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CLINICAL ARTICLE

Clinical and Radiologic Outcomes of Gamma Knife Radiosurgery for Jugular Foramen Schwannoma

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Objective: Resection, the current first-line treatment for jugular foramen schwannomas (JFSs), can result in postoperative neurological deterioration caused by damage to adjacent cranial nerves, highlighting the need for less invasive treatment options. The objective of this study was to evaluate the tumor control rate and functional outcomes in patients who underwent gamma knife radiosurgery (GKRS) for JFS.

Methods: We analyzed the 12 patients with JFS who underwent GKRS at our center since 2000. The patients comprised of four men and eight women (mean age 55.3 years, range 37–78 years). At the time of GKRS, the patients were experiencing the following symptoms: swallowing disturbance (5 patients), tongue deviation (2 patients), tinnitus (2 patients), facial pain (2 patients), dizziness (1 patient), headache (1 patient), hoarseness (1 patient), and gait disturbance (1 patient). 3 patients had two symptoms each. GKRS was used as an initial treatment without conventional surgery in 11 patients, and after initial subtotal resection in 1 patient. The mean tumor volume was 4,018mm^3 (range 540–11,245mm^3). The average maximum and marginal tumor doses were 25Gy (range 24–27Gy), and 12.5Gy (range 11.5–14Gy), respectively.

Results: The mean radiological and clinical follow-up time was 41.5 months (range 6–170 months). Tumor growth control was achieved in 11 patients (91.7%). Six patients showed improvement of neurological symptoms after GKRS. In 2 of these 6 patients, two symptoms each were resolved after GKRS. In the other 6 patients, the symptoms remained unchanged after GKRS.

Conclusions: Our findings indicate that GKRS is an effective alternative to surgical resection for patients with JFSs. Given the excellent long-term tumor control and clinical outcomes, GKRS might represent first–line treatment for JFS patients with neurologic deficits.

KEY WORDS: Gamma knife · Radiosurgery · Jugular foramen · Schwannoma · Stereotactic.

INTRODUCTION

Intracranial schwannomas are benign tumors that comprise approximately 8% of all primary brain tumors.[16] Schwannomas arising from the jugular foramen are very rare, and because of their location, it is very difficult to resect such tumors completely without causing cranial nerve dysfunction. To date, resection has been considered the primary course of treatment for jugular foramen schwannomas (JFSs). However, many patients develop postoperative neurological deterioration as a result of injury to adjacent cranial nerves during the operation.[13][15][22] Therefore, alternative strategies that are less invasive than surgical resection must be considered for patients with JFSs. Recently, Gamma Knife radiosurgery (GKRS) has been shown to be a safe and effective treatment modality for the management of vestibular schwannomas.[9] However, few reports have described the functional outcomes of JFS patients treated with GKRS. Therefore, in this study, we aimed to evaluate the tumor control rate and functional outcomes of GKRS in patients with JFSs.

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METHODS

Since 2000, a total of 12 patients with JFS have undergone GKRS at our center (Table 1). The patients comprised of four men and eight women (mean age 55.3 years, range 37−78 years). At the time of GKRS, the patients were experiencing the following symptoms: swallowing disturbance (5 patients), tongue deviation (2 patients), tinnitus (2 patients), facial pain (2 patients), dizziness (1 patient), headache (1 patient), hoarseness (1 patient), and gait disturbance (1 patient). Among these 12 patients, 3 patients had two symptoms each: one with swallowing disturbance

Table 1. Characteristics of the 12 patients who underwent gamma knife radiosurgery for jugular foramen schwannoma

Case No.	Patient age, sex	Symptoms	Prior treatment	Tumor volume (mm^3)	Radiation dose (Gy)	
					Max	Margin
1	54, M	Swallowing disturbance, Tongue deviation	None	4,514	24	12
2	42, F	Tinnitus	None	6,498	24	12
3	37, M	Facial pain	Subtotal resection	2,397	26	13
4	54, M	Swallowing disturbance	None	2,278	27	13.5
5	61, F	Tinnitus	None	2,922	25	12.5
6	57, F	Dizziness, Tongue deviation	None	4,700	27	14
7	78, F	Facial pain	None	3,554	23	11.5
8	55, F	Swallowing disturbances, Hoarseness	None	1,618	24	12
9	57, F	Swallowing disturbance	None	540	26	13
10	54, M	Swallowing disturbance	None	4,611	24	12
11	47, F	Headache	None	3,340	26	13
12	68, F	Gait disturbance	None	11,245	24	12

and tongue deviation, another with dizziness and tongue deviation, and another with hoarseness and swallowing disturbance. One patient had previously undergone subtotal tumor resection, resulting in a histopathological diagnosis of schwannoma. For the other 11 patients, the diagnosis was based on clinical findings and imaging criteria.[26]

