Hearing preservation in acoustic neurinoma surgery

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The authors have reviewed results obtained in 99 patients operated on via the suboccipital approach for acoustic neurinoma, who were not deaf prior to surgery (pure tone average < 70 dB). Tumor size was less than 10 mm in four cases, 10 to 19 mm in 26 cases, 20 to 29 mm in 39 cases, and 30 mm or greater in 30 cases. Removal was macroscopically complete in 92 cases and incomplete in seven, including four cases with bilateral acoustic neurofibromatosis. Hearing was preserved in 29 patients (29.3%), of whom 23 had neurinomas smaller than 30 mm and six had tumors exceeding 30 mm in size. Postoperative hearing was good in eight cases (four with neurinomas < 20 mm and four with neurinomas > 20 mm), serviceable in four cases (three with neurinomas < 20 mm and one with a tumor > 30 mm), and poor in 17 cases (eight with neurinomas < 20 mm and nine with tumors > 20 mm). Fifty-seven patients underwent intraoperative brain-stem auditory evoked potential monitoring: the rate of hearing preservation was found to be higher in this group than in the 42 without monitoring (p < 0.05). A statistical study using stepwise regression analysis showed that the two preoperative factors most significantly associated with postoperative hearing preservation are a good auditory level for low frequencies measured by pure tone audiometry and a small-sized tumor. Overall results indicate that, even if hearing is more easily preserved when the neurinoma is small and the preoperative auditory condition is good, the surgeon should try to save hearing in all patients who have preserved hearing before surgery.

Key Words • acoustic neurinoma • suboccipital approach • hearing • audiometry • brain-stem auditory evoked potentials • intraoperative monitoring

The arguments put forward in the old debate regarding the most appropriate route for acoustic neurinoma surgery have evolved over the past few years. Until recently, in the large series treated by qualified surgeons using the translabyrinthine route13, 23,31 or the suboccipital route,10,25,29 the mortality rate ranged from 1% to 5% and the rate of success in preserving facial nerve function was 80% to 90%. Since 1985, overall results have been improved steadily and hearing preservation has increasingly been documented.14,17,20,22,23 However, the successful results reported were chiefly obtained with smaller neurinomas. Furthermore, according to many authors,1,11,13,15,16,19,24,28,29 it seems that attempting to preserve hearing is worthwhile only in patients with neurinomas smaller than 20 mm. In 1980, the successful preservation of hearing, with restitutio ad integrum, in a patient after excision of a 30-mm neurinoma3 led us to reject such opinions, in agreement with other authors.17,20,22 Retrospective analysis of our series of 270 cases of acoustic neurinomas operated on by the suboccipital route between 1970 and 1989 and, above all, our experience over the past 10 years has enabled us to evaluate prognostic factors of hearing preservation and to report our hearing preservation results.

Clinical Material and Methods

Patient Population

Our experience is based on 314 operations for acoustic neurinoma performed between 1970 and 1989. Of these, 270 were carried out by the suboccipital route at the Hôpital Neurologique Pierre Wertheimer in Lyon, France, by one surgeon (G.F.). Our series included 243 patients; 24 patients had bilateral neurinoma, some of whom underwent several operations.

This study is retrospective. All operations conducted by the suboccipital route for removal of an acoustic tumor responsible for loss of hearing (< 70 dB measured as the pure tone average (PTA)) have been included. By this standard, 141 patients suffered from preoperative deafness and 102 did not. The present
Hearing preservation in acoustic neurinoma surgery

study deals with 102 acoustic tumor patients with some degree of hearing prior to surgery who underwent surgical removal by the suboccipital route between 1970 and 1989. Three patients (2.9%) died; thus, the preand postoperative hearing status was studied in 99 patients (60 women and 39 men). The mean age of patients with unilateral neurinoma was 46.8 ± 1.36 years (range 21 to 69 years) and the mean age of patients with bilateral neurinoma was 25.1 ± 2.63 years (range 16 to 58 years). There were 50 operations for left-sided neurinomas and 49 for right-sided tumors. Of the 99 patients, 14 had bilateral acoustic neurefibromatosis (eight women and six men); three of these patients were operated on bilaterally.

