmann grade</th>
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<tbody>
<tr>
<td>I</td>
</tr>
<tr>
<td>Near-total (n = 44)</td>
</tr>
<tr>
<td>Subtotal (n = 21)</td>
</tr>
</tbody>
</table>

Fig 2. (A) Near-total residual (arrow) seen in mid-CPA on MRI 1 year after an RS resection. The patient had been previously treated at another institution with an RS resection and presented with brain stem compression and a recurrence involving the internal auditory canal. (B) Subtotal residual seen on MRI following a TL resection. A thin rind (arrow) is seen along the brain stem extending to the porus acusticus.
and often use the subtotal technique to treat patients for whom stereotactic radiation has failed. This is done to minimize the attendant risks engendered from radiation-induced changes. Microsurgery is often difficult due to inflammation and fibrosis that interfere with the identification of normal dissection planes, leading to poorer facial nerve outcomes.6

Fig 3. Frequency of visible tumor remnants on postoperative enhanced MRI. A cross-sectional plot of patients at 1-, 3-, and >3-year MRI. Roughly 20% of the patients with near-total tumor resections had visible tumor on follow-up MRI, as opposed to the 80% of patients with subtotal resections. Because not all patients followed the recommended protocol of an annual scan, the number of patients at each time frame varies. Most studies were MRI (1 year: 53 MRI, 2 CT; 3 years: 26 MRI, 2 CT; >3 years: 32 MRI, 1 CT). The average follow-up time for the patients in the >3-year category was 6.3 years.

Fig 4. Recurrence rates of near-total versus subtotal residuals (n = 52). Recurrence was determined by documented growth or recommended treatment. No recurrence was defined by tumor that was stable on serial scans or not visible for a minimum of 3 years. The mean follow-up time was 5 years. There was a substantially higher risk of developing a recurrence if a subtotal resection (32%) was performed compared with a near-total resection (3%) (odds ratio, 12; P = 0.033; details of multiple logistic regression analysis given in text).
However, we have a particular concern about performing a subtotal resection in tumors with large cystic components. The cyst should not simply be marsupialized; the wall needs to be carefully microdissected from the surrounding normal structures and removed. A tendency exists for the residual cyst wall to reseal. Brain stem compression may result from the cyst recurrence even though the solid (neoplastic) residual has not grown. Stereotactic radiosurgery is not very effective in such cystic recurrences because it is not caused by rapid cell division. It is possible that radiosurgery may even stimulate further cyst expansion in such patients. Thus, a cystic recurrence likely necessitates reoperation.

ANs do not have true capsules. The histopathology includes compressed neoplastic cells at the margin of the tumor surrounded by connective tissue only a few micrometers in thickness. The entire mass contains viable tumor cells that carry the potential for recurrence. Thus, “complete resection leaving only a small amount of capsule” is

Table 4. Characteristics of patients with recurrent tumors

<table>
<thead>
<tr>
<th>Age* (yr)</th>
<th>Initial tumor size† (mm)</th>
<th>Resection Approach</th>
<th>Year recurred/treated</th>
<th>Treatment</th>
<th>Reason for retreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td>NT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>25</td>
<td>X</td>
<td>TL</td>
<td>3/8</td>
<td>SR</td>
</tr>
<tr>
<td>54</td>
<td>40</td>
<td>X</td>
<td>TL</td>
<td>5/5</td>
<td>SR</td>
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<tr>
<td>66</td>
<td>32</td>
<td>X</td>
<td>TL</td>
<td>5/5</td>
<td>MS</td>
</tr>
<tr>
<td>51</td>
<td>65</td>
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<td>TL</td>
<td>3/5</td>
<td>SR</td>
</tr>
<tr>
<td>70</td>
<td>35</td>
<td>X</td>
<td>TL</td>
<td>1/1</td>
<td>Proton therapy</td>
</tr>
<tr>
<td>67</td>
<td>35</td>
<td>X</td>
<td>TL</td>
<td>3/3</td>
<td>SR</td>
</tr>
<tr>
<td>78</td>
<td>25</td>
<td>X</td>
<td>TL</td>
<td>2/2</td>
<td>MS</td>
</tr>
</tbody>
</table>

*P = 0.19; †P = 0.001; ST, Subtotal; NT, near-total; TL, translabyrinthine; SR, stereotactic radiation; MS, microsurgical (retrosigmoid approach used in both cases).

Fig 5. (A) Near-total recurrence (arrow) seen on MRI 8 years after a TL resection. The tumor recurrence was detected on a 3-year scan and has continued to grow asymptptomatically from 3 mm to 18 mm at 8 years after surgery (first patient, Table 4). (B) Subtotal recurrence (arrow) in the mid-CPA seen on MRI 3 years after a TL resection (sixth patient, Table 4).
really incomplete tumor removal. Based on the volume of tumor and “capsule” remaining, it is best defined as a near-total or subtotal removal. Every effort should be made to remove as much of the tumor as possible while only leaving a small rind at areas with difficult planes of dissection. Limiting the gross volume of residual tumor has been shown to improve outcome.\(^8\) One of the pitfalls in performing an incomplete resection occurs with the RS approach when tumors are truncated at the internal auditory canal without drilling out the intracanalicular component. We do not recommend this technique because these extensive residuals carry a high risk of recurrence. Indeed, even the need to perform a “blind sweep” of the fundus after a proper internal auditory canal drill-out with the RS approach carries a higher incidence of tumor recurrence.\(^9\)

In contrast, all of the recurrences in our study were centered in the CPA and followed a TL resection. Because the majority of the near-total remnants and some of the subtotal remnants remained undetectable on serial follow-up imaging, we suspect that there was postoperative tumor regression. Other plausible explanations include tumor necrosis, detection limitations of the MRI, or an interruption of the blood supply preventing contrast enhancement. Residual remnants have been shown to be relatively avascular in a study looking at tumors managed with staged procedures.\(^3\) Nonetheless, the bipolar electrocautery should be used to coagulate the remnant to cause further devascularization. The location of remnant appears to influence the recurrence risk. The blood supply of the internal auditory canal and brain stem may lead to an increased propensity for recurrence in these locations compared with remnants along the facial nerve in the mid-CPA that have a poor vascular supply.

