Gamma Knife surgery for abducent nerve schwannoma

Report of 4 cases

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Abducent nerve schwannomas are extremely rare. The authors recently performed Gamma Knife surgery (GKS) in 4 patients with such tumors and describe their experiences with these cases.

The patients consisted of 3 women and 1 man whose ages varied from 31 to 60 years (mean 46 years). Two patients had no symptoms, 1 complained of slight visual disturbances, and the other 1 had abducent nerve palsy. Neurofibromatosis was not diagnosed in any case. All 4 tumors were located in the cavernous sinus: 2 of these tumors within the borders of the sinus, 1 tumor extending into the orbit, and 1 tumor extending into the preptonnine cistern. The volume of the neoplasms varied from 1.7 to 4.9 cm³ (mean 3.0 cm³). No patient underwent tumor resection. Treatment was delivered with the aid of a Leksell Gamma Knife model C unit and the automatic positioning system. The dose directed to the tumor margin was 12 Gy in all cases. The dose directed to the anterior visual pathways was kept below 10 Gy and that to the brainstem below 14 Gy. The length of follow-up varied between 7 and 43 months (mean 27 months).

There were no acute complications or side effects. Imaging studies showed temporary enlargement of all tumors during the 1st posttreatment year, but thereafter, there was a trend toward reduction in volume. None of the neoplasms displayed regrowth. In the 3 patients who did not have abducent nerve palsy before GKS, it appeared, at least temporarily, after the procedure. Purely intracavernous neoplasms in general followed uneventful posttreatment courses, but dumbbell-shaped tumors were associated with significant morbidity. The cisternocavernous schwannoma underwent cystic degeneration 2 years after GKS, and the patient developed diplopia. After GKS, the patient treated for an orbitocavernous schwannoma experienced a significant deterioration in vision, temporary blindness in 1 eye, and late development of permanent abducent nerve palsy, which were seemingly caused by compression of neurovascular structures within the anulus of Zinn during a temporary increase in the lesion’s volume after irradiation.

Gamma Knife surgery controls the growth of abducent nerve schwannomas and may be effectively used to manage intracavernous neoplasms. Caution, however, should be used in cases of dumbbell-shaped tumors, particularly those extending through the superior orbital fissure. (DOI: 10.3171/2010.8.GKS10947)

KEY WORDS • Gamma Knife surgery • abducent nerve schwannoma • management • complication • patient outcome

Abbreviations used in this paper: GKS = Gamma Knife surgery; SRT = stereotactic radiotherapy.
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performed GKS in 4 patients with abducent nerve schwannomas. Our experience with these cases is highlighted in this report.

**Methods**

Between January 2003 and September 2009, the first author (M.H.) performed 5105 radiosurgical procedures, of which 521 were for management of intracranial schwannomas. Among the latter procedures, 4 were performed on tumors that arose from the abducent nerve. All clinical, imaging, and radiosurgical data in these cases, both at the time of treatment and during follow-up, were collected in prospectively maintained computer databases.

The clinical summary of the 4 cases is presented in Table 1. There were 3 women and 1 man, ranging in age from 31 to 60 years (mean 46 years). At the time of treatment, all of these patients were in good general condition, with Karnofsky Performance Scale scores of either 90 (2 cases) or 100 (2 cases). Two patients had no symptoms, 1 patient noted slight visual disturbances that first appeared on the day before GKS, and 1 patient had abducent nerve palsy with associated diplopia on lateral gaze. Neurofibromatosis Type II was not diagnosed in any case.

No patient underwent tumor resection before or after GKS, and therefore, the diagnosis of abducent nerve schwannoma was established based on the following factors: 1) typical pretreatment neuroimaging characteristics of the lesion, including a hypo- or isointense signal on T1-weighted MR images, a hyperintense signal on T2-weighted MR images, and the presence of a contrast-enhancing lesion; 2) evaluation of the adjacent microanatomy at the time of radiosurgery using the Leksell GammaPlan (Elekta AB); 3) the presence of an isolated abducent nerve palsy during the course of the disease either before or after GKS; and 4) typical neuroimaging changes in the lesion after irradiation, with the appearance of central lucency. Two tumors were located solely in the cavernous sinus. The other 2 lesions were dumbbell shaped, with a portion located in the cavernous sinus and extension into the orbit (1 case) or preponite cistern (1 case). The volume of the neoplasms varied between 1.7 and 4.9 cm³ (mean 3.0 cm³).

