I


Efficacy of facial nerve–sparing approach in patients with vestibular schwannomas

Clinical article

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Object. The goal of this article was to show that a combination of facial nerve–sparing microsurgical resection and Gamma Knife surgery (GKS) for expansion of any residual tumor can preserve good facial nerve function in patients with recurrent vestibular schwannoma (VS).

Methods. Records of individuals treated by a single surgeon with a facial nerve–sparing technique for a VS between 1998 and 2009 were retrospectively analyzed for tumor recurrence. Of the 383 patients treated for VS, 151 underwent microsurgical resection, and 20 (13.2%) of these patients required postoperative retreatment for a significant expansion of residual tumor after microsurgery. These 20 patients were re-treated with GKS.

Results. The rate of preservation of good facial nerve function (Grade I or II on the House-Brackmann scale) in patients treated with microsurgery for VS was 97%. Both subtotal and gross-total resection had excellent facial nerve preservation rates (97% vs 96%), although subtotal resection carried a higher risk that patients would require retreatment. In patients re-treated with GKS after microsurgery, the rate of facial nerve preservation was 95%.

Conclusions. In patients with tumors that cannot be managed with radiosurgery alone, a facial nerve–sparing resection followed by GKS for any significant regrowth provides excellent facial nerve preservation rates. (DOI: 10.3171/2011.7.JNS101921)

KEY WORDS • vestibular schwannoma • facial nerve • Gamma Knife surgery • tumor recurrence • peripheral nerve

Injury to the facial nerve is a common complication in the natural course and treatment of VS. Preserving facial nerve function is particularly important to patients because injury to the nerve produces a disfiguring, disabling palsy that severely impacts patients' quality of life. Evaluating current methods of treating VSs and new approaches can help clinicians provide patients with the best possible outcome for their treatment.

Both microsurgical resection and GKS can be used to treat VS. Although resection of VSs encroaching on the facial nerve can impact facial nerve function, microsurgery is often necessary, particularly for treating large tumors. Microsurgery has excellent tumor control rates and preserves good facial nerve function in 65%–97% of patients (good facial function is defined as Grade I or II on the HB scale). Facial nerve outcome after resection is largely a function of tumor size. Larger tumors are associated with worse outcomes; only 35%–85% of patients with tumors > 3 cm retain good facial nerve function after resection. Gamma Knife surgery is an excellent option for treating VSs without damaging the facial nerve. Early studies of radiosurgery for VSs showed that this treatment offered excellent tumor control (98%) with a low risk of facial nerve injury in patients with an average tumor size of 2.2 cm. Facial nerve preservation with GKS is excellent (96.2%), but the treatment is not benign; some symptoms of facial nerve injury are observed in a small percentage of patients treated with radiosurgery (14%). Although radiosurgery has had good results in treating VSs, many patients, particularly those with larger tumors, cannot be treated with GKS without a resultant mass effect that may potentially jeopardize adjacent structures.

Various factors have been correlated with facial nerve function in the treatment of VS. Patients with larger tumors have consistently had worse outcomes than patients with smaller tumors after both radiosurgery and microsurgery. A patient’s facial nerve function before surgery is an important determinant of posttreatment outcome;
patients presenting with poor preoperative facial nerve status more often have deterioration of facial nerve function than patients with a better preoperative status. Age may also be an important factor to consider in treating VSs—younger patients have a higher likelihood of facial nerve preservation. There are also specific techniques in microsurgery and radiosurgery linked with improved facial nerve outcome. Although careful facial nerve dissection is helpful, even cases in which the facial nerve is anatomically preserved may exhibit facial muscle weakness. Intraoperative monitoring of the facial nerve is the key for optimal facial nerve preservation, even though not all patients' clinical courses correlate with their intraoperative electrophysiological results. Radiosurgical dosing of <13 Gy also correlates with decreased risk of facial palsy, which is a useful consideration in Gamma Knife therapy for VSs.

Treatment failure is a significant concern in treating VS. Controlling growth of the VS is critical for ensuring a good outcome, and with an STR there is a risk that additional tumor treatment will be needed, with additional morbidity and risk of facial nerve injury. In cases of subtotal resection, revision surgery increases the risk of injuring the facial nerve, making a complete initial resection desirable. Repeat operation is also associated with an increased risk of complications, including poor facial nerve outcome—only 50% of patients preserve their good facial nerve function. In cases in which GKS fails and microsurgical resection is required, facial nerve preservation is 52%, a significant drop from the expected chance of facial nerve preservation with either treatment alone. Patients in whom initial treatment (either radiosurgery or microsurgery) failed, who are re-treated with radiosurgery for their residual tumor, have had better outcomes; 90% of patients with good facial nerve function prior to radiosurgery had preservation of their facial function. These results indicate that radiosurgery is a good approach for patients who need retreatment of their VSs.