The mean time interval between surgery and tumor recurrence was 3 years (range, 1 to 5 years). All recurrences were seen on either the initial postoperative scan or serial scans that demonstrated growth. No patients had a clinical recurrence after an established quiescent period. This is contrasted by a study that revealed tumor growth in 17 patients after a median of 3.6 years with no evidence of tumor growth.\(^8\) These conflicting observations may be explained by the use of lower-sensitivity CT scanning for follow-up in the other study. Consistent with our findings was that once growth was identified, it continued unabated until institution of treatment.\(^8\)

AN recurrences are often asymptomatic due to the typical postoperative sequelae of hearing loss and vestibular ablation. It is imperative to follow these patients diligently with other diagnostic modalities that permit early detection and intervention before the need for urgent decompression surgery. The pre- and post–gadolinium enhanced T1-weighted MRI with fat saturation is the imaging of choice due to signal characteristics that allow the differentiation of postoperative scarring, blood, and fat graft from tumor.\(^10\)

Treatment options for a recurrent tumor include stereotactic radiosurgery or reoperation typically done via a different approach. In this series, all recurrences followed TL removals, presumably because this is the method typically used for tumors in the size range where less-than-complete removal is most likely to be chosen. When a reoperation is needed following the TL approach, we choose the RS method to avoid having to dissect the fat graft off of the facial nerve. Similarly, we use the TL approach to manage recurrences after other surgeons have left tumor (particularly in the internal auditory canal) during an RS approach to avoid the region of surgical scarring.

**CONCLUSION**

There has been an evolution in the management of ANs reflecting advances made in medical technology and an improved understanding of the natural progression of the disease. Historically, the goal of complete tumor removal took precedence over other considerations. Patients often presented with advanced disease, leading to unacceptable death rates. Today, high-quality imaging often leads to the diagnosis in patients with less severe symptoms and smaller tumors. A therapeutic dilemma arises when balancing the risk and benefits of a complete versus a less-than-complete resection of a benign tumor. Near-total resection has a low risk of recurrence and may be used in any patient as a concession to neural integrity. There is a substantially higher risk of recurrence with subtotal resections. Meticulous attention is needed to thin the tumor remnant as much as possible, limit
it to the CPA, and coagulate it with the electrocautery. The postoperative management should include vigilant surveillance with serial MRI to detect early recurrence. Detection of recurrent tumors was evident relatively early within the first 5 years after surgery.

The authors extend their appreciation to Charles McCulloch, PhD, for statistical analysis.

REFERENCES
Is It Worthwhile to Attempt Hearing Preservation in Larger Acoustic Neuromas?

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Departments of *Otolaryngology-Head and Neck Surgery and †Neurologic Surgery, University of California, San Francisco, California, U.S.A.

Objective: To determine the hearing outcome in patients undergoing surgery via the retrosigmoid approach for acoustic neuromas with a substantial component in the cerebellopontine angle.

Study Design: Retrospective case review.

Setting: Tertiary referral center.

Patients: The medical records of all patients undergoing acoustic neuroma removal via the retrosigmoid approach at a tertiary referral center were retrospectively reviewed. Sixty-four patients with both cerebellopontine angle component ≥15 mm and preoperative audiometry of class A or B (American Academy of Otolaryngology–Head and Neck Surgery) were identified.

Main Outcome Measures: Postoperative average pure tone threshold and word recognition scores, categorized according to the classification of the American Academy of Otolaryngology–Head and Neck Surgery, were used to assess hearing outcome.

Results: Overall, only 6.3% (4 of 63) retained good hearing (class A or B) postoperatively. Hearing preservation rate in the smallest (15- to 19-mm) group was 17.6% (3 of 17), which was better than that for the larger groups. No successful hearing preservation was achieved in tumors with ≥25 mm cerebellopontine angle component (0 of 23).

Conclusions: Surgeon and patient alike would always choose a hearing preservation technique if there was no potential for increased morbidity in making the attempt. When compared with the non–hearing preservation translabyrinthine approach, the retrosigmoid approach had a higher incidence of persistent headache. In addition, efforts to conserve the auditory nerve prolong operating time, increase the incidence of postoperative vestibular dysfunction, and carry a slightly higher risk of tumor recurrence. Nevertheless, even though the probability of success is disappointingly small, when excellent hearing is present we favor offering the option of a hearing conservation attempt when the patient has been well informed of the pros and cons of the endeavor. Factors weighing against undertaking this effort include larger cerebellopontine angle component (≥25 mm), deep involvement of the fundus, wide erosion of the porus, and marginal residual hearing.

Key Words: Acoustic neuroma (vestibular schwannoma)—Hearing preservation—Retrosigmoid approach.


The three principal surgical approaches for acoustic neuroma (AN) removal are the translabyrinthine (TL), retrosigmoid (RS), and middle fossa (MF) approach. Only the latter two approaches provide the possibility of hearing preservation. The results of hearing preservation surgery have been shown to be superior for small tumors when the MF approach is used (1). However, the MF approach is only practicable in tumors with a limited cerebellopontine angle (CPA) extension. This leaves the RS approach as the only alternative when attempting to preserve hearing in larger ANs. Because tumor size is the most important variable influencing hearing outcome, the question arises as to whether hearing preservation surgery should still be attempted via the RS approach in patients with large tumors but serviceable hearing (2–5).

Tumor size itself should not be a criterion in choosing between the RS and TL approach, because both approaches provide adequate exposure, but the potential higher morbidity associated with the RS approach does need to be taken into account. This study was undertaken to determine the rate of hearing preservation in patients with ANs that have a substantial CPA component (≥15 mm) so that patients can be appropriately counseled before choosing between a RS and TL approach.

PATIENT POPULATION

This study is a retrospective review of the medical records of patients who have had surgical removal of a histologically confirmed AN in a single tertiary referral center between the years 1984 and 2001. Selection criteria for inclusion in the study were tumor removal via the RS approach, ≥15 mm CPA component, and preoperative hearing of class A or B. Because not every patient with a ≥15 mm AN and preoperative hearing...
of class A or B was operated on via the RS approach in the institutional series, some selection bias may be present. Several otherwise qualified patients underwent TL removal, especially when adverse predictors, such as deep penetration of the fundus of the internal acoustic canal (IAC) or wide erosion of the porous acusticus, were present. These criteria would have been analyzed in the present study were the data available in our medical records more complete. Arbitrary patient preference was also sometimes a factor in the choice of operative approach.