**Measurement of Neurinoma Size**

All 99 patients underwent computerized tomography (CT) and those who were operated on more recently were also examined by magnetic resonance (MR) imaging. The size of the tumors was measured from scans of axial sections encompassing the whole tumor. For each neurinoma, four measurements were used: 1) the tumor size in the cerebellopontine angle parallel to the porus acusticus; 2) the largest size of the tumor growth into the cerebellopontine angle from the plane of the porus acusticus; and 3) the size of the tumor development lengthwise inside the internal auditory canal; and 4) the sum of Measurements 2 and 3. The largest size observed was used for determining the neurinoma grade according to the classification of Koos, et al.:18 in 61 cases, this was Measurement 4, which includes internal auditory canal growth. In other cases, because of the shape and growth of the neurinoma in the cerebellopontine angle, Measurement 1 was used (16 cases). Measurements 1 and 4 were equal in 22 cases. According to the classification system, tumors less than 10 mm were in Grade I; they corresponded to internal auditory canal neurinomas. Tumors measuring 10 to 19 mm were in Grade II, those measuring 20 to 29 mm were in Grade III, and those measuring 30 mm or greater were in Grade IV. We observed four neurinomas in Grade I (4.1%), 26 in Grade II (26.2%), 39 in Grade III (39.4%), and 30 in Grade IV (30.3%). Thus, 69 (69.7%) of 99 patients had neurinomas exceeding 20 mm (Table 1). In contrast, in our overall series of 270 neurinomas operated on by the suboccipital route, 92% of the tumors exceeding 20 mm were among the 156 neurinomas responsible for preoperative loss of hearing greater than 70 dB. All patients were examined postoperatively by CT before the 10th day, then again 1 year later, and then every 3 years (or earlier in case of hearing level decrease).

**Audiometric Examination**

All pre- and postoperative audiometric examinations were carried out by the same otorhinolaryngology department team in our hospital. Evaluation was performed for all patients within 1 to 4 days prior to surgery, consisting of: PTA with contralateral ear masking 30 dB lower, speech discrimination score (SDS), and speech reception threshold (SRT) when the last two parameters proved measurable. When possible, audiometric examination was carried out on the 10th postoperative day, otherwise before the 3rd postoperative month. The patients whose hearing was preserved after surgery had yearly audiometric examinations.

Three classes of hearing results (pre- and postoperative) are presented according to the Los Angeles group classification.28 The breakdown of these results is as follows: Class A = good (SRT < 30 dB and SDS > 70%); Class B = serviceable (SRT < 50 dB and SDS > 50%); and Class C = measurable (any measurable hearing). We also indicate the PTA value, following the recommendations of Gardner and Robertson.

**Brain-Stem Auditory Evoked Potentials**

The functional condition of auditory pathways has been evaluated by brain-stem auditory evoked potentials (BAEP's) since 1981. Preoperative recording of BAEP's during the 4 days preceding surgery was carried out for 85 of the 102 acoustic neurinomas. Recordings were repeated within 2 weeks following surgery and again before the 3rd postoperative month, then once a year, in association with the audiometric examination, in those patients who had no loss of hearing.

Intraoperative BAEP monitoring has been performed since 1984 in 57 patients of our series whose BAEP's were present before surgery, therefore in whom BAEP monitoring was technically possible. The technique used has been discussed in a previous publication.4 The following categories were used: 1) persistence of waves I and V at the end of surgery; 2) only wave I persists at the end of surgery; 3) transiently abolished BAEP's; 4) total obliteration of all waves.

**Assessment of Facial Nerve Function**

The anatomical continuity of the facial nerve was assessed intraoperatively as either intact, bruised, or cut. Nerve function results were evaluated at 10 days, at 1 year, and then once a year. Three categories were used: excellent or good; fair; and poor or bad. This facial nerve grading system is simple and corresponds to the House-Brackmann scale13 proposed in 1985. The excellent or good score is equivalent to Grades I and II.

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**TABLE 1**

Tumor size in 99 patients with preoperative hearing

<table>
<thead>
<tr>
<th>Tumor Grade</th>
<th>No. of Cases</th>
<th>No. With Postop Hearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>II</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>III</td>
<td>39</td>
<td>8</td>
</tr>
<tr>
<td>IV</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>total cases</td>
<td>99</td>
<td>29</td>
</tr>
</tbody>
</table>

* Tumor size graded by the classification of Koos, et al.,18 as follows: I = < 10 mm; II = 10–19 mm; III = 20–29 mm; IV = ≥ 30 mm.
of the House-Brackmann scale, fair to Grade III, and poor or bad to Grades IV, V, and VI.

