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Initial clinical experience with image-guided linear accelerator-based spinal radiosurgery for treatment of benign nerve sheath tumors

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Abstract

Background: Stereotactic radiosurgery has proven a safe and effective treatment of cranial nerve sheath tumors. A similar approach should be successful for histologically identical spinal nerve sheath tumors.

Methods: The preliminary results of linear accelerator–based spinal radiosurgery were retrospectively reviewed for a group of 25 nerve sheath tumors. Tumor location was cervical 11, lumbar 10, and thoracic 4. Thirteen tumors caused sensory disturbance, 12 pain, and 9 weakness. Tumor size varied from 0.9 to 4.1 cm (median, 2.1 cm). Radiosurgery was performed with a 60-MV linear accelerator equipped with a micro-multileaf collimator. Median peripheral dose and prescription isodose were 12 Gy and 90%, respectively. Image guidance involved optical tracking of infrared reflectors, fusion of amorphous silicon radiographs with dynamically reconstructed digital radiographs, and automatic patient positioning. Follow-up varied from 12 to 58 months (median, 18).

Results: There have been no local failures. Tumor size remained stable in 18 cases, and 7 (28%) demonstrated more than 2 mm reduction in tumor size. Of 34 neurologic symptoms, 4 improved. There has been no clinical or imaging evidence for spinal cord injury. One patient had transient increase in pain and one transient increase in numbness.

Conclusions: Results of this limited experience indicate linear accelerator–based spinal radiosurgery is feasible for treatment of benign nerve sheath tumors. Further follow-up is necessary, but our results imply spinal radiosurgery may represent a therapeutic alternative to surgery for nerve sheath tumors. Symptom resolution may require a prescribed dose of more than 12 Gy.

Keywords: Image-guided radiosurgery; Spinal nerve sheath tumor

1. Introduction

Schwannomas and NFs arising from the spinal nerve sheath occur with an incidence of 0.3 to 0.5 per 100 000 and account for one third of spinal tumors [6]. Nerve sheath tumors are associated with a long history of radicular pain, paresthesia, and/or weakness [5,6,38]. Surgical removal represents the standard of care for these tumors [5,6,25,38,39]. Resection may result in transient neurologic worsening or cause new deficits [6,17,38,39].

Stereotactic radiosurgery is a method for administering a large single dose of irradiation to an intracranial site [20]. Physical protection of normal tissue adjacent to the target is afforded by the steep dose gradient between the target and the periphery. Stereotactic radiosurgery has proven safe and effective for benign cranial nerve sheath tumors [11,22,26-31,33,41,43]. Results for cranial tumors imply radiosurgery may be efficacious for spinal lesions of similar histology.

Abbreviations: CT, computed tomography; D_{max}, maximum dose; CTV, clinical target volume; GTV, gross tumor volume; MRI, magnetic resonance imaging; NF, neurofibroma; SCH, schwannoma; SRS, stereotactic radiosurgery; UCLA, University of California-Los Angeles.

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Target localization and patient immobilization during cranial SRS are ensured by application of a minimally invasive head frame with attached fiducials. Spinal radiosurgery based on implanted vertebral fiducials or external body frames have been developed but represent complex processes [3,12,14,24]. Advances in image guidance allow accurate patient positioning and precise delivery of radiosurgical doses to spinal targets independent of fiducials [7]. Results of image-guided spinal radiosurgery for benign tumors have been reported by investigators using CyberKnife technology (Accuracy Inc, Sunnyvale, CA) [8,9,13,37]. We report preliminary clinical experience with image-guided spinal radiosurgery for treatment of benign spinal nerve sheath tumors using a dedicated linear accelerator.

