Gamma Knife surgery for patients with facial nerve schwannomas: a multiinstitutional retrospective study in Japan

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OBJECTIVE The aim of this study was to explore the efficacy and safety of stereotactic radiosurgery for patients with facial nerve schwannomas (FNSs).

METHODS This study was a multiinstitutional retrospective analysis of 42 patients with FNSs treated with Gamma Knife surgery (GKS) at 1 of 10 medical centers of the Japan Leksell Gamma Knife Society (JLGK1301). The median age of the patients was 50 years. Twenty-nine patients underwent GKS as the initial treatment, and 13 patients had previously undergone surgery. At the time of the GKS, 33 (79%) patients had some degree of facial palsy, and 21 (50%) did not retain serviceable hearing. Thirty-five (83%) tumors were solid, and 7 (17%) had cystic components. The median tumor volume was 2.5 cm³, and the median prescription dose to the tumor margin was 12 Gy.

RESULTS The median follow-up period was 48 months. The last follow-up images showed partial remission in 23 patients and stable tumors in 19 patients. Only 1 patient experienced tumor progression at 60 months, but repeat GKS led to tumor shrinkage. The actuarial 3- and 5-year progression-free survival rates were 100% and 92%, respectively. During the follow-up period, 8 patients presented with newly developed or worsened preexisting facial palsy. The condition was transient in 3 of these patients. At the last clinical follow-up, facial nerve function improved in 8 (19%) patients, remained stable in 29 (69%), and worsened in 5 (12%; House-Brackmann Grade III in 4 patients, Grade IV in 1 patient). With respect to hearing function, 18 (90%) of 20 evaluated patients with a pure tone average of \( \leq 50 \) dB before treatment retained serviceable hearing.

CONCLUSIONS GKS is a safe and effective treatment option for patients with either primary or residual FNSs. All patients, including 1 patient who required repeat GKS, achieved good tumor control at the last follow-up. The incidence of newly developed or worsened preexisting facial palsy was 12% at the last clinical follow-up. In addition, the risk of hearing deterioration as an adverse effect of radiation was low. These results suggest that GKS is a safe alternative to resection.

http://thejns.org/doi/abs/10.3171/2015.3.JNS142677

KEY WORDS facial nerve schwannoma; functional neurosurgery; functional outcome; Gamma Knife; stereotactic radiosurgery; tumor control
Intracranial schwannomas are generally slow-growing benign tumors that arise from Schwann cells of the nerve sheath. The most frequent schwannomas are vestibular schwannomas that originate from the eighth cranial nerve, whereas facial nerve schwannomas (FNSs) are rare tumors that can occur in any segment of the facial nerve. The geniculate ganglion is the most commonly involved segment, followed by the labyrinthine and the tympanic segments. Facial palsy and hearing disturbance are the most common symptoms of FNSs. Diagnosis of FNSs is sometimes difficult, particularly in those confined to the cerebellopontine angle (CPA) and intracanalicular portion, because patients often present with the same symptoms as those with vestibular schwannoma, such as hearing disturbance, tinnitus, or vertigo. More recently, advances in radiological imaging and increases in sensitivity have enabled the identification of brain disease in patients who are still asymptomatic. The treatment strategy for FNSs remains controversial and includes surveillance, resection, and radiation therapy. Although these benign tumors are certainly curable with total tumor resection, complete resection without any complications is nearly impossible, even for highly experienced surgeons. Despite recent microsurgical techniques, it is still challenging to avoid deterioration of facial nerve function after complete resection. Tumor resection with nerve reconstruction results in facial nerve recovery of House-Brackmann (HB) Grade III at best. Consequently, observation using serial follow-up imaging has been the primary course of management for most asymptomatic patients or those with mild facial palsy. Recently, stereotactic radiosurgery (SRS) has emerged as a minimally invasive treatment. There have been a number of articles demonstrating the safety and efficacy of SRS for vestibular schwannomas. However, to our knowledge, there is little information about the results of FNSs treated with SRS because of the rarity of the disease. Therefore, we aimed to evaluate the safety and efficacy of SRS for FNSs in this multiinstitutional retrospective study.