Surgical Approach

All of the patients in this series were operated on in the sitting position. The retrosigmoid suboccipital approach requires the creating of a lateral bone flap as well as resection of the mastoid process, allowing the sigmoid sinus to be exposed. The remaining mastoid cells are filled with bone wax and covered with a muscle fragment. The foramen magnum is opened only in cases of very large neurinomas. The dura mater is incised most laterally. Installation of the retractor is guided by BAEP monitoring in such a way that no traction will be exerted on the auditory tract. After the useful landmarks have been localized on the posterior aspect of the temporal bone, the internal auditory meatus, the fossa subarcuata, and (if possible) the endolymphatic fossula, the dura mater on the posterior lip of the internal auditory canal is incised flush with and parallel to the porus acusticus. A small dural flap with anterior base is cut as far as possible away from the area of the endolymphatic sac. This resection of the dura is the limit beyond which there is a risk of impairing the endolymphatic sac. The posterior wall of the internal auditory canal is drilled with a diamond drill-bit. Drilling should provide as wide an opening as required by the size of the intracanalicular tumor, yet care should be taken to avoid opening the posterior semicircular canal.

Tumor removal should be started at the level of the internal auditory canal. The facial nerve and the cochlear nerve are then identified. The labyrinthine arteries should, whenever possible, be kept intact. Dissection is continued, working inward from outside, following the courses of the cochlear and facial nerves. These nerves will be all the more protected as the arachnoid has been preserved. The vestibular nerves need not be spared. Tumor removal should be complete. This is performed by fragmentation, processing with gentle coagulation as possible, and (where patient hearing is still at stake) abstaining from using the ultrasonic surgical aspirator or the laser, which can have harmful indirect or uncontrollable effects. The drilling area in the internal auditory canal is refilled with bone wax and covered with a piece of fat. The risk of a cerebrospinal fluid leak is avoided by sealing the dura mater properly, using a procedure of aponeuroplasty and effecting restituto ad integrum of the overlying planes. A detailed description of our technique has been reported in a previous publication.1

Statistical Analysis

Both the chi-squared test and the paired or unpaired Student t-test were used for statistical analysis. Multivariate analysis using stepwise logistic regression was employed to identify factors of significance in predicting postoperative hearing preservation in relation to the following preoperative factors: patient age; side affected by the neurinoma; whether the tumor is uni- or bilateral; neurinoma measurements; PTA; hearing loss at 500, 1000, 2000, and 4000 Hz; SRT; SDS; results from BAEP recordings (increase in I–V interpeak latency, wave I alone, and absent BAEPs); I–V interpeak latency; and use of BAEP monitoring.

Results

Hearing preservation was observed in 29 (29.3%) of the 99 patients with neurinoma who were studied after surgery (Table 2).

Patient Age and Sex

The success rate was similar in the 61 patients under 50 years of age (29.5% success) as in the 38 patients over 50 years old (28.9% success). All 11 patients over 60 years old exhibited Class C results (any measurable hearing). The success rate was not significantly different among the 39 men (14 cases, or 36%) and the 60 women (15 cases, or 25%), and there was an identical distribution of Class A (good), B (serviceable), and C results.

Bilateral Acoustic Neurofibromatosis

Fourteen patients had bilateral neurinomas and 17 tumors were resected in this population. In only three cases (17.6%) was some hearing preserved (two Class B and one Class C) after tumor removal that was deliberately incomplete in order to save some degree of hearing in these patients whose other ear was already deaf due to the contralateral neurinoma.

Size of Neurinoma

Hearing was preserved in 23 patients with a tumor smaller than 30 mm (Grades I, II, and III). The rate of hearing preservation and neurinoma size were inversely proportional: there was a 75% success rate in the Grade I tumors (three of four cases), 46% in the Grade II tumors (12 of 26 cases), 20.5% in the Grade III tumors (eight of 39 cases), and 20% in the Grade IV tumors (six of 30 cases). But, remarkably enough, although the success rate for the 30 tumors smaller than 20 mm was 50% (15 of 30 cases), that for tumors 20 mm or larger was as high as 20% (14 of 69 cases). The quality of preserved hearing in patients operated on for neurinomas 20 mm or larger was really noteworthy: four with Class A results, one with a Class B result, and nine with Class C results (Table 2).

