Preservation of hearing in patients undergoing excision of acoustic neuromas and other cerebellopontine angle tumors

Charles H. Tator, M.D., Ph.D., F.R.C.S.(C), and Julian M. Nedzelski, M.D., F.R.C.S.(C)

Division of Neurosurgery, Toronto Western Hospital, and Department of Otolaryngology, Sunnybrook Medical Centre and University of Toronto, Toronto, Ontario, Canada

Microsurgical techniques have made it possible to identify and preserve the cochlear nerve from its origin at the brain stem and along its course through the internal auditory canal in patients undergoing removal of small or medium-sized acoustic neuromas or other cerebellopontine angle (CPA) tumors. In a consecutive series of 100 patients with such tumors operated on between 1975 and 1981, an attempt was made to preserve the cochlear nerve in 23. The decision to attempt to preserve hearing was based on tumor size and the degree of associated hearing loss. In cases of unilateral acoustic neuroma, the criteria for attempted preservation of hearing were tumor size (2.5 cm or less), speech reception threshold (50 dB or less), and speech discrimination score (60% or greater). In patients with bilateral acoustic neuromas or tumors of other types, the size and hearing criteria were significantly broadened. All patients were operated on through a suboccipital approach.

Hearing was preserved postoperatively in six (31.6%) of the 19 patients with unilateral acoustic neuromas, although the cochlear nerve was preserved in 16. Of the six patients with postoperative hearing, three retained excellent hearing, and the other three had only sound awareness and poor discrimination. Hearing was preserved in three cases with other CPA tumors, including an epidermoid cyst and small petrous meningiomas in the internal auditory canal. Of the two cases with bilateral tumors, hearing was preserved in one. Of the 23 patients in whom hearing preservation was attempted, nine (39.1%) had some postoperative hearing, which in six was equal to or better than the preoperative level. Thus, it is worthwhile to attempt hearing preservation in selected patients with CPA tumors.

KEY WORDS • acoustic neuroma • cochlear nerve • surgical excision • cerebellopontine angle tumor

With the use of microsurgical techniques during posterior fossa surgery on acoustic neuromas or other cerebellopontine angle (CPA) tumors, it is possible to identify the entire intracranial course of the cochlear nerve from its origin at the pontomedullary junction to the fundus or lateral end of the internal auditory canal just proximal to its entrance into the cochlea. Thus, in selected patients with these tumors, preservation of the cochlear nerve and hearing may be attainable. Furthermore, cochlear nerve preservation is compatible with total tumor removal because most acoustic neuromas arise from one of the vestibular nerves, usually the superior vestibular nerve, and only rarely from the cochlear nerve. Hearing preservation is especially important in patients with bilateral acoustic neuromas or in patients with unilateral CPA tumors of any type whose contralateral hearing is already impaired.

The present report is a detailed analysis including pre- and postoperative auditory parameters of 23 patients with CPA tumors, mainly acoustic neuromas, in whom cochlear nerve preservation was attempted. These patients underwent surgery between 1975 and 1981.

Clinical Material and Methods

Of the 23 cases, 19 had unilateral acoustic neuromas, and one had bilateral acoustic neuromas (Table 1). There was one patient with a unilateral petrous meningioma, one with bilateral petrous meningiomas, and one with an epidermoid cyst in the CPA. Some of these nonacoustic neuroma cases have been described else-
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### TABLE 1

<table>
<thead>
<tr>
<th>Type of Tumor</th>
<th>No. of Cases</th>
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</thead>
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<tr>
<td>acoustic neuroma, unilateral</td>
<td>19</td>
</tr>
<tr>
<td>acoustic neuroma, bilateral</td>
<td>1</td>
</tr>
<tr>
<td>meningioma, unilateral</td>
<td>1</td>
</tr>
<tr>
<td>meningioma, bilateral</td>
<td>1</td>
</tr>
<tr>
<td>epidermoid cyst, unilateral</td>
<td>1</td>
</tr>
<tr>
<td>total cases</td>
<td>23</td>
</tr>
</tbody>
</table>

where. The 23 patients in whom cochlear nerve preservation was attempted were from a consecutive series of 100 patients with CPA tumors operated on between 1975 and 1981.