**Radiosurgery Procedures**

On the day of GKS, a local anesthetic agent was applied to the patient’s head, and a Leksell G stereotactic frame (Eleka AB) was affixed. According to the protocol adopted in our clinic for GKS for skull base tumors, axial thin-slice bone-window CT scans and axial and coronal high-resolution MR images (Gd-enhanced T1-weighted, T2-weighted, plain, and Gd-enhanced constructive interference in steady state and Gd-enhanced modified time-of-flight images) were obtained in stereotactic conditions, and the image files were transferred to the Leksell GammaPlan. Radiosurgical treatment planning was done by reference to a simultaneous onscreen display of all obtained images within the 3D workspace. After the tumor and various adjacent anatomical structures had been delineated, complete coverage of the neoplasm with a 50% prescription isodose line was attained using a multislicer technique, performed according to our concept of “robotic microra-

**TABLE 1: Summary of patients with abducent nerve schwannoma who were treated with GKS**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Sex, Age (yrs)</th>
<th>Tumor Location</th>
<th>Presenting Symptoms</th>
<th>Margin Dose in Gy (isodose line)</th>
<th>Tumor Volume (cm³)</th>
<th>Posttreatment Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M, 47</td>
<td>lt CS &amp; orbit</td>
<td>visual impairment</td>
<td>12 (50%)</td>
<td>4.9</td>
<td>5.9 (at 10 mos) 3.8 43 Progressive visual impairment in lt eye began 4 mos post-GKS w/ subsequent appearance of transitory amaurosis. ANP palsy developed 18 mos post-GKS. Stabilization &amp; improvement in visual function by 31 mos post-GKS, but diplopia due to ANP persisted.</td>
</tr>
<tr>
<td>2</td>
<td>F, 45</td>
<td>lt CS &amp; pre-pontine cistern</td>
<td>none</td>
<td>12 (50%)</td>
<td>3.2</td>
<td>4.8† (at 6 mos) 5.6† 40 Transient diplopia due to ANP initially started 2 mos post-GKS w/ complete resolution 2 mos later &amp; reappear- ance at 2 yrs post-GKS, at time of cyst formation.</td>
</tr>
<tr>
<td>3</td>
<td>F, 31</td>
<td>lt CS</td>
<td>ANP &amp; diplopia</td>
<td>12 (50%)</td>
<td>2.1</td>
<td>2.5 (at 6 mos) 1.8 18 Uncomplicated posttreatment course w/ significant improvement in preexisting diplopia at time of last FU.</td>
</tr>
<tr>
<td>4</td>
<td>F, 60</td>
<td>lt CS</td>
<td>none</td>
<td>12 (50%)</td>
<td>1.7</td>
<td>3.4 (at 6 mos) 3.4 7 Transient diplopia due to ANP during 1st mo post-GKS w/ complete resolution later. No neurological symptoms at time of last FU.</td>
</tr>
</tbody>
</table>

* ANP = abducent nerve palsy; CS = cavernous sinus; FU = follow-up.
† The lesion in Case 2 had reduced by 3.0 cm³ by 12 months posttreatment, but increased thereafter to 5.6 cm³ due to intratumoral cyst formation.
MR images. Artifacts evaluated in 3D using fused bone-window CT and inters was adjusted according to the presence of distortion completion of the treatment plan, the position of all isocenters was adjusted according to the presence of distortion artifacts evaluated in 3D using fused bone-window CT and MR images.

Patient Follow-Up

All patients were followed up by the treating neurosurgeon with regular clinical examinations and serial neuroimaging sessions, which were scheduled once every 3 months during the 1st year after GKS, every 6 months during the 2nd year, and yearly thereafter. Additional MR imaging studies were performed in cases with significant clinical changes. The patient with visual disturbances was also followed up by an ophthalmologist. The length of follow-up varied from 7 to 43 months (mean 27 months).

Results

The treatment itself was not accompanied by any complications or side effects, and all 4 patients were released from the hospital the day after GKS.

Tumor growth was controlled in all cases. All neoplasms exhibited a more or less similar volumetric course, with some enlargement between 4 and 12 months after GKS, associated with the appearance of central lucency on imaging studies and followed by a trend toward reduction in the lesion’s volume, at least to the pretreatment level. One tumor underwent cystic degeneration by 24 months after GKS. None of the neoplasms displayed regrowth during the follow-up period.