2. Materials and methods

Between March 2003 and July 2007, 20 patients with 25 nerve sheath tumors underwent spinal radiosurgery in the UCLA Department of Radiation Oncology. Table 1 provides a summary of the clinical, anatomic, and histologic characteristics of the tumors. Patients were eligible for spinal radiosurgery if they refused surgical intervention, had recurrent or residual disease after surgery, or were judged inoperable because of comorbid conditions after evaluation by a neurosurgeon. There were 12 females and 8 males. Patient age ranged from 17 to 78 years (median, 61 years). Four patients had neurofibromatosis type 1 and 4 had neurofibromatosis type 2. Patients typically presented with more than one neurologic complaint. Of the 14 tumors causing sensory disturbance, 11 also produced pain and/or weakness. Three patients presenting with only sensory disturbance were treated for numbness affecting their dominant hand. Histopathology was available in 7 patients after subtotal tumor removal 2 to 36 months before radiosurgery (4 SCHs, 3 NFs). These patients underwent radiosurgery because of clinical and imaging evidence of tumor regrowth (3) or persistent symptoms (4). Of the remaining 18 lesions, presumptive histopathology in 9 was established after removal of peripheral nerve sheath tumors elsewhere in the patient (5 NFs, 4 SCHs). These lesions underwent because of clinical and imaging documentation of interval growth (3) or for persistent or worsening symptoms (6). Nine tumors without histopathologic confirmation were treated based on symptoms and imaging findings consistent with nerve sheath tumor. These lesions underwent radiosurgery due to clinical and imaging documentation of interval growth (4) or for persistent or worsening symptoms (5). Among the 10 tumors with documented progression before irradiation, average tumor growth was 1.42 cm (range, 0.2-2.6 cm) occurring over an average of 1.56 years of observation (range, 0.8-3 years). It was not possible to determine in this retrospective review the association of tumor growth and exacerbation of underlying symptoms. Asymptomatic targets were detected in the cervical spine during evaluation of a patient with neurofibromatosis and treated

Table 1
Characteristics of 25 benign nerve sheath tumors before spinal radiosurgery

Patient	Neurofibromatosis	Level	Morphology	Volume (mL)	Size (cm)	Surgery	Histology	Symptoms	Interval growth
1	–	C3	Dumbbell	1.9	3	STR	NF	M,S	No
2	–	L2	Intra-foraminal	1.6	1.7	STR	SCH	P,S	No
3	Type 2	T12	Intradural	1.3	1.4	–	SCH	M,P	Yes
		L2	Intradural	0.7	1	–	SCH	M,P	Yes
4	Type 2	L4	Extra-foraminal	1	2	–	NF	M,P	No
5	Type 1	C2	Dumbbell	4.3	3.3	–	–	–	No
		T1	Intradural	1.2	2	–	–	–	No
6	–	L4	Dumbbell	11.5	4.1	–	–	P,S	No
7	–	C6	Dumbbell	3.1	2	STR	SCH	S	Yes
8	Type 1	C6	Intradural	1.9	2	–	NF	M,P	Yes
9	Type 1	C3	Dumbbell	1.1	2	STR	NF	M	No
		C4	Intradural	2.6	1.8	–	NF	P,S	No
10	–	L4	Extra-foraminal	12	4	–	–	M,P	Yes
11	Type 1	L4	Extra-foraminal	13.7	4	–	NF	P,S	No
		L4	Extra-foraminal	3.6	1.3	–	NF	M,P,S	No
12		C5	Dumbbell	10	3	STR	SCH	P,S	Yes
13	–	C6	Dumbbell	3.5	2.1	–	–	S	No
14	–	C3	Intradural	1	0.9	–	–	P	No
15	–	L4	Extra-foraminal	2.5	2.2	–	–	P,S	Yes
16	–	T1	Dumbbell	6.2	3.2	STR	SCH	S	No
17	–	L3	Dumbbell	3.5	2.4	STR	NF	P,S	Yes
18	–	C3	Dumbbell	2	1.8	–	–	P	Yes
19	Type 2	T12	Extra-foraminal	5.3	3.6	–	SCH	M,S	No
		L1	Intra-foraminal	1.2	1.8	–	SCH	M,S	No
20	Type 2	C2	Intradural	0.5	1	–	–	M,S	Yes

M indicates motor weakness; P, pain; S, sensory disturbance; STR, subtotal removal.

based on location without intervening documentation of tumor progression.

The technique of image-guided spinal radiosurgery has been described elsewhere [7,35]. Patient immobilization was performed using a noninvasive, custom-fitted device (BodyFix, Medical Intelligence, Schwabmunchen, Germany). Patient positioning on the accelerator couch was performed using Novalis Body (Novalis®, BrainLAB AG, Feldkirchen, Germany). The system depends on optical tracking of skin surface infrared reflectors and amorphous silicon kilovoltage x-ray imaging. Patient radiographs are fused with digitally reconstructed radiographs from the treatment planning CT scan. Isocenter deviations from the ideal are corrected by automatic adjustment of the linear accelerator treatment couch. The precision of this approach has been documented [47]. Spinal radiosurgery was delivered in a single fraction using a dedicated linear accelerator (Clinac® 600SR, Varian Associates, Palo Alto, Calif). The accelerator is equipped with a micro-multileaf collimator (m_3™, BrainLAB). The entire treatment process typically required 20 minutes.