**Diagnostic Methods**

Patients with unilateral or bilateral sensorineural hearing loss had an audiometric test battery including pure-tone thresholds and speech discrimination, as well as stapedial acoustic reflex tests and vestibular function tests (electronystagmography). Auditory brainstem evoked potentials have been added to the tests since 1979. During this period, polytomography of the temporal bones was superseded by high-resolution computerized tomography (CT) scanning of the petrous bones, using a bone window and thin slices, performed at the same time as a positive contrast-enhanced CT scan. The enhanced CT scan displayed tumors of approximately 1 cm or larger (Fig. 1 left). Smaller tumors were detected by air CT cisternography, which is currently the method of choice for suspected cases with a normal enhanced CT scan (Fig. 1 right). Positive-contrast posterior fossa myelography is no longer performed.

**Choice of Surgical Approach**

In our unit, three different surgical approaches are used for removing acoustic neuromas. The translabyrinthine approach is used for intracanalicular tumors and for small to medium-sized (≤ 2.5 cm) CPA tumors in patients without serviceable hearing. For tumors of this size, the translabyrinthine approach is preferred because of its reduced morbidity. Serviceable hearing is defined as a speech reception threshold of less than 50 dB and a speech discrimination score of greater than 60%. It is our opinion that hearing acuity of this degree can be utilized if necessary. In our view, it is not worth attempting to preserve the cochlear nerve in patients with less than serviceable hearing, as defined above, because the nerve will usually be irretrievably altered by the combined effects of the tumor and surgery. The second operative technique is the lateral approach utilizing a combined translabyrinthine and middle fossa exposure, with or without division of the tentorium. This approach is used for tumors larger than 2.5 cm, even in patients with serviceable hearing. We prefer this approach in these patients because of our ability to achieve total tumor removal, with minimal morbidity and a high probability of facial nerve preservation. The third method is the standard suboccipital approach. This is used in patients with tumors of 2.5 cm or less who have serviceable hearing, as defined above. Thus, the decision to strive for hearing preservation was based on tumor size and the severity of the preoperative hearing loss. In cases of unilateral acoustic neuroma, the criteria for attempted hearing preservation were tumor size (less than 2.5 cm), speech reception threshold (less than 50 dB), and speech discrimination score (more than 60%). With bilateral acoustic neuromas, or unilateral tumors of other types, the size and hearing criteria were significantly broadened.

**Surgery With Cochlear Nerve Preservation**

Patients were placed prone on bolsters with the head supported by the Gardner three-point fixation headrest and turned 20° to the side of the tumor. A standard unilateral suboccipital craniotomy was performed through a sigmoid-shaped incision approximately one-third of the way from the mastoid process to the inion. After a three-hole free bone flap was turned, additional bone was removed superiorly and laterally to expose the inferior edge of the transverse sinus and the medial edge of the sigmoid sinus. Care was taken to expose the junction of the transverse and sigmoid sinuses and to occlude the mastoid air cells which were almost invariably opened. The dura was opened in cruciate fashion with the superolateral incision extending to the junction of the two sinuses, and the inferomedial incision sufficiently low to allow cerebrospinal fluid (CSF) to be drained from the cisterna magna, a procedure easily accomplished by retraction of the cerebellar hemisphere. It was usually unnecessary to extend the bone incision to the foramen magnum. In patients with larger
tumors or hydrocephalus, CSF drainage was established through a ventricular catheter inserted via a posterior parietal burr hole. Even with smaller tumors, mannitol was administered prior to dural opening, if the dura was tense. However, drainage of CSF from the cisterna magna produced sufficient dural relaxation in most cases.

The Greenberg self-retaining brain retractor was used for medial retraction of the cerebellar hemisphere. Then, the ninth, 10th, and 11th cranial nerves were identified either before or after the arachnoid was divided between the cerebellum and these nerves at the jugular foramen. Division of the arachnoid allowed safe retraction of the cerebellum, and usually permitted complete visualization of smaller tumors although the medial surface of larger tumors remained obscured by the overlying or adherent cerebellum and pontomedullary junction. The flocculonodular lobe of the cerebellum was then easily visualized and retracted medially so that the tela choroidea of the fourth ventricle could be identified. The tela was a good anatomical landmark for it almost always lay over the origin of the eighth nerve at the pontomedullary junction. With smaller tumors of 1 cm or less, it was usually then possible to see the entire course of the eighth nerve from the brain stem to the inferior aspect of the porus acusticus, where the nerve lay alongside the posteroinferior aspect of the tumor. However, with larger tumors, the intermediate portion of the eighth nerve was usually covered by the overlying tumor, and was not visualized until a portion of the tumor was removed.

