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Long-term outcomes following Gamma Knife radiosurgery for small, newly diagnosed meningiomas

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ABSTRACT

Object: Although stereotactic radiosurgery were established as an effective treatment modality for intracranial meningiomas, there have been no comprehensive studies focused on long-term outcomes and histologic results for purely small-sized meningiomas after radiosurgery. Therefore, we investigated long-term outcomes and histology of small-sized meningiomas after radiosurgery.
Methods: The authors reviewed the data retrospectively of a total of 920 patients treated with single-session Gamma Knife radiosurgery with intracranial meningioma (Radiosurgery center, Asan Medical Center). After stratifying meningiomas by size, it was defined as small-sized meningiomas less than 1000 mm^3 in tumor volume. The patients with newly diagnosed small-sized meningiomas were enrolled in this study (113 patients). All patients had a minimum follow up of 12 months (12–120 months), clinical symptoms and brain MRI were checked by neurosurgeons. When the tumors grew readily with newly developed neurologic symptoms, microsurgical resection was performed. Histologic analysis was done with resected tumors by neuropathologists.
Results: Among 113 patients, 9 patients (7.9%) showed the increased tumors with clinical symptoms after radiosurgery, followed by microsurgical resection in 4 patients (3.5%). The other 5 (4.4%) patients showed that the size of tumor slightly increased after GKRS that is transient. Interestingly, the histologic results of resected meningiomas due to increased volume after radiosurgery were all revealed as WHO grade II meningiomas (1 clear cell type and 3 atypical meningiomas). Although the histologic confirmation was performed only in 4 patients underwent surgery, it is interesting that all tumors readily grew after radiosurgery were high grade meningiomas.
Conclusion: In this study, we revealed the long-term outcomes of small meningiomas following stereotactic radiosurgery in the aspect of tumor control. The tumor control rate of radiosurgery in small meningiomas reached to 92.1% and there were perilesional edema in 6.1%. The 7.9% of tumors grew readily and 3.5% were finally underwent microsurgical resection. The histologic results were all WHO grade II meningiomas (1 clear cell and 3 atypical meningiomas).

1. Introduction

Radiosurgery is an effective treatment modality for several brain tumors. Recent studies has solidified its effectiveness in specific benign brain tumors including schwannoma and meningioma [1,2]. Although the effectiveness of Gamma Knife radiosurgery in tumor control is certain, adverse effect including tumor progression and peritumoral edema could be accidently occurred after radiosurgery. The adverse effect of radiosurgery occurred more often in large-sized tumor. Thus, there have been many studies about radiosurgery-related complications and tumor progression focused on large-sized tumor. These propensity for large-sized tumor deviated researches were also applicable for intracranial meningioma. As a result, it has been already known that large-sized or medium-sized meningioma could induce peritumoral edema and tumor progression after radiosurgery in certain population. However, with less severity of symptoms in small-sized meningioma, clinicians tends to disregard its progress and long-term outcomes after radiosurgery. Thus, there are no comprehensive studies about the small-sized meningiomas in the aspect of the long-term outcomes and tumor progression. Hence, in this study,

Abbreviations: CT, computed tomography; CPA, cerebellopontine angle; CS, cavernous sinus; GKRS, Gamma Knife radiosurgery; MR, imagnetic resonance image.

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Table 1
Baseline characteristics of the overall patients population, tumor and radiosurgery management.