Hearing was preserved in 34% of patients with left-sided neurinomas (17 of 50 cases) and 24% of those with right-sided neurinomas (12 of 49). This difference was not significant.

Extent of Removal

Removal of the neurinoma was macroscopically complete in 92 cases. Recurrent neurinoma was found in eight patients, including seven patients with bilateral neurinoma, within 3 to 14 years. Of the seven neurinomas with macroscopically incomplete removal, four had recurrences within 4 to 12 years (these were patients

G. Fischer, C. Fischer, and J. Rémond
Hearing preservation in acoustic neurinoma surgery

### TABLE 2
Pre- and postoperative data in 29 patients with preserved hearing*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Tumor Grade†</th>
<th>Preoperative Hearing</th>
<th>Postoperative Hearing</th>
<th>Facial Nerve Function‡</th>
<th>Follow-Up Interval (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PTA (dB)</td>
<td>SRT (dB)</td>
<td>SDS</td>
<td>Class‡</td>
</tr>
<tr>
<td>1</td>
<td>40, F</td>
<td>I</td>
<td>3.3</td>
<td>0</td>
<td>95%</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>45, F</td>
<td>III</td>
<td>3.3</td>
<td>15</td>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>3†</td>
<td>17, M</td>
<td>III</td>
<td>6.6</td>
<td>20</td>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>23, F</td>
<td>IV</td>
<td>1.6</td>
<td>0</td>
<td>95%</td>
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<tr>
<td>5</td>
<td>32, F</td>
<td>I</td>
<td>35.4</td>
<td>45</td>
<td>90%</td>
<td>B</td>
</tr>
<tr>
<td>6</td>
<td>50, M</td>
<td>II</td>
<td>1.6</td>
<td>30</td>
<td>90%</td>
<td>B</td>
</tr>
<tr>
<td>7</td>
<td>43, M</td>
<td>II</td>
<td>31.6</td>
<td>30</td>
<td>90%</td>
<td>B</td>
</tr>
<tr>
<td>8</td>
<td>25, F</td>
<td>IV</td>
<td>35</td>
<td>45</td>
<td>60%</td>
<td>B</td>
</tr>
<tr>
<td>9</td>
<td>59, M</td>
<td>I</td>
<td>33.3</td>
<td>25</td>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>47, F</td>
<td>II</td>
<td>5</td>
<td>25</td>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>11</td>
<td>52, F</td>
<td>II</td>
<td>6.6</td>
<td>5</td>
<td>80%</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>35, M</td>
<td>IV</td>
<td>13.3</td>
<td>0</td>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>60, F</td>
<td>II</td>
<td>30</td>
<td>0</td>
<td>85%</td>
<td>A</td>
</tr>
<tr>
<td>14‡</td>
<td>19, F</td>
<td>II</td>
<td>8.3</td>
<td>0</td>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>15</td>
<td>52, F</td>
<td>II</td>
<td>20</td>
<td>25</td>
<td>100%</td>
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</tr>
<tr>
<td>16</td>
<td>43, M</td>
<td>IV</td>
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</tr>
<tr>
<td>17</td>
<td>50, M</td>
<td>II</td>
<td>26.6</td>
<td>45</td>
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<tr>
<td>18</td>
<td>52, F</td>
<td>III</td>
<td>36.6</td>
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<tr>
<td>19‡</td>
<td>17, F</td>
<td>II</td>
<td>48.3</td>
<td>30</td>
<td>70%</td>
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<tr>
<td>20</td>
<td>44, F</td>
<td>III</td>
<td>31.6</td>
<td>25</td>
<td>70%</td>
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</tr>
<tr>
<td>21</td>
<td>33, M</td>
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<td>48.3</td>
<td>45</td>
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<tr>
<td>22</td>
<td>59, M</td>
<td>IV</td>
<td>41.6</td>
<td>40</td>
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<td>B</td>
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<td>23</td>
<td>54, F</td>
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<td>46.6</td>
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<td>45%</td>
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<td>24</td>
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<td>II</td>
<td>33.3</td>
<td>55</td>
<td>95%</td>
<td>C</td>
</tr>
<tr>
<td>25</td>
<td>43, M</td>
<td>II</td>
<td>46.6</td>
<td>55</td>
<td>85%</td>
<td>C</td>
</tr>
<tr>
<td>26</td>
<td>42, F</td>
<td>II</td>
<td>31.5</td>
<td>60</td>
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<td>C</td>
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<td>III</td>
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<td>50</td>
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<td>28</td>
<td>43, M</td>
<td>III</td>
<td>30</td>
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<td>60%</td>
<td>C</td>
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<tr>
<td>29</td>
<td>59, F</td>
<td>III</td>
<td>51.6</td>
<td>60</td>
<td>45%</td>
<td>C</td>
</tr>
</tbody>
</table>