Before removal of small or entirely intracanalicular tumors, the posterior wall of the internal auditory canal was removed with an air drill. The dura of the canal wall lining was preserved. However, with larger tumors, the central mass of the tumor was gutted before the canal was opened. The contents were removed through a window in the posterior aspect of the tumor capsule with small, specially designed straight and curved tumor dissectors and cup forceps of varying sizes. In drilling the posterior canal wall, care was taken to avoid entering the posterior semicircular canal, and to occlude any air cells encountered so as to avoid a postoperative CSF leak. It was helpful to probe the depth and direction of the canal with a long blunt nerve hook. The transverse length of the canal could also be estimated from the tomograms.

Dissection of the seventh and eighth nerves then proceeded, and in most instances the nerves were followed in a medial-to-lateral direction. The eighth nerve was best located at its exit from the brain stem just medial to the tela choroidea of the fourth ventricle. With larger tumors, extreme care was necessary at this point because the medial edge of the tumor was often adherent to the brain stem, in which case there was usually one or more arteries or veins passing between the tumor capsule and the brain stem at the eighth nerve origin. By exerting slight lateral traction on the tumor capsule these vessels were either dissected free or, if necessary, coagulated at low bipolar current with microforceps, with care taken to avoid contact with the nerve. Care should be taken here to avoid dividing any large vessel running to the nerve rather than to the capsule as this might be the artery of the internal auditory canal or another important vessel supplying the cochlea.

It was usually possible at this point to identify the facial nerve at the pontomedullary junction medial and anterior to the eighth nerve. Confirmation of the identity of the facial nerve was obtained by stimulating it with an electrode at 0.2 to 0.6 V and 10 Hz, and recording the muscle action potentials with a needle electrode in the orbicularis oris.16 The remaining tumor in the CPA was then elevated away from the nerves, working from a medial-to-lateral direction almost to the porus acusticus.

Attention was then directed to the fundus or lateral end of the internal auditory canal, where the facial and cochlear nerves were displayed by opening the dura along the posterior canal wall and by elevating the tumor away from the nerves in a lateral-to-medial direction. At this point, the magnification of the microscope was increased. Most acoustic neuromas extended to the lateral end of the canal with no CSF persisting in the canal; however, in two patients, a small amount of CSF persisted laterally. Almost all the acoustic tumors of which the origin was identifiable arose within the superior vestibular nerve. However, the lateral stump of this nerve was not always infiltrated by tumor and could often be dissected away from the facial nerve, which lay anteriorly and superiorly in the lateral third of the canal. The identity of the facial nerve in the canal was then confirmed by electrical stimulation. The facial nerve lay superior to the cochlear and inferior vestibular nerves, with the latter posterior to the cochlear nerve. When possible, the inferior vestibular nerve was left intact as a support for the cochlear nerve. Care was taken to avoid dissecting anteriorly and inferiorly in the internal auditory canal to prevent damage to the cochlear nerve. In several cases, intraoperative auditory evoked brain-stem potentials were recorded in an attempt to detect operative interference with the cochlear nerve. Indeed, in some cases, there was a reduction in the amplitude of Wave 5 during dissection of the cochlear nerve. After identification of the facial and cochlear nerves both medial and lateral to the porus acusticus, the remainder of the tumor was dissected from the nerves, working from both directions toward the porus, where the nerves were almost invariably the most attenuated and at greatest risk of damage from dissection.

There was often difficulty in distinguishing the cochlear from the vestibular nerves in the CPA. Usually, the cochlear nerve appeared whiter and had a small vessel on its posterior surface, whereas the vestibular nerves tended to be grayish and "gelatinous" in appearance, without surface vessels. At or near the brain stem, there was almost invariably a large artery and/or vein between the cochlear and vestibular nerves and a large artery
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Fig. 2. Preoperative (solid line) and postoperative (broken line) audiograms in the six patients with hearing preserved after acoustic neuroma removal (see Table 3). SRT = speech reception threshold (dB); S.D. = speech discrimination score (%); NR = not recordable. a-c: Unmasked air conduction studies in the right ear. d and e: Unmasked air conduction studies in the left ear. f: Studies in the right ear: unmasked air conduction (circles), masked air conduction (open triangles), and masked bone conduction (closed triangles).

separating the facial nerve from the cochleovestibular bundle. In some instances there was as much as a 2-mm separation of the facial and cochleovestibular bundle at the brain stem, although the average was approximately 1 mm. In the minority of cases, the seventh and eighth nerves were adherent to each other at the brain stem.

Following total tumor removal, the dura was closed in watertight fashion. The bone flap was replaced and held with wire sutures through small drilled holes.