The 3 patients who had no abducent nerve palsy before GKS, experienced it, at least temporarily, afterward. Abducent nerve palsy was noted 3 days after GKS in Case 4 and 18 months after GKS in Case 1. In Case 2, abducent nerve palsy was marked 2 months after radiosurgery, regressed completely within the subsequent 2 months, and reappeared 2 years after treatment at the time of intratumoral cyst formation.

In general, the dynamics of neurological symptoms after GKS differed strikingly between patients with tumors located solely in the cavernous sinus and those with dumbbell-shaped neoplasms. Whereas the former patients generally experienced an uncomplicated clinical course, the latter faced more profound morbidity. These complicated cases are presented in detail in the following section.

Illustrative Case Reports

Case 1

Examination. This 47-year-old man underwent clinical evaluation for nonspecific headache, and MR images showed the presence of a dumbbell-shaped tumor located in the left cavernous sinus and orbit. No neurological symptoms were present. A detailed evaluation of the microanatomy in the vicinity of the lesion gave rise to the suspicion of an abducent nerve schwannoma. Taking into account the absence of neurological symptoms, we decided to perform GKS.

Radiosurgery. The day before treatment, the patient experienced, for the first time, a slight transient visual deterioration in his left eye. Radiosurgery itself was uneventful. A 12-Gy radiation dose was delivered to the tumor margin at the 50% prescription isodose line. The optic pathways were kept outside the 40% prescription isodose line, where the radiation dose was 9.6 Gy (Fig. 1). On the day after treatment, the patient was released from the hospital.

Follow-Up Course. Four months after GKS, the patient presented at the outpatient clinic with visual deterioration. On examination, he was found to have impaired visual acuity and fields in the left eye with central scotomas (Fig. 2). In addition, the tumor had slightly increased in volume. Steroid therapy was initiated, but the man’s visual impairment progressed further, and he experienced transitory amaurosis. At 10 months after GKS, the left eye only retained a small residual visual field in the upper-inner corner. An additional increase in tumor volume and central lucency were evident on MR images. We proposed resection of the lesion, but this was rejected by the patient and his family. At 13 months after radiosurgery, the patient became completely blind in the left eye with loss of light perception. At that time, fundoscopy revealed a pale optic disc. Steroid therapy (Rinderon 20–30 mg/day) was continued, but no other treatment was added. Nevertheless, 2 months later, the patient’s vision returned and steadily improved. The improvement in vision was accompanied by a steady reduction in the size of the tumor (Fig. 2). At 18 months after GKS, the patient began to experience left-sided abducent nerve palsy with associated diplopia. By 24 months, vision in his left eye had nearly completely recovered, whereas the central scotomas still remained. At the last follow-up examination, 43 months after GKS, the tumor was found to be approximately 20% smaller than it had been before treatment and approximately 35% smaller than its maximum volume 10 months after radiosurgery. The patient has serviceable vision in his left eye but still experiences diplopia on left lateral gaze.

Case 2

Examination. This 45-year-old woman underwent clinical evaluation for nonspecific headache, and a dumbbell-shaped tumor was identified in the left cavernous sinus and prepontine cistern using MR imaging. No neurological symptoms were present. A detailed evaluation of the microanatomy in the vicinity of the lesion led us to a diagnosis of abducent nerve schwannoma (Fig. 3). Taking into account the patient’s absence of neurological symptoms, we decided to perform GKS.
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Radiosurgery. In itself, the GKS was uneventful. The radiation dose to the tumor margin (50% prescription isodose line) was 12 Gy (Fig. 4). The day after treatment, the patient was released from the hospital.

Follow-Up Course. Two months after GKS, the patient began to experience diplopia and left-sided abducent nerve palsy. The tumor volume at the time was stable, but central lucency appeared on imaging studies. Steroid therapy was initiated, and within 2 months, the woman’s symptoms resolved completely. Later she experienced no symptoms, despite a slight increase in tumor volume observed on MR images between 6 and 9 months after GKS (Fig. 5). Nevertheless, the left-sided abducent nerve palsy with associated diplopia reappeared 2 years after treatment. At that time, MR images revealed cystic degeneration of the portion of neoplasm in the prepontine cistern. Currently the patient is being closely observed; her further treatment will depend on the dynamics of cyst volume and associated neurological symptoms.

