Tumor origin and hearing preservation in vestibular schwannoma surgery

Clinical article

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Object. Preservation of cochlear nerve function in vestibular schwannoma (VS) removal is usually dependent on tumor size and preoperative hearing status. Tumor origin as an independent factor has not been systematically investigated.

Methods. A series of 90 patients with VSs, who underwent surgery via a suboccipitotemporal route, was evaluated with respect to cochlear nerve function, tumor size, radiological findings, and intraoperatively confirmed tumor origin. All patients were reevaluated 12 months after surgery.

Results. Despite comparable preoperative cochlear nerve status and larger tumor sizes, hearing preservation was achieved in 42% of patients with tumor originating from the superior vestibular nerve, compared with 16% of those with tumor originating from the inferior vestibular nerve.

Conclusions. Tumor origin is an important prognostic factor for cochlear nerve preservation in VS surgery. (DOI: 10.3171/2011.7.JNS102092)

Key Words • vestibular schwannoma • tumor origin • inferior vestibular nerve • superior vestibular nerve • hearing preservation

Hearing outcome in VS surgery is influenced by numerous factors. Tumor size and preoperative hearing status have been identified as the most important independent factors.\(^4,11,14,20–22\) A metanalysis by Khrais and Sanna\(^11\) in 2006, based on almost 2000 patients from 16 publications, revealed an inverse relation between preoperative hearing quality and tumor size and the preservation of postoperative hearing. Recently, tumor origin with respect to the IVN and SVN has also been addressed as a possible predictive factor,\(^4,9\) although identification both on preoperative MR imaging and during surgery may be difficult, particularly in tumors with complete obliteration of the IAC and in larger schwannomas.\(^4,6,10,12,13\)

Methods

A retrospective study with respect to intraoperative tumor origin and hearing outcome was undertaken in 90 patients who underwent surgery via a suboccipital route from a total series of 179 patients. Patients in whom intraoperative identification of tumor origin was not possible were not included (44 patients), as well as those with preoperative deafness, previous radiotherapy, and recurrent tumors (45 patients). All patients were treated by the senior author (C. Strauss), identification of tumor origin was performed by this author as well, and was based on intraoperative findings after careful preparation and dissection.

The average age of the patients was 47 years (range 20–71 years). The mean axial mediolateral tumor extension measured 25 mm, ranging from 6 to 56 mm. The mean intrameatal tumor size measured 8 mm, ranging from 0 to 15 mm; the mean extrameatal size measured 16 mm (range 0–50 mm). Hearing was classified according to the guidelines of the Committee on Hearing and Equilibrium for the evaluation of hearing preservation in acoustic neuroma of the AAO-HNS Foundation.\(^1\) Preoperative hearing was categorized as Class A in 30 patients, Class B in 24, Class C in 12, and Class D with residual hearing remnants in 24 patients. A suboccipital approach was used in all patients. Histological diagnosis was confirmed in all cases.
Intraoperative monitoring was performed using continuous facial nerve electromyography, based on multiple-channel recordings (orbicularis oris, nasalis, and orbicularis oculi muscles).\textsuperscript{17–19} Brainstem auditory evoked potentials were monitored in all patients.\textsuperscript{3,16} In 72 patients nimodipine (30 μg/kg body weight/hour) and hydroxyethylstarch (up to 2 × 500 ml/day) were given intravenously for 7–10 days following the surgical procedure, to improve postoperative microcirculation. Treatment was based on intraoperative brainstem auditory evoked potential patterns suggestive of delayed hearing loss (especially a temporary loss of wave V),\textsuperscript{16} or because the intraoperative presence of A trains on electromyography studies indicated a possible postoperative facial nerve deficit.\textsuperscript{3,24,25,27}

All patients were reevaluated within 1 year, including pure tone and speech audiometry and MR imaging.