* Abbreviations: PTA = pure tone average; SRT = speech reception threshold; SDS = speech discrimination score; R = recurrence.
† Tumor size graded by the classification of Koos, et al., as follows: I = < 10 mm; II = 10-19 mm; III = 20-29 mm; IV = ≥ 30 mm.
‡ Hearing classification: A = good, SRT < 30 dB, SDS > 70%; B = serviceable, SRT < 50 dB, SDS > 50%; C = any measurable hearing, PTA < 70 dB.
§ Facial nerve function: 1 = excellent or good; 2 = fair; 3 = poor.
‡ This patient suffered from bilateral acoustic neurofibromatosis.

...and one had a Grade IV tumor. The latter (Case 4), who showed an excellent result, had excellent preoperative hearing which was preserved after surgery.

Following surgery, four (13.8%) of 29 cases were rated as having Class B hearing. All had been rated Class A before surgery. Postoperatively, 17 cases (58.6%) were rated as having Class C hearing; preoperatively, seven of these had Class C hearing, six had Class B hearing, and four had Class A hearing (Table 2). The overall success rate in the 99 patients with a preoperative PTA lower than 70 dB was therefore 29.3%. Before surgery, the mean PTA for the 29 patients in whom hearing was preserved after surgery was 26.1 ± 3.11 dB, and that of patients whose hearing was not preserved was 31.2 ± 1.93 dB (difference not significant). After surgery, the mean PTA in the 29 patients whose hearing was preserved was 40 ± 3.7 dB (p < 0.001).

**Brain-Stem Auditory Evoked Potentials**

Of the 29 patients with preserved hearing, 26 had undergone preoperative BAEP recording, yielding the

J. Neurosurg. / Volume 76 / June, 1992

913
following results: one case was normal and 25 were abnormal (increased I-V interpeak latency in 20 cases and presence of only wave I in five cases). Only two cases exhibited contralateral abnormalities (increased III-V interpeak latency), and in three cases the contralateral evoked response was abolished by the presence of a bilateral neurinoma. During the first postoperative recording, the one case rated as normal before surgery remained normal after surgery. Likewise, the 25 cases rated as abnormal before surgery remained in the abnormal range.

Among the 99 patients included in this study, 42 patients had no intraoperative BAEP monitoring, either because they were operated on before this technique was available at our hospital or because the quality of their evoked potential response was insufficient for effective intraoperative monitoring. Hearing was preserved in seven of these 42 unmonitored patients. Of the 57 patients who were monitored, hearing was preserved in 22. Upon completion of surgery, results of BAEP monitoring were as follows (Table 3): persistence of waves I and V in 14 cases (postoperative hearing results: five patients rated Class A, one rated Class B, and eight rated Class C); persistence of wave I only in five cases (postoperative hearing results: five cases rated Class C); and obliteration of BAEP’s during the last minutes of intraoperative monitoring but presence of BAEP’s on the postoperative recording in three cases (postoperative hearing results; all three patients rated Class C).

Thus, the number of patients with preserved hearing proved better in the monitored group (22 of 57 cases) than in the unmonitored group (seven of 42 cases) ($p < 0.05$). Hearing was lost in 35 of the 57 monitored patients; at the end of monitoring, BAEP’s were totally abolished in 26 patients and only wave I persisted in nine other patients; no patient retained wave V.