Treatment planning was carried out with a commercially available system (iPlan 3.0 and BrainSCAN® 5.3x, BrainLAB). All patients underwent CT and MRI, which were fused by the mutual information technique. The formula $x + y + z/3$ was used to calculate mean tumor diameter. GTV was determined on T1-weighted contrast-enhanced axial, coronal, and sagittal MRI scans. All tumors demonstrated homogeneous contrast enhancement and none had a cystic component. A margin of normal tissue (range, 1-3 mm; median, 2 mm) was added to the GTV to create the CTV. The prescription isodose encompassed the CTV. Twenty-four targets received 12 Gy and 1 received 15 Gy. Dose was prescribed at the 90% isodose line in 22 targets and 95% in 3 targets. In all cases, 95% or more of the target volume was included within the prescription isodose line. There was no specific guideline for determining the amount of spinal cord contoured during treatment planning. The volume of spinal cord contoured in this series varied from 2 to 6 mm above and below the GTV. In all cases, the spinal cord D_{max} was $\leq$12 Gy, and $\leq$10 Gy was allowed to 10% of the spinal cord volume as previously defined. Forward treatment planning was used for 20 lesions and inverse planning for 5 lesions. Forward planned targets were irradiated with 3 to 4 dynamics arcs and inverse planned targets with 6 modulated beams. All targets were treated with a single isocenter.

Follow-up varied from 12 to 58 months (median, 18). Ten patients (12 targets) were followed at least 24 months. Follow-up included contrast-enhanced MRI and clinical examination every 6 months for 24 months and yearly thereafter. Computer-generated tumor volumes were not available on follow-up MRI examinations. Tumor progression was defined as an increase in mean tumor dimension of more than 2 mm persisting on 2 or more consecutive studies. Tumor response was defined as decrease in mean tumor dimension of more than 2 mm persisting on 2 or more consecutive studies. Stable tumor was defined as no change in size or change of 2 mm or less.

3. Results

The local control rate was 100% (Table 2). Eighteen tumors (72%) remained stable and 7 tumors (28%) responded. Among the stable lesions, none enlarged by 2 mm or less. Two of the responding tumors demonstrated more than 50% reduction in mean dimension (Fig. 1). A 2-cm recurrent cervical SCH with a 3.14-mL volume responded at 12 months and a 3.6-cm lumbar tumor with a 12-mL volume diagnosed clinically responded at 18 months. Each received 12 Gy prescribed at 90%. Tumor response was maintained for another 18 months in the first patient. No further follow-up is available in the other responding target. Posttreatment MRI demonstrated central tumor hypodensity in 2 tumors (Fig. 2). Both were NFs treated in a single patient. The loss of enhancement occurred at the first follow-up for each target and remained unchanged at the 12 month evaluation. Loss of enhancement in these targets was not associated with imaging evidence for perilesional edema. No target developed imaging evidence for cystic degeneration.

Neurologic symptom improvement occurred in 4 (12%) of 34 specific deficits. Subjective reduction in numbness occurred in 2 sites, an increase in motor strength in 1 site, and a decrease in radicular pain in 1 site. Pain reduction occurred 6 months after treatment while the other symptom improvements occurred at 12 months.

Table 2
Outcome of 25 benign nerve sheath tumors after spinal radiosurgery

Patient	Follow-up (mo)	Imaging outcome	Clinical outcome
1	58	Stable	Stable
2	48	Stable	Decreased pain
3	42	Response	Stable
	42	Stable	Stable
4	40	Stable	Stable
5	36	Stable	Stable
	36	Stable	Stable
6	36	Stable	Stable
7	36	Response	Decreased numbness
8	24	Response	Transient increased pain
9	24	Stable	Increased motor strength
	18	Stable	Stable
10	18	Response	Stable
11	18	Stable	Transient increased numbness
	18	Stable	Stable
12	18	Response	Decreased numbness
13	15	Stable	Stable
14	12	Stable	Stable
15	12	Response	Stable
16	12	Stable	Stable
17	12	Response	Stable
18	12	Stable	Stable
19	12	Stable	Stable
	12	Stable	Stable
20	12	Stable	Stable