Methods

Patient Characteristics

This was a multiinstitutional retrospective study by 10 medical centers of the Japan Leksell Gamma Knife Society (JLGK1301). Data on patients with FNSs treated with Gamma Knife surgery (GKS) between 1991 and 2013 were obtained from individual institutional review board–approved databases. Each of the 10 participating centers had institutional review board approval to combine and analyze the data. Inclusion criteria for tumors without histological confirmation were the following: 1) the tumor was confined to the course of the facial nerve, generally with extension from the internal auditory canal to the geniculate ganglion and middle fossa (Fig. 1B) according to thin-sliced axial T1-weighted images and constructive interference in steady-state (or fast imaging using steady-state acquisition) images, and 2) the intracanalicular and/or CPA tumor presented with ipsilateral facial palsy or spasms despite a relatively small tumor volume and presumed FNS but not vestibular schwannoma. Tumors diagnosed as FNSs during microsurgical observation were also included in this study. Patients with neurofibromatosis Type 2 were excluded. Primary large CPA tumors that caused cranial nerve deficits other than those of the facial or cochlear nerve were also excluded because of the possibility of other cranial nerve origin. A total of 42 patients with FNSs were eligible for this study. Of these patients, 13 who had previously undergone surgery were diagnosed on the basis of microsurgical observation. GKS as the initial treatment was performed in 29 patients, all of whom met the first or second inclusion criterion. Patient characteristics are shown in Table 1. Initial symptoms were facial palsy in 23 (55%) patients, hearing disturbance in 19 (45%), facial spasms in 3 (7%), and dizziness in 3 (7%). At the time of GKS, 33 (79%) patients had some degree of facial palsy, 21 (50%) did not retain serviceable hearing, 5 (12%) had facial spasms, 2 (5%) had facial dysesthesia, 1 (2%) had gait disturbance, and 1 (2%) had dizziness and tinnitus. Facial palsy was assessed by using the HB grading system, and hearing function was assessed by using the pure tone average (PTA), calculated with the formula \(a + b + c)/4\), where \(a\), \(b\), and \(c\) are the hearing threshold levels of 500, 1000, and 2000 Hz, respectively, and classified as 1 of 4 categories: A (PTA < 30 dB), B (PTA = 31–50 dB), C (PTA = 51–90 dB), D (PTA ≥ 91 dB); or E (scale out). Pre-GKS facial and hearing functions are shown in Table 2. Twenty-three (55%) tumors were located on the right side, and 19 (45%) were located on the left. Thirty-five (83%) tumors were solid, and 7 (17%) had cystic components. Tumor location was classified as 1 of 4 types, as described by Litre et al. (Table 3, Fig. 1). Brainstem compression was found in 4 (10%) tumors, 1 (2%) of which had resulted in brainstem edema at the time of GKS. Of 29 patients who underwent GKS as the initial treatment, 6 (21%) had pre-GKS tumor enlargement (mean interval 36 months). Of 13 patients who underwent previous surgeries, 9 required GKS for tumor recurrence and 4 for residual tumors.

Radiosurgical Techniques

GKS was performed with the aid of the Leksell model G stereotactic frame (AB Elekta). After the administration of a mild sedative and local anesthesia, the frame was applied. Patient treatment was planned with the KULA system (Elekta Instruments) until 1996; thereafter, GammaPlan software (AB Elekta) was used. In all participating centers, thin-sliced axial T1-weighted or spoiled-gradient echo images with Gd enhancement were used for tumor delineation. No patient’s treatment was planned using CT scans alone, although in some cases CT scans were fused for dose planning. After dose planning, patients were treated with Gamma Knife models B, C, 4C, or Perfexion (AB Elekta) at a participating center. The median tumor volume was 2.5 cm³ (range 0.7–12.8 cm³); the median maximum dose was 24 Gy (range 16.5–35 Gy), and the median margin dose was 12 Gy (range 10–16 Gy), prescribed to a median isodose line of 50% (range 50%–80%). The mean cochlear dose varied from 2.0 to 17.8 Gy (median 7.3 Gy). The mean cochlear dose was calculated with GammaPlan by delineation of the cochlea on a T2-weighted image or a CT scan. One patient underwent volume-staged GKS with
radiosurgery for facial schwannomas

a tumor margin dose of 12 Gy. The tumor located from the CPA to the internal auditory canal, with a tumor volume of 1.4 cm³, was treated with the first procedure, and the tumor on the geniculate ganglion and middle fossa, with a tumor volume of 1.9 cm³, was treated with the second procedure.