Long-Term Follow-Up Study

Hearing Results. The 29 patients in whom hearing was preserved after surgery (eight with Class A hearing, four with Class B hearing, and 17 with Class C hearing) were followed as outpatients for periods ranging from 2 to 12 years. Postoperative results remained unchanged from the date of surgery in 20 patients (seven with Class A hearing, three with Class B hearing, and 10 with Class C hearing) at follow-up intervals of 2 to 12 years. Postoperative results declined in nine patients (one with Class A hearing, one with Class B hearing, and seven with Class C hearing) at follow-up intervals between 2 and 10 years. Of those nine patients, three suffered postoperative recurrence (one within 2 years and two within 3 years). All three had bilateral acoustic neurofibromatosis. The other six patients exhibited no recurrent pathology on CT or MR imaging at 8 years (Case 10), 4 years (Case 16), 10 years (Case 21), 3 years (Cases 22 and 28), and 6 years (Case 23) postoperatively.

Secondary impairment of postoperative hearing always occurred within 4 years postoperatively. Such impairment affected seven patients whose postoperative hearing was rated as Class C (two of them with bilateral acoustic neurofibromatosis), one rated Class A (also with bilateral acoustic neurofibromatosis), and one rated Class B (without recurrence after 8 years).

Hearing Loss and Tinnitus. Among the 99 patients in our series, 70% lost hearing. Eight patients reported transient or faint tinnitus; only two of these had retained some postoperative hearing. In contrast, in the group of 29 patients with preserved postoperative hearing, 12 of the 15 who experienced tinnitus before surgery were free from it after surgery, and in the other three patients tinnitus remained faint and nondisturbing. Four of the 29 patients with hearing preservation, two of whom had bilateral acoustic neurofibromatosis, stated that they experienced increased comfort while using hearing aids.

Facial Nerve Function. The anatomical continuity of the facial nerve was preserved in all except one of the patients in this series. The facial nerve was left intact in 89 patients, was injured to some degree during dissection in nine patients, and in one patient could not be preserved. The long-term functional results ($\geq 2$ years after surgery) fell into three groups: Group 1 (excellent or good) included 65 cases (65.65%); Group 2 (fair) included 22 cases (22.22%); and Group 3 (poor or bad) included 12 cases (12.12%). The results of patients with some postoperative hearing are categorized as follows: 27 in Group 1, two in Group 2, none in Group 3 (Table 2).

Dysgeusia was present preoperatively in three patients but disappeared after surgery. Dysgeusia occurred postoperatively in three other patients. None of the patients in whom hearing was preserved complained of dysgeusia.

Postoperative Surgical Complications. Rhinorrhea was observed in three patients. Thrombophlebitis of a lower limb occurred in one patient (1%). The 99 patients with long-term monitoring suffered no permanent morbidity or other complications. They all resumed their normal way of life and their preoperative occupations. Of the total 102 patients in the series, three patients (2.9%) operated on before 1985 died: one from stroke, one from postoperative hematoma, and one from pulmonary embolism.

<table>
<thead>
<tr>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing results related to intraoperative brain-stem auditory evoked potential (BAEP) monitoring</td>
</tr>
<tr>
<td>BAEP Monitoring Results</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>wave I &amp; wave V preserved</td>
</tr>
<tr>
<td>only wave I preserved</td>
</tr>
<tr>
<td>transient obliteration</td>
</tr>
<tr>
<td>total obliteration</td>
</tr>
<tr>
<td>total cases</td>
</tr>
</tbody>
</table>

G. Fischer, C. Fischer, and J. Rémont | 914 | J. Neurosurg. / Volume 76 / June, 1992 |
Hearing preservation in acoustic neurinoma surgery

**Statistical Analysis**

Among the factors studied in the 99 patients with postoperative review, two preoperative factors correlated with postoperative preservation of hearing: hearing loss at 500 Hz and the size of the neurinoma. The SDS and SRT factors could not be entered in the study of the 99 patients as they were not measurable in some patients; however, in the statistical analysis concerning the 78 patients presenting all the factors including SRT and SDS, the size of neurinoma and hearing loss at 500 Hz were the most significant. Patient age, sex, PTA, SRT, and SDS were not significant. The rate of hearing preservation in the monitored patients proved hardly significant (p < 0.05).