All radiosurgery procedures in this study were carried out using a Leksell Gamma knife (Model B and C Elekta, Stockholm, Sweden). After applying a Leksell stereotactic coordinate frame to the patient's head, we acquire T1-weighted magnetic resonance images with gadolinium contrast, and reconstructed the slices every 2mm in the axial plane. During the study period, dose planning was accomplished using a Leksell Gamma knife C-model from January 2000 to December 2010 and a Leksell Gamma knife Perfexion™ (ELEKTA) model after January 2011. The mean tumor volume was 4,018mm^3 (range 540−11,245mm^3). The average maximum tumor dose was 25Gy (range 24−27Gy), and the mean tumor marginal dose was 12.5Gy (range 11.5−14Gy). After performing GKRS, we evaluated patients with regularly scheduled imaging and clinical assessments. Follow-up imaging studies were performed at 1-year intervals for the first 3 years, and once every 2 years thereafter, depending on the medical condition of the patient. Additional imaging scans were acquired and evaluated every 6 months when symptoms were aggravated. An average of 2.5 imaging studies were performed for all patients. Tumor control was assessed using follow-up magnetic resonance imaging. Tumor control was classified as increased (volume enlargement of $\geq$10%), stable (volume enlargement of $<$10% or reduction of $<$10%), or decreased (volume reduction of $\geq$10%).

All data were obtained from hospital chart and imaging study databases; the study was approved by Asan Medical Center Institutional Review Board.

RESULTS

The mean radiological and clinical follow-up time was 41.5 months (range 6−170 months). None of the patients died during follow-up.

Tumor control

On the last follow-up imaging evaluations, tumor decrease was observed in 6 patients (50.0%) (Fig. 1), tumor stability was observed in 5 patients (41.7%), and tumor increase was observed in 1 patient (8.3%). Tumor growth control was achieved in 11 patients (91.7%) (Table 2).

Functional outcomes

Six patients showed improvement of neurological symptoms after GKRS: swallowing disturbance was ameliorated in 4 patients, tongue deviation in 1 patient, facial pain in 2 patients, and hoarseness in 1 patient. In 2 of these 6 patients, two symptoms each were ameliorated after GKRS: swallowing disturbance and tongue deviation were ameliorated in 1 patient, and swallowing disturbance and hoarseness in the other. In the other 6 patients, the symptoms remained unchanged after GKRS (Table 3).

DISCUSSION

JFSs arising from the glossopharyngeal, vagus, and accessory nerves are rare, constituting approximately 2.9% to 4% of all intracranial schwannomas.[23] Although it is often not possible to distinguish the exact nerve of origin, most JFSs originate either from cranial nerve IX or X, and only rarely arise from cranial nerve XI or the cervical sympathetic chain.[2][11][25] Patients with JFSs can present with dysfunction of the affected nerve, but they can also be asymptomatic. The most common initial symptoms are swallowing disturbance, tinnitus, hearing loss, gait disturbance, and dizziness. Other forms of cranial nerve dysfunction and cerebellar symptoms occur less commonly.[8][24]

The current therapeutic options for patients with JFS include observation, resection, and radiation therapies such as stereotactic radiosurgery.[3][5][7] Traditionally, resection had been considered the mainstay treatment for patients with JFS. The results of various studies have suggested that surgical treatment is effective for tumor growth control. However, complete removal of these tumors al-

Table 2. Summary of imaging changes after gamma knife radiosurgery

Case No.	Initial tumor volume (mm^3)	Status at last follow-up	Follow-up (months)
1	4,514	Increased	170
2	6,498	Stable	73
3	2,397	Decreased	49
4	2,278	Decreased	44
5	2,922	Decreased	41
6	4,700	Stable	36
7	3,554	Decreased	24
8	1,618	Decreased	18
9	540	Decreased	13
10	4,611	Stable	12
11	3,340	Stable	12
12	11,245	Stable	6