Hearing class was documented as recommended by the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) (6). Tumor size was defined as the largest diameter of the CPA portion of the tumor measured from axial magnetic resonance imaging (MRI) scan or axial computerized tomography (CT) scan if MRI was not available. The patients were divided into the following four groups according to tumor size: 15 to 19 mm, 20 to 24 mm, 25 to 29 mm, and ≥30 mm. The pure tone thresholds at 0.5, 1, 2, and 3 kHz (4 kHz was used when 3kHz was not recorded) were averaged, and this pure tone average (PTA) was used along with the best speech discrimination score (SDS) to determine hearing class according to the nomogram provided in the AAO-HNS guidelines. SDS is reported at sensation levels of up to 40 dB or maximum comfortable loudness, whichever is less. This system was used to classify both preoperative and postoperative hearing results.

Several other parameters were recorded at the time of data collection, including age, sex, side of tumor, extent of tumor resection, and facial nerve function. The extent of tumor resection was categorized as total, near total (indicating a small area of tumor capsule no more than 2 mm thick and 5 mm in diameter was left to protect a splayed and adherent facial nerve), or subtotal (indicating a larger remnant of tumor). Postoperative facial nerve outcome was reported according to the House-Brackmann grading system (7).

Statistical analysis was performed in SPSS program for Windows (Release 7.5, 1996), and statistical significance was set at p < 0.05. Each tumor-size category was compared with the others in paired comparisons. Age, preoperative PTA and SDS, and postoperative PTA and SDS were compared using Mann-Whitney U test. Intergroup comparison of preoperative and postoperative hearing class was made using Pearson’s χ² test.

To compare our results with those of other centers performing AN surgery, a review of the literature was performed. A literature search was performed on MEDLINE using the keywords acoustic neuroma, hearing preservation, and retrosigmoid approach. If more than one series had been published by major centers. A recent study carried out in our department has demonstrated that more than 60% of tumors with less than 10 mm of CPA extension operated on by the MF approach will retain functional hearing (class A or B), and approximately 95% of these patients will have good hearing (class A or B). The functional preservation of the cochlear nerve has increased with the development of modern microsurgical techniques and intraoperative nerve monitoring. Hearing conservation is possible, in certain cases, using either the MF or RS approach. For tumors with limited extension into the CPA, the MF approach has become the method of choice in several major centers. A recent study carried out in our department has demonstrated that more than 60% of tumors with less than 10 mm of CPA extension operated on by the MF approach will retain functional hearing (class A or B), and approximately 95% of these patients will

<p>| TABLE 1. Cross-reference of preoperative and postoperative hearing [AAO-HNS class (9)] |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|</p>
<table>
<thead>
<tr>
<th>Intracranial size (mm) (n)</th>
<th>Preoperative class</th>
<th>Postoperative hearing (n)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>15–19 (%) (17)</td>
<td>A</td>
<td>0</td>
<td>15.8 (2)</td>
<td>0</td>
<td>35.3 (6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>5.9 (1)</td>
<td>11.8 (2)</td>
<td>35.3 (6)</td>
<td></td>
</tr>
<tr>
<td>20–24 (%) (23)</td>
<td>A</td>
<td>0</td>
<td>4.3 (1)</td>
<td>0</td>
<td>47.8 (11)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>47.8 (11)</td>
<td></td>
</tr>
<tr>
<td>25–29 (%) (12)</td>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50 (6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50 (6)</td>
<td></td>
</tr>
<tr>
<td>≥30 (%) (11)</td>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>81.8 (9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18.2 (2)</td>
<td></td>
</tr>
</tbody>
</table>

maintain good (grade 1 or 2) facial nerve function. Tumors with a larger CPA component (10 to 19 mm) had a significantly lower rate of hearing preservation (34%), along with a lower rate of good facial nerve outcome (81%) (8). Because the MF approach is not suitable for removal of tumors with more than minor brainstem contact, attempts at hearing conservation in tumors exceeding approximately 18 mm are feasible only via the RS approach.

In an earlier study, a comparative analysis between the MF and RS approaches for small ANs (<10 mm CPA component) revealed markedly greater success for the MF approach in these small tumors (1). Compared with our results using the MF approach (for smaller tumors), hearing preservation rates after RS procedures can only be described as disappointing. In the present study, good hearing (A or B) was retained in only 10% of tumors measuring 15 to 24 mm and in no tumors with ≥25 mm in the CPA.

A review of the literature identified a total of 21 studies that contained data on a significant number of tumors of ≥15 mm and focused on hearing preservation surgery by the RS approach (2,4,9–27). Unfortunately, many of these studies provide insufficient data to undertake an analysis stratified by tumor according to the AAO-HNS hearing classification. Among those that do, some adhere to the AAO-HNS guidelines by reporting tumor size in the CPA (Table 2), whereas others report size of the tumor based on the RS approach (2,4,9–27). The latter method may overestimate tumor size by as much as 10 mm. The data from one study is presented by virtue of its large patient population (Table 3). However, the difficulty of comparing results among different methods of measurement precludes meaningful comparison. Although those studies reporting CPA diameter, most results are more or less comparable with our own for smaller tumors, except for the Mount Sinai series, which, although small in numbers of patients, is somewhat better (Table 2) (23). Results for larger tumors (≥30 mm) are generally modest, although, in contrast to our own experience, a few successes were recorded. Reviewing the four series with a ≥30 mm category, 9.1% (3 of 33) of these large tumors retained hearing of class A or B. It is of interest to consider studies using the entire tumor diameter (including the IAC), because, in aggregate, they represent a sizable patient population (Table 3). However, the different method of measurement precludes meaningful comparison.

Both surgeon and patient alike would always select a hearing-conservative approach, no matter how remote

<table>
<thead>
<tr>
<th>Tumor size*</th>
<th>Study</th>
<th>Postoperative hearing [% (n)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n)</td>
<td></td>
<td>A or B</td>
</tr>
<tr>
<td>Tumor size</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 4. Hearing preservation via the retrosigmoid approach in patients with good preoperative hearing using the new Hannover hearing classification and tumor measurement system**

<table>
<thead>
<tr>
<th>Study</th>
<th>Tumor size†</th>
<th>Postoperative hearing [% (n)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>H1 or 2</td>
</tr>
</tbody>
</table>

*New Hannover classification for tumor extension (11): T1, purely intrameatal; T2, intrameatal and extrameatal; T3b, filling the cerebellar pontine cistern; T3b, reaching the brain stem; T4a, compressing the brain stem; T4b, severely dislocating the brain stem and compressing the fourth ventricle.

