Preservation of hearing after surgery for acoustic schwannomas: correlation between cochlear nerve function and operative findings

HIROMICHI UMEZU, M.D. AND TADASHI AIBA, M.D.

Department of Neurosurgery, Toranomon Hospital, Tokyo, Japan

The results of surgery in 66 patients with acoustic schwannoma in whom total tumor removal was accomplished are reviewed in terms of the relationships among tumor size, preoperative hearing level, operative findings (including the shape and location of the cochlear nerve at the tumor surface), and the extent of postoperative hearing preservation. Both tumor size and the preoperative hearing level were correlated with the shape of the cochlear nerve, which more frequently formed a solid bundle when the tumor was small or the preoperative hearing was excellent. Hearing was retained postoperatively only in cases in which the nerve formed a solid bundle and could be differentiated and separated from the tumor capsule without difficulty. These findings suggest that tumor size and preoperative hearing level, which have been reported to be the main prognostic factors of postoperative hearing preservation, may influence the results of surgery for acoustic schwannoma through the shape of the cochlear nerve.

Key Words • acoustic schwannoma • audiometry • cochlear nerve • hearing preservation • suboccipital approach

Advances in neuroimaging, microsurgical techniques, and intraoperative monitoring of neuronal function have led to increasing reports of hearing preservation following total removal of acoustic schwannomas.1-3,5-8,10,12-16,18,19,21,22,24,25 The incidence of hearing preservation after surgery ranges from 12% to 71%. When compared with facial nerve function, the postoperative maintenance of hearing in the serviceable range continues to be a difficult challenge. Most patients already have some degree of hearing impairment preoperatively, and hearing rarely improves after surgery. It is well known that the smaller the tumor and/or the better the preoperative hearing, the more likely it is that hearing will be preserved after surgery.1,5-8,10,11,14-16,18,20,21,23,25

In this article, we report our experience in attempting to preserve serviceable hearing in patients with surgery for acoustic schwannomas. In addition, the relationships among tumor size, preoperative hearing level, operative findings, and the results of surgery aimed at hearing preservation are discussed in order to clarify how the known prognostic factors, such as tumor size and extent of preoperative hearing, affect postoperative hearing preservation.

Clinical Material and Methods

We evaluated the cases of 66 patients who underwent microsurgical removal of an acoustic schwannoma at our institution during the last 5 years. All patients were operated on by one of the authors (T.A.) via the posterior fossa approach. Our surgical technique has been described in detail in a previous publication.1 Preoperative evaluation chiefly consisted of neuro-otological examinations (pure-tone audiometry, speech discrimination, and electrystagmography), measurement of auditory brain-stem responses, high-resolution computerized tomography (CT), and magnetic resonance (MR) imaging. Tumor size was defined as the maximum diameter in the cerebellopontine angle, as measured by enhanced MR imaging or CT, and was divided into three classifications: small (≤ 15 mm), medium-sized (16 to 30 mm), and large (> 30 mm). Criteria for serviceable hearing were defined as a pure-tone average of 50 dB or less and a speech discrimination score of 50% or more. Hearing was considered to be successfully preserved if it remained in the serviceable range after surgery.

Special attention was focused on the shape and location of the cochlear nerve at the tumor surface, based on the operative record. The cochlear nerve was defined as one of three possible shapes; the classification scheme is modified from that proposed by Koos and Peneczky.15 In Type 1, the cochlear nerve fibers are dispersed on the tumor surface and cannot be differentiated from the tumor capsule. In Type 2, the nerve fans out but is distinguishable from the tumor capsule (Fig. 1 left). In Type 3, the cochlear nerve forms a solid bundle at the tumor surface (Fig. 1 right). The location
of the cochlear nerve at the tumor surface was described as being either at the dorsal, ventral, cranial, or caudal surface of the tumor. The results were analyzed for statistical significance by the chi-squared test.

**Results**

There were 23 patients with a tumor of 15 mm or less (small), 24 with a tumor between 16 and 30 mm (medium-sized), and 19 with a tumor exceeding 30 mm (large). Of the 66 patients, 27 (40.9%) had serviceable hearing preoperatively and eight (29.6%) of the 27 retained hearing in the serviceable range following surgery.

