The impact of decompression with instrumentation on local failure following spine stereotactic radiosurgery

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OBJECTIVE Spine stereotactic radiosurgery (SRS) is a safe and effective treatment for spinal metastases. However, it is unknown whether this highly conformal radiation technique is suitable at instrumented sites given the potential for microscopic disease seeding. The authors hypothesized that spinal decompression with instrumentation is not associated with increased local failure (LF) following SRS.

METHODS A 2:1 propensity-matched retrospective cohort study of patients undergoing SRS for spinal metastasis was conducted. Patients with less than 1 month of radiographic follow-up were excluded. Each SRS treatment with spinal decompression and instrumentation was propensity matched to 2 controls without decompression or instrumentation on the basis of demographic, disease-related, dosimetric, and treatment-site characteristics. Standardized differences were used to assess for balance between matched cohorts.

The primary outcome was the 12-month cumulative incidence of LF, with death as a competing risk. Lesions demonstrating any in-field progression were considered LFs. Secondary outcomes of interest were post-SRS pain flare, vertebral compression fracture, instrumentation failure, and any Grade ≥ 3 toxicity. Cumulative incidences analysis was used to estimate LF in each cohort, which were compared via Gray's test. Multivariate competing-risks regression was then used to adjust for prespecified covariates.

RESULTS Of 650 candidates for the control group, 166 were propensity matched to 83 patients with instrumentation. Baseline characteristics were well balanced. The median prescription dose was 16 Gy in each cohort. The 12-month cumulative incidence of LF was not statistically significantly different between cohorts (22.8% [instrumentation] vs 15.8% [control], $p = 0.25$). After adjusting for the prespecified covariates in a multivariate competing-risks model, decompression with instrumentation did not contribute to a greater risk of LF (HR 1.21, 95% CI 0.74–1.98, $p = 0.45$). The incidences of post-SRS pain flare (11% vs 14%, $p = 0.55$), vertebral compression fracture (12% vs 22%, $p = 0.04$), and Grade ≥ 3 toxicity (1% vs 1%, $p = 1.00$) were not increased at instrumented sites. No instrumentation failures were observed.

CONCLUSIONS In this propensity-matched analysis, LF and toxicity were similar among cohorts, suggesting that decompression with instrumentation does not significantly impact the efficacy or safety of spine SRS. Accordingly, spinal instrumentation may not be a contraindication to SRS. Future studies comparing SRS to conventional radiotherapy at instrumented sites in matched populations are warranted.

<https://thejns.org/doi/abs/10.3171/2017.3.SPINE161015>

KEY WORDS spine metastasis; stereotactic radiosurgery; spinal instrumentation; local failure; oncology

ABBREVIATIONS KPS = Karnofsky Performance Scale; LF = local failure; NFS = neurological function scale; OS = overall survival; PTV = planning treatment volume; SRS = stereotactic radiosurgery.

SUBMITTED August 28, 2016. **ACCEPTED** March 6, 2017.

INCLUDE WHEN CITING Published online July 21, 2017; DOI: 10.3171/2017.3.SPINE161015.

RADIATION therapy and oncological resection with stabilization are the primary modalities for the management of gross spinal metastatic disease. For patients with metastatic spinal cord compression, randomized data have demonstrated superior functional outcomes following decompression with postoperative radiotherapy compared with radiotherapy alone.^{14,15,18} For patients without spinal cord compression or emergency spinal instability, radiotherapy alone offers palliation, local control, and prophylaxis against cord compression without the morbidity and cost of surgery. In an effort to provide dose escalation while sparing organs at risk, highly conformal radiation techniques have been developed. Spine stereotactic radiosurgery (SRS) is increasingly being used in the management of recurrent vertebral metastasis, radioresistant disease, and oligometastatic disease.⁴ Although no randomized data have been reported, many retrospective studies suggest that spine SRS offers superior local control relative to conventional radiotherapy.^{2,3,8}

Patients with spinal instability or cord compression are specifically excluded from the Radiation Therapy Oncology Group (RTOG) study 0631, which is currently randomizing patients to single-fraction SRS or single-fraction conventional radiotherapy in an effort to better evaluate the benefits of SRS.¹⁹ In the postoperative setting, small retrospective studies have suggested that SRS is safe and effective.^{5,12,16} These studies have generally been noncomparative, and therefore the ability to draw meaningful conclusions is limited. In particular, it is unclear whether SRS is safe and effective at instrumented sites given the possibility of microscopic disease seeding at the time of decompression and instrumentation. Although greater conformality may offer spinal cord sparing, local failure (LF) at instrumented sites may be increased. We hypothesized that decompression with instrumentation is not associated with a greater cumulative incidence of LF following SRS, compared with SRS at surgically naïve sites.