†New Hannover classification for hearing: H1, 0 to 30 dB and 100% to 70% SDS; H2, 31 to 50 dB and 69% to 50% SDS; H3, 51 to 90 dB and 49% to 5% SDS; H4, 91 to 120 dB and 4% to 1% SDS; H5, ≥120 dB and 0% SDS.

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the chance of success, were there not some additional morbidity from having made the attempt. In this case, intelligent clinical decision making requires a quantitative assessment of associated morbidities such as facial function, balance, cerebrospinal fluid (CSF) leak, persistent headache, operating time, and tumor recurrence.

Facial function is widely considered to be a most important criterion for success in AN surgery. An earlier analysis of size-matched tumors comparing the RS and TL approaches in our own series detected no difference in outcome (28). These findings are supported by several other studies on this subject (26, 29, 30). Although the ultimate results may be similar, preserving the auditory nerve occasionally makes the facial nerve dissection more tedious and time consuming. A clean proximal (at the brain stem exit) and distal (in the IAC) division of the entire eighth nerve helps to establish the facial nerve dissection plane and thus facilitates more rapid removal. During dissection from the region of greatest adherence, typically just outside of the porus acousticus, visualization of the facial nerve can be obscured by overlying spayed and sometimes adherent fibers of the eighth nerve. Thus, although choice of a hearing conservation RS approach may not alter facial nerve functional outcome, it may prolong surgery.

The RS approach requires a greater degree of cerebellar retraction than the TL approach. Although postoperative T2-weighted MRI images often show a greater degree of cerebellar encephalomalacia after a RS approach, we have not noted a particular tendency toward ataxia. Another factor on balance outcome is the effect of leaving residual vestibular nerve fibers in the course of a hearing conservation attempt. To maximize the possibility of hearing preservation, most surgeons leave intact fibers of the eighth nerve that are not involved by tumor. These vestibular nerve remnants may generate perverse impulses that hinder vestibular compensation. It is our anecdotal impression that patients undergoing hearing conservation attempts are at higher risk of suffering persistent vestibular symptoms, although our results have yet to be studied formally.

A recent retrospective study conducted in our department compared CSF leak rates among the different approaches used for AN surgery (31). With 100 surgeries in each cohort, this study identified no statistically significant difference in CSF leakage rates between the RS (10%) and TL (13%) approaches. Equally, there was no difference in the requirement for surgical closure of the CSF leak (3% of RS and 4% of TL patients). The finding that there is no difference seen in CSP leaks between these approaches is supported by data published in a recent study by Brennan et al. (32).

Prolonged postoperative headache is a recognized complication of AN surgery that may have significant morbidity for the patient (33–35). A recent study by Levo et al. (36) demonstrated that the RS approach carried a 3.8-times higher risk than the TL approach for postoperative headache. A study performed in our department has also confirmed a substantially higher incidence of postoperative headache after RS surgery compared with the TL approach (unpublished data). Attempts have been made to reduce the rate of postoperative headache after the RS approach by performing craniotomy instead of craniectomy. Although this technique has been shown to produce significantly reduced postoperative headache rate, a study by Ruckenstein et al. (38) demonstrated that, despite the performance of a cranioplasty, patients undergoing RS craniotomies experience significantly more postoperative pain than those patients having undergone TL resections (37–39).

The RS approach seems to have a higher rate of tumor recurrence that the TL. Although the TL method affords direct microsurgical exposure of the entire length of the IAC, when attempting hearing preservation via the RS approach, it is possible to visualize only approximately the medial two thirds of the canal (40). Although the fundus could be visualized directly via the RS route, this necessitates removal of a portion of the inner ear and thus precludes hearing preservation. When the lateral one third of the IAC is involved with tumor, the surgeon may elect to blindly dissect the portion in the fundus using angled instruments that reach beneath the overhanging inner ear. In such cases, a small button of tumor can easily be left in the canal’s distal recess. Because such a remnant has an intact blood supply, it has the potential to generate a recurrence. Indeed, this phenomenon of regrowth from residual tumor left in the fundus during a RS hearing conservation approach is well-known (41). The incidence of its occurrence, however, is not known. Endoscopic inspection of the fundus has been proposed as a means of reducing this risk (42). Because of this heightened risk of recurrence, we consider tumor involvement of the lateral one third of the IAC to be a factor weighing against choice of the RS technique.

It is our hope that the outcome data provided in this study, together with those of others, will help surgeons and patients with larger ANs to select an approach to their tumor that maximizes the probability of favorable outcome. To some extent, it depends on the valuation the patient places on his or her residual hearing. To help determine this, we encourage patients to wear an earplug in the tumor ear for a few days, to assess how much difficulty this poses in day-to-day life. If it has little impact, then the RS hearing conservation approach is probably not worth attempting because of the potential greater morbidity. Because of the numerous outcome variables involved, as well as the vicissitudes of patient preference, it is not practical to adhere to a formula-driven decision tree. By way of illustration, we would encourage using the RS approach to attempt hearing preservation for a 20-mm tumor with normal hearing, minimal involvement of the proximal IAC, and no porus erosion and discourage its use for a 35-mm tumor with marginal class B hearing that deeply invades the fundus and widely erodes the porus. A special circumstance, worthy of mention, is a CPA tumor that is suspected of being other than an AN (e.g., meningioma). In such cases, hearing preservation is much more probable than...
with eighth nerve tumors, and the RS approach is well justified.

Finally, we would like to make mention of the difficulty encountered in performing meaningful meta-analysis of the published literature in this field. The limitations posed by use of noncomparable data presentations highlight the need for investigators to use comparable minimal reporting standards (such as those adopted by the AAO-HNS) when conveying results after acoustic neuroma surgery.

Acknowledgments: Philip Yates’ fellowship at Department of Otolaryngology-Head and Neck Surgery, University of California, San Francisco, was funded by the TWJ Foundation.

