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Optimal Extent of Resection in Vestibular Schwannoma Surgery: Relationship to Recurrence and Facial Nerve Preservation

Ho Jun SEOL*,***, Choong-hyo KIM*,***, Chul-Kee PARK**,***, Chi Heon KIM**,***, Dong Gyu KIM**,***, Young-Seob CHUNG**,***, and Hee-Won JUNG**,***

**Department of Neurosurgery, Kangwon National University College of Medicine, Chuncheon, R.O.K.; **Department of Neurosurgery, Seoul National University College of Medicine, Seoul, R.O.K.; ***Neuroscience Research Institute, Medical Research Center, Seoul National University, Seoul, R.O.K.*

Abstract

Surgical treatment of vestibular schwannoma is targeted at complete removal with preserved neurological function. Complete removal may cause significant deficits, whereas subtotal tumor removal is associated with a high recurrence rate. The present study assessed the risk of tumor recurrence and postoperative facial nerve function in relation to the extent of surgical resection by reviewing the clinical records and radiological findings of 116 patients with vestibular schwannoma treated between 1990 and 1999. The extent of resection was classified as follows: gross total resection (GTR), near total resection (NTR), and subtotal resection (STR). Facial nerve function was graded using the modified House-Brackmann grade, and patients grouped into good (grades 1–2) and intermediate or poor (grades 3–6). Of the 116 patients, 26 (22%) underwent GTR, 32 (28%) NTR, and 58 (50%) STR. The recurrence rates were 3.8% (1/26 cases), 9.4% (3/32), and 27.6% (16/58) for GTR, NTR, and STR, respectively. GTR and NTR showed no statistically significant difference in terms of recurrence rate ($p = 0.620$). However, recurrence was significantly less after NTR than STR ($p = 0.043$). Immediately postoperative facial nerve function was good in 15.4% of patients after GTR, 40.6% after NTR, and 46.6% after STR. The STR and NTR carried a lower risk of facial nerve palsy than GTR in the immediately postoperative stage ($p = 0.006$ and 0.036, respectively). Nevertheless, no statistical significance was observed in extent of resection and postoperative facial nerve outcome between the groups at last follow up ($p = 0.227$). GTR is the ideal surgical treatment for vestibular schwannoma, but NTR is a good option, with better facial nerve function preservation than GTR without significantly increasing the risk of recurrence.

Key words: vestibular schwannoma, near total resection, recurrence, facial nerve

Introduction

The neurosurgical treatment of vestibular schwannoma (VS) has two major goals: complete tumor removal and the preservation of facial nerve function.[5] Improved surgical methods now allow complete tumor removal with lower morbidity and mortality, but complete tumor removal carries a significant risk of facial nerve injury. The incidence of postoperative facial nerve palsy remains high at 37% to 80%, particularly for large tumors.[1,2,12] Partial tumor removal is less likely to cause facial nerve palsy, but the risk of tumor recurrence is high at 20% to 80%.[5,12] However, several recent studies have indicated that incomplete resection is not associated with a significant increase in recurrence rate.[5,9,10,12]

This retrospective study examined the recurrence rate and postoperative facial nerve function in relation to the extent of surgical resection.

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Materials and Methods

I. Patient population

Three hundred thirty-six patients with VS were

Table 1 Patient population

	No. of patients	Sex	Median age (year)	Mean tumor size (mm)	Median follow up (month)
GTR	26 (22%)	9:17	47	37.2	59
NTR	32 (28%)	11:21	44	41.1	48
STR	58 (50%)	23:35	45	39.5	60
Total	116	43:73	46	39.6	55

Sex: male:female. GTR: gross total resection, NTR: near total resection, STR: subtotal resection.

treated at Seoul National University Hospital during the period from 1978 to 2002. Patients with available records who underwent surgical resection for VS between 1990 and 1999 were retrospectively reviewed (N = 179). Data were obtained from the medical records, from our computerized brain tumor databank, and from imaging studies. Patients with neurofibromatosis (N = 27) and patients without complete medical records (N = 12) were excluded, as were 15 patients harboring unusually aggressive VS (annual growth rate > 15 mm/yr), as reported by our clinical institute in 2002.[8] A small tumor (≤ 20 mm) is not so difficult to remove totally with preservation of the facial nerve. Therefore, small VSs (N = 9) were also excluded. Eventually, 116 patients were included (43 males and 73 females, aged 19 to 73 years, median 46 years). The median follow-up period was 55 months (24–188 months). Patient demographics are summarized in Table 1.