Follow-Up Evaluations
Radiological imaging studies were performed at each center with an interval of 3 to 6 months during the first 3 years and annually thereafter. Clinical data, including neurological signs, were evaluated simultaneously. Clinical follow-up data were obtained from either the patients or their referring doctors. For each patient, facial nerve or hearing function was assessed by a neurosurgeon or otologist. On the basis of radiological follow-up studies, complete remission was defined as tumor disappearance, partial remission as a ≥ 25% volume reduction, no change as a < 25% volume reduction or an increase, and tumor progression as a ≥ 25% volume increase. In addition, transient expansion was defined as any enlargement before tumor shrinkage. Central necrosis was defined as the loss of central enhancement of the tumor.

<table>
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<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>No. of patients</td>
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<tr>
<td>Range</td>
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<tr>
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<td>50</td>
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<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>9 (21)</td>
</tr>
<tr>
<td>Female</td>
<td>33 (79)</td>
</tr>
<tr>
<td>Karnofsky Performance Scale score</td>
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</tr>
<tr>
<td>100</td>
<td>11 (26)</td>
</tr>
<tr>
<td>90</td>
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<td>60</td>
<td>1 (2)</td>
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<tr>
<td>Previous tumor resections</td>
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<td>2</td>
<td>4 (10)</td>
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<tr>
<td>Facial nerve reconstruction</td>
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</tr>
<tr>
<td>Previous irradiation</td>
<td>0 (0)</td>
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</tbody>
</table>

* Values are presented as the number (%) of patients unless otherwise indicated.
TABLE 3. Tumor classifications based on tumor location

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>No. of Tumors (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I, located on GG &amp;/or MF</td>
<td>7 (17)</td>
</tr>
<tr>
<td>II, dumbbell shaped on CPA, IAC, Lab, GG, &amp;/or MF</td>
<td>22 (52)</td>
</tr>
<tr>
<td>III, located on Tym &amp;/or Mast</td>
<td>2 (5)</td>
</tr>
<tr>
<td>IV, located on CPA &amp;/or IAC</td>
<td>11 (26)</td>
</tr>
</tbody>
</table>

GG = geniculate ganglion; IAC = internal auditory canal; Lab = labyrinthine segment; Mast = mastoid segment; MF = middle fossa; Tym = tympanic segment.

Statistical Analysis

Progression-free survival after GKS was calculated by using the Kaplan-Meier estimator. To analyze factors that correlated with worsened facial function, we assessed the following data: age, sex (male vs female), number of previous surgeries, pre-GKS HB grading, tumor nature (solid vs cyst), tumor location (Type I or III vs Type II or IV), marginal dose, tumor volume, and radiological findings after treatment, including transient expansion and central necrosis. Factors that affected worsened facial function were assessed with the Cox proportional hazards model, in which the continuous variables used were age, number of previous surgeries, marginal dose, and tumor volume. A final multivariate analysis was calculated by using a stepwise forward selection method. Hazard ratios are reported with 95% confidence intervals. Statistical analysis was performed with SPSS 21.0 for windows (SPSS, Inc.). A p value of < 0.05 was considered statistically significant.

Results

The mean and median clinical follow-up periods were 61 and 48 months (range 12–166 months), respectively. Sixteen patients were followed up for 5 years or longer. The mean and median radiological follow-up periods were 57 and 48 months (range 12–154 months), respectively. During the follow-up periods, 1 patient died as a result of lung cancer 52 months after GKS.

Tumor Control

On the last follow-up image, partial remission was observed in 23 (55%) patients and no change in 19 (45%). During the follow-up period, tumor progression was observed in an 80-year-old woman with pre-GKS HB Grade VI nerve function 60 months after GKS, but tumor shrinkage was eventually achieved without complications after repeat GKS. The actuarial 3- and 5-year progression-free survival rates were 100% and 92%, respectively (Fig. 2). Transient expansion and central necrosis were evaluated in 41 patients, excluding 1 patient for whom no radiological image within 1 year after treatment was available. Transient expansion was found in 12 (29%) patients (median interval 5.5 months), whereas central necrosis was found in 24 (59%) patients (median interval 6 months).