REFERENCES

Risk–Benefit Analysis of Using the Middle Fossa Approach for Acoustic Neuromas With >10 mm Cerebellopontine Angle Component

Bulent Satar, MD; Robert K. Jackler, MD; John Oghalai, MD; Lawrence H. Pitts, MD; Philip D. Yates, MD

INTRODUCTION

Surgeons who manage acoustic neuroma (AN) want to select an operative approach that optimizes both tumor control and functional outcome. Until relatively recently, the vast majority of AN surgery conducted around the world used either the retrosigmoid (RS) or translabyrinthine (TL) approach. Traditionally, the middle fossa (MF) approach has been reserved for small tumors confined to the internal auditory canal (IAC). Over the last two decades, two teams (one each in Germany and Japan) have advocated for the use of the MF technique for larger tumors possessing a substantial component in the cerebellopontine angle (CPA). Over the last 5 years, the MF approach has undergone a marked resurgence as a result of its proven superiority over the RS approach in hearing conservation. The MF approach is currently used in between 30% and 50% of AN microsurgicacies in certain major American centers.

The use of the MF approach in tumors of 10 to 20 mm in diameter within the CPA remains controversial, because few data exist concerning hearing preservation and facial nerve function for tumors in this larger size range. Because the facial nerve (FN) lies in a surgically less favorable orientation when viewed from above (MF) as opposed to from the lateral perspective (TL or RS), concern has been raised as to whether FN functional outcome is adversely affected. In an earlier study, we demonstrated that choice of the MF approach for hearing preservation carries an increased risk of transient FN dysfunction, but that that long-term outcome was similar to that with the RS approach. The intention of the present study is to ascertain whether the enhanced hearing preservation capability of the MF approach has an impact on long-term facial function in larger tumors (>10 mm).

Patient Population

The primary study population consisted of a retrospective chart review of 153 MF resections for AN. Because 3 patients with neurofibromatosis type 2 underwent staged, bilateral approaches, the primary study group included 150 individuals. There were 76 female and 74 male patients. All patients had a confirmed histopathologic di-
agnosis of AN and had completed at least 1-year follow-up. Complying with the recommendations of the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology–Head and Neck Surgery, tumor size was estimated on axial enhanced-T1 magnetic resonance images (MRI) by excluding the intracanalicular segment and measuring only the size of the CPA component. Tumors completely confined to the IAC were reported as an intracanalicular (IC) tumor. For tumors extending outside of the IAC, the largest linear diameter was measured in a direction either parallel or perpendicular to the petrous ridge. Tumors were stratified into three size categories: IC (64), 1–9 mm CPA (42), or 10–18 mm CPA (47). Tumor resection was total in 93.4% (143 of 153) patients, near total in 5.2% (8 of 153), and subtotal in 1.3% (2 of 153) (Table I). Near-total resection refers to leaving only a miniscule part of the tumor surface no more than 2 mm thick and 5 mm in diameter. Subtotal resection refers to any remnant larger than this.

Auditory function was assigned classification (A, B, C, or D) through pure-tone average and speech discrimination scores (SDS) according to the guidelines described by the American Academy of Otolaryngology–Head and Neck Surgery (AAO–HNS). Pure-tone threshold average (PTA) was reported as an average of the air-conduction thresholds at 0.5, 1, 2, and 3 kHz (4 kHz when the threshold at 3 kHz was not determined). SDSs were obtained at presentation levels of up to 40-dB sensation level. Measurable hearing preservation was described as a PTA <90 dB hearing loss with any SDS. Rate of the functional hearing preservation was described as the ratio of the postoperative AAO–HNS class B and better results to preoperative class B and better hearing.

FN function was graded according to the House-Brackmann system as recommended by the AAO–HNS and reported as early (within 48 h) and late (1 y postoperatively) outcome. The rate of good FN function was expressed as the percentage of grade II and better result. A secondary study population was created to serve as a matched comparison for the largest MF subset when assessing facial function. This consisted of a group of 40 cases (tumor size 10–18 mm) that had undergone the MF approach by the same skull base team over the same patients (tumor size 10–18 mm) that had undergone the MF approach using the same statistical test. Results of the 15- to 18-mm tumor subset removed with the MF approach were reported separately without statistical analysis resulting in a small sample size. Patient ages and the length of the recovery time for FN function achieved were compared among the tumor-size categories using a two-tailed independent-samples t test. The correlation of tumor size with hearing result and FN outcome and the correlation of hearing outcome with FN function were analyzed with Pearson’s bivariate correlation test.

RESULTS

Auditory Function

Anatomic integrity of the cochlear nerve was preserved in 90.8% (139 of 153) of cases. The rate of cochlear nerve integrity preservation was slightly better for IC tumors (93.8%) than it was for 1- to 9-mm (90.5%) and 10- to 18-mm (87.2%) tumors. There was no significant difference in preoperative PTA and SDS among the tumor-size categories (Table II). There was a strong correlation observed between tumor size and postoperative PTA (R = 0.226, P <.05). SDS was also inversely correlated with tumor size (R = -0.197, P <.05).

The rate of postoperative functional hearing preservation (class A/B) was 53.3% overall (72 of 135 patients...
with A or B preoperatively). The 10- to 18-mm CPA group had significantly poorer rates of hearing than the two small tumor size groups (Table II). No significant difference in hearing outcome was observed between the IC and small CPA component (1–9 mm) groups. Pre- and postoperative hearing levels are presented in greater detail, categorized according to tumor size and AAO–HNS hearing class, in Table III. A statistical analysis of these categorical data also demonstrated poorer hearing in the largest tumor size group (Table IV). Hearing improvement sufficient to alter AAO–HNS class (from B to A) was observed in only 2 patients (one each IC and 1–9 mm). No ears with either class C or D hearing preoperatively achieved good hearing (A or B) postoperatively.

Because our primary interest is with tumors >10 mm in CPA diameter, special mention will be made of the results in this group. Only 15 of 44 ears (34%) with preoperative A or B hearing maintained this level following tumor removal. This is only approximately one half of the success rate achieved with the IC (62.2%) and 1- to 9-mm (63.1%) groups. To screen for size effect within the 10- to 18-mm cohort, we separately considered the 11 patients with tumor diameter of 15 to 18 mm in the CPA. Preoperative hearing was class A7 and B4 of whom 36.4% (4 of 11) retained good hearing (A or B) postoperatively. This result is similar to that of the entire 10- to 18-mm group.