Methods

Patient Selection and Data Collection

An institutional review board–approved, retrospective, 2:1 propensity-matched cohort study was conducted to compare patients with and without decompression on receiving instrumentation. All patients undergoing spine SRS for either multiple myeloma or solid-tumor metastasis between 2006 and 2014 were eligible for inclusion. Treatments with less than 1 month of radiographic follow-up were excluded. Indications for radiosurgery were either related to symptoms (pain, neurological deficit) or radiographic progression (control of primary tumor or epidural disease). Patients with rapidly progressive neurological deficits or emergency spinal instability were not eligible for SRS alone. However, patients were not excluded on the basis of epidural disease or number of involved vertebrae. The instrumentation cohort comprised all treatment sites in patients with any instrumentation following decompression, including pedicle screws, plates, interbody cages, or fixation rods. Treatment sites with prior surgical decompression without fixation or vertebral augmentation alone were not included in the instrumentation cohort and were not eligible for the control cohort.

Radiosurgical Treatment

The SRS was conducted as described previously.^{3,17} Briefly, treatment planning used CT simulation with 1.5-mm slice thickness fused to a high-definition MRI. The CT and MRI fusion was performed in BrainScan or iPlan software (Brainlab) or MIM (MIM Software, Inc.). In general, target volumes were contoured according to the International Spine Radiosurgery Consortium Consensus Guidelines.⁶ At instrumented sites, the gross tumor volume was the residual disease extent on the postoperative MRI, whereas the clinical target volume contained the preoperative disease extent, as well as adjacent bony compartments that were at risk for disease extension. The spinal cord or cauda equina planning risk volume was contoured approximately 5 mm above and below the target volume. For patients with significant instrumentation artifact, CT myelograms were obtained to define normal anatomy. The spinal cord volume was constrained to V10 Gy < 10% and a maximum point dose of 14 Gy for single-fraction SRS. The cauda equina was constrained to V12 Gy < 10% and a maximum point dose of 16 Gy. The most common single-fraction prescription dose was 16 Gy (range 10–18 Gy), whereas hypofractionated regimens included 21 or 24 Gy in 3 fractions. Image guidance was achieved with cone-beam CT and/or the ExacTrac system (Brainlab). At 6–8 weeks following SRS, patients were seen in clinic after spine MRI or CT myelograms were obtained and then followed every 3 months thereafter.

Primary and Secondary Outcomes

The primary outcome was the cumulative incidence of LF, whereas secondary outcomes included overall survival (OS) and the incidences of post-SRS pain flare, vertebral fracture, instrumentation failure, and any Grade $\geq$ 3 toxicity. Lesions demonstrating any in-field progression as assessed by radiation oncologists, neurosurgeons, and/or neuroradiologists were considered LFs. Patients experiencing a transient increase in pain responsive to steroids within 14 days of SRS were considered to have a pain flare. Radiographic evidence of de novo or progressed vertebral body collapse was considered a vertebral compression fracture. These practices were standard throughout the study period. All outcomes were calculated from the date of SRS completion.

Statistical Analysis

Each SRS treatment with in-field decompression and instrumentation was propensity matched to 2 controls without decompression and instrumentation on the basis of demographic, disease-related, dosimetric, and treatment-site characteristics. An optimal matching algorithm was used.¹¹ Standardized differences were used to assess balance between matched cohorts.²¹ Data were analyzed on a per-treatment basis. Baseline continuous data were compared with Wilcoxon rank-sum tests, whereas categorical data were compared with Fisher exact tests. The Kaplan-Meier method was used to determine estimates of OS, which were compared with log-rank tests. Based on the subdistribution method, cumulative incidence analysis was used to determine estimates of LF, with death as a competing risk.¹⁰ Noninformative censoring was per-