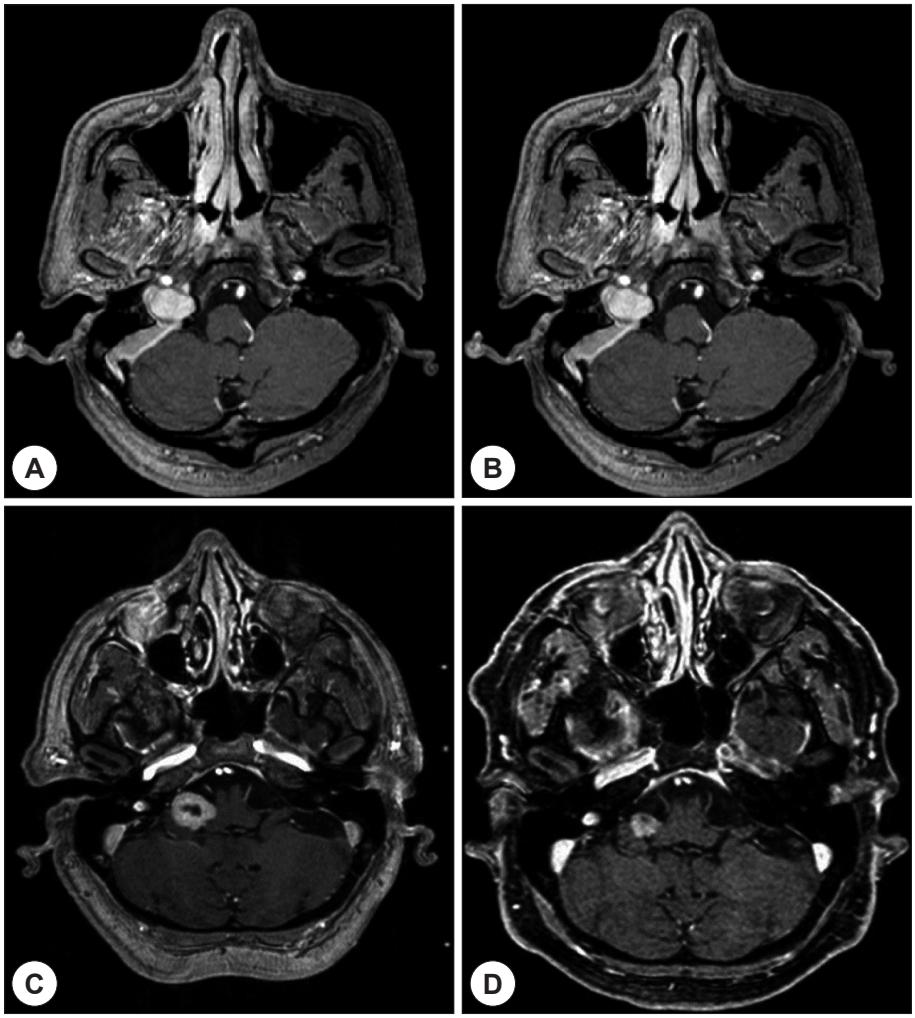

Fig. 1. The scans show marked shrinkage of the jugular foramen schwannoma. Axial T1-weighted contrast-enhanced magnetic resonance images obtained before gamma knife radiosurgery (A and C), and 24 (B) and 41 months (D) after gamma knife radiosurgery (A and B: Case No. 4, C and D: Case No. 5).

Table 3. Summary of functional outcomes after gamma knife radiosurgery

Case No.	Initial symptoms	Clinical outcomes	New symptoms	Follow-up (months)
1	Swallowing disturbance, Tongue deviation	Improved	None	170
2	Tinnitus	No change	None	73
3	Facial pain	Improved	None	49
4	Swallowing disturbance	Improved	None	44
5	Tinnitus	No change	None	41
6	Dizziness, Tongue deviation	No change	None	36
7	Facial pain	Improved	None	24
8	Swallowing disturbance, Hoarseness	Improved	None	18
9	Swallowing disturbance	Improved	None	13
10	Swallowing disturbance	No change	None	12
11	Headache	No change	None	12
12	Gait disturbance	No change	None	6

Table 4. Summary of the literature on the surgical treatment of jugular foramen schwannomas