**Facial Nerve Function**

In the MF approach, the rate of anatomic FN preservation was 96% (147 of 153) overall: IC = 96.9%, 1–9 mm = 97.6%, and 10–18 mm = 93.6%. With the TL approach (tumors 10–18 mm), the FN was preserved in all 40 cases (100%). The early and late FN outcome in all MF size categories as well as the comparison TL series appears in Table V. The most important measure of success is long-term functional outcome. Good FN function (grade I/II) at 1 year postoperatively was achieved in 90.8% (139 of 153) of MF patients compared with 100% (40 of 40) of TL cases. A statistical analysis ($\chi^2$) of comparisons between MF and TL results as well as among the various MF tumor size groups is presented in Table VI. In sized-matched cohorts (each 10–18 mm in CPA), the long-term MF FN outcome was significantly worse than the TL. Among the three MF size groups, FN outcome in the largest tumor size group (10–18 mm) was significantly less favorable than the two small groups. The rate of good facial function for the 15- to 18-mm tumor subset (11 patients) was 45.5% and 100% for early and late time frames, respectively. A Pearson’s bivariate correlation analysis of late FN function with tumor size in the 153 MF patients demonstrated a significant ($R = 0.182, P < .05$) correlation.

**Linkage Between Auditory Function and Facial Nerve Outcome**

A linkage was observed between late FN function and hearing outcome (Table VII). Patients with success at hearing preservation were more likely to have a favorable FN outcome. This relationship was present for all three size categories.

A Pearson’s bivariate correlation analysis of the 153 MF patients showed a correlation between hearing and facial outcome ($R = 0.305, P < .01$). The same correlation was found for tumors ≥10 mm in the CPA (including IC tumors; $R = 0.210, P < .05$) and tumors 10 to 18 mm ($R = 0.306, P < .05$).

**DISCUSSION**

Widespread use of magnetic resonance imaging has resulted in an increased detection of small-sized AN and an increased number of interventions for hearing preservation. As major centers have accumulated considerable experience in hearing conservation in recent years, success rates in preserving useful hearing have improved substantially. A well-established trend has been the increased use of the MF approach and its application in tumors with extracanalicular components in the CPA. The literature concerning outcomes for MF approaches in tumors larger than 10 mm in the CPA is limited. Many teams have been hesitant to adopt this method for larger tumors because of concerns regarding the unfavorable position of the facial nerve, limited access to the inferior aspect of the CPA, and the need for lengthy and more forceful retraction of the temporal lobe. Other teams, particularly those who have had favorable experiences with smaller tumors, have begun to explore using this method in larger lesions. It is generally accepted that the upper size limit for the MF approach is in the range of 16 to 20 mm in CPA component. The reason that the upper limit is

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**TABLE II.**

Mean Pre- and Postoperative Pure-Tone Threshold Average (PTA) and Speech Discrimination Score (SDS) in Intracanalicular (IC) Tumors and Those With a Component in Cerebellopontine Angle (CPA).

<table>
<thead>
<tr>
<th>Tumor Size Categories (no.)</th>
<th>PTA (dB HL) ± SD</th>
<th>SDS (%) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
</tr>
<tr>
<td>IC (64)</td>
<td>34 ± 17.6</td>
<td>58 ± 35.3</td>
</tr>
<tr>
<td>1–9 mm in CPA (42)</td>
<td>33 ± 16.8</td>
<td>54 ± 34.4</td>
</tr>
<tr>
<td>10–18 mm in CPA (47)</td>
<td>32 ± 15.7</td>
<td>79 ± 34.2</td>
</tr>
</tbody>
</table>

Statistical Analysis

- $P$ (IC vs 1–9 mm) = .928
- $P$ (IC vs 10–18 mm) = .689
- $P$ (1–9 mm vs 10–18 mm) = .776

<table>
<thead>
<tr>
<th>Statistical Analysis</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$ (IC vs 1–9 mm)</td>
<td>.928</td>
<td>.574</td>
<td>.065</td>
<td>.395</td>
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<tr>
<td>$P$ (IC vs 10–18 mm)</td>
<td>.689</td>
<td>.002</td>
<td>.303</td>
<td>.006</td>
</tr>
<tr>
<td>$P$ (1–9 mm vs 10–18 mm)</td>
<td>.776</td>
<td>.001</td>
<td>.357</td>
<td>.001</td>
</tr>
</tbody>
</table>

HL = hearing loss; SD = standard deviation.
not a fixed number is explained by the variable geometry of the CPA itself. As a general rule of thumb, we think it unwise to undertake MF approaches to AN when more than minor brainstem contact has occurred.

In terms of osseous exposure, some authors have argued that a family of MF approaches are used to address AN with the “standard” approach for IC and an “enlarged” approach for tumors with a significant CPA component.\(^1^,\)\(^1\)\(^0\) As we have done more MF cases, we have found that it is beneficial to make a fairly wide exposure of the IAC and adjacent posterior fossa dura regardless of the tumor size. In the TL approach, it is generally acknowledged that there is but one fundamental technique used for AN of all sizes. Admittedly, the opening is made somewhat wider for larger tumors, but this is a variation on the same theme. We think the same principle applies to the MF approach.

In the present study, the maximum diameter of the tumor resected using the MF approach was 18 mm. There were 11 cases with a tumor in the 15- to 18-mm range and 47 larger than 10 mm in the CPA. Our primary reason for undertaking this study was to determine the degree of success in hearing preservation for these larger tumors and to ascertain whether undertaking this effort carries a cost in terms of long-term FN outcome. There are three means of measuring “success” in hearing conservation surgery: integrity of the cochlear nerve, presence of any degree of measurable hearing, and maintenance of useful levels of hearing. Because we think the latter measure is by far the most valid indicator of success, our analysis will emphasize this measure. In the present study, of 135 MF patients with good preoperative hearing (class A/B) (includes tumors of all sizes), 53.3% maintained good hearing after tumor resection. When examined according to tumor size, larger tumors (10–18-mm CPA) retained good hearing (A or B) approximately half as often (34%) as the IC (62.2%) and \(<\)9-mm CPA (63.1%). There is a paucity of data on hearing outcomes in the MF approach to tumors with substantial extracanalicular components. The earlier literature includes 156 patients (239 patients for evaluation of FN function) with a 10- to 20-mm CPA component from four studies.\(^4^,\)\(^1\)\(^\text{1\text{0}}\)–\(^1\)\(^\text{1\text{2}}\) In these, the rate of good hearing (A or B) preservation was 33.3% (Table VIII). These data are similar to our own. Only studies with sufficient detail could be tabulated in this manner. Much of the literature was not suitable for comparison as a result of inconsistent methods of reporting tumor size and hearing outcome. A number of studies reported overall tumor size, including the IAC component. This tends to overestimate the size of the tumor by as much as 10 mm, a huge factor when evaluating small tumor components within the CPA. In the future, we are hopeful that every study will include data in a standardized format, such as that recommended by the AAO–HNS, to facilitate meta-analyses.\(^6\)

