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Predictors of hearing outcomes following low-dose stereotactic radiosurgery in patients with vestibular schwannomas: A retrospective cohort review

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ABSTRACT

Objectives: Hearing deterioration is a major concern for hearing-preserved patients with vestibular schwannomas who are treated with stereotactic radiosurgery (SRS). Thus, determining which patients are more likely to have worse hearing outcomes following SRS may facilitate clinicians in deciding whether conservative policy should be applied in the interest of hearing preservation. This study aimed to define the predictors of hearing outcomes following SRS.

Patients and methods: This retrospective study included 100 patients who underwent low-dose SRS (12- to 13-Gy marginal dose) for vestibular schwannomas between January 2004 and January 2014. Clinical factors and hearing outcomes following radiosurgery were reviewed.

Results: All patients had serviceable hearing at diagnosis and prior to SRS. The median follow-up period was 6.5 years (range, 3–10 years). The hearing preservation rate in the first, third, and fifth year after radiosurgery was 89%, 68%, and 63%, respectively. A mean cochlear dose lower than 4 Gy was a favorable predictor of hearing outcome. Maximal cochlear dose, patient age, pre-treatment pure-tone average, and imaging characteristics were not associated with post-treatment hearing preservation. Our study showed an accelerated rate of deterioration of serial pure-tone average in the first 3 years, followed by a more gradual decline after radiosurgery.

Conclusion: Our results suggest that cochlear dose constraint is the most crucial factor for hearing preservation. This study provides insight into the rate of hearing preservation and the pattern of hearing deterioration following radiosurgery and can help clinicians advise patients of hearing outcomes following SRS.

1. Introduction

Vestibular schwannomas account for approximately 6% of all intracranial tumors and 85% of all cerebellopontine angle tumors [1]. The incidence rate is reported to be 1.9 tumors per 100,000 people per year [2]. Stereotactic radiosurgery (SRS) has emerged as an effective alternative to microsurgical resection in the treatment of vestibular schwannoma, providing good tumor control and functional outcomes. Many studies have shown its long-term safety and effectiveness [3,4]. A local control rate of 90–100% has been reported in the literature; however, hearing deterioration can eventually developed following SRS [5]. Long-term follow-up studies have indicated that the rate of functional hearing preservation decreases to 25% at 10 years post-SRS [6,7]. Therefore, a conservative policy that does not include radiosurgery is generally recommended for patients with small tumors, limited hearing loss, or slow tumor growth rate (≤ 2.5 mm/year) in order to maintain a higher chance of long-term hearing preservation [7,8]. Additionally, identifying patients who are likely to have worse hearing outcomes following SRS can help physicians and patients decide whether a conservative policy should be applied in the interest of hearing preservation. Previous studies have reported that hearing preservation after SRS was associated with patient age, pretreatment PTA, and tumor size. Cochlear dose was recently recognized as a clinical factor of hearing outcomes after SRS, but the cut-off value of cochlear dose is still in dispute. Bedsides, the relationship between image characteristics and hearing outcomes after SRS has not yet been discussed sufficiently in previous literature. This study aimed to define the above-mentioned predictors of hearing outcomes following SRS [9–12].

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2. Materials and methods

This was a retrospective study of 210 patients with vestibular schwannomas who were treated at a single tertiary center between January 2004 and January 2014. Audiologic examinations were performed before and every 6 months after SRS and were recorded in a prospectively maintained clinical database by well-trained audiologists. After institutional review board approval, all patients diagnosed with vestibular schwannomas were reviewed in this database. We excluded patients who did not receive adequate audiological examination (n = 23); patients with other middle ear or inner ear diseases (n = 5); patients who were managed with a conservative strategy or surgical intervention (n = 25); patients who received an average marginal dose of > 13 Gy (n = 12); patients without preserved pre-treatment hearing, defined as an American Association of Otolaryngology-Head and Neck Surgery (AAO-HNS) classification of C or D (n = 28); and patients who were lost to follow-up (n = 17).

One hundred patients were enrolled in this study. Their demographic data, clinical presentation, imaging characteristics, pure-tone average (PTA), speech discrimination scores (SDS), stapedial reflex, auditory brainstem response (ABR), oculomotor control (pursuit, saccade, optokinetic nystagmus), caloric test, and hearing outcomes every 6 months following SRS were reviewed. PTA and SDS decline during the follow-up period after SRS were also analyzed.