formed at loss to radiographic follow-up. Differences in cumulative incidences were compared via Gray's tests.¹⁰ Based on the method of Fine and Gray, multivariate competing-risks regression was used to model LF, with death as a competing risk.⁷ Models were adjusted for the following covariates: age; sex; smoking status; neurological function scale (NFS) score; Karnofsky Performance Scale (KPS) score; number of prior chemotherapy regimens; tumor pathology; systemic disease status; extent of spinal disease; treatment site location; number of treated vertebrae; presence of epidural, neural foraminal, paraspinal, or posterior elements disease; any prior in-field irradiation; and dosimetric characteristics. Covariates demonstrating an association ($p \leq 0.20$) with LF on univariate analysis were evaluated in a multivariate model including all 2-way interactions. Covariate inclusion into the final model required $p \leq 0.10$. Analyses were conducted using the R "cmprsk" statistical software package. Two-sided tests with $p < 0.05$ were considered statistically significant.

Results

Patient and Treatment Characteristics

Of 650 candidates for the control group, 166 were propensity matched to 83 patients with instrumentation. Excellent balance (standardized difference ≤ 0.10) was achieved for nearly all characteristics between cohorts (Table 1). Characteristics with standardized differences exceeding an absolute value of 0.10 included the following: KPS score (median 80 vs 80, $p = 0.17$); NFS score (median 1 vs 1, $p = 0.12$); radioresistant (39% vs 33%, $p = 0.73$) and lung (12% vs 19%, $p = 0.73$) histological types; presence of extraspinal bone metastases (43% vs 50%, $p = 0.35$); pre-SRS vertebral body fracture (35% vs 28%, $p = 0.31$); maximum dose (mean 18.2 vs 17.6 Gy, $p = 0.24$); planning treatment volume (PTV) (mean 115.9 vs 101.5 cm³, $p = 0.22$); and the conformality index (mean 1.3 vs 1.4, $p = 0.11$). No statistically significant differences in baseline characteristics were observed.

The median time from spinal instrumentation to SRS was 1.7 months. Posterior-only approaches (51 sites, 61%) were more common than anterior (17 sites, 21%) or combined anterior-posterior (15 sites, 18%) approaches. Corpectomy with cage or strut placement was performed at 48 sites (58%). All patients underwent spinal fixation with screws and either plates or rods.

In each cohort, the median prescription dose was 16 Gy in a single fraction. Patients were followed radiographically for a median of 9 months (range 1–87 months) in the instrumentation cohort and 6 months (range 1–86 months) in the control cohort ($p = 0.18$). The median OS was 18 months among patients in the instrumentation cohort (95% CI 12–29 months), compared with 12 months in the control cohort (95% CI 9–19 months; $p = 0.17$, Fig. 1). In a comparison between the instrumentation and control cohorts, the 12-month cumulative incidences of LF were 22.8% (95% CI 13.4%–32.1%) and 15.8% (95% CI 10.0%–21.5%), respectively ($p = 0.25$; Fig. 2, Table 2). The incidences of in-field salvage surgery (7% vs 4%, $p = 0.37$) and reirradiation (16% vs 12%, $p = 0.43$) did not significantly differ between cohorts. Furthermore, we found

fewer incidences of pain flare (11% vs 14%, $p = 0.55$) and post-SRS vertebral fracture (12% vs 22%, $p = 0.04$), and no difference in Grade ≥ 3 toxicity (1% vs 1%, $p = 1.00$) at instrumented sites. No instrumentation failures were observed after SRS.

Multivariate competing-risks regression was then used to adjust for measured differences between cohorts. Several covariates were associated ($p \leq 0.20$) with LF on univariate analysis and were evaluated alongside spinal instrumentation in a multivariate model (Table 3). Multivariate analysis demonstrated that controlled systemic disease (HR 1.72, 95% CI 1.06–2.78, $p = 0.03$), PTV coverage (HR 0.89, 95% CI 0.81–0.99, $p = 0.03$), and PTV (HR 1.01, 95% CI 1.01–1.03, $p = 0.02$) were significantly associated with LF. However, the presence of spinal instrumentation was not significantly associated with LF following multivariate analysis (HR 1.21, 95% CI 0.74–1.98, $p = 0.45$).

Discussion

The use of highly conformal radiation therapy at instrumented sites is controversial secondary to concerns for intraoperative seeding that may increase the risk for LF. Given a lack of comparative data in the literature, we performed a propensity-matched retrospective cohort study. We hypothesized that decompression with instrumentation would not significantly increase the cumulative incidence of LF. With respect to measured confounders, matching achieved comparable cohorts with very similar baseline characteristics. Following multivariate competing-risks regression, a statistically significant increase in the rate of LF attributable to decompression with instrumentation was not observed (HR 1.21, 95% CI 0.74–1.98, $p = 0.45$).