Some clinicians have proposed that a facial nerve–sparing STR followed by GKS can preserve facial nerve function and provide reasonable tumor control. Studies of tumors treated with microsurgery followed by radiosurgery have been encouraging; facial nerve–sparing techniques can retain facial nerve function in 85% of cases. Despite these encouraging results, the risk of regrowth increases with STR, with resulting morbidities as discussed previously. Larger case studies from a single surgeon will provide stronger support for this facial nerve–preservation technique.

In this study, we analyzed the efficacy of facial nerve–sparing resection followed by radiosurgery in preserving facial nerve function in patients with VS. We analyzed a large pool of patients treated by 1 surgeon at a single institution according to a dedicated facial nerve–sparing paradigm between 1998 and 2009, combining conservative resection and GKS. Our goal was to minimize facial nerve injury and mortality rates during treatment of VSs. Larger tumors were initially treated with microsurgical resection, whereas smaller tumors were treated with GKS. A large report of nearly 1000 VSs, published by Samii and Matthes, showed a mortality rate of 1.1%.

We decided to attempt a similar approach of intentional STR, with an ideal result of minimizing the mortality rate and facial nerve deficits. Our goal was to attempt a GTR, but to transition to an STR if electrophysiological monitoring revealed that the facial nerve was endangered (requiring >0.3 mA or >0.1 mA above baseline). Because the IAC is the most frequent site for injury of the facial nerve, we were cautious about drilling into the canal, attempting this only if electrophysiology and inspection revealed that the facial nerve would not be compromised. Any fragments of tumor remaining on the facial nerve or left in the IAC could be monitored with MR imaging, and any significant regrowth could be treated with GKS.

We decided that smaller tumors and small tumor remnants would be ideal candidates for GKS. An extensive study of GKS by Kondziolka et al. in a series of patients with an average tumor size of 2.2 cm, showed excellent tumor control and facial nerve preservation. Given the promising results from that study with its average tumor size as stated, we decided that tumors <2.2 cm would be excellent candidates for GKS. By this size criterion, small fragments of tumor remaining from the facial nerve–sparing surgery described previously would also be ideal for radiosurgical treatment. Patients presenting with tumors <2.2 cm and without severe vertigo or other tumor-related symptoms were treated with GKS, whereas patients with larger or more symptomatic tumors were treated with microsurgery. A small subset of patients treated initially with microsurgery required radiosurgical treatment for regrowth of remnant tumor. In this report we analyzed the facial nerve function in patients initially treated with microsurgery. We analyzed the outcomes of patients treated with the facial nerve–sparing technique, recording the following: facial nerve function before and after treatment (using the modified HB scale); any morbidity associated with the procedure, such as CSF leaks and hydrocephalus; and whether further treatment was needed to control tumor growth. Our findings in this patient set ascertained the efficacy of a dedicated, facial nerve–sparing microsurgical approach in treating patients with VS.

Methods

All procedures were done in accordance with the Columbia University Institutional Review Board guidelines and approved as IRB No. AAAE2047. We retrospectively reviewed charts from 433 patients treated for a VS either with microsurgical resection by a single surgeon (M.B.S.) or GKS by a team of that same surgeon and a single radiation oncologist (S.R.I.). Patients with documented NF2, any previous treatment with microsurgery or radiosurgery, pathological findings inconsistent with a VS, or patients for whom Drs. Sisti and Isaacs were not the primary treatment providers were excluded from our analysis. Using these criteria, 383 patients were included in subsequent analysis (Fig. 1). Patients were selected for a facial nerve–sparing microsurgical approach according to a surgeon paradigm based on tumor size and symptoms. Patients with tumors ≥2.2 cm, debilitating symptoms such as severe vertigo or tinnitus, or mass effect on surround-
Fixm structures were deemed poor candidates for GKS and were chosen for microsurgery. Patients with tumors < 2.2 cm and mild symptoms were treated with GKS.