**Results**

During surgery, the IVN could be identified as the site of tumor origin in 45 patients. In the other 45 patients, the SVN appeared as the nerve of origin (Figs. 1 and 2). For the intraoperative determination of tumor origin, the situation within the IAC and around its fundus proved to be of utmost importance. Preservation of cochlear nerve function was attempted in all 90 patients regardless of the extent of preoperative hearing loss. Definite hearing preservation was achieved in 26 patients. In 19 of them the tumor originated from the SVN, and in 7 patients it originated from the IVN. This difference was highly significant (p = 0.005, chi-square test).

**Comparability of Data**

**Preoperative Hearing.** As shown in Table 1, preconditions for hearing preservation did not vary between tumor origins. Preoperative hearing assessments showed comparable AAO-HNS classes in both groups (p = 0.766, Mann-Whitney U-test). For schwannomas originating in the SVN, Class A was seen in 15, Class B in 12, Class C in 8, and Class D in 10 patients. For IVN tumor origin, Class A was documented in 15, Class B in 12, Class C in 4, and Class D in the remaining 14 patients.

**Tumor Size.** Regarding the mean preoperative overall tumor size (maximal intra-/extrameatal axial diameter), tumors originating from the SVN were larger (26.1 mm, range 10–50 mm) compared with IVN schwannomas (22.9 mm, range 6–56 mm). This difference did not reach statistical significance (p = 0.080, Mann-Whitney U-test), but a tendency can be assumed. When comparing intra- and extrameatal extension separately, no relevant differences were documented (p = 0.743 for intrameatal extension, p = 0.120 for extrameatal tumor size; Mann-Whitney U-test).

We also compared sizes based on the classification developed by Koos, which in contrast to absolute sizes rather addresses anatomical relations to other cranial nerves and the brainstem, as well as chances for hearing preservation.\textsuperscript{14} For tumors arising from the SVN, Grade I was documented in 1 patient, Grade II in 7, Grade III in 21, and Grade IV in 16 patients. For tumors of the IVN, 5 tumors were classified as Grade I, 9 as Grade II, 20 as Grade III, and 11 tumors as Grade IV. No significant differences were seen between the 2 tumor origins (p = 0.09, Mann-Whitney U-test) with respect to the Koos classification. Because the chances for hearing preservation decrease with tumor size, we also calculated probabilities by using the chi-square test, grouping small (Grades I and II) versus large (Grades III and IV) schwannomas. No difference was seen (p = 0.141).

**Patient Age.** No significant differences were identified between the 2 groups regarding age. The mean age was 47 years in both groups, ranging from 21 to 71 years in the SVN group and from 20 to 68 years in the IVN group (p = 0.793, t-test).

**Completeness of Resection.** Gross-total resection was achieved and documented by MR imaging 1 year after surgery in 82 patients (91.1%). In the other 8 patients, capsule remnants had to be left. Five of these tumors originated from the SVN, resulting in a rate of gross-total resection of 88.9% for the SVN group and 93.3% for the IVN group. However, among patients with a capsule remnant there was only 1 with preserved hearing. In this case the tumor originated from the SVN, and the hearing classification was Class D pre- and postoperatively.

*Fig. 1.* Axial MR image (left) and intraoperative photograph (right) showing a tumor arising from the IVN. The lesion depicted is a left-sided tumor, resected via a suboccipitolateral approach. CN = cochlear nerve; VII = facial nerve.
Facial Nerve Outcome in Patients With Preserved Hearing. In the IVN group, preoperative facial nerve function was Grade I according to the House-Brackmann scale in all patients, and no deterioration was found on control studies. In the SVN cohort, facial nerve function was Grade I or II according to the House-Brackmann scale in all patients. Postoperatively, facial nerve function was unchanged or improved in 15 patients, and in 4 patients the nerve function deteriorated by a single House-Brackmann grade.

Factors Influencing Hearing Outcome

Hearing Preservation and Tumor Origin. As shown in Table 2, hearing was preserved in 26 patients. In 19 cases the tumor originated from the SVN, and in 7 the IVN was identified as the nerve of origin (Fig. 3 upper). This difference in hearing outcome proved to be statistically significant ($p = 0.0053$, chi-square test). Hearing quality revealed AAO-HNS Class A in 7 patients (1 IVN, 6 SVNs), Class B in 7 (2 IVNs, 3 SVNs), Class C in 6 (3 IVNs, 3 SVNs), and Class D with hearing remnants in 8 (1 IVN, 7 SVNs).