Authors and year of publication	Case No.	Method (resection)	Tumor control rate (%)	Complication (No. of patients)
Bulsara, et al., 2008	53	GTR (48), other (4)	94 (crude)	VII deficit (2), VIII deficit (4), IX&X deficit (14), XI deficit (6), XII deficit (7)
Chibbaro, et al., 2009	16	GTR (13), STR (3)	100	Aspiration pneumonia (1), CSF leakage (1)
Fukuda, et al., 2009	15	NTR (10), STR (5)	70	IX-X deficit (3)
Sedney, et al., 2013	81	GTR (54), NTR (23), STR (1)	91 (crude)	VI deficit (1), VII deficit (3), VIII deficit (5), IX/X deficit (16), XI deficit (7), XII deficit (8), CSF leakage (3), postoperative ICH (2)
Arkadiusz, et al., 2014	10	GTR (10)	90	VII deficit (3), VIII deficit (2), IX deficit (3), X deficit (3), XII deficit (1)

GTR : gross-total resection, NTR : near-total resection, STR : subtotal resection

Table 5. Summary of the literature on radiosurgery for jugular foramen schwannomas

Authors and year of publication	Case no.	Method	Mean dose (Gy)	Tumor control rate (%)	Complication (No. of patients)
Pollock, et al., 2002	10	GKRS	18	96	None
Zhang, et al., 2002	27	GKRS	14.6	96	None
Martin, et al., 2007	34	GKRS	14	94	IX&X deficit (1)
Peker, et al., 2012	17	GKRS	13	100	None
Hasegawa, et al., 2016	117	GKRS	12	89	VII deficit (3), VIII deficit (6), IX/X deficit (5), XII deficit (3)
Present report	12	GKRS	12.5	91.7	None

GKRS : gamma knife radiosurgery

most inevitably results in complications. These commonly occurring complications such as swallowing disturbance, hearing loss, and facial palsy not only significantly worsen the patients' quality of life, but also can be life threatening in some patients.[13)15)22)] The outcomes and complications of recent reports on the surgical treatment of JFSs are listed in Table 4.[1)4)10)19)24)] Bulsara, et al. treated 53 patients with surgical resection,[1)] achieving a tumor control rate of approximately 94%; however, glossopharyngeal and vagus nerve function worsened postoperatively in 30% of the patients. Arkadiusz, et al. reported a tumor control rate was 90%, with cranial nerve dysfunction occurring in 4 out of 10 patients.[19)]

Therefore, stereotactic radiosurgery represents a viable alternative for preserving lower cranial nerve function and controlling the tumor volume. Previously published studies on GKRS for JFSs indicate that this treatment modality results in excellent tumor control rates and functional outcomes (Table 5).[12)14)20)21)27)] Pollock, et al. treated 10 patients with GKRS, achieving a tumor control rate