One hundred fifty-one patients with a diagnosis of VS were treated with an initial facial nerve–sparing resection (according to records from March 1998 to June 2009). As described previously, only patients with no history of prior treatment for VS, a final histological diagnosis of VS, and for whom 2 of the authors (M.B.S. and S.R.I.) were the primary providers were included in our analysis. We excluded patients with a diagnosis of NF2. Surgery was performed via a retrosigmoid approach, due to neurosurgeon preference, with a goal for maximum (>90%) resection without compromising the facial nerve. Hearing preservation was not the primary goal of this treatment paradigm. All patients were surgically treated with this facial nerve–sparing approach, with intraoperative electrophysiological monitoring. A GTR was attempted in all patients. If the facial nerve required >0.3 mA of stimulation or an increase of ≥0.1 mA above the baseline level of nerve stimulation, the surgeon ceased resection of the tumor. If the facial nerve was in the porus acusticus and this structure was at risk, the acoustic canal was not drilled. In patients for whom the facial nerve was not at risk during surgery, we proceeded with GTR of the tumor, drilling into the IAC if needed for complete removal of all tumor remnants. This surgical approach is our facial nerve–sparing resection. With this approach, 36% of tumors were totally excised (55 patients) with no residual, and in the remaining 64% (96 patients) we achieved an STR (>90% of tumor removed).

Postoperative scans were repeated every 6-12 months. Regrowth was defined for an expansion of at least 5 mm from the postoperative size. Any postoperative complications were noted. Residual postsurgical VSs treated with GKS were analyzed (20 patients). Gamma Knife surgery was the stereotactic treatment chosen for all patients with postoperative regrowth of their tumor. Patients were treated with 12 Gy to the 50% isodose line. We noted the time between microsurgery and retreatment with GKS, facial nerve function before and after radiosurgery (according to the HB scale), any complications associated with radiosurgical retreatment, and any significant tumor regrowth after GKS.

Results

Of the 151 patients treated with a facial nerve–sparing resection for a VS, 20 (13.2%) required retreatment for a recurrent tumor. Of the 232 patients treated with GKS, 3 (1.3%) required further treatment. In all 383 patients treated according to the single-surgeon treatment paradigm we describe, a total of 23 (6%) required retreatment. In patients treated with microsurgical resection, the age range was 18–92 years at the time of microsurgery (average 49 years), tumor sizes ranged from 1.8 to 6 cm (average 3.3 cm; 8 patients had tumors < 2.2 cm), and follow-up durations ranged from 0.4 to 11.1 years (average 6 years), as shown in Table 1.

The 8 patients with tumors ranging from 1.8 to 2.1 cm were selected for microsurgery due to severe symptoms, such as vertigo. These patients required more immediate tumor resection, making microsurgery a better option than GKS. There was no statistically significant difference in age or tumor size between patients who did and those who did not have regrowth of residual tumor (p = 0.63 for age, p = 0.08 for tumor size; Student t-test). Age and preoperative tumor size in patients who had STR (96 patients, 64%) were compared with age and tumor size in patients who had GTR (55 patients, 36%). We found that patients who had STR were significantly older (p = 0.01)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>age at op (yrs)</td>
<td>18–92</td>
<td>49.0</td>
</tr>
<tr>
<td>tumor size preop (cm)</td>
<td>1.8–6.0</td>
<td>3.3</td>
</tr>
<tr>
<td>postop follow-up time (yrs)</td>
<td>0.4–11.1</td>
<td>6.0</td>
</tr>
</tbody>
</table>
and had significantly larger tumors \((p = 0.0001)\) than patients who had GTR (Table 2). Figure 2 shows MR imaging studies obtained in a representative patient who was treated with STR, with no evidence of tumor regrowth at the 4-year follow-up evaluation.

We further analyzed characteristics of the subgroup of patients who required retreatment with GKS for postoperative expansion of residual tumor. In these patients, the time from microsurgery to retreatment with GKS ranged from 6 months to 7.7 years (average 3.9 years). The ages of these patients ranged from 18 to 82 years at the time of microsurgery (average 47 years), the tumor sizes ranged from 2.5 to 6 cm (average 3.6 cm), and the follow-up durations ranged from 1.0 to 4.4 years (average 2 years), as shown in Table 3. Figure 3 shows MR imaging studies obtained in a representative patient who was initially treated with microsurgical resection and who had little residual tumor on a postoperative MR imaging study, showed expansion of residual tumor on a later image, was treated with GKS, and had good control of tumor growth thereafter.

Pathology reports on surgical tumor samples indicated that all resected tumors were benign neoplasms (WHO Grade I). Fourteen patients had postoperative complications after microsurgery (11 CSF leaks, 2 cases of hydrocephalus, and 1 case of meningitis), from which all patients recovered. One patient experienced transient focal seizures after retreatment with GKS; these resolved within 5 months. Four patients required gold-weight tarsorrhaphy for facial nerve palsy. There were no postoperative deaths after microsurgery or GKS.