**Tumor Size and Shape of the Cochlear Nerve**

The relationship between tumor size and shape of the cochlear nerve was examined (Table 1). Significantly more tumors of 15 mm or less were observed with a Type 3 variant of the cochlear nerve (p < 0.05) than 16 mm or greater. In contrast, the larger the tumor, the more frequently the cochlear nerve became fusiformly flattened (Type 2) or indistinguishable from the tumor capsule (Type 1).

**Tumor Size and Location of the Cochlear Nerve**

When the tumor was small, the cochlear nerve coursed along the ventral surface of the tumor in nine patients (39.1%), the caudal surface in 13 (56.5%), and the dorsal surface in one (4.3%). In cases of medium-sized tumors, the nerve passed along the ventral surface in seven patients (29.2%), the caudal surface in 12 (50%), and the dorsal surface in three (12.5%); its course was unknown in two (8.3%). With large tumors, the nerve was found to course along the ventral circumference in six patients (31.6%), the caudal surface in four (21.1%), and the dorsal surface in three (15.8%); its course was unknown in six (31.6%). Regardless of the tumor size, the cochlear nerve traversed the caudal-to-ventral circumference of the tumor in the majority of patients.

**Tumor Size and Preoperative Hearing Level**

The percentage of patients with serviceable hearing preoperatively in each of the three groups was nearly the same; there was no apparent relationship between tumor size and the preoperative hearing level (Table 2).

**Preoperative Hearing Level and Shape of the Cochlear Nerve**

The relationship between the preoperative hearing

### Table 1

<table>
<thead>
<tr>
<th>Tumor Size (mm)</th>
<th>No. of Cases</th>
<th>Shape of Cochlear Nerve*</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 15</td>
<td>23</td>
<td>4 (17.4%) 2 (8.7%) 17 (73.9%)</td>
</tr>
<tr>
<td>16–30</td>
<td>24</td>
<td>12 (50%) 10 (41.7%) 2 (8.3%)</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>19</td>
<td>14 (73.7%) 3 (15.8%) 2 (10.5%)</td>
</tr>
</tbody>
</table>

* Modified from the classification of Koos and Perneczky; see text for definitions.
Hearing Location

Table 2

<table>
<thead>
<tr>
<th>Tumor Size (mm)</th>
<th>No. of Cases</th>
<th>Preop Hearing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 15</td>
<td>23</td>
<td>9 (39.1%)</td>
</tr>
<tr>
<td>16–30</td>
<td>24</td>
<td>11 (45.8%)</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>19</td>
<td>7 (36.8%)</td>
</tr>
</tbody>
</table>

* Serviceable hearing is defined as a pure-tone average of 50 dB or less with a speech discrimination score of 50% or more.

Hearing and the shape of the cochlear nerve was examined (Table 3). The percentage of the Type 1 variant of the cochlear nerve in cases of poor preoperative hearing was significantly higher than that in cases of serviceable preoperative hearing (p < 0.05).

Preoperative Hearing Level and Location of the Cochlear Nerve

In the 27 patients with serviceable preoperative hearing, the cochlear nerve coursed along the ventral surface of the tumor in 10 cases (37%), the caudal surface in 14 (51.9%), and the dorsal surface in two (7.4%); its course was unknown in one (3.7%). In the 39 patients with poor preoperative hearing, the nerve passed over the ventral circumference in 12 (30.8%), the caudal surface in 15 (38.5%), and the dorsal surface in five (12.8%); its course was unknown in seven (17.9%). There was no significant difference in location of the cochlear nerve between patients with and without serviceable preoperative hearing.

Tumor Size and Postoperative Hearing Preservation

Among patients with serviceable preoperative hearing, hearing level was retained after surgery in four (44.4%) of nine with small tumors, in three (27.3%) of 11 with medium-sized tumors, and in one (14.3%) of seven with large tumors (Table 4). Thus, the rate of hearing preservation declined with increasing tumor size.

Shape of the Cochlear Nerve and Postoperative Hearing Preservation

Postoperatively, serviceable hearing was retained in one (16.7%) of six patients with a Type 1 variant of the cochlear nerve, in one (11.1%) of nine with a Type 2 variant, and in six (50%) of 12 with a Type 3 variant (Table 5). The incidence of hearing preservation was the highest in Type 3, in which the cochlear nerve was morphologically intact.