Discussion

Tumors arising from the abducent nerve usually represent typical schwannomas, although on occasion a cellular schwannoma with a high proliferative activity or a neoplasm of another histopathological type have been reported. As expected, the most typical symptom at presentation is diplopia caused by a deficit in eye abduction, although other symptoms can be present, such as hydrocephalus and intracranial hypertension, headache, dizziness, vertigo, nystagmus, ataxia, visual disturbances, oculomotor nerve palsy, dysgeusia, facial pain, paresthesia, and/or hypesthesia (usually within the distribution of the ophthalmic nerve), facial palsy, tinnitus, hypacusis and hearing loss, proptosis, chemosis, emotional liability, and mental and memory abnormalities. It is evident that neurological signs in such cases are mainly determined by the location and size of the lesion. The long abducent nerve can be divided into 5 segments: cisternal, gulfar (the intradural part within the sphenopetroclival venous gulf), cavernous, fissural, and intraconal. Correspondingly, neoplasms originating from the abducent nerve may be located in several anatomical areas or may be dumbbell shaped. Initially, Tung et al. defined 2 types of abducent nerve schwannomas according to their location in the cavernous sinus (Type I) or prepontine and cerebellopontine cisterns (Type II). Later, Celli et al. noted the possibility of cisternocavernous lesions as well. Tumors confined to the borders of 1 anatomical structure seem to be much more common than those inhabiting > 1 region. A literature review of 24 abducent nerve schwannomas revealed that, in 11 cases (46%), the mass was located in the infratentorial subarachnoid cisterns, in 8 cases (33%), in the cavernous sinus with possible extension into the middle fossa, and in 1 case (4%), in the orbit. There were only 4 reports (17%) of dumbbell-shaped cisternocavernous neoplasms extending through the Dorello canal. Moreover, to the best of
our knowledge, before this report, no other orbitocavernous abducent nerve schwannoma extending through the superior orbital fissure was reported.

Given this type of tumor’s location near the brainstem and functionally important neurovascular structures, total resection of abducent nerve schwannomas has been attained in less than one-half of surgically treated cases.1–6,10,13,15,19,22,31–33,36–38,41,42,45,49,52,54 Moreover, at least a temporary postoperative deficit in eye abduction was noted in 78% of patients, although complete resolution of the deficit within several months is definitely possible.37,38,54 Other postoperative complications have included disturbances of cranial nerves III, IV, VII, and VIII and the ophthalmic division of cranial nerve V, as well as aphasia, hemiparesis, dysphagia, hypertensive pneumocephalus, stroke, and intracerebral hemorrhage.5,19,31,33,45,49,52,54

Taking into account the risk of such morbidity, the indications for resection of these benign and slow-growing neoplasms in asymptomatic or elderly patients seem, at least, debatable.43

Kim et al.26 retrospectively reviewed 8 cases of schwannomas of cranial nerves III, IV, and VI that had been treated with GKS using a dose of between 11 and 13 Gy directed to the tumor margin. During a mean follow-up of 21 months, all tumors had reduced in volume, and there was improvement in neurological symptoms, including diplopia, in 5 cases. Their series included 1 cisternal abducent nerve schwannoma. Its size was significantly reduced after treatment, its growth was controlled throughout 40 months of follow-up, and an associated preexisting headache was improved. Chakrabarti et al.5 reported a case of recurrent abducent nerve schwannoma, located in the cavernous sinus, that was treated using linear accelerator–based radiosurgery with a 15-Gy dose directed to the tumor margin. Ten months later, the tumor had stabilized in size, and a central low-intensity signal area with marked peripheral enhancement was shown on imaging studies; this was accompanied by complete disappearance of the preexisting proptosis and an improvement in the abducent nerve palsy. Showalter et al.48 reported a series of nonacoustic cranial nerve schwannomas treated either with radiosurgery or SRT, which included 3 patients with abducent nerve tumors; unfortunately, these authors did not include clinical details of the lesions’ management and patient outcomes. Finally, there have been sev-
eral reports on successful radiosurgery for intraorbital and cavernous sinus schwannomas, but the nerve from which the tumor originated is not identified.