Facial Nerve Function

At the last clinical follow-up, facial nerve function improved in 8 (19%) patients, remained unchanged in 29 (69%), and worsened in 5 (12%). Of the 29 patients who underwent GKS as the initial treatment, 6 (21%) had improved facial palsy, 18 (62%) remained stable, and 5 (17%) worsened. Pre-GKS and post-GKS facial nerve functions are illustrated in Fig. 3. Eight patients had improved facial palsy (mean interval 18 months [range 1–48 months]). Facial palsy completely resolved in 4 patients after their GKS. Six of 8 patients who had improved facial palsy underwent GKS as their initial treatment. Follow-up images showed tumor shrinkage in 5 patients and stable tumor in 3. On the other hand, 8 patients experienced newly developed or worsened preexisting facial palsy; the condition was transient in 3 patients and persistent in 5. Transient facial palsy developed 3 days, 1 month, and 18 months after GKS in the 3 patients, respectively; 1 patient recovered within several days after corticosteroid administration, and the other 2 patients recovered 6 months after GKS with observation or with corticosteroid and vitamin administration. The onset of persistent facial palsy was 1 day after GKS in 2 patients, 3 days in 1, and 6 months in 2. All 8 patients who experienced newly developed or worsened preexisting facial palsy underwent GKS as the initial treatment. A statistically significant association was found between the development of transient or persistent facial palsy and transient expansion during the follow-up period (hazard ratio 7.15 [95% CI 1.379–37.065]; p = 0.019). Five (42%) of 12 patients who had transient expansion developed transient or persistent facial palsy. No other factor affected the worsening of facial nerve function.

Hearing Function

Data on post-GKS hearing were obtained for 40 patients. The other 2 patients had no hearing follow-up evaluations after GKS. Of the 40 evaluated patients, hearing function improved in 1 (3%) patient, remained stable in 35 (88%), and worsened in 4 (10%). All patients who had improved or worsened hearing had undergone GKS as the initial treatment. Detailed hearing results are shown in Fig. 4. Of 20 patients who had serviceable hearing with a PTA of ≤ 50 dB before GKS, 18 (90%) retained it at the last clinical follow-up.

Other Functional Outcomes

During the follow-up period, pre-GKS facial spasms improved in 4 of 5 patients and remained unchanged in 1. Improvement was seen in both patients with pre-GKS facial dysesthesia. Dysgeusia remained unchanged in 1 of 2 patients and was unknown in 1. Gait disturbance improved in 1 patient. Dizziness and tinnitus improved in 1 patient. After GKS, 2 patients newly developed facial spasms, which were transient in 1 patient. Transient dizziness, persistent atypical trigeminal neuralgia, and transient temporal headaches developed in 1 patient each. Comparisons of the Karnofsky Performance Scale scores at the time of GKS and the last clinical follow-up are shown in Table 4.

Discussion

Treatment Options

Currently, the safe resection of FNSs is one of the big-
radiosurgery for facial schwannomas

gest challenges for neurosurgeons. Despite the recent remarkable refinement of microsurgical techniques and neuronavigation, complete tumor resection often results in severe facial palsy or possible sacrifice of the facial nerve, even when performed by experienced neurosurgeons. McMonagle et al.\textsuperscript{23} reported a series of 53 patients with FNSs, 33 (62\%) of whom underwent resection (with a total of 36 procedures). Although total tumor resection was achieved in 21 of the 36 procedures, the facial nerve was sacrificed in 20 of the 21 total resections. Eventually, 21 (64\%) of the 33 patients in their study who underwent resection required facial nerve reconstructions. McRackan et al.\textsuperscript{24} also reported the results of 56 patients with FNSs, 53 (95\%) of whom underwent surgery. Although total resection was achieved in 45 (85\%) patients and subtotal resection was achieved

\begin{figure}[h]
\begin{center}
\includegraphics[width=\textwidth]{Fig2.png}
\end{center}
\caption{The Kaplan-Meier curve shows progression-free survival rates in 42 patients with FNSs. The actuarial 3- and 5-year progression-free survival rates were 100\% and 92\%, respectively.}
\end{figure}

\begin{figure}[h]
\begin{center}
\includegraphics[width=\textwidth]{Fig3.png}
\end{center}
\caption{The schema shows preradiosurgical and postradiosurgical HB grades in 42 patients with FNSs. Eight patients had improved facial nerve function, 29 remained unchanged, and 5 worsened. Of the 5 patients who had worsened facial nerve function, 4 had HB Grade III nerve function and only 1 had Grade IV.}
\end{figure}

