Early Changes in Volume and Non-enhanced Volume of Acoustic Neurinoma after Stereotactic Gamma-radiosurgery

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Abstract

The effectiveness of stereotactic gamma-radiosurgery for treating acoustic neurinoma was evaluated by measuring the volumes of the tumor, non-enhanced tumor, and cerebellar edema in 13 patients with acoustic neurinoma who were followed up for 9 to 15 months (median 12.7 mos) after treatment. The tumor volume and non-enhanced volume tended to reach a maximum after 6 months, and cerebellar edema volume after 9 months, then decreased gradually thereafter. Hearing loss tended to increase gradually, but involvement of the facial nerve was transient.

Key words: stereotactic radiosurgery, gamma knife, acoustic neurinoma, early change

Introduction

Stereotactic gamma-radiosurgery, which can focus collimated gamma rays from 201 60Co sources into a small volume, is widely used to treat intracranial lesions such as arteriovenous malformation, acoustic neurinoma, and other neoplasms.3,6,10,11,18 Acoustic neurinoma shrinks and demonstrates less contrast enhancement on magnetic resonance (MR) images after stereotactic radiosurgery. Obliteration of the blood supply to the tumor caused by radiation-induced vascular injury may be the most important mechanism controlling tumor growth.2,8,9,12,16,19 However, only the average tumor diameter was measured in most cases and few precise volumetric analyses have been performed.

This study measured the change in whole tumor and non-enhanced volumes and the functions of the acoustic, facial, and trigeminal nerves during the early posttreatment stage. Patients and Methods

This study evaluated 13 patients with acoustic neurinoma treated with stereotactic radiosurgery and followed up for 9 to 15 months (median 12.7 mos) after treatment (Table 1). Radiosurgery was performed...

Table 1 Clinical characteristics of acoustic neurinoma patients

<table>
<thead>
<tr>
<th>Sex</th>
<th>2 cases</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age*</td>
<td>56.2 ± 11.9 yrs</td>
<td></td>
</tr>
<tr>
<td>Prior treatment</td>
<td>operation</td>
<td>6 cases</td>
</tr>
<tr>
<td>Irradiation dose*</td>
<td>maximum</td>
<td>28.7 ± 3.0 Gy</td>
</tr>
<tr>
<td></td>
<td>marginal</td>
<td>14.9 ± 1.7</td>
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</tbody>
</table>

*Values are mean ± SD.
ed with a Leksell gamma unit (Elekta Instruments, Stockholm, Sweden) using a marginal dose below 15 Gy, almost 50% of the maximum dose, to avoid radiation injury to the trigeminal, facial, and acoustic nerves. MR imaging studies were carried out for 9 to 15 months (median 12.8 mos) after treatment in 12 of the 13 patients, and the acoustic, facial, and trigeminal nerve functions were evaluated for 6 to 12 months (median 9.9 mos) after treatment in seven of these 12 patients.

Serial gadolinium (Gd)-enhanced T<sub>1</sub>- and T<sub>2</sub>-weighted MR images were taken with 3 mm-thick slices before and 3, 6, 9, 12, and 15 months after treatment. The volumes of the tumor, the non-enhanced area, and the cerebellar edema were calculated by integrating the area of the lesion in each slice multiplied by the slice thickness (3 mm) using the Image 1.47 software (Apple Computer Inc., Cupertino, Cal., U.S.A.). Hearing was evaluated with a pure-tone audiogram (250, 500, 1000, 2000, and 4000 Hz) for air conduction before and 3, 6, 9, and 12 months after treatment.

Changes in volume and hearing function were statistically analyzed with Dunnett's test, and p < 0.05 was considered significant.

**Results**

The tumor volume tended to increase slightly 6 months after radiosurgery and to decrease to almost the same volume as pretreatment after 9 months. The tumor volume was stable in seven patients, slightly increased in three, and decreased in three during the follow-up of 9-15 months (Fig. 1). The non-enhanced tumor volume reached the maximum (44.2% of total tumor volume) after 6 months and decreased thereafter (p < 0.01). Absence of central enhancement increased in all patients, appearing in five and increasing in another eight compared to pretreatment during the follow-up of 9-15 months. The volume of cerebellar edema tended to reach a maximum after 9 months and decreased thereafter (not significant). New cerebellar edema developed in only one patient of the seven without cerebellar edema before radiosurgery, and pretreatment edema increased in another five patients during the follow-up of 9-15 months. However, the edema was transient and caused no symptoms in any patient. A representative case which responded well to the treatment is shown in Fig. 2. The tumor volume decreased markedly 15 months after treatment, while the non-enhanced volume increased prominently after 6 months and decreased after 15 months.