Hearing Preservation and Tumor Size. As expected, smaller tumors tend to have better hearing results. Based on the results presented in Table 2, tumor size was smaller in patients with preserved hearing ($p < 0.005$, Mann-Whitney U-test). This finding is consistent with previous studies demonstrating a correlation between tumor size and hearing preservation.

TABLE 1: Comparability of data with respect to tumor origin in 90 patients with VSs*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Tumor Origin</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>mean age in yrs</td>
<td>47 (21–71)</td>
<td>47 (20–68)</td>
</tr>
<tr>
<td>mean intrameatal extension in mm</td>
<td>8.2 (2–15)</td>
<td>8.1 (0–13)</td>
</tr>
<tr>
<td>mean extrameatal extension in mm</td>
<td>17.9 (0–45)</td>
<td>14.9 (0–50)</td>
</tr>
<tr>
<td>mean tumor size in mm</td>
<td>26.1 (10–50)</td>
<td>22.9 (6–56)</td>
</tr>
<tr>
<td>Koos grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>II</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>III</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>IV</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>AAO-HNS hearing class</td>
<td></td>
<td>0.766‡</td>
</tr>
<tr>
<td>A</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>

* Values in parentheses represent the range.
† Calculated according to the Student t-test.
‡ Calculated according to the Mann-Whitney U-test.

TABLE 2: Factors influencing hearing outcome in 90 patients with VSs

<table>
<thead>
<tr>
<th>Factor</th>
<th>Hearing Preservation (26 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>tumor origin</td>
<td>$p = 0.005$, chi-square test</td>
</tr>
<tr>
<td>total tumor size</td>
<td>$p &lt; 0.005$, Mann-Whitney U-test</td>
</tr>
<tr>
<td>extrameatal extension</td>
<td>$p &lt; 0.005$, Mann-Whitney U-test</td>
</tr>
<tr>
<td>intrameatal extension</td>
<td>$p = 0.688$, Mann-Whitney U-test</td>
</tr>
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</table>
The ongoing discussion on optimal treatment modalities and functional outcomes in VS treatment focuses on the issue of hearing preservation. Whereas isolated Gamma Knife centers report preservation rates up to 87% with unchanged hearing levels, at least in small tumors (1.7 mm) and young patients,15 a recent metaanalysis investigating 254 studies and more than 4000 patients has extracted an overall hearing preservation rate of 51%.29 No matter what treatment modality is applied, the social impact of unilateral deafness warrants every effort to improve hearing outcome.8 It is important for the surgeon to offer the patient a realistic perspective.

Tumor size and the quality of preoperative hearing are well-established prognostic criteria.4,9,14,20,21 These findings have been verified by a metaanalysis of 11 studies including 797 patients.25 In particular, an extrameatal tumor size of 10 mm and subsequently the extrameatal length of cochlear nerve adhesion have been addressed as isolated factors for hearing preservation. Medial schwannomas not extending into the IAC and tumors not completely obliterating the fundus also seem to be good candidates for hearing preservation,7 and even in large tumors, surprisingly reasonable hearing outcome has been reported.20 A primarily extrameatal growth pattern and little extension into the meatus seems favorable, because a free fundus results in less intrameatal pressure,7 and therefore may improve the chances for cochlear nerve preservation.25

Taking these established prognostic criteria into consideration, most surgical series contain patients with ideal characteristics, small tumors, excellent preoperative hearing, and yet complete postoperative hearing loss. Deafness occurs despite meticulous microsurgical techniques, despite intraoperative cochlear nerve monitoring, and despite perioperative neuroprotection with calcium channel blockers.3,24