We determined that the rate of preservation of good facial nerve function after microsurgery (Grade I or II on the HB scale in the most recent follow-up) was 97%. Eight patients (5%) presented for initial treatment with a marked initial facial nerve deficit (a preoperative facial nerve function \(>\) Grade II on the HB scale), but only 5 patients (3%) had a marked deficit at final follow-up after microsurgery (Table 4). We compared facial nerve function after STR and GTR. Before microsurgery, 88 (92%) of 96 patients who received an STR presented with good facial nerve function, compared with 55 (100% of the patients who received a GTR) (Table 5). The difference in preoperative HB grade in patients who had GTR compared with those who had STR was statistically significant \((p = 0.01)\). Postoperative HB grade in patients who had GTR compared with those who had STR was not statistically significant \((p = 0.19)\). Overall, 92% of patients retained or improved their preoperative facial nerve function. There was no significant difference in facial nerve change over the treatment course between STR and GTR \((p = 0.21)\) (Table 6).

<table>
<thead>
<tr>
<th>Extent of Resection</th>
<th>Range Average</th>
<th>Range Average</th>
<th>p value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTR</td>
<td>21–71 45</td>
<td>1.8–6.0 2.9</td>
<td>0.01</td>
</tr>
<tr>
<td>STR</td>
<td>18–92 52</td>
<td>2.0–6.0 3.5</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

* MS = microsurgery.
† The Student t-test was used to evaluate whether there was a significant \((p < 0.05)\) difference in age or tumor size between patients who had GTR and those who had STR.

**TABLE 2: Characteristics of 55 patients with GTR versus 96 with STR**

**TABLE 3: Characteristics of 20 patients with postoperative tumor regrowth**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range Average</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>age at op (yrs)</td>
<td>18–82</td>
<td>47.0</td>
</tr>
<tr>
<td>tumor size preop (cm)</td>
<td>2.5–6.0</td>
<td>3.6</td>
</tr>
<tr>
<td>time btwn MS &amp; GKS (yrs)</td>
<td>0.5–7.7</td>
<td>3.9</td>
</tr>
<tr>
<td>follow-up time (yrs)</td>
<td>1.0–4.4</td>
<td>2.0</td>
</tr>
</tbody>
</table>

A: Preoperative MR imaging study showing a 6-cm VS. B: A 1-year postoperative MR imaging study showing a small residual tumor. C: A 4-year postoperative MR imaging study obtained at the time of GKS, showing expansion of the residual tumor, now measuring 1.2 cm. D: An MR imaging study obtained 7 years after GKS (11 years after initial microsurgery), showing postradiosurgical changes.

**Fig. 2.** Axial T1-weighted MR images obtained with Gd contrast at the level of the IAC in a patient treated with STR for a VS. This patient had HB Grade I facial nerve function. **Left:** Preoperative MR imaging study showing a 4.5-cm VS. **Right:** An MR imaging study obtained 4 years after STR, demonstrating no change over the follow-up interval.

**Fig. 3.** Axial T1-weighted MR imaging studies obtained with Gd contrast at the level of the IAC in a patient treated with microsurgery and re-treated with GKS for a VS. This patient had HB Grade I facial nerve function. **A:** Preoperative MR imaging study showing a 6-cm VS. **B:** A 1-year postoperative MR imaging study showing a small residual tumor. **C:** A 4-year postoperative MR imaging study obtained at the time of GKS, showing expansion of the residual tumor, now measuring 1.2 cm. **D:** An MR imaging study obtained 7 years after GKS (11 years after initial microsurgery), showing postradiosurgical changes.
Facial nerve–sparing approach for VS

In the set of 20 patients treated with GKS for regrowth of their VS, the rate of preservation of good facial nerve function (Grade I or II on the HB scale) was 95% (Table 7), with 80% of patients retaining or improving on preoperative facial nerve function (Table 8). Three patients (15%) presented for initial treatment with a marked initial facial nerve deficit (a preoperative facial nerve function > Grade II on the HB scale), but only 1 patient (5%) had a marked deficit at final follow-up after GKS.

Multivariate linear regression showed that age, tumor size, and time interval between microsurgery and GKS were not statistically significant predictors of change in facial nerve function before microsurgery and after radiosurgical retreatment (p = 0.67 for age, p = 0.35 for tumor size, p = 0.25 for time from microsurgery to GKS; statistical significance defined as p < 0.05).