II. Clinical features

The extent of tumor removal was evaluated using the operation records and postoperative magnetic resonance (MR) imaging. The degree of resection was classified as gross total resection (GTR), near total resection (NTR), and subtotal resection (STR).[5,10] NTR was defined as remnants of intracanalicular tumor or tumor adhering to the facial nerve or brainstem. STR was defined as resection of less than 95% of the tumor.[10]

GTR was performed only if a clear arachnoid plane was observed. If changes in intraoperative monitoring or vital signs during dissection of the tumor from the brainstem were detected, further radical extirpation was avoided. STR or NTR was planned in patients with advanced age or medical co-morbidities.

Facial nerve functions were graded using the modified House-Brackmann (H-B) grade,[7] and were obtained from postoperative records and the last follow-up examination. These grades were grouped into two categories: good (H-B grades 1–2), and intermediate or poor (H-B grades 3–6).[12]

III. Neuroimaging findings

Initial tumor size was based on the greatest extracanalicular dimension on preoperative MR imaging or computed tomography. Patients also underwent MR imaging within 3 months of the surgery to evaluate the extent of removal. The current protocol is to obtain MR images at 3, 6, and 12 months after surgery, and every year thereafter. Tumor recurrence or regrowth was defined as an increase in the greatest dimension on follow-up imaging.

IV. Statistical analysis

Commercially available software (SPSS for Windows, version 11.0; SPSS Inc., Chicago, Ill., U.S.A.) was used for statistical evaluation. Statistical significance was determined using the Pearson's chi-square test. A value of $p < 0.05$ was considered significant. The Kaplan-Meier method was used to compare the recurrence rates for GTR, NTR, and STR over the follow-up periods. The log-rank test was used for analyses of the groups.

Results

I. Surgical approach

GTR was performed in 26 (22%) of the 116 patients, NTR in 32 (28%), and STR in 58 (50%). All patients underwent unilateral surgery. The suboccipital approach was used in 100, the translabyrinthine approach in 11, the transcochlear approach in two, and the posterior transpetrosal approach in three. The suboccipital approach offers excellent exposure of the posterior fossa in most cases of large VS, but exposure of the internal auditory canal, especially the lateral one third, is hampered by the posterior semicircular canal and vestibule. The translabyrinthine approach offers excellent exposure of the internal auditory canal as well as the posterior fossa, but the auditory nerve has to be sacrificed. Therefore, this approach was used in not so large tumors (< 3 cm) and in patients with deafness. The transcochlear or posterior transpetrosal approach was used for large tumors (> 5 cm) which extended into the middle fossa.

Postoperative complications are shown in Table 2. There was no remarkable difference between the three groups. Only two cases of surgery-related mortality due to cerebral infarction occurred in the GTR group.

Table 2 Postoperative complications

	GTR	NTR	STR
Cerebrospinal fluid leakage	3	5	9
Infections	2	1	1
Cerebral infarction	2	0	0
Hydrocephalus requiring shunt	2	1	4
Death	2	0	0

GTR: gross total resection, NTR: near total resection, STR: subtotal resection.

Table 3 Tumor size and extent of resection, facial nerve preservation, and recurrence rate

Tumor size (mm)	No. of patients	GTR	Facial nerve preservation at last follow up	Recurrence rate
21–30	27	9 (33%)	15 (56%)	4 (15%)
31–40	41	11 (27%)	13 (32%)	6 (15%)
≥41	48	6 (13%)	22 (46%)	10 (21%)
Total	116	26 (22%)	50 (43%)	20 (17%)

GTR: gross total resection.

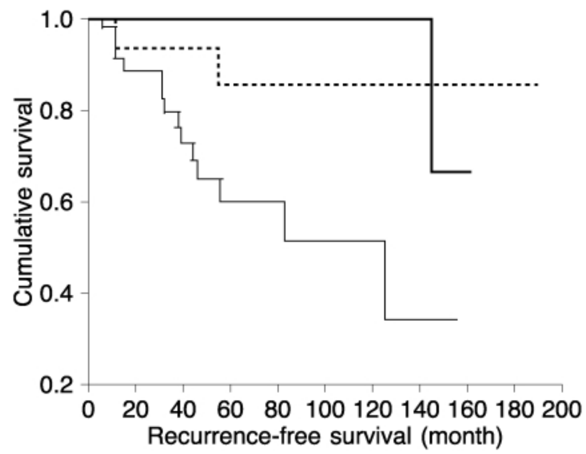

Fig. 1 Kaplan-Meier recurrence-free survival curve according to extent of resection. *thick line*: Gross total resection, *dotted line*: near total resection, *thin line*: subtotal resection.