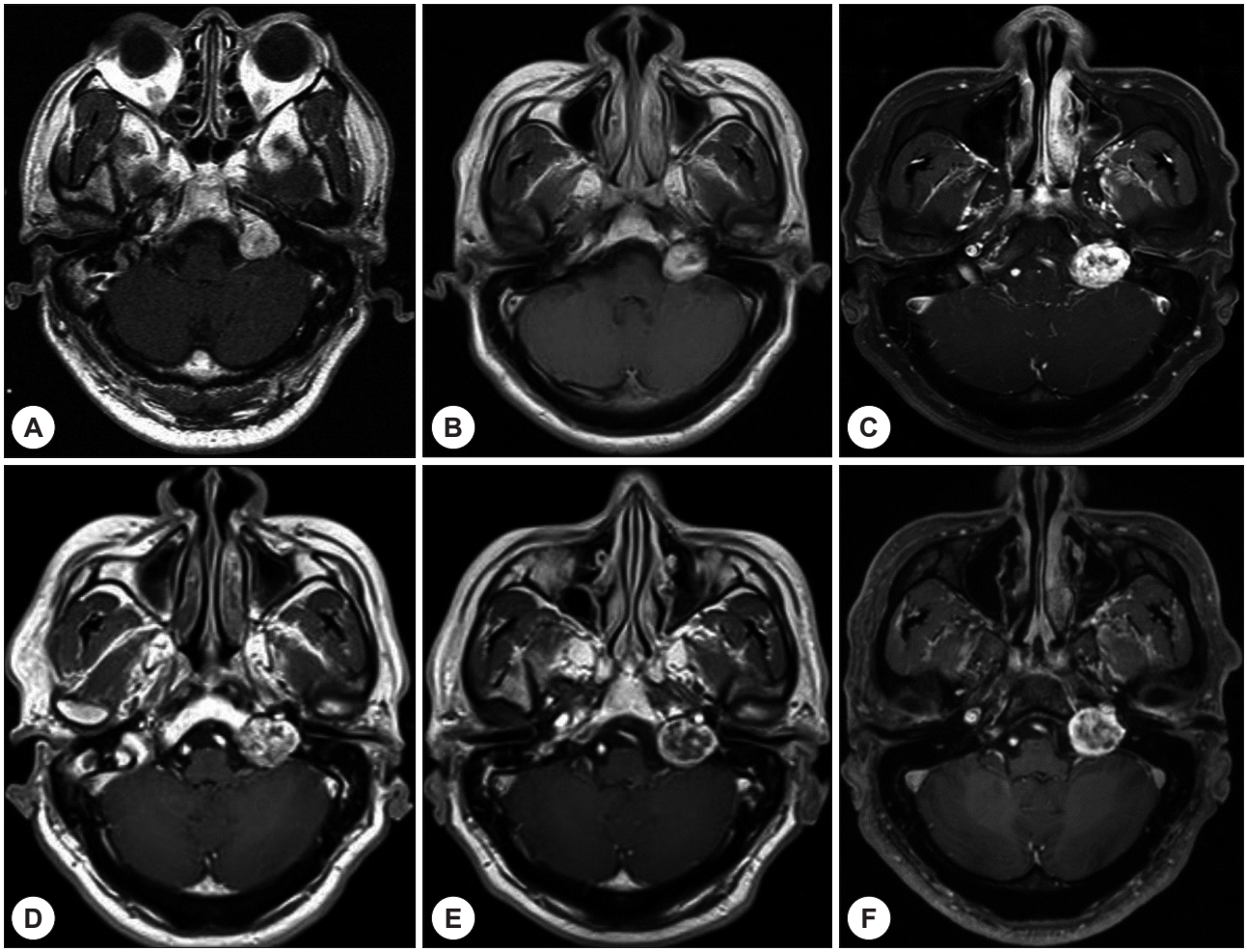

Fig. 2. The tumor size increased gradually up to 60 months after gamma knife radiosurgery, and it steadily decreased thereafter. (A) Image acquired before gamma knife radiosurgery (4,514mm^3), and (B) 24 months (5,793mm^3), (C) 60 months (8,913mm^3), (D) 104 months (6,905mm^3), (E) 130 months (6,548mm^3), and (F) 170 months after gamma knife radiosurgery (6,193mm^3).

of 96%, with none of these patients developing new cranial nerve deficits.[21] Martin, et al. also treated 34 JFS patients, achieving a 10-year tumor control of 94%, with only one patient experiencing worsening of previous glossopharyngeal and vagus nerve deficits.[14]

In our study, a tumor control rate of 91.7% was achieved, and no patient developed new cranial nerve deficits over a median follow-up period of 41.5 months. Tumor size was increased over baseline in 1 patient at the final 170-month follow-up imaging evaluation. In this case, the tumor size increased gradually because of central necrosis up to 60 months after GKRS, and the size steadily decreased thereafter (Fig. 2). The initial symptoms of swallowing disturbance and tongue deviation also improved with a decrease in tumor size on imaging evaluation. Although central necrosis-related GKRS usually occurs 1−12 months after GKRS,[6][17][18] such radiological changes were observed at 60 months after GKRS in this patient. Martin, et al. also reported temporary tumor volume enlargement between 6 and 18 months after radiosurgery in as many as 5% of patients.[14] Hence, tumor size is expected to be smaller in further follow-up imaging evaluations. A longer follow-up period is needed to confirm the reduction in the tumor volume.

CONCLUSION

In this study, we found that GKRS is a relatively safe and effective management tool for JFS. Given the excellent long-term tumor control and clinical outcomes, GKRS might represent a first-line treatment for patients with JFS patients with neurologic deficits. Further study is needed

to identify optimal radiosurgical strategies and long-term outcomes.

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