Patient characteristics		
Sex	Male:Female = 29:84	
Age (years)	Overall = 52.0 ± 11.3	Min–Max = 21–72
	Male = 51.7 ± 11.3	Min–Max = 21–72
	Female = 52.5 ± 10.9	Min–Max = 21–72
Presenting symptom	Headache 60 (54.2%)	
	Dizziness 17 (15.0%)	
	Trauma 4 (3.2%)	
	Health check-up 4 (3.2%)	
	Seizure 2 (1.6%)	
	Facial pain 1 (0.8%)	
	Diplopia 1 (0.8%)	
	Other brain surgery 12 (10.6%)	
	Undefined 12 (10.6%)	
Follow-up duration (month)	Overall = 46.1 ± 24.4	Min–Max = 12–120
Tumor characteristics		
Ellipsoidal volume (mm^3)	574.7 ± 244.6	Min–Max (125.3–985.7)
Location	Convexity 44 (39.4%)	
	Frontal 30 (27.3%)	
	Parietal 11 (9.7%)	
	Temporal 3 (2.4%)	
	Falx 37 (32.7%)	
	Parasagittal 12 (10.6%)	
	Tentorium 11 (9.7%)	
	Sphenoid ridge 5 (4.4%)	
	Olfactory groove 3 (2.4%)	
	Clinoid 1 (0.8%)	
Cystic mass	3 (2.6%)	
Radiosurgery management		
Prescription dose (Gy)	Overall 13.3 ± 1.4	Min–Max = 10–20
	10 Gy: 1 (0.8%)	
	12 Gy: 29 (25.6%)	
	13 Gy: 41 (36.8%)	
	14 Gy: 33 (29.2%)	
	15 Gy: 5 (4.4%)	
	18 Gy: 3 (2.4%)	
	20 Gy: 1 (0.8%)	
Isodose line (%)	50 ± 3%	Min–Max = 40–60
		Total 113

we investigated the long-term outcomes of small-sized meningioma after radiosurgery regarding tumor progression and its histology. Additionally, we would illustrate the case that tumor progressed with considerable peritumoral edema after radiosurgery.

2. Materials and methods

2.1. Patient selection

This study was approved by our institutional review board. Between 2000 and 2012, a total of 920 patients with small meningioma (<1000 mm^3) underwent Gamma Knife radiosurgery at Asan Medical center. Among 920 patients, small-sized (<1000 mm^3) meningiomas were focused on this study, 748 patients were excluded. Among them, 484 and 264 patients were classified respectively into intermediate-sized meningioma ranged from 1000 to 4000 mm^3 and large-sized meningioma ranged from 4000 to 10,000 mm^3. The 21 patients were not eligible for this study due to follow-up loss, harboring systemic cancers, and recurrence or residuals of preexisted meningioma. In the cases with systemic cancers, although radiologic findings favor for meningioma, it could not be excluded definitely the possibility for metastatic brain tumors. Exceptional location meningiomas such as cerebellopontine angle, clivus, cavernous sinus which are not faced directly with brain parenchyme were also excluded (38 patients). Because, in the aspect of tumor growth, the adjacent microenvironment of meningioma are not identical between brain parenchyme and cistern space of cerebellopontine angle. Finally, 113 patients were enrolled in this study (Fig. 1).

2.2. Stereotactic radiosurgery and radiosurgical parameters

The Leksell model G stereotactic frame (ELEKTA Instruments Inc., Sweden) was placed in patients with small-sized meningiomas. Treatment plans were generated using the Elekta GammaPlan system based on gadolinium-enhanced axial 3-dimensional T1-magnetization-prepared rapid acquisition gradient echo MR images (1.25 mm slice thickness). The optimal plan was produced by adjustment of the collimators and sectors such that optimal dose coverage of the target was achieved while minimizing dose to the surrounding normal tissues. In general, maximal dose to optic apparatus was kept under 8 Gy. The Leksell Gamma Knife Unit Model B type was used until June 2005, replaced by C type from July 2005 to January 2011. After then, the Gamma Knife Perfexion unit has been adopted to treat patients from February 2011. Single session radiosurgery was performed in all patients in this study. Initial tumor volume was measured using Kula or Gamma Plan software. Serial volume changes after Gamma Knife radiosurgery was measured by delineation of tumor contour, followed by merging the images based on ellipsoidal method. The mean dose to the meningioma margin was 13.3 ± 1.4 Gy ranged from 10 to 20 Gy, with a mean maximal dose of 25 ± 5 Gy ranged from 20 to 30 Gy. Most patients (n = 103, 91.6%) received a marginal dose ranged from 12 to 14 Gy, 9 patients (7.4%) was received ranged from 15 to 20 Gy. Only 1 patients received a 10 Gy marginal dose. The majority of