Results

Table 2 shows the operative results in 23 cases with attempted preservation of the cochlear nerve. Of the 19 patients with unilateral acoustic neuromas, the cochlear nerve was preserved in 16 (84.2%), but in only six patients (31.6%) was hearing preserved postoperatively. The largest tumor that was removed with preservation of both the cochlear nerve and hearing was 2.0 x 1.5 cm. The tumors were completely excised in all 19 patients. Figure 2 shows the results of the pre- and postoperative audiograms in these six patients.

The patient with bilateral acoustic neuromas had neurofibromatosis, and the acoustic neuroma on one side had been removed several years earlier with resulting complete unilateral deafness. The remaining tumor was 5.0 x 5.0 cm, and therefore a partial excision was performed in the hope that her adequate preoperative hearing would be preserved. Unfortunately, she was deaf postoperatively even though an intracapsular removal was performed without dissection of the internal auditory canal. Accordingly, a second procedure was performed 3 weeks later with complete excision of the remaining tumor. The cochlear nerve was preserved in all three patients with tumors other than acoustic neuromas, with postoperative preservation of hearing in all of them.

In the six patients with unilateral acoustic neuromas with postoperative hearing preservation, there was deterioration in the speech reception threshold in five, and deterioration in the speech discrimination score in two (Table 3) as compared with preoperative levels. Conversely, postoperative improvement in speech reception threshold was noted in one, and in speech discrimination score in four. In the two patients with petrous bone meningiomas, the pre- and postoperative hearing records were similar, and in the patient with

<table>
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<tr>
<th>Type of Tumor</th>
<th>No. of Cases</th>
<th>Preservation of Cochlear Nerve No.</th>
<th>Postop Hearing Preservation Percent</th>
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<tr>
<td>unilateral acoustic neuroma</td>
<td>19</td>
<td>16 84.2</td>
<td>6 31.6</td>
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<td>1</td>
<td>1 100</td>
<td>0 0</td>
</tr>
<tr>
<td>other</td>
<td>3</td>
<td>3 100</td>
<td>3 100</td>
</tr>
<tr>
<td>no. of cases</td>
<td>23</td>
<td>20</td>
<td>9</td>
</tr>
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Table 2 Preserves of cochlear nerve and hearing in 23 attempts

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neuromas with preservation of the facial nerve, the goal of cochlear nerve preservation restricts the choice to only two, the suboccipital route, as used here, or the middle fossa transtemporal approach described in 1961 by House and in 1962 by Kurze and Doyle. The middle fossa approach continues to be used by some with a high incidence of cochlear nerve preservation in patients with small tumors. For example, Fisch was able to preserve hearing function in four of 10 patients. We have had no personal experience with this approach. In 1954, Elliott and McKissock were the first to report cases of cochlear nerve preservation and preserved hearing associated with tumor excision by the posterior fossa route, and, in 1968, Rand and Kurzen reported cases with preserved vestibular nerve and vestibular function after total tumor removal. Since then, there have been numerous other reports of cochlear nerve preservation at surgery with persistence of useful hearing after total tumor removal; Hullay and Tomits preserved hearing in one of 50 cases in 1965, McKissock preserved hearing in five of 270 cases in 1965, Yaşargil preserved hearing in one of 270 cases in 1965, Yaşargil preserved hearing in two of 164 cases in 1978, and DiTullio, et al., reported hearing improvement after removal of a 3-cm acoustic neuroma, and in 1982, Wanxing reported hearing improvement after removal of a massive acoustic neuroma measuring 7 × 5.5 × 5 cm, although this particular tumor had no intracanalicular component, being totally in the CPA. Other recent positive reports include those of Sugita and Kobayashi, who preserved hearing in six of 14 patients, and Ojemann and Crowell, who recorded pre- and postoperative audiograms in their patient with excellent hearing preservation. Smith recently reported some hearing preservation in 13 of 19 patients, and Ransohoff and Cohen preserved the serviceable hearing (defined as a speech discrimination score of 60% or better) in the CPA epidermoid cyst there was marked improvement in hearing (Table 4).