Patients tolerated immobilization and delivery of spinal radiosurgery without acute morbidity. No patient experienced acute exacerbation of preexisting neurologic symptoms. Delayed morbidity was noted in 2 patients with preexisting deficits. A patient with a 1.9-mL cervical NF experienced transient increase in radicular pain 6 months after receiving 12 Gy to the 90% isodose. Pain returned to pretreatment level spontaneously within 21 days. The patient with 2 NFs experienced transient increase in numbness 6 months after receiving 12 Gy to the 90% isodose line to a 2.6-cm lumbar tumor with a 13.7-mL volume. Increase in numbness occurred simultaneously with appearance of central hypodensity noted above. Numbness returned to pretreatment level with a course of Tegretol (Novartis, East Hanover, NJ). No other patient developed signs or symptoms suggestive of spinal nerve injury. There has been no imaging or clinical evidence for spinal cord injury after radiosurgery. No patient developed major organ toxicity or malignancy.

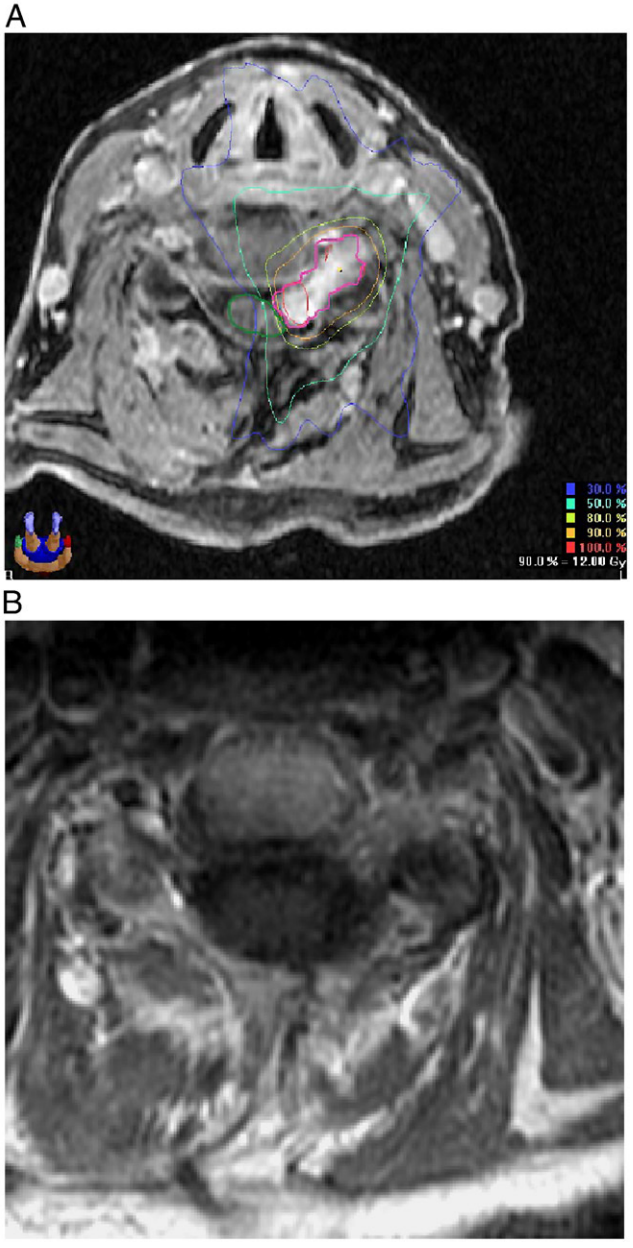

Fig. 1. A: Axial contrast-enhanced MRI demonstrates a 2 cm/3.14 mL C6 SCH. Isodose lines displayed: 100% (thin red), 90% (yellow), 80% (light green), 50% (teal), 30% (blue). The target (thick pink) received 12 Gy prescribed at the 90% isodose. B: Axial contrast-enhanced MRI 18 months after radiosurgery.