Hearing loss gradually increased in almost all frequency bands after treatment (not significant) (Fig. 3). The average hearing loss in the 250- to 4000-Hz bands was stable after radiosurgery in three patients whose pretreatment hearing losses were over or equal to 80 dB, and increased in four patients whose pretreatment hearing losses were under 80 dB.

Figure 4 shows the changes with time in acoustic, facial, and trigeminal nerve function, and tumor and edema volume in seven patients. Sensory disturbance on the face deteriorated gradually after radiosurgery in one patient, improved in two, and was stable in

![Fig. 1 Changes in tumor (left, closed columns), non-enhanced tumor (left, shaded columns), and cerebellar edema volumes (right) after stereotactic radiosurgery. Bar shows SD. Number of cases shown in parentheses. Asterisk indicates significance (p < 0.01).](image)
four. Facial paralysis appeared in one patient and deteriorated in another, but the deterioration was transient in both. The facial nerve symptoms were stable in the other five patients.

Discussion

Our MR imaging study showed that acoustic neurinoma volume tended to increase transiently 6 months after radiosurgery treatment. The follow-up was too short to evaluate the long-term effects of the treatment, but we expect tumor shrinkage to occur during further follow-up.4,9,11,15,17,19

Loss of central tumor enhancement occurred in all patients, and the non-enhanced volume increased significantly 6 months after treatment, although decreasing again after 15 months. Linskey et al.9 reported a similar course, with loss of central tumor enhancement in 78% of cases between 1 and 18 months (median 6 mos) after gamma-radiosurgery, while 17% of patients with decreased central enhancement showed a reincrease 6 to 29 months (median 13 mos) later. Such loss of central contrast enhancement may result from radiation-induced vascular injury and occlusion.9,13

New cerebellar edema developed in only one of our 12 patients, but caused no additional symptoms. Edema tended to reach a maximum after 9 months, almost agreeing with Linskey et al.9 who found 9% of patients developed new adjacent parenchymal changes (edema) 5 to 15 months (median 8 mos) after treatment, which normalized 13 to 19 months later in 25% of cases. The maximization of cerebellar edema
Fig. 4 Changes in acoustic (●), facial (VII), and trigeminal nerve function (V), and tumor (■) and edema volume (□) after radiosurgery in individual patients. Nerve dysfunction is shown as the black column while the white column indicates no symptoms. Previous operative treatment and maximum/marginal irradiation doses are: 69-year-old female, operation (−) and 30/18 Gy (A); 36-year-old female, operation (−) and 25/15 Gy (B); 65-year-old female, operation (+) and 25/11 Gy (C); 59-year-old female, operation (+) and 30/15 Gy (D); 66-year-old female, operation (−) and 36/18 Gy (E); 54-year-old male, operation (−) and 28/14 Gy (F); 54-year-old female, operation (+) and 28/14 Gy (G).
occurred 3 months after the greatest volumes of tumor and non-enhanced portion were reached.

Hearing loss tended to increase gradually after radiosurgery. New facial nerve dysfunction developed in one of seven patients and the previous dysfunction deteriorated in another, but was transient in both. Previous trigeminal nerve dysfunction deteriorated in one patient, but improved in two. Linskey et al. found that useful hearing preservation (pure-tone average threshold < 50 dB and speech discrimination > 50%) was achieved in 50% of patients after 6 months and 38% after 1 year, and loss of useful hearing began 1 week to 12 months (median 6 mos) after treatment. New facial nerve dysfunction occurred in 22% after 6 months and 30% after 1 year, beginning after 1 day to 16 months (median 5 mos), but completely disappeared in 20% and improved in 53% of patients after 1 to 9 months (median 6 mos). New trigeminal nerve dysfunction appeared in 19% of patients after 6 months and 33% after 1 year, starting after 2 to 19 months (median 6 mos). Only 10% of new trigeminal neuropathy resolved completely, but the majority of patients improved to varying degrees. Dysfunction of cranial nerves is thought to be related to demyelination or compromised vascular supply, but the sensitivity to radiosurgery varies among the cranial nerves.1,9,14)

Stereotactic radiosurgery apparently controls tumor growth with relatively low risk and is an attractive method, especially for patients who are elderly, have medical problems, or refuse surgery. Further follow-up is necessary for the assessment of this new treatment modality.

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