\begin{figure}[h]
\begin{center}
\includegraphics[width=\textwidth]{Fig4.png}
\end{center}
\caption{The schema shows preradiosurgical and postradiosurgical hearing function in 42 patients with FNSs. Of the 40 evaluated patients, hearing function improved in 1 patient, remained stable in 35, and worsened in 4. Of 4 patients who had worsened hearing function, only 2 developed unserviceable hearing. The majority of patients retained their preradiosurgical hearing level. NF = no follow-up.}
\end{figure}
in 8 (15%) patients, the facial nerve was sacrificed in 36 (68%) patients. Despite preoperative facial nerve function of HB Grade I in 33 (59%) of the 56 patients, only 7 (13%) of 53 patients who underwent surgery retained HB Grade I nerve function 12 months after the operation. These results indicate that total tumor resection leads to a high rate of severe facial palsy; even with facial nerve reconstruction, the outcome would be HB Grade III nerve function at best. Although subtotal resection can contribute to better facial nerve function, tumor regrowth is not uncommon in the long term. Li et al.20 described a tumor recurrence rate of 27% in a mean follow-up period of 7 years in patients who had 70%–95% subtotal resection. In such cases, there is a much higher risk of sacrifice of the facial nerve during the second operation. Because FNSs are benign tumors, the risk of tumor recurrence or permanent facial palsy after surgery is a major issue, particularly for young patients. Therefore, observation with serial follow-up imaging has been the primary course of management for patients with FNSs who are asymptomatic or have mild HB Grade II or III facial palsy. Microsurgical resection is restricted to patients who have severe HB Grade IV to VI facial palsy.23 During the last 3 decades, SRS has emerged as another possible treatment option. There are several reports that showed the safety and efficacy of SRS for patients with FNSs who are asymptomatic or have mild HB Grade II or III facial palsy. Microsurgical resection is restricted to patients who have severe HB Grade IV to VI facial palsy.23 During the last 3 decades, SRS has emerged as another possible treatment option. There are several reports that showed the safety and efficacy of SRS for patients with FNSs who are asymptomatic or have mild HB Grade II or III facial palsy. Microsurgical resection is restricted to patients who have severe HB Grade IV to VI facial palsy.23 During the last 3 decades, SRS has emerged as another possible treatment option. There are several reports that showed the safety and efficacy of SRS for patients with FNSs who are asymptomatic or have mild HB Grade II or III facial palsy. Microsurgical resection is restricted to patients who have severe HB Grade IV to VI facial palsy.23

<table>
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<th>KPS Score</th>
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<td>100</td>
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</tr>
<tr>
<td>0</td>
<td>0</td>
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</table>

FU = follow-up; KPS = Karnofsky Performance Scale.
* Died of lung cancer.

In our study, facial nerve function had improved in 8 (19%) patients, remained stable in 29 (69%), and worsened in only 5 (12%) as of the last follow-up. Of the 5 patients with worsened facial nerve function, 2 patients with pre-GKS HB Grade I nerve function developed HB Grade III, and 3 patients with pre-GKS HB Grade II nerve function developed HB Grade III (2 patients) or Grade IV (1 patient). Unlike with surgery, no patient experienced severe HB Grade V or VI facial palsy, and 4 patients achieved HB Grade III nerve function, equal to the best recovery after facial nerve reconstruction. The advantage of SRS is that the facial nerve is not sacrificed, and other frequent postoperative complications, such as wound infection and cerebrospinal fluid leakage, do not occur. It is interesting to note that facial nerve deterioration occurred within 3 days after GKS in 4 of the 8 patients who had transient or persistent facial nerve deterioration. The cause of this acute radiation injury is unclear but may have been caused by acute radiation-induced edema. When GKS is applied as the initial treatment, acute facial palsy should be monitored carefully and treated promptly with corticosteroid administration. Transient expansion after GKS affected transient or persistent facial nerve deterioration significantly. Because the facial nerve goes through the narrow bony structure from the internal auditory canal to the stylomastoid foramen, even slight tumor volume expansion may cause facial nerve compression with vascular insufficiency.