In these patients, tumor origin could be of importance. The true origin ratio for VSs is not clear. Several studies, mostly based on data from the translabyrinthine approach, identified the IVN in between 70% and 90% of studies, mostly based on data from the translabyrinthine approach, identified the IVN in between 70% and 90% of studies, mostly based on data from the translabyrinthine approach, identified the IVN in between 70% and 90% of studies, mostly based on data from the translabyrinthine approach, identified the IVN in between 70% and 90% of cases as the nerve of origin.9,10,13 Other series, including ours, show a more balanced proportion.5 For the middle fossa approach, poor hearing results have been observed in patients with a tumor origin from the IVN.4 The close anatomical relationship between an IVN schwannoma and the cochlear nerve requires a more deliberate dissection, and thus may compromise blood supply and traumatize the cochlear nerve directly.9

In contrast to other authors,4,9 we performed a study specifically designed to evaluate the importance of tumor origin for hearing preservation. It features a standard neurosurgical, retrosigmoidal approach; a single surgeon; and a homogeneous patient population, especially regarding the preoperative hearing status. This series of 90 tumors with equal distribution of tumor origin (45 patients each) suggests that tumor origin is of at least equal importance to tumor size, because in 42% of IVN schwannomas hearing was preserved, compared with 16% preservation in tumors arising from the SVN. Patients were comparable in terms of age, tumor size, and preoperative hearing levels. We did observe a tendency toward larger tumor sizes in SVN schwannomas for both total axial diameter (p = 0.080, Mann-Whitney U-test) and the Koos classification (p = 0.09, Mann-Whitney U-test). Compar-
ing the prognostically important smaller tumor classes (Koos Grades I and II), which do have an impact on the chances for cochlear nerve preservation, we did not find a relevant difference between the 2 tumor origins. The same applied to the category “Preoperative hearing quality,” which showed identical distribution for prognostically relevant AAO-HNS Classes A and B. Class D, with a speech discrimination below 50%, was more often documented in tumors arising from the IVN.

It must be acknowledged that, despite comparable preconditions, good functional hearing was considerably more often preserved for Classes A and B in SVN schwannomas (3 in the IVN, 9 in the SVN).

Tumor size does matter. This becomes evident when comparing overall sizes in all 26 hearing (mean tumor size 20 mm) versus 64 deaf (mean size 26 mm) patients. This difference is statistically significant and clinically relevant (p = 0.003, Mann-Whitney U-test). Surprisingly, the mean tumor diameter for SVN schwannomas in patients with hearing preservation averaged 23 mm. This size was significantly larger compared with the 14-mm mean size in IVN schwannomas (p = 0.02, Mann-Whitney U-test). In conclusion, these data suggest that tumor origin might be more important than tumor size.

We could not identify the intrameatal extension as a prognostic factor, although in other studies on small series such an influence was observed. This is surprising, because data in the recent literature address a free fundus with CSF between the fundus and intrameatal tumor as a prognostic factor for favorable hearing results, particularly in larger extrameatal medial tumors. Again, this may point to the clinical relevance of tumor origin as an important prognostic factor.

Our results as well as those of others warrant a more systematic approach to tumor origin as an independent prognostic factor regarding hearing outcome, next to tumor size and preoperative hearing level.4,9 Vestibular testing does not yet sufficiently reveal the nerve of tumor origin.28 The same is true for specific MR imaging techniques such as 3D-construction interference in steady state imaging, which rely on a fundus free of tumor.6,12 Reliable preoperative information regarding tumor origin would actually be of value to meet the patient’s expectations and to individualize treatment strategies.

Conclusions

Tumor origin is an important predictive factor for hearing preservation in VS surgery. Tumors arising from the SVN are associated with a relevant chance for hearing preservation. Tumor size is important, although in the present series SVN schwannomas in patients with preserved hearing were significantly larger compared with schwannomas originating from the IVN.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Rachinger, Scheller, Strauss. Acquisition of data: Rachinger, Prell, Alfieri, Strauss. Analysis and interpretation of data: Rachinger, Rampp, Alfieri, Strauss. Drafting the article: Rachinger. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Rachinger. Statistical analysis: Rampp. Administrative/technical/material support: Prell, Scheller. Study supervision: Strauss.

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