It seems worthwhile to make mention of the points in operative technique which enhance the possibility of hear-

### TABLE III.
Cross-referencing Data of Pre- and Postoperative Hearing Levels (AAO-HNS classification).

<table>
<thead>
<tr>
<th>Tumor Size Categories</th>
<th>Preoperative Class (no.)</th>
<th>Postoperative Class (no., %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (26)</td>
<td>13 (50%) 5 (19.2%) 1 (3.9%) 7 (26.9%)</td>
</tr>
<tr>
<td></td>
<td>B (27)</td>
<td>1 (3.7%) 14 (51.9%) 5 (18.5%) 7 (25.9%)</td>
</tr>
<tr>
<td></td>
<td>C (4)</td>
<td>— — 1 (25%) 3 (75%)</td>
</tr>
<tr>
<td></td>
<td>D (7)</td>
<td>— — — 7 (100%)</td>
</tr>
<tr>
<td>Total (64)</td>
<td>14 (21%) 19 (29%) 7 (11%) 25 (39%)</td>
<td></td>
</tr>
<tr>
<td>1–9 mm in CPA</td>
<td>A (17)</td>
<td>9 (52.9%) 3 (17.6%) 2 (11.8%) 3 (17.6%)</td>
</tr>
<tr>
<td></td>
<td>B (21)</td>
<td>1 (4.8%) 11 (52.4%) 4 (19%) 5 (23.8%)</td>
</tr>
<tr>
<td></td>
<td>C (3)</td>
<td>— — 2 (66.7%) 1 (33.3%)</td>
</tr>
<tr>
<td></td>
<td>D (1)</td>
<td>— — — 1 (100%)</td>
</tr>
<tr>
<td>Total (42)</td>
<td>10 (23.8%) 14 (33.4%) 8 (19.1%) 10 (23.8%)</td>
<td></td>
</tr>
<tr>
<td>10–18 mm in CPA</td>
<td>A (21)</td>
<td>6 (28.6%) 2 (9.5%) — 13 (61.9%)</td>
</tr>
<tr>
<td></td>
<td>B (23)</td>
<td>— 7 (30.4%) 3 (13%) 13 (56.5%)</td>
</tr>
<tr>
<td></td>
<td>C (1)</td>
<td>— — 1 (100%)</td>
</tr>
<tr>
<td></td>
<td>D (2)</td>
<td>— — 2 (100%)</td>
</tr>
<tr>
<td>Total (47)</td>
<td>6 (12.7%) 9 (19.2%) 3 (6.3%) 29 (61.8%)</td>
<td></td>
</tr>
</tbody>
</table>

CPA = cerebellopontine angle.

### TABLE IV.
Chi-square (P values given) of the Data in Table III.*

<table>
<thead>
<tr>
<th>Tumor Size Categories</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1–9 mm in CPA</td>
<td>10–18 mm in CPA</td>
</tr>
<tr>
<td></td>
<td>1–9 mm in CPA</td>
<td>10–18 mm in CPA</td>
</tr>
<tr>
<td>Intracanalicular</td>
<td>.268</td>
<td>.090</td>
</tr>
<tr>
<td>10–18 mm in CPA</td>
<td>.583</td>
<td>.009</td>
</tr>
</tbody>
</table>

* Tumor size categories are compared with reference to the rate of functional hearing preservation (postoperative class A and B/preoperative class A and B).

CPA = cerebellopontine angle.

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ing conservation. Several points are often mentioned by surgeons in the field with sufficient regularity to constitute conventional wisdom: work only medial to lateral to avoid traction of the fragile eighth nerve entering the modiolus, cut the vestibular nerves early, avoid using bipolar cautery, and work "underwater" using copious irrigation. Use of long angled instruments (e.g., curettes, hooks, and ball-hooks) is helpful for any size of AN, preservation of the FN is technically more challenging using the MF approach. Often the nerve is located on the superior surface of the tumor interposed between the tumor and the surgeon’s point of view. Thus, the surgeon must work past the nerve, and it must be manipulated from side to side during tumor dissection. By contrast, in the RS and TL approaches, the FN can remain undisturbed in its deflected course and thus sustains a lesser degree of trauma. In an earlier study, we found that although transient FN dysfunction was substantially higher in small tumors (<10 mm CPA), long-term outcome was the same as with other approaches. In the present study, it has become clear that with larger tumors (10–18-mm CPA) the MF approach carries a significantly higher risk of long-term residual FN dysfunction, the most informative comparison in the 10- to 18-mm CPA size group between the MF and TL approaches. With the MF, good long-term FN function (grade I/II) was achieved in only 80.9% (38 of 47) of cases, whereas in TL 100% (40 of 40) achieved this result. This difference was statistically significant (P = .003). A potential source of bias should be noted in these data. Less-than-complete tumor resection was performed in 8.6% of MF cases and 17.5% of TL. This more conservative resection could have boosted the FN outcome in the TL group. Two earlier studies on the MF approach contain long-term FN outcome data in the size range of interest. In these, good FN function (1 or 2) was achieved in 85.2% (167 of 196). It is interesting that a concurrence was found between good FN function and functional hearing outcome (Table VII). The linkage between either good or bad outcome for both functions probably relates to the biologic properties of the tumor such as the tendency to have an adhesive tumor interface.