**Discussion**

**Preservation of Hearing**

The literature dealing with hearing preservation during acoustic neurinoma surgery is abundant. Extrapolating from their own negative experience, Thomsen, *et al.* concluded that the chances of preserving hearing belonged in the realm of fiction. Yet the middle fossa approach is considered by those who currently use both this and the translabyrinthine approach the best option for patients whose preoperative hearing is still good (SRT < 30 dB and SDS > 70%) or serviceable (SRT < 50 dB and SDS > 50%).

There is a significant restriction, however, since according to them the tumor should not exceed 15 mm in size. This is why some authors consider that the candidates for attempts at hearing preservation represent a minority of cases (not more than 5% of the total number of patients subjected to acoustic nerve tumor removal). Under the best circumstances, the success rate was 59% (57 of 97) for the Los Angeles group. Our experience, as reported here, prompted us to disregard this restriction concerning tumor size and preoperative hearing level. The cases reported with postoperative hearing preservation were too numerous to be coincidental.

It is not surprising that surgeons, who use the suboccipital route to approach neurinomas as well as other tumors occurring in this area, have acquired full control of the technique and can record very significant overall improvements, including a marked decrease in mortality (2%) and permanent morbidity rates. We agree with Jannetta, *et al.*, and Samii, *et al.* that “the surgeon should try to save hearing in all patients who have preserved hearing before surgery, despite size of tumor.” We agree with them all the more as our hearing results were obtained in a population with a higher number of neurinomas 20 mm and greater than neurinomas up to 20 mm (Table 1), the latter being known for ensuring better results (the smaller the neurinomas, the better the results). However, it should once again be emphasized that the best surgical route is always that which each surgeon knows best.

We share the wish expressed by several authors that the presentation of results should be clarified and standardized. Several types of classification have been proposed, in particular by Jannetta, *et al.*, and by Gardner and Robertson, who analyzed the results of 394 acoustic tumor removals. For the presentation of our results we adopted the classification of Koos, *et al.* for data on tumor size (with details about how to calculate them), the Los Angeles group classification for hearing results (with additional data on PTA values), and a three-level scoring method for postoperative facial nerve function using a simplified version of the House-Brackmann scale.

**Hearing Preservation and Extent of Tumor Removal**

Macroscopically complete removal of an acoustic neurinoma is sometimes difficult to achieve, whatever the surgical route employed. For a trained surgeon using the suboccipital route, preserving the patient’s hearing is the foremost concern. Final success can only be achieved by perfect management of the surgical approach, that is, by faultless drilling of the internal auditory canal performed without damaging the cochlear and facial nerves. Dissection must withstand three dangers that are totally unpredictable before surgery is started: 1) frequent variations of the course of the labyrinthine artery (the faint vascularization of the cochlea depends on this artery); 2) difficulty in separating the tumor from the cochlear and facial nerves owing to tumoral infiltration or reaction fibrosis to tumor-induced compression inside the internal auditory canal; and 3) difficulty in removing the distal portion of the neurinoma located in the most lateral portion of the auditory canal. Macroscopically complete removal of this last fragment has been the cause of several of our failures to preserve hearing. We always favored tumor removal at the expense of hearing preservation.

**Selection Criteria**

The patients who stand a good chance of retaining some level of hearing after surgery are those who still have useful hearing preoperatively. According to Josey, *et al.* this is defined as hearing in the involved ear with a PTA of at least 50 dB with at least 70% speech discrimination. However, the definition of serviceable hearing is not considered quite the same by most authors. In the present work, we have attempted to extend the scope of selection to all patients whose PTA was less than 70 dB. Actually, the suboccipital surgical procedure was performed routinely and was the same for all patients whatever their preoperative hearing level. This may account for our relatively low success rate (30%). Thus, the only criterion for selection was absence of deafness prior to surgery; this policy allowed us to attempt to preserve hearing in patients with Grade III and Grade IV neurinomas, cases that would have been rejected had the selection policy been focused on small-sized neurinomas only. Of course, hearing results prove better if neurinomas are small; this is confirmed both by the literature and by the present work as we
observed a 75% success rate with Grade I tumors, 46% with Grade II, and 20% with Grade III and Grade IV.