**Hearing Function**

Some studies have reported the role of cochlear dose as a significant factor that affects hearing loss with vestibular schwannomas.1,8,10,13,15 Kano et al.15 reported that a central cochlear dose of < 4.2 Gy was significant in patients with vestibular schwannoma retaining their hearing function. Similarly, Hasegawa et al.8 demonstrated that hearing preservation was significantly better in patients with vestibular schwannoma with a mean cochlear dose of < 6 Gy. In our study, however, hearing function was preserved in the majority of patients with FNSs. Some degree of hearing deterioration developed in 4 patients, 2 of whom retained serviceable hearing (PTA ≤ 50 dB). Consequently, 18 (90%) of the 20 patients who had serviceable hearing before GKS retained it after GKS. This result indicates that the cochlear dose in patients with vestibular schwannoma is not directly related to hearing deterioration, because the cochlear dose in patients with FNSs is usually higher than that in patients with vestibular schwannoma, especially in patients with Type II tumors that extend from the internal auditory canal to the geniculate ganglion. Despite a relatively higher median mean cochlear dose of 7.3 Gy, most patients in our study retained their hearing function.

**Treatment Strategy**

In cases of asymptomatic small FNSs, surveillance should be the primary course of management. However, when a tumor grows or causes symptoms, we recommend SRS as the initial treatment. Because FNSs are benign tumors, the final goal of management is not necessarily to completely abolish all visible traces of the tumor but to ensure that good neurological function is preserved. As shown in this study, SRS for FNSs seems to be a rela-
tively safe and effective alternative to resection at present. Complete tumor resection is almost impossible without sacrificing the facial nerve. Although subtotal resection or fallopian canal decompression can be a reasonable surgical option for preserving facial nerve function, tumor regrowth is not uncommon in the long term, whereas FNSs are controlled after SRS, which suggests that microsurgery should be restricted to patients with severe HB Grade IV or higher facial palsy and large tumors compressing the brainstem, which are inappropriate for SRS. When the tumor size is too large to be treated by a single session of radiosurgery, stereotactic radiotherapy may be an acceptable treatment option.26,29,31

Study Limitations

In this study, 29 patients underwent GKS as the initial treatment without histological confirmation. Most of the tumors were diagnosed on the basis of typical radiological findings confined to the course of the facial nerve. However, a few tumors confined to the intracanalicular and/ or CPA were diagnosed on the basis of initial symptoms of facial weakness despite a relatively small tumor volume, which is suggestive of FNSs rather than vestibular schwannomas. Hence, it is possible that tumors other than FNSs were included in this study. In addition, because this was a retrospective multinstitutional study, radiosurgical techniques or patient selection may have varied among the participating centers. These biases may have affected our results. Although all the patients with FNSs eventually achieved good tumor control in a median follow-up period of 4 years, this follow-up period is too short to conclude the efficacy of SRS, especially for young patients. Therefore, it is important to collect additional long-term follow-up data along with information on late adverse radiation effects such as cyst formation and malignant change. As demonstrated in the long-term outcomes of vestibular schwannomas treated with SRS,5,7,8,19,25 satisfactory long-term results should be expected in patients with FNSs.

Conclusions

GKS contributed to good tumor control for selected patients with FNSs. Only 1 patient experienced tumor progression, but repeat GKS resulted in tumor shrinkage. Newly developed or worsened preexisting facial palsy occurred in 8 patients, but the condition was transient in 3 patients. Eight patients achieved some degree of improvement in their preexisting facial palsy. The risk of hearing disturbance as an adverse effect of radiation was low. In conclusion, GKS is a safe and effective treatment option for selected patients with FNSs and an alternative to resection.

Acknowledgment

We thank Ayaka Sasaki, Department of Neurosurgery, Tokyo Women’s Medical University, for assistance with data acquisition.

References


J Neurosurg Volume 124 • February 2016


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
Conception and design: Hasegawa. Acquisition of data: all authors. Analysis and interpretation of data: Hasegawa. Drafting the article: Hasegawa. Critically revising the article: Hasegawa. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Hasegawa. Statistical analysis: Hasegawa. Administrative/technical/material support: Hasegawa. Study supervision: Hasegawa.

Supplementary Information
Previous Presentation
Portions of this work were presented in abstract form at the 23rd Annual Meeting of the Japanese Society of Stereotactic Radiosurgery, Osaka, Japan, June 27, 2014.

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