Discussion

Patients with large tumors have historically had poor facial nerve preservation rates. These patients are not good candidates for treatment with any current form of GKS. Our approach of STR provides a treatment for these patients that does not necessitate sacrificing the facial nerve. Subsequent treatment with GKS controls any regrowth of residual tumor and preserves good facial nerve outcome. The rate of regrowth requiring retreatment for all patients treated with facial nerve resection (13.2%) shows that our approach provides good tumor control. This is only slightly higher than the risk of regrowth for more complete resection, and not nearly as high as the risk of recurrence with other STR strategies. All patients who later had regrowth of their tumors had initially been treated with a subtotal microsurgical resection. None of the patients treated with GTR required retreatment. This increased risk of regrowth requiring treatment with a subtotal, facial nerve–sparing approach was anticipated during treatment planning.

We found significant differences in age (p = 0.01) and tumor size (p = 0.0001) between patients who had STR and those who underwent GTR. Older patients and those with larger tumors are known to have an increased risk of facial nerve injury after microsurgery.5,9 In larger tumors extending to the facial nerve, the nerve is at greater risk during surgery and more likely to show intraoperative electrophysiological irritation which, by the treatment methods we described, would lead us to elect an STR. This explains why patients with STR had larger tumors than patients with GTR. The significant difference in age between patients who had STR and those who had GTR potentially indicates that older patients had an increased risk of facial nerve irritation during tumor resection, leading to our decision in favor of STR.

The tumor size in patients who had regrowth of their initial lesion compared with those patients who had no regrowth approached significance (p = 0.08), indicating that larger tumors are possibly more likely to require retreatment after subtotal, facial nerve–sparing microsurgery. Patients re-treated with GKS after microsurgery had no significant further tumor growth after radiosurgery. Given our relatively short period of follow-up after GKS in patients treated for residual tumor expansion, this indicates that radiosurgery is an effective strategy for managing regrowth of residual VSs. Our findings indicate that the facial nerve–sparing approach provides good tumor control, with a preliminary indication that GKS provides excellent control of tumors requiring retreatment.

Transient facial nerve deficits after microsurgery are well documented.3 In this series, several patients experienced moderate temporary postoperative facial nerve weakness. These patients recovered function after a period of time, but it is useful to note that there was a tempo-

![TABLE 4: Facial nerve grading in 151 patients after facial nerve–sparing surgery*](image)

<table>
<thead>
<tr>
<th>HB Grade</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>136</td>
<td>130</td>
</tr>
<tr>
<td>II</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>III</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>total w/ good function†</td>
<td>143 of 151 (95%)</td>
<td>146 of 151 (97%)</td>
</tr>
</tbody>
</table>

* Distribution of facial nerve function, as determined by the HB scale, before microsurgery (pretreatment) and at most recent follow-up (posttreatment).
† Good facial nerve function is defined a Grade I or II on the HB scale.

![TABLE 5: Good facial nerve function after GTR compared with STR in 151 patients](image)

<table>
<thead>
<tr>
<th>Extent of Resection</th>
<th>Good Function Preop</th>
<th>Good Function Postop</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTR</td>
<td>55 of 55 (100%)</td>
<td>53 of 55 (96%)</td>
</tr>
<tr>
<td>STR</td>
<td>88 of 96 (92%)</td>
<td>93 of 96 (97%)</td>
</tr>
<tr>
<td>all patients</td>
<td>143 of 151 (95%)</td>
<td>146 of 151 (97%)</td>
</tr>
<tr>
<td>p value*</td>
<td>0.01</td>
<td>0.19</td>
</tr>
</tbody>
</table>

* The Student t-test was used to evaluate whether there was a significant (p < 0.05) difference in the pretreatment and posttreatment HB grade in patients with STR compared with GTR.