**Evoked Potential Monitoring and Hearing Preservation**

The value of intraoperative BAEP monitoring has been discussed in several reports and reviews published over the past few years. With a few exceptions, it can be admitted that patients in whom hearing was preserved exhibited wave I at the end of surgery. Persistence of wave V is literally a guarantee that hearing will be preserved. In our series, only a few patients exhibiting wave V had Class A (good) postoperative hearing. All those exhibiting only wave I had a postoperative hearing level rated Class C (only measurable hearing). In the present work, where all patients were operated on by the same surgeon, the percentage of patients in whom hearing was preserved was significantly higher in those who were operated on since intraoperative BAEP monitoring was introduced. It may, of course, be noted that during this period, when BAEP monitoring was routinely performed and when the rate of hearing preservation was statistically higher, acquired experience had much improved the surgeon’s skill. This might suffice to account for the better results obtained; however, there is no evidence that BAEP monitoring may have been superfluous. It is our opinion that, by enhancing the surgeon’s awareness of procedural steps that may endanger the cochlear function and a number of other operative parameters, BAEP monitoring is a useful technique in attempts to preserve hearing in acoustic neurinoma surgery.

**Causes of Hearing Loss**

Whenever hearing preservation has been deemed possible and desirable, one should try to analyze the mechanisms of intraoperative loss of hearing, with a view to improving the surgical procedure involved. The mechanisms of hearing loss are numerous and often cumulative. It has not been possible to determine the precise cause among all of our 70 patients who suffered loss of hearing during surgery. The cochlear nerve was sectioned in eight patients and injured in eight others. Among the 54 patients in whom the cochlear nerve was preserved, the vascular mechanism after coagulation of one labyrinthine artery was thought to be involved in 11 cases. The cause of hearing loss could not be traced with certainty in the other patients. However, some mechanisms of hearing loss were suspected. Intraoperative BAEP monitoring made it possible to identify certain mechanisms of hearing loss occurring during the surgical removal of acoustic neurinomas. When the BAEP disappears immediately on incision of the dura mater and before any manipulation of the nerve structures of the posterior fossa, the causative factor may be the disruption of a precarious balance within the cisternal system resulting in stretching or squeezing of the labyrinthine artery or its branches in the cerebellopontine angle.

Hearing is at risk when the self-retaining retractor exerts excessive traction on the auditory tract. For this reason, the position of the retractor should be adjusted according to the indications provided by BAEP monitoring. The physiopathology of the effects of cerebellar retraction has been thoroughly studied. The internal auditory canal should be drilled with caution so as to avoid injuring the nerve and vascular structures within it either directly or by drill-induced heat. While drilling, one should take care to avoid both cutting into the posterior semicircular canal and moving as far as the area of the endolymphatic sac. Even if not apparent in some cases, any damage to the endolymphatic sac will cause loss of hearing. During dissection and removal of the neurinoma, the BAEP may be modified by pressing or by direct or indirect traction exerted on the auditory tract, which should cause the surgeon to discontinue his action momentarily. Coagulation is always dangerous; it should be short and precise, and used as sparingly as possible. Transient changes in the BAEP are presumed to entail no risk of total hearing loss. Total and irreversible loss of BAEP is most frequently related to coagulation of a damaged vessel, preventing vascularization of the cochlea or the cochlear nerve. In the case of large neurinomas, the BAEP is seen to fade slowly and gradually but no single or precise mechanism can be identified as the causative factor of this loss. In our experiments, the most dangerous step for the BAEP and for hearing preservation is the removal of the very last tumor fragment located at the far end of the internal auditory canal, a step during which the bone, vessels, or nerve structures essential to hearing preservation may be injured. As a rule, the removal of neurinomas exceeding 20 mm in size entails risks of hearing loss caused by any local injury while traversing the cerebellopontine angle or at the level of the foramen of Luschka, owing to the risk of damaging the proximal labyrinthine arterial supply.

**Acknowledgments**

Special thanks are due to our colleagues of the Otorhinolaryngology Department, Hôpital Neurologique, Lyon. Above all, we are deeply grateful to Professor Jean-Paul Haguenauer and to Marie Morin. We are also grateful to Philippe Messy for statistical analysis of the data.

**References**

Hearing preservation in acoustic neurinoma surgery


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