Discussion

Our selection of surgical approach for total excision of unilateral acoustic neuromas depends upon two main criteria: the size of the tumor and the severity of the hearing loss. Tumors larger than 2.5 cm can be removed via the posterior fossa route or the combined lateral route, but it is our conclusion that the lateral route improves the possibility of facial nerve preservation and reduces operative morbidity. Large tumors cause so much distortion and thinning of the cochlear nerve that there is very little likelihood of avoiding further irreparable damage to the cochlear nerve, even in patients with good preoperative hearing. With tumors of 2.5 cm or less, the cochlear and facial nerves can almost always be identified and preserved. The second criterion, the presence of serviceable hearing as described above, relates to the preoperative condition of the cochlear nerve. The nerve with poor hearing is already too badly affected to withstand surgical trauma. Our definition of serviceable hearing differs slightly from that used by others as a criterion for attempted hearing preservation. For example, Brackmann recommended the translabyrinthine approach if the speech reception threshold is poorer than 50 dB and the speech discrimination score is less than 80%.

Although there are numerous surgical approaches that can be used to accomplish total removal of acoustic

### Table 3

Results in six acoustic neuroma patients with postoperative preservation of hearing

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Size of Tumor (cm)</th>
<th>Preop</th>
<th>Postop</th>
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<tr>
<td></td>
<td>SRT</td>
<td>SD</td>
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</tr>
<tr>
<td>1</td>
<td>2.0 x 1.3</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td>2</td>
<td>2.0 x 1.5</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>1.2 x 1.2</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>1.0 x 1.0</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>5</td>
<td>1.5 x 1.5</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>1.5 x 1.5</td>
<td>15</td>
<td>NR</td>
</tr>
</tbody>
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* SRT = speech reception threshold (dB); SD = speech discrimination score (%); NR = not recordable.

### Table 4

Results in three nonacoustic neuroma patients with postoperative preservation of hearing

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Diagnosis</th>
<th>Preop</th>
<th>Postop</th>
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<tr>
<td></td>
<td>SRT</td>
<td>SD</td>
<td>SRT</td>
</tr>
<tr>
<td>7</td>
<td>meningioma</td>
<td>55</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>meningioma</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>epidermoid cyst</td>
<td>NR</td>
<td>NR</td>
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</table>

* SRT = speech reception threshold (dB); SD = speech discrimination score (%); NR = not recordable.
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of other CPA tumors. They reported improvement in major preoperative hearing loss after removal of an epidermoid cyst. Improvement has also been reported after removal of a posterior fossa meningioma and a cerebellar cyst.12

Of the patients with preserved cochlear nerves who did not retain hearing postoperatively, the inner ear was entered in one, thus eliminating hearing. In the others, the reason the nerve did not function postoperatively is unknown. The possibilities include direct mechanical trauma to the nerve, interference with the blood supply to either the nerve or the inner ear, or postoperative edema of the nerve. The latter possibility was recently commented upon by Rand.20 This is being studied further with intraoperative recording of the auditory evoked brain-stem potentials or potentials from the cochlear nerve. The incidence of postoperative tinnitus was not higher in those with preserved cochlear nerves than in our other patients treated by the translabyrinthine route in whom the cochlear and vestibular nerves were interrupted.

It is of interest that one of the acoustic neuromas arose in the cochlear nerve itself, thus eliminating any possibility of hearing preservation. Indeed, of the 19 unilateral acoustic neuromas in which a definite site of origin could be determined, three arose in the inferior vestibular nerve, one in both the superior and inferior vestibular nerves, and one in the cochlear nerve. Hardy and Crowe9 found that two of six small acoustic neuromas arose in the cochlear nerve. We presume that most of the other tumors in our series arose in the superior vestibular nerve because we could identify an uninvolved inferior vestibular nerve in each case.

The facial nerve was spared in all 23 patients. In 18, facial nerve function was normal at follow-up examination, with only slight weakness in the remaining five. Thus, attempts to preserve the cochlear nerve do not compromise facial nerve preservation.

The attempt to preserve hearing is especially worthwhile in patients with bilateral tumors. In the one patient with bilateral acoustic neuromas in this series, the attempt failed even though a partial resection of this huge tumor was performed initially. The other patient with bilateral tumors had an intracanalicular petrous meningioma, and hearing was preserved. The results in this patient and in the other patient with a petrous meningioma are especially rewarding since both patients would have been rendered deaf if they had been operated on by the translabyrinthine approach, which in some centers is routinely used for small tumors regardless of the hearing status. These cases emphasize the advantages of a system of management of CPA tumors in which several surgical approaches are available, and selection is tailored to the individual patient.

References


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Address reprint requests to: Charles H. Tator, M.D., Division of Neurosurgery, Toronto Western Hospital, 399 Bathurst Street, Toronto, Ontario M5T 2S8, Canada.