The results of this risk–benefit analysis are useful in advising AN patients with good hearing and a sizable CPA component. For patients with tumors <10 mm in diameter, the MF approach is clearly superior because it has an equivalent long-term FN result (compared with RS and TL approaches) and allows for a >60% retention of good hearing. For patients with good hearing and a tumor in the 10- to 18-mm CPA range, the deliberation is more

---

**TABLE V.**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Tumor-Size (no.)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF early</td>
<td>Intracanalicular (64)</td>
<td>21 (32.8%)</td>
<td>12 (18.8%)</td>
<td>6 (9.4%)</td>
<td>4 (6.3%)</td>
<td>4 (6.3%)</td>
<td>17 (26.6%)</td>
</tr>
<tr>
<td>Early 10–18 mm in CPA (47)</td>
<td>9 (19.1%)</td>
<td>5 (10.6%)</td>
<td>6 (12.8%)</td>
<td>2 (4.3%)</td>
<td>2 (4.3%)</td>
<td>23 (48.9%)</td>
<td></td>
</tr>
<tr>
<td>TL 10–18 mm in CPA (40)</td>
<td>16 (40%)</td>
<td>7 (17.5%)</td>
<td>1 (2.5%)</td>
<td>5 (12.5%)</td>
<td>5 (2.5%)</td>
<td>9 (22.5%)</td>
<td></td>
</tr>
<tr>
<td>Late 1–9 mm in CPA (42)</td>
<td>40 (95.2%)</td>
<td>1 (2.4%)</td>
<td>2 (4.3%)</td>
<td>2 (4.3%)</td>
<td>——</td>
<td>——</td>
<td></td>
</tr>
<tr>
<td>MF Late 10–18 mm in CPA (40)</td>
<td>35 (87.5%)</td>
<td>5 (12.5%)</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td>——</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE VI.**

<table>
<thead>
<tr>
<th>Facial Function</th>
<th>Tumor Size</th>
<th>Early</th>
<th>Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among the MF Categories</td>
<td>IC vs 1–9 mm</td>
<td>.294</td>
<td>.358</td>
</tr>
<tr>
<td>IC vs 10–18 mm</td>
<td>.022</td>
<td>.037</td>
<td></td>
</tr>
<tr>
<td>1–9 mm vs 10–18 mm</td>
<td>.002</td>
<td>.012</td>
<td></td>
</tr>
<tr>
<td>MF vs TL</td>
<td>10–18 mm vs 10–18 mm</td>
<td>.009</td>
<td>.003</td>
</tr>
</tbody>
</table>

* Tumor size categories are compared with reference to the rate of good facial nerve function (grade VII) at early and late time frames.

MF = middle fossa; TL = translabyrinthine.
complicated. Although good hearing can be preserved in over one third of patients, cosmetically significant long-term FN dysfunction (grade III, 15%; IV, 2%; VI, 2%) is higher than with the TL or RS methods. Earlier, we have shown that long-term FN results are equivalent between the RS and TL techniques. Recently, we have observed that the RS approach is only approximately half as successful in preserving hearing for tumors in this size range. With its superior FN results compared with the MF approach, this may seem a reasonable alternative. However, the RS approach does not permit adequate access of the fundus of the IAC without removing a portion of the vestibule and common crus, a maneuver incompatible with hearing preservation. The RS approach is also associated with a significantly higher incidence of persistent postoperative headache. For these reasons, when tumor extends deep into the fundus of the IAC, we tend to avoid the RS approach.

The results of this study have altered our recommendations to patients. Formerly, we recommended the MF approach for all tumors with good hearing up to 18 mm diameter in the CPA. Our current practice is to inform patients with 10- to 18-mm CPA components that while the MF approach is clearly superior for hearing, it carries with it a somewhat higher incidence of persistent facial paresis and synkinesis. We explain the probabilities involved and allow the patient to judge the relative importance of hearing and facial function. The surgeon should not assume that patients would automatically choose a lowered risk of facial neuropathy over a possibility of saving hearing. In an earlier study of patient-perceived outcomes following AN surgery, we were surprised to note that many patients with both facial dysfunction and unilateral deafness actually rated the auditory deficit as more life disturbing.

It should be noted that certain other factors (not quantified in the present study as a result of incompleteness of the available data) are also considered in risk stratification. For example, we suspect that extensive osseous erosion of the porus acusticus and deep penetration of the fundus are adverse predictors of success in hearing preservation. The limited hard data available and complexity of the variables involved makes it difficult to codify such factors into an explicit set of rules. To illustrate how these factors come into play in our advice to patients, we would be more enthusiastic in our recommendation for a hearing conservation approach in a 12-mm CPA tumor with normal hearing, an empty fundus, and a narrow porous than we would be in an 18-mm CPA tumor with marginal class B hearing, deep fundus involvement, and a widely eroded porous acusticus.

Because of the technical challenges faced in obtaining adequate exposure and conducting an effective dissection, we recommend that microsurgical teams not undertake the MF approach to tumors with sizable CPA components until they have become facile with smaller lesions.

**CONCLUSION**

When considering surgical options, patients with >10-mm tumors should be advised that choosing the MF approach for hearing preservation carries a somewhat higher risk of persistent FN dysfunction than the TL approach.

<table>
<thead>
<tr>
<th>Study</th>
<th>Institution</th>
<th>Year</th>
<th>CPA Component</th>
<th>Patients</th>
<th>Good Hearing</th>
<th>Good Facial Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dornhoffer et al.</td>
<td>Wuerzburg</td>
<td>1995</td>
<td>10–15 mm</td>
<td>17</td>
<td>47%</td>
<td>NA</td>
</tr>
<tr>
<td>Staecker et al.</td>
<td>Harvard</td>
<td>2000</td>
<td>10–15 mm</td>
<td>4</td>
<td>75%</td>
<td>75%*</td>
</tr>
<tr>
<td>Gjuric et al.</td>
<td>Erlangen</td>
<td>2001</td>
<td>10–19 mm</td>
<td>109</td>
<td>28.4%</td>
<td>85% in 192 patients†</td>
</tr>
<tr>
<td>Kanzaki et al.</td>
<td>Keio</td>
<td>2001</td>
<td>11–20 mm</td>
<td>26</td>
<td>30.7%</td>
<td>NA</td>
</tr>
<tr>
<td>Satar et al.</td>
<td>UCSF</td>
<td>2002</td>
<td>10–18 mm</td>
<td>44</td>
<td>34%</td>
<td>80.8% in 47 patients‡</td>
</tr>
</tbody>
</table>

* 3 months postoperatively.
† 1 year postoperatively and includes also preoperative class C/D patients.
CPA = cerebellopontine angle; NA = data not available.
Acknowledgments
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BIBLIOGRAPHY