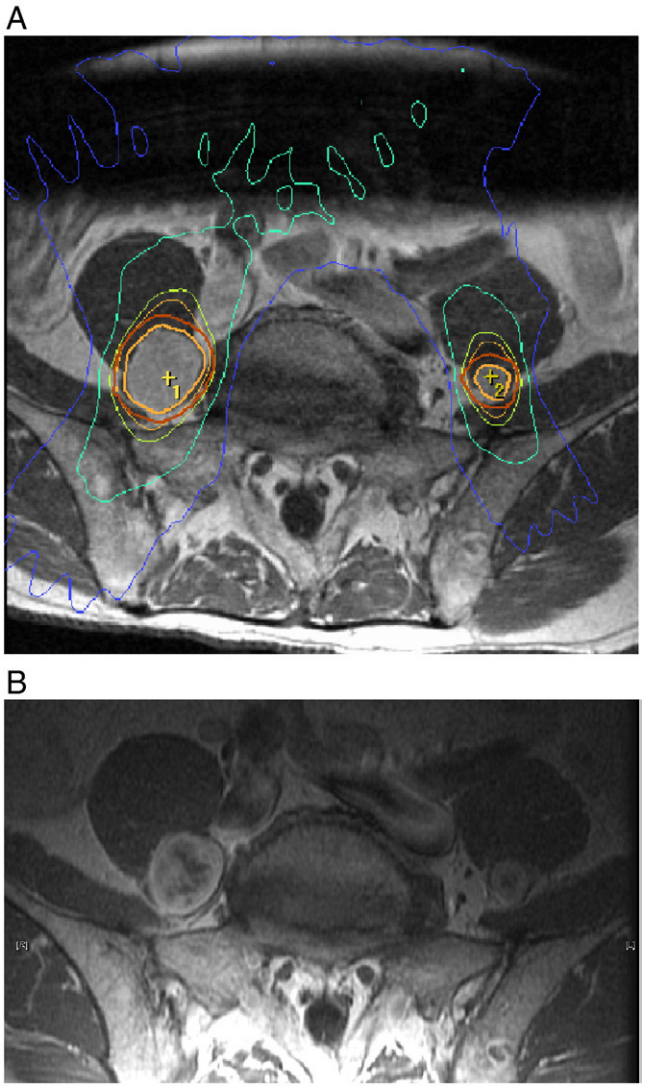

Fig. 2. A: Axial contrast-enhanced MRI demonstrates 2 NFs at L4. Isodose lines displayed: 90% yellow, 80% (light green), 50% (teal), 30% (blue). The target (thick yellow) received 12 Gy prescribed at the 90% isodose encompassing the target plus a 2-mm margin (thick orange). B: Axial contrast-enhanced MRI 6 months after radiosurgery demonstrating loss of central contrast enhancement.

4. Discussion

Surgery represents the standard of care for patients with benign spinal nerve sheath tumors [6,38]. Total removal rates

vary from 79% to 96% [5,6,25,38,39]. Local relapse after total removal is unusual. Surgical treatment of spinal nerve sheath tumors, however, is not without challenges. Complete removal often necessitates sacrifice of a nerve root [17,38]. After surgical intervention, 7% to 16% of patients report exacerbation of preexisting neurologic symptoms, and 7% to 23% report new, permanent deficits [5,6,21,38,39]. Serious delayed morbidity includes dysesthesia, arachnoiditis, and cystic myelopathy [25,38,39]. Subtotal removal in an attempt to mitigate morbidity may result in tumor regrowth [21,25,39].

Stereotactic radiosurgery involves delivery of irradiation by collimated beams directed at a target defined by stereotactic principles. Stereotactic radiosurgery has proven safe and effective for cranial nerve sheath tumors [11,22,26-31,33,41,43]. Several groups have developed spinal radiosurgery approaches dependent on external fiducials or transcutaneously implanted bone fiducials [3,14,24]. Image-guided techniques allow accurate spinal radiosurgery independent of invasive fiducial markers or rigid patient immobilization. In a phantom study, Yan et al demonstrated lateral, longitudinal, and vertical positioning errors of a planned isocenter of 0.6 ± 0.3, 0.5 ± 0.2, and 0.7 ± 0.2 mm, respectively, using the image-guided system used in our series [47]. These deviations are comparable to results reported for the CyberKnife or systems using external fiducials [4].

The local control rate for benign nerve sheath tumors after linear accelerator–based radiosurgery was 100% in our series. This result, although preliminary, is in agreement with outcome reported by CyberKnife investigators. Gerszten and colleagues [13] treated 73 benign spinal tumors, including 35 SCHs and 25 NFs. No local relapses were reported after a median 37-month follow-up period. Dodd et al [8] treated 55 benign spinal tumors, including 30 SCHs and 9 NFs. After a 23-month median follow-up, 3 tumors enlarged less than 10%. Enlargement proved transient in 2 and the third lesion was removed to alleviate preexisting myelopathy. Sahgal and associates [37] reported local relapse in 2 of 11 spinal NFs followed a median of 25 months.