Location of the Cochlear Nerve and Postoperative Hearing Preservation

Serviceable hearing was preserved after surgery in three (30%) of 10 patients in whom the cochlear nerve passed through the ventral surface of the tumor and in four (28.6%) of 14 in whom the nerve lay along the caudal circumference. This difference was not significant. Neither of the two patients with serviceable preoperative hearing in whom the nerve was located on the dorsal surface of the tumor retained their hearing following surgery.

Discussion

Correlation Between Tumor Size and Operative Findings

There have been few reports describing operative findings, especially concerning the shape and location of the cochlear nerve in relation to tumor size. Koos and Perneczky classified acoustic schwannomas into four size groups on the basis of their longitudinal diameter, including the intracanalicular portion: Grade 1 (≤ 10 mm), Grade 2 (11 to 20 mm), Grade 3 (21 to 30 mm), and Grade 4 (> 30 mm). In assessing the shape and location of the cochlear nerve at the tumor surface, those authors noted that, of tumors larger than 20 mm, the nerve was unidentifiable (Type 1) in about 50% and fanned out (Type 2) in 40%. In 10% of these cases, the nerve appeared as a solid bundle and coursed along the caudal (80%) or ventral (20%) surface of the tumor. In the present series, the shape of the cochlear nerve was correlated with the tumor size. The incidence of a Type 1 configuration, in which the nerve was spread out and indistinguishable from the tumor capsule, was directly proportional to tumor size. In contrast, in cases in which the nerve was an intact solid band (Type 3), small tumors were encountered with significantly higher frequency. Examination of the relationship between the location of the cochlear nerve and tumor size revealed that the nerve passed through the caudal-to-ventral circumference of the tumor in most cases, regardless of tumor size (95.6% of small, 79.2% of
Hearing preservation and cochlear nerve morphology

<table>
<thead>
<tr>
<th>Shape of Cochlear Nerve</th>
<th>No. of Cases</th>
<th>Servicable Hearing†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preop</td>
<td>Postop</td>
</tr>
<tr>
<td>type 1</td>
<td>30</td>
<td>6 (20%)</td>
</tr>
<tr>
<td>type 2</td>
<td>15</td>
<td>9 (60%)</td>
</tr>
<tr>
<td>type 3</td>
<td>21</td>
<td>12 (57.1%)</td>
</tr>
</tbody>
</table>

* Modified from the classification of Koos and Perneczky: see text for definitions.
† Servicable hearing is defined as a pure-tone average of 50 dB or less with a speech discrimination score of 50% or more.

medium-sized, and 52.7% of large tumors). The relatively low incidence in patients with large tumors seemed to be attributable to the fact that this group included six cases (31.6%) in which the nerve could not be identified at all. Because the cochlear nerve coursed along the ventrocaudal quadrant of the internal auditory canal and most of the acoustic schwannomas originated from the vestibular portions of the eighth cranial nerve (which were situated dorsal to the cochlear portion in the internal auditory canal), this location of the cochlear nerve at the tumor surface was expected, and the incidence was almost the same as that reported previously.

**Correlation Between Preoperative Hearing Level and Operative Findings**

Generally, servicable postoperative hearing is retained more frequently in patients whose preoperative hearing was relatively good, primarily because hearing rarely improves and usually declines after surgery, even if some hearing is retained postoperatively. Few reports have addressed the relationship between preoperative hearing and operative findings. Koos and Perneczky stated that patients with Type 1 and 2 variants of the cochlear nerve had invariably lost hearing preoperatively. On examining the relationship between preoperative hearing and the shape of the cochlear nerve in the present series, we found that the nerve was most often Type 3 (44.4%) or Type 2 (33.3%) in patients with servicable preoperative hearing. Patients with poor preoperative hearing had a significantly higher frequency of the Type 1 variant. Thus, preoperative hearing was correlated with the shape of the cochlear nerve, and the better the preoperative hearing, the more frequently an anatomically continuous nerve was observed at the tumor surface under the operating microscope.