II. Hearing and trigeminal nerve preservation

Because most of the tumors were large, unserviceable hearing loss (pure-tone audiogram threshold ≥50 dB) was detected preoperatively in 111 of 116 patients. Therefore, our surgical strategy was to remove the tumors as far as possible and to preserve the facial nerve, rather than to preserve the hearing, in many patients. Hearing was preserved in only two of the five patients (40%) with preoperative serviceable hearing loss. Disturbance of trigeminal nerve function was found as preoperative eye dryness in eight patients (6.9%), and postoperative eye dryness in 22 (19%).

III. Tumor size and regrowth

The mean tumor size was 39.6 mm (range 21 to 70 mm). The mean tumor size was 37.2 mm, 41.1 mm, and 39.5 mm in the GTR, NTR, and STR groups, respectively. Tumor size was not statistically related to recurrence ($p = 0.12$) or extent of resection ($p = 0.31$). However, tumor size was significantly related to postoperative deterioration of facial nerve function ($p = 0.001$). The relationships between tumor size and extent of tumor removal, facial nerve preservation, and recurrence rate are summarized in Table 3.

The overall growth rate of residual tumors was 0.6 mm/yr in the 81 patients with residual tumor on MR imaging at follow up of more than 2 years. The annual growth rate after STR ($N = 48$) was 0.8 mm/yr.

IV. Recurrence rate and the extent of resection

The recurrence rates for the GTR, NTR, and STR groups were 3.8% (1/26 cases), 9.4% (3/32), and 27.6% (16/58), respectively, and the time to recurrence ranged from 6 to 143 months (median 22 months). Ten patients with recurrent tumor underwent reoperation and 16 patients underwent stereotactic radiosurgery. Overall, the extent of resection was significantly related to the recurrence rate by Pearson's chi-square test ($p = 0.01$). There was no statistically significant difference between the recurrence rates of the GTR and NTR groups ($p = 0.620$). Nonetheless, the NTR and GTR groups showed less recurrence than the STR group ($p = 0.043$ and 0.012, respectively). The recurrence-free survival curve showed a significant difference between the three groups ($p = 0.003$) (Fig. 1). All recurrences arose from residual tumors in the internal auditory canal in the patients with NTR or STR.

V. Postoperative facial nerve function

Preoperative and postoperative (immediately after operation and at last follow up) facial nerve function is summarized in Table 4. Immediately postoperative facial nerve function was good in 13 (40.6%) of the 32 patients in the NTR group and in 27 (46.6%) of the 58 in the STR group, in contrast to four (15.4%) of the 26 in the GTR group. The extent of resection was significantly related to postoperative facial

Table 4 Preoperative and postoperative facial nerve function with extent of resection

House-Brackmann grade	GTR	NTR	STR
I	23/4/4	25/5/7	48/19/18
II	2/0/4	2/8/8	5/8/9
III	0/7/7	4/6/8	4/9/7
IV	1/10/8	1/11/7	1/20/22
V	0/0/0	0/0/0	0/1/1
VI	0/5/3	0/2/2	0/1/1

Grade was assessed preoperatively/immediately after surgery/at last follow up. GTR: gross total resection, NTR: near total resection, STR: subtotal resection.

nerve outcome ($p = 0.010$).

Good facial nerve function was preserved immediately after surgery in four (16.0%) of the 25 patients with good preoperative nerve function in the GTR group, 13 (48.1%) of 27 in the NTR group, and 27 (50.9%) of 53 in the STR group. The STR and NTR groups had a lower incidence of facial nerve palsy than the GTR group ($p = 0.006$ and 0.036, respectively). There was no significant difference between the STR and NTR groups ($p = 0.588$).

Facial nerve outcomes differed at the last follow up from the immediate postoperative results. Facial nerve function showed improvement in some patients. No statistical significance was observed between the extent of resection and postoperative facial nerve outcome ($p = 0.227$).