Longer follow-up is required to establish the ultimate efficacy of linear accelerator–based spinal radiosurgery for nerve sheath tumors. Kondziolka et al reported the local relapse rate after SRS for acoustic neuromas increased over the first 3 years of follow-up [19]. Local relapse has been documented as long as 60 months after radiosurgery for non–eighth nerve tumors [27-31,41]. Neurofibromatosis may predispose to late relapse of nerve sheath tumors [16,22]. In our series, 16 tumors were followed less than 3 years—8 associated with neurofibromatosis and 8 de novo tumors.

Imaging response, defined as more than 2 mm reduction in tumor dimension, was documented in 28% of lesions in our series. This rate is lower than the 39% reduction in tumor size after CyberKnife treatment reported by Dodd et al [8]. These authors, however, did not specify criteria for imaging response.

The lower response rate in our series may be a consequence of the short follow-up duration. The response rate reported by Dodd et al was documented in a subgroup of 28 tumors with greater than 24 months of follow-up [8]. In our series, by contrast, only12 tumors were followed for 2 or more years. With longer follow-up, the imaging response rate after linear accelerator–based spinal radiosurgery may resemble that reported elsewhere.

The lower imaging response rate in our series is not likely related to tumor and treatment parameters. Seven tumors in our series were treated after prior surgical intervention. Prasad et al [33] reported a significantly lower response rate among acoustic neuroma patients receiving SRS for post-operative residual/recurrent tumor compared to those receiving primary SRS. In our series, response was documented in 2 of the 7 tumors treated postoperatively compared to 5 of 18 treated primarily. Twenty-four tumors in this series received a prescribed dose of 12 Gy. Dodd et al [8] delivered a mean of 18.7 Gy for SCHs and 19.8 Gy for NFs. Flickinger et al, however, reported no significant difference ($P = .994$) in imaging response rate between acoustic neuromas treated to a median dose of 13 Gy or lower compared to a median of 14 Gy or higher [10].

Improvement in neurologic symptoms occurred in 12% of deficits in this series, including reduction in pain in one of 12 sites. Gerszten et al [13], using a visual analog scale, reported significant pain relief in 14 of 17 Schwannoma patients and 8 of 13 NF patients. According to Gerszten et al and Dodd et al, the rate of pain relief after spinal radiosurgery appears lower for nerve sheath tumors arising in the setting of NF-1 compared to NF-2 or for patients with de novo tumors [8,13]. The incidence of NF-1 in our series (6/25 lesions) was no higher than reported by Gerszten et al (21/60 lesions) and Dodd et al (9/39 lesions). The impact of the difference in dose between our series and CyberKnife series on symptom resolution is uncertain. There is no dose-response analysis available in the literature to establish the most efficacious radiosurgery approach for palliation of symptoms due to spinal nerve sheath tumors. Ryu et al [36], however, reported a strong but statistically nonsignificant trend toward better pain relief after doses of 14 Gy or higher in a series of patients with spinal column metastases.

No patient developed acute morbidity. Transient esophagitis and tracheitis have been reported after spinal radiosurgery for metastatic disease [2,45]. Acute spinal radiculopathy was not encountered in our series despite 9 patients with neurofibromatosis and 13 tumors located within the bony foramen. Acute neuropathy after cranial radiosurgery has been reported in the setting of neurofibromatosis or for tumor within the bony internal auditory canal [32,43,44]. Delayed, transient worsening of preexisting neuropathy occurred in 2 cases (8%). No patient developed new neuropathy, whether transient or permanent. CyberKnife investigators similarly report no treatment associated spinal neuropathy despite their higher prescribed dose.

Follow-up in our series is not sufficient to detect all delayed neuropathies. According to Flickinger et al [10], the incidence curve for posttreatment neuropathy is not flat until 15 months after treatment. Eight tumors in our series have been followed less than 15 months.

There was no clinical or imaging evidence for spinal cord injury in our series. Spinal cord toxicity has been reported after CyberKnife treatment of benign spinal tumors. Dodd et al [8] reported posterior column dysfunction accompanied by T2-weighted MRI signal change 8 months after 24 Gy in 3 fractions to a cervical spine meningioma. Tumor maximum dose was 34.5 Gy, and dose-volume histogram analysis revealed that 1.7 cm^3 of the adjacent spinal cord received more than 8 Gy per fraction. Gerszten et al [13] reported 3 cases of spinal cord toxicity 5 to 13 months after treatment of cervical spine lesions. In all 3 cases, tumor marginal dose was 20 Gy in a single treatment, the volume of spinal cord receiving more than 8 Gy was less than 0.02 cm^3, and there were associated T2-weighted signal changes. Of these 4 reported cases of myelitis, 3 had undergone surgical intervention before spinal radiosurgery.