In agreement with the aforementioned reports, our results demonstrate that GKS can effectively control the growth of an abducent nerve schwannoma; this was attained in all our patients during a short-to-intermediate follow-up period. Nevertheless, outcome is seemingly determined by tumor location and extension. In both cases of purely intracavernous neoplasm, satisfactory treatment results were obtained with a generally uneventful post-treatment course. In 1 of these patients (Case 3), GKS resulted in a significant improvement in preexisting diplopia, whereas in 1 other patient (Case 4), only transient abducent nerve palsy was observed during the 1st month after GKS, and this subsequently completely resolved. These results correspond to known favorable outcomes after radiosurgery for cavernous sinus tumors, including schwannomas, particularly if the maximal radiation dose is kept below 40 Gy.

Contrary to purely intracavernous abducent nerve schwannomas, radiosurgical management of dumbbell-shaped tumors in our patients was associated with more profound morbidity. In 1 patient with a cisternocavernous neoplasm extending through the Dorello canal (Case 2), delayed cyst formation was noted 2 years after GKS and was associated with a reappearance of diplopia. Such a complication is mainly reported after radiosurgery for

![Fig. 4. Case 2. Treatment plan of GKS for a left cisternocavernous abducent nerve schwannoma. Prescription isodose lines of 80% and 50% are shown.](image)

![Fig. 5. Case 2. Dynamics of tumor volume and structure after GKS for a left cisternocavernous abducent nerve schwannoma. The central lucency initially appeared 2 months after treatment and was followed by a slight increase in tumor volume at 6 months after irradiation. At 24 months after GKS, formation of the cyst in the preptontine cistern became evident.](image)
intracranial arteriovenous malformations and is only infrequently noted in cases of intracranial tumors including schwannomas. Complications were even more severe in our patient with an orbitocavernous tumor extending through the superior orbital fissure (Case 1). The posttreatment course in this patient was affected by a significant deterioration in vision with temporary blindness in 1 eye and late development of permanent abducens nerve palsy with associated diplopia. Because the radiation dose to the optic nerve did not exceed 10 Gy, it is very unlikely that a direct irradiation injury occurred. A much more plausible cause of clinical deterioration in this case is a temporary increase in lesion volume after radiosurgery with resultant compression of the optic nerve and/or interruption of its blood supply within the anulus of Zinn. Previously, Del-santi et al. reported that 54% of vestibular schwannomas exhibited swelling 6 months after GKS, and approximately one-half of these neoplasms increased in volume > 30%. Lunsford et al. noted that trigeminal schwannomas have a much higher likelihood of such changes. In accordance with these findings, all tumors in this series demonstrated temporary enlargement after radiosurgery, which was associated with an appearance of central lucency; later, the lesions tended to decrease in size, at least to pretreatment level. It seems evident that if such a temporary increase in lesion volume occurs in tightly confined areas, such as the superior orbital fissure, anulus of Zinn, or Dorello canal, it may cause compression of adjacent neurovascular structures and consequently aggravate neurological symptoms. Therefore, based on our limited experience with GKS for dumbbell-shaped abducens nerve schwannomas, it is possible to speculate that application of multistage GKS, or combined treatment (initial microneurosurgical decompression and subsequent radiosurgery or SRT) may be more reasonable in such cases.

Conclusions

Based on our experience with 4 cases of abducens nerve schwannoma, we can conclude that GKS may effectively control growth of these tumors. If such a neoplasm is confined to 1 anatomical area, such as the cavernous sinus, radiosurgery can be considered the preferable treatment option, especially in asymptomatic and elderly patients. Caution, however, should be used in cases of dumbbell-shaped tumors, particularly those extending through the superior orbital fissure into the orbit. In such cases, a temporary increase in tumor volume after irradiation may result in aggravation of neurological symptoms caused by compression of adjacent anatomical structures within the anulus of Zinn.

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: Hayashi. Acquisition of data: Hayashi, N Tamura, Yomo, Ochiai, Nagai, Izawa. Analysis and interpretation of data: Chernov. Drafting the article: Chernov. Critically revising the article: Hayashi, Chernov, M Tamura, Izawa, Muragaki, Iseki, Okada, Takakura. Reviewed final version of the manuscript and approved it for submission: all authors. Administrative/technical/material support: Izawa. Study supervision: Hayashi, Iseki, Okada, Takakura.

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