**Prognostic Factors of Postoperative Hearing Preservation**

A review of the literature on hearing preservation after surgery for acoustic schwannomas indicates that the major factors influencing the outcome of surgery are tumor size and/or preoperative hearing function, regardless of whether the surgical approach is via the middle or the posterior fossa. As to tumor size, the rate of hearing preservation falls significantly when the tumor exceeds 10 to 20 mm in maximum diameter. Concerning preoperative hearing, the 50/50 rule of Wade and House, which is a pure-tone loss of no greater than 50 dB and a speech discrimination score of 50% or higher, is generally accepted as the preoperative criterion for hearing preservation. Wade and House also pointed out that the ideal candidate for surgery was a patient who had no greater than a 30-dB pure-tone loss and a 70% or higher speech discrimination score. This provides a cushion for additional hearing loss incurred at surgery or over time. As to other preoperative factors predictive of postoperative hearing preservation, Harner, et al., noted a shorter duration of hearing loss. Glasscock, et al., did not find patient age, sex, side of lesion, preoperative hearing level, and duration of symptoms to be very useful predictors, and they proposed that the preoperative auditory brain-stem response might be an accurate indicator of hearing conservation. Palva, et al., drew attention to the location of the vessels supplying the cochlear nerve and labyrinth and reported that, when the vessels were on the anterior surface of the cochlear nerve and did not require handling during surgery, hearing preservation was almost the rule. Koos and Perneczky stated that postoperative hearing could be preserved only if the cochlear nerve was a Type 3 variant according to their classification. In our series, although preoperative hearing was not correlated with tumor size, the extent of hearing preservation was closely related to tumor size. Among patients with large tumors, servicable hearing was retained in only one (14.3%) whose tumor was almost entirely cystic, while the percentage with servicable preoperative hearing was almost the same as that of patients with small or medium-sized tumors. Concerning the shape of the cochlear nerve and the surgical outcome, the extent of postoperative hearing preservation was acceptable only in patients with a Type 3 variant. In other words, the results of our attempts to preserve servicable hearing following surgery were disappointing when the tumor was large, despite good preoperative hearing, and when the normal shape of the cochlear nerve had not been retained, despite a small tumor size and good preoperative hearing. Thus, the shape of the cochlear nerve seems to be an important predictor of postoperative hearing preservation and may influence the radicality of the operation. When the cochlear nerve forms a solid bundle at the tumor surface, it is easily identified and is preserved anatomically along its entire course. When the nerve fans out or disperses at the tumor surface, electrophysiological techniques, including direct recording of the eighth cranial nerve potential, are needed to differentiate the nerve fibers from the tumor capsule. Also, if the cochlear nerve is markedly deformed and has a paper-thin appearance, a very small amount of the tumor capsule or substances tightly adherent to the nerve may have to be left to preserve the anatomical continuity of the nerve.

Concerning hearing preservation and the extent of
surgery, Marquet et al., rejected the principle of surgery aimed at hearing preservation on the grounds that tumor invasion of the cochlear nerve is to be expected in cases in which adhesion of the cochlear nerve and the tumor has occurred. They proposed that surgery be postponed if the tumor is very small and bilateral hearing is excellent and that, when surgery is performed, the goal should be total tumor removal. However, if preoperative hearing on the affected side is serviceable, we believe that an attempt to preserve hearing is worthwhile regardless of tumor size for the following reasons: 1) the hearing impairment caused by acoustic schwannomas does not always progress in parallel with enlargement of the tumor and sometimes advances as rapidly as in cases of sudden deafness; 2) the attempt to preserve hearing does not increase the surgical risk or complications; 3) although the rate of postoperative hearing preservation is lower with larger than with small tumors, serviceable hearing can be maintained if the cochlear nerve is a solid bundle and/or the tumor is cystic; 4) significant postoperative improvement in hearing has been reported; and 5) it has not been confirmed that microscopic residual tumor within the cochlear nerve actually progresses to clinical recurrence.

Conclusions

Hearing preservation following surgical removal of acoustic schwannoma is a realistic goal in patients with serviceable preoperative hearing. This study shows that the smaller the tumor and/or the better the preoperative hearing level, the greater the likelihood that the cochlear nerve is morphologically intact. Therefore, because preservation of the anatomical continuity of the cochlear nerve is the first step in maintaining its function, the results of surgery aimed at hearing preservation are better from a technical standpoint when the tumor is small and/or preoperative hearing is good.

References


Manuscript received April 20, 1993. Accepted in final form September 9, 1993.
Address reprint requests to: Hiromichi UmezU, M.D., Department of Neurosurgery, Toranomon Hospital, 2–2–2 Toranomon, Minato-ku, Tokyo 105, Japan.