Treatment planning in our series involved adding a margin to the GTV. The prescription isodose line encompassed this additional margin. As a result, a small volume of spinal cord parenchyma was included within the prescription isodose for all but the extra-foraminal tumors and received dose equivalent to the target lesion. Absence of myelitis in our series implies a small volume of spinal cord (10%) may safely receive a radiosurgery dose of at least 10 Gy and a point maximum dose of 12 Gy. This is in agreement with a mouse model demonstrating absence of myelitis after single-fraction doses less than 16 Gy [23]. Hopewell et al [15] demonstrated no myelitis after single doses 20 Gy or lower in a rat model. These authors found a steep increase single-dosed tolerance of the spinal cord as the length of exposed cord decreased below one centimeter. Further clinical experience is necessary to establish the threshold dose-volume parameters for myelitis after spinal radiosurgery.

Finally, no solid organ toxicity or second malignancy was encountered. Second malignancy has not been reported as a consequence of spinal radiosurgery. Follow-up is too short to conclude that there is no risk of oncogenesis associated with this treatment. Transformation of acoustic neuroma to malignant peripheral nerve sheath tumor and induction of secondary glioblastoma and sarcoma have been reported after cranial SRS [1,18,40,42,46]. Patients with neurofibromatosis may be at particular risk for sarcoma induction [46]. Latency to secondary malignancies after cranial SRS varies from 7 to 16 years in these reports. Median follow-up of spinal radiosurgery series, including our own, is less than these latencies. Clearly, longer follow-up is required to establish the absolute risk of treatment-associated malignancy. Currently, this risk appears low. In a cohort study, Rowe and colleagues [34] reviewed 4877 cranial γ-knife patients, including 3517 with benign lesions. After a median 6-year follow-up, representing nearly 29 000 patient-years of evaluation, there was no increase in the relative risk of either central nervous system or non–central nervous system malignancies.

5. Conclusions

The outcome of this limited experience indicates that image-guided radiosurgery using a linear accelerator for benign nerve sheath tumors is feasible. Further follow-up is necessary, but our preliminary results imply that spinal radiosurgery may represent a therapeutic alternative to surgery for spinal nerve sheath tumors in selected patients. Dose escalation beyond 12 Gy may be necessary to achieve resolution of neurologic symptoms due to tumor.

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Commentary

Advancements in radiosurgery have led to its use for the treatment of benign nerve sheath tumors and meningiomas in the spinal area, and literature regarding its use is beginning to be seen in the journals. Selch et al, in their article entitled "Image-Guided Linear Accelerator-Based Spinal Radiosurgery for Treatment of Benign Nerve Sheath Tumors," present their experience regarding 20 patients with 25 nerve sheath tumors that were treated with spinal radiosurgery. The indications for spinal radiosurgery as noted by the authors included patients who refused surgical intervention or had recurrent or residual disease after surgery or were judged to be inoperable due to comorbid conditions.

Nine patients were reported to have interval tumor growth before spinal radiosurgery. One of the 9 patients had 2 spinal tumors that increased in size before spinal radiosurgery, for a total of 10 tumors that increased in size before spinal radiosurgery. Of the 10 tumors that showed interval tumor growth before spinal radiosurgery, 7 responded to spinal radiosurgery, that is, showed more than 2 mm reduction in size during the follow-up period. The other 18 tumors were reported to remain stable, and none of the stable tumors enlarged more than 2 mm. None of the tumors that showed no growth before spinal radiosurgery showed reduction in size after spinal radiosurgery. Seven patients underwent spinal radiosurgery after subtotal tumor removal 2 to 36 months before radiosurgery, 3 because of evidence of tumor regrowth, and 4 because of persistent symptoms. Of these 7 patients, only 3 realized improvement in their symptoms consisting of decreased pain (1), decreased numbness (1), and increased motor strength (1). Of the other 13 patients, only one realized improvement manifested by decreased numbness. In total, only 4 of the 25 locations treated were reported to be improved (4 patients) with regard to their