The analyzed ABR waveforms included the absolute latency of waves I, III, and V; the interpeak latency of wave I–III, I–V, and III-V; and the interaural latency differences of waves I–III, I–V, and III–V. All patients underwent fast imaging employing steady-state acquisition (FIESTA) for brain magnetic resonance imaging (MRI). The imaging characteristics, including tumor size, location, fundus involvement, brainstem compression, and internal auditory canal dilatation, were studied to determine whether different types of vestibular schwannoma were correlated with the results of the audiological examination. The image characteristics were classified according to a previous reporting system [13] (Fig. 1) and are shown in Table 1. Preserved hearing was defined as a PTA ≤ 50 dB and SDS ≥ 50%, and classified as AAO-HNS class A or B.

2.1. Radiosurgical technique strategy

Radiosurgery was performed using the Leksell Gamma Knife C model (Elekta, Stockholm, Sweden). The Leksell stereotactic head frame was applied after the administration of local anesthesia and sedation. Contrast-enhanced MRI scans were acquired with a 1-mm slice thickness to outline the lesion and identify organs at risk. Image data were then transferred to a treatment planning workstation. Treatment plans were designed using Leksell GammaPlan Wizard 5.34, a three-dimensional gamma knife radiosurgery treatment planning system. The planning target volume was defined as the area of the T1-weighted MRI contrast-enhancing lesion. A radiation dose of 12 or 13 Gy was prescribed to the 50% isodose line at the periphery of the tumor to maximize the dose delivered to the target volume while limiting the dose delivered to the inner ear structures. The recommended dose constraint to the cochlea is a mean dose of less than 5 Gy for patients with pretreatment serviceable hearing. Minimum, maximum, and mean cochlear doses were obtained from dose volume histograms calculated by the Leksell GammaPlan planning software.

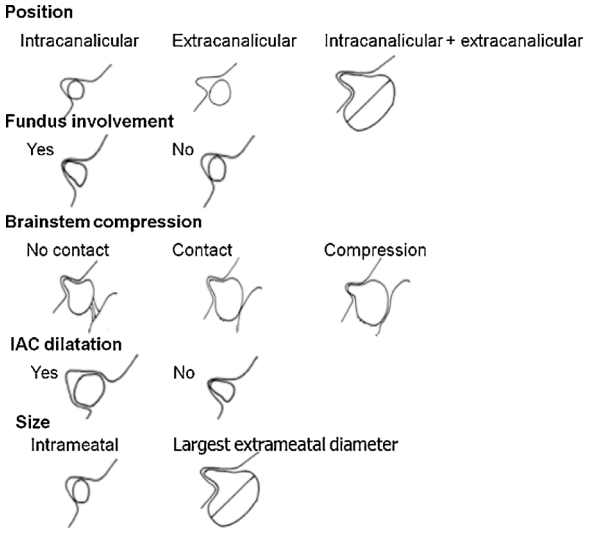

Fig. 1. The image characteristics of vestibular schwannomas.

Table 1
Image Characteristics.

	No. of patients(%)
Position	
Extracanalicular	8 (8)
Intracanalicular	19 (19)
Intracanalicular + extracanalicular	73 (73)
Fundus involvement	
Yes	37 (37)
No	63 (63)
Brainstem compression	
No contact	40 (40)
Contact	15 (15)
Compression	45 (45)
[a]IAC dilatation	
Yes	82 (82)
No	18 (18)
[b]Size (mm)	
Intrameatal	17 (17)
1–10	21 (21)
11–20	29 (29)
21–30	18 (18)
31–40	9 (9)
41–	6 (6)

[a] Internal auditory canal.
[b] Measurement of acoustic neuromas was based on the largest extrameatal diameter.

2.2. Statistical analysis

Continuous variables are presented as mean ± SD, and categorical variables are presented as frequency counts. Logistic regressions were applied to assess the associations between tumor size and stapedial reflex, oculomotor control, ABR, and caloric tests, respectively. Simple linear regression models were applied to assess the relationship between tumor size and the absolute latency of waves I, III, and V; the interpeak latency of wave I–III, I–V, and III-V; and the interaural latency differences of waves I–III, I–V, and III–V. Multivariate analysis was performed using multiple regression to statistically analyze the image characteristics, including tumor size, location, fundus involvement, brainstem compression, and internal auditory canal dilatation, associated with PTA and SDS before SRS. We compared patient age, pretreatment PTA, pretreatment SDS, maximal and mean cochlear dose, and image characteristics between hearing preserved and non-preserved patients using a Cox regression model. Cut-off values were determined using receiver operating characteristic curves. A p-value less than 0.05 was considered to be significant. The analyses were performed using SAS version 9.2 (SAS Institute, Cary, North Carolina, U.S.).

2.3. Ethical considerations

A retrospective review of the data was performed with strict discretion and confidentiality. All data were de-identified. This study was reviewed and approved by the Institutional Review Board (IRB) of our