Discussion

Most of our patients underwent VS surgery for tumor removal with the aim of preservation of the facial nerve function. Only four patients required hearing saving operation, of whom one achieved serviceable hearing (pure-tone average < 50 dB, speech discrimination score $> 50\%$).[15] Our findings suggest that the risk of tumor recurrence after NTR is quite low. Substantial adherence of the tumor to the facial nerve presents a high risk of poor facial nerve outcome. Incomplete resection is helpful for preserving facial nerve integrity because the enlarged tumor compresses the facial nerve and the tumor-arachnoid membrane plane is lost.[3] Therefore, we tried to assess recurrence and postoperative facial nerve function in relation to the extent of surgical resection.

I. Tumor recurrence

Two previous studies have been conducted on the risk of recurrent tumor in relation to resection using similar GTR, NTR, and STR group definitions to the present study. Recurrence rates of 29% and 25% were reported for NTR (90–99% resection) and STR, respectively, but no recurrence occurred following GTR.[13] Recurrence rates were 12% and 65% for NTR (95–99% resection) and STR, respectively, with no recurrence after more than 98% resection.[5] These different recurrence rates for NTR and STR may have resulted from the use of different definitions for the extent of tumor resection.[13]

In the present study, NTR was defined as 95% to 99% tumor resection, with remnant tumor at the intracanalicular origin or adhering to the facial nerve or brainstem. Our recurrence rates were 3.8% for GTR, 9.4% for NTR, and 27.6% for STR, and the extent of resection was significantly related to the recurrence rate ($p = 0.01$). Only three recurrences occurred among patients who underwent NTR, whereas 29 patients showed no recurrence, and no statistically significant difference was observed between the recurrence rates of the GTR and NTR groups ($p = 0.620$). The NTR group showed less recurrence than the STR group ($p = 0.043$). Therefore, GTR is not always necessary and NTR is sufficient for prevention of recurrence. Thus, NTR is a good surgical strategy for VS in terms of recurrence risk. In contrast, STR is associated with a substantially higher risk of recurrence.

The low recurrence rate after NTR may be due to the results of surgical devascularization. The growth rate of VS appears to be governed by many factors, such as patient age, tumor size, and presence of von Recklinghausen's disease. However, cellularity and vascularity also affect growth rate.[8,9] Vascularization occurs due to tumor angiogenesis within VS larger than 2 cm. The principal factor affecting the postoperative growth potential of residual tumor is vascularity rather than cellularity.[9] The low recurrence rate of intracanalicular residual tumor is attributed to the devascularizing effect of surgery.

II. Facial nerve preservation

In our study, tumor size was significantly related to postoperative facial nerve function ($p = 0.001$). The correlation between postoperative facial nerve function and tumor size is generally accepted.[7,9] The incidence of facial nerve palsy was 80% for tumors greater than 2 cm in diameter.[11] The incidence of postoperative facial nerve paresis or paralysis was 46% for large tumors greater than 3 cm in diameter.[14] Tumor size is the most important predictor of facial nerve palsy.[6] Other predictors of facial nerve function are displacement of the fourth ventricle, image heterogeneity (necrosis, edema, cystic change), and the threshold stimulus eliciting a facial nerve response.[4]

Good postoperative facial nerve function was achieved in 44.4% of patients after NTR or STR, in contrast to 15.4% after GTR, which is worse than outcomes previously reported.[10] The reason may be related to the majority of large tumors in the present study. However, we found that the extent of resection was significantly related to postoperative facial nerve outcome ($p = 0.010$), and NTR had a lower risk of facial nerve palsy than GTR ($p = 0.036$). Thus, we propose that NTR is a good surgical strategy for VS, as it provides more opportunity for preserving facial nerve function.

III. Conclusion

GTR is the ideal surgical treatment for VS, but carries a significant risk of facial nerve dysfunction. NTR (95% to 99% resection) is a good strategy with high likelihood of preserving facial nerve function without significantly increasing the risk of recurrence.

Acknowledgments

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Address reprint requests to: H.-W. Jung, M.D., Department of Neurosurgery, Seoul National University College of Medicine, 28 Yeongeon-dong, Jongno-gu, Seoul 110-744, R.O.K.
e-mail: hwnjung@snu.ac.kr

Commentary

Surgery for vestibular schwannomas constitutes a major component of neurosurgical training. The authors in the present paper discuss their surgical experience with vestibular schwannomas having an average size of about 4 cm.