![TABLE 6: Facial nerve grading scale changes over the duration of treatment in 151 patients](image)

<table>
<thead>
<tr>
<th>Change in HB Grade*</th>
<th>GTR</th>
<th>STR</th>
<th>All Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>improved or unchanged</td>
<td>51 of 55 (93%)</td>
<td>88 of 96 (92%)</td>
<td>139 of 151 (92%)</td>
</tr>
<tr>
<td>worsened function</td>
<td>4 of 55 (7%)</td>
<td>8 of 96 (8%)</td>
<td>12 of 151 (8%)</td>
</tr>
</tbody>
</table>

* Change from initial presentation to final follow-up; changes in facial nerve grading according to the HB scale, from initiation of treatment (before microsurgery) to the most recent follow-up, with percentages of patients showing improvement, no change in function, or an increased facial nerve deficit. The overall change in facial nerve function was not significantly different between patients who had GTR and those who had STR (p = 0.21).
Have a significant risk of facial nerve dysfunction. Vents facial nerve deficits in patients who might otherwise control of tumor growth with GKS for tumor expansion pre-sparing technique. Combining surgery for good con-
trary problem, possibly a result of intraoperative irritation of the facial nerve. Although some patients experienced postoperative deficits in facial nerve function, they usually recovered within 3 months, often fully recovering to their preoperative level of facial nerve function.

The 97% rate of facial nerve preservation in patients treated with microsurgery is close to the rate of facial nerve preservation in patients treated with GKS alone. This is particularly impressive for this patient set, because these individuals had particularly large tumors (average tumor size 3.3 cm) and often presented with initial facial nerve deficits. One possible concern is that patients who had a GTR would have worse facial nerve function, due to the more extensive tumor removal. Our data show that, by attempting a GTR in all patients and converting to an STR when the facial nerve seemed at risk, patients had excellent facial nerve outcomes regardless of whether they had a GTR or an STR. The rate of preservation of good facial nerve function with both techniques was excellent (96% with GTR, 97% with STR). Patients who had STR significantly worse preoperative facial nerve function compared with those who had GTR (p = 0.01). Yet, there was no significant difference between postoperative facial nerve function after STR and after GTR. This may indicate that patients with worse preoperative facial nerve function have more frail facial nerves, which would be reflected on electrophysiological monitoring and would increase the chance of stopping dissection when facial nerve irritation arises.

In patients who required retreatment, the facial nerve preservation rate was similarly high (95%), showing that the combined approach of microsurgery and GKS provides patients with excellent facial nerve function, even if they ultimately require retreatment. This work confirms previous studies indicating that microsurgical resection followed by GKS for recurrence yields better rates of facial nerve function than total resection alone for tumors of this size. Patients received intraoperative electrophysiological monitoring and lower radiation doses (12 Gy to the 50% isodose line), techniques that are shown to have a better prognosis of facial nerve preservation, which may contribute to the efficacy of our facial nerve-sparing technique. Combining surgery for good control of tumor growth with GKS for tumor expansion prevents facial nerve deficits in patients who might otherwise have a significant risk of facial nerve dysfunction.

Continued analysis of our series of patients initially treated with microsurgery will expand on the data presented here. Of note, significant regrowth of VS is possible even 10 years after treatment. Follow-up will reveal whether the tumors in patients who have not yet required retreatment after microsurgery will remain dormant.

Previous case studies have focused on small subsets of patients who were initially treated with microsurgery and later treated with GKS. This series corresponds to patients who were dedicated to the combined approach of microsurgery and GKS from the beginning of their treatment. We show that this approach provides excellent facial nerve function (97% good facial nerve function) with a low risk of tumor regrowth (13.2% of patients required retreatment).

### Conclusions

Facial nerve injury is common in patients who are surgically treated for large VSs. Stereotactic radiosurgery is inadequate for controlling large tumors, and surgery is often necessary. In our series, a facial nerve-sparing technique for VS provided a low incidence of tumor regrowth requiring retreatment (13.2%), with a high rate of facial nerve preservation (97%). Both STR and GTR had excellent facial nerve preservation rates (97% vs 96%), although STR carried a higher risk that patients would require retreatment. Of patients treated initially with microsurgery who required retreatment with GKS, 80% maintained facial nerve function that was the same or better than their initial preoperative function, and 95% maintained good facial nerve function (defined as HB Grade I or II). No patients required further treatment after GKS, tentatively establishing that the combination of microsurgical resection and GKS provides good tumor control.

### Disclosure

No outside financial sources were used to fund this work. The authors have no perceived conflicts of interest.

Author contributions to the study and manuscript preparation include the following. Conception and design: Isaacson, Sisti. Acquisition of data: Isaacson, Sisti. Analysis and interpretation of data: Haque, Wojtasiewicz, Gigante, Attiah, Sisti. Drafting the article: Haque, Wojtasiewicz, Gigante, Sisti. 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: Haque. Statistical analysis: Haque, Wojtasiewicz, Attiah. Administrative/technical/material support: Gigante, Attiah, Huang. Study supervision: Isaacson, Sisti.
Facial nerve–sparing approach for VS

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