Surgery for large vestibular schwannomas is relatively difficult and has to be learnt over a period of time. Anatomical and functional preservation of the facial nerve is the main surgical challenge in such tumors. A number of papers have been written and presented in meetings demonstrating cases where the complete facial nerve is preserved and the patient is able to hear on the phone and has an intact facial nerve function. It is natural that most neurosurgeons can get carried away by such presentations. From personal experience with over 1000 large vestibular schwannomas, I conclude that complete resection of a large vestibular schwannoma with preservation of the entire facial nerve anatomically and functionally is possible in only a minority of cases. The surgeon must realize that preservation of the facial function is extremely important for the patient and determines the success of the operation. The facial nerve fibers are markedly flattened and adherent to the tumor capsule in large tumors. On some occasions, it is difficult even to identify the nerve in continuity over the tumor capsule. Although possible, dissection of these fibers from the tumor capsule is wrought with high danger of postoperative facial nerve palsy. Over the years, I have now even stopped attempting complete teasing of the nerve from the tumor capsule in most cases. Whilst preserving the nerve, leaving behind a portion of the tumor should never be considered as technical inefficiency.

The authors divide incomplete resection into two groups; near total resection group (over 95% tumor resection) and subtotal resection group (less than 95% tumor resection). It is redeeming to learn from the authors that the recurrence rate is not much different in groups undergoing complete tumor resection and those undergoing near total tumor resection. Subtotal, partial or only intra-capsular resection of the tumor can be considered as an inadequate operation. However, even such an operation is more efficient than the effect of any kind of radiosurgery for small or large tumors. It should also be realized that the surgery for vestibular schwannomas is losing the favor of the patient over radiosurgery only because of the high risk of post-operative facial nerve dysfunction. My parameter for success of surgery in a large vestibular schwannoma is near total tumor resection with the patient having the ability to close the eyelid following the operation.

Atul GOEL, M.D.
Head, Department of Neurosurgery
King Edward VII Memorial Hospital
& Seth G.S. Medical College
Parel, Mumbai, India

This article is timely and of concern to all neurosurgeons operating on patients with vestibular schwannoma, particularly when it is repeatedly argued whether microsurgery is preferable over stereotactic radiosurgery, which has become an important treatment option for this tumor because of the high rate of hearing preservation, few treatment-related complications including facial nerve function and the durability of tumor control.

The authors have carefully documented a series of 116 patients with vestibular schwannoma larger than 20 mm in diameter, and studied the recurrence rate and postoperative facial nerve function in relation to the extent of the tumor. I agree with the statement that "gross total removal can carry a significant risk of facial nerve function and near total removal (95% to 99% resection) is a good strategy with high likelihood of preserving facial nerve function without significantly increasing the risk of recurrence for the medium follow-up period of 55 months." We also have experienced that even such tumors can remain dormant during a long follow-up period.

At present, I believe that total tumor removal should be the goal when dealing with vestibular schwannoma. This is particularly true in patients with smaller tumors. Therefore, I disagree with the authors that near total removal is a good strategy for all the patients. In some cases, in order to preserve anatomical continuity of the facial nerve, complete removal is impossible, and the tumor overlying it must be left. I propose that total removal should be avoided only when it appears that it could become extremely difficult to remove the last remaining tumor from the facial nerve. The usual site of greatest difficulty in separating the tumor from the facial nerve is in the region just medial to the porus, where the facial nerve is usually displaced, fan-shaped and quite thin. During surgery, however, it is extremely difficult for us to know whether or not these remaining tumors (some tumors left behind) are viable and might become a cause for tumor recurrence. This problem is troublesome for neurosurgeons trying to remove a tumor gross-totally or near-totally, and it will continue to be a major unsolved problem. Because during suboccipital-transmeatal removal of a tumor, we unknowingly may leave tumor remnants leading to regrowth, attention should be directed to the location of the nerves distal to the tumor in the lateral aspect of the internal acoustic canal after adequate drilling of the posterior wall, even when residual tumor is left overlying the facial nerve outside the canal.

Further follow-up is needed to draw the conclusion that near total removal is a good treatment strategy without significantly increasing the risk of recurrence, particularly for younger patients, because it is unlikely that elderly patients will develop regrowth of the remaining tumor. These patients should be monitored and carefully followed up for regrowth of residual tumor remnants. When the recurrence is apparent, further surgery or stereotactic radiosurgery may be the next treatment choice. In any case, this article strongly suggests that this strategy may be of benefit in a selected patient population.

Ryoji ISHII, M.D.
Department of Neurosurgery
Kawasaki Medical School
Kurashiki, Okayama, Japan