Several retrospective case series and cohort studies have reported local control following SRS at sites of surgical decompression, without an emphasis on instrumentation. In 2013, Laufer et al.¹⁶ reported a noncomparative series of 186 patients who underwent posterior surgical decompression followed by SRS. The median follow-up was 8 months, and the 12-month cumulative incidence of LF was 16.4% (comparable to the present investigation). Patients undergoing high-dose hypofractionated SRS (24–30 Gy in 3 fractions) or single-fraction SRS (24 Gy) had a lower cumulative incidence of LF relative to low-dose hypofractionated SRS (18–36 Gy in 5 or 6 fractions) (4.1% and 9.0% vs 22.2%, $p = 0.04$). Although this offers insight into useful fractionation schemes, this investigation does not offer a comparison between instrumented and noninstrumented sites. However, this relatively large investigation did offer a precedent for epidural decompression with adjuvant SRS as a possible alternative to corpectomy with stabilization.

In a comparative retrospective cohort study reported by Bate et al., 48 treatment sites underwent SRS alone, while 21 underwent epidural decompression with adjuvant SRS.⁵ No matching or multivariate methods were used in an attempt to control for differences between cohorts. The median follow-up was 10 months, and the 12-month cumulative incidences of LF were 4.2% (SRS alone) and

TABLE 1. Baseline characteristics of matched populations of patients with spinal metastases

Characteristic	Instrumentation Group	Control Group	Standardized Diff	p Value
No. of treatments	83	166		
Patient characteristics				
Age (yrs)	60.6 ± 11.9	60.6 ± 12.8	0.00	0.99
Sex: male	52 (63)	103 (62)	0.00	1.00
Race: Caucasian	72 (87)	141 (85)	0.05	0.85
Prior smoker	49 (59)	99 (60)	-0.01	1.00
Current smoker	8 (10)	14 (8)	0.04	0.81
KPS score	80 [60–100]	80 [60–100]	-0.20	0.17
NFS score	1 [0–4]	1 [0–4]	0.19	0.12
BMI	27.2 ± 5.7	27.2 ± 5.2	0.01	0.95
Diabetes	10 (12)	21 (13)	-0.02	1.00
No. of prior chemo regimens	1 [0–4]	1 [0–3]	-0.01	0.15
Disease characteristics				
Primary pathology				0.73
Radioresistant*	32 (39)	54 (33)	0.12	
Other	25 (30)	43 (26)	0.09	
Lung	10 (12)	31 (19)	-0.20	
Breast	7 (8)	17 (10)	-0.06	
Prostate	5 (6)	11 (7)	-0.03	
Radiosensitive	4 (5)	10 (6)	-0.06	
Controlled primary	47 (57)	102 (61)	-0.10	0.49
Controlled systemic disease	38 (46)	83 (50)	-0.06	0.59
Visceral metastases	34 (41)	73 (44)	-0.06	0.69
Extraspinal bone metastases	36 (43)	83 (50)	-0.13	0.35
Spinal disease burden				0.90
Single level	30 (36)	58 (35)	0.02	
Multilevel (2–5 vertebrae)	41 (49)	80 (48)	0.02	
Diffuse (>5 vertebrae)	12 (15)	28 (17)	0.07	
Treatment site characteristics				
Location				0.68
Cervical	18 (22)	30 (18)	0.09	
Thoracic	47 (57)	92 (55)	0.01	
Lumbosacral	18 (22)	43 (26)	-0.10	
No. of treated vertebrae	1 [0–5]	1 [0–6]	0.08	0.39
Vertebral body disease	80 (96)	159 (96)	0.03	1.00
Epidural disease	73 (88)	142 (86)	0.07	0.70
Neural foramen disease	59 (71)	120 (72)	-0.03	0.88
Paraspinal disease	42 (51)	81 (49)	0.04	0.79
Posterior elements disease	40 (48)	83 (50)	-0.04	0.89
Vertebral body fracture	29 (35)	47 (28)	0.14	0.31
Prior radiotherapy	34 (41)	60 (36)	-0.01	0.58
Dosimetric characteristics				
Fractions	1 [0–5]	1 [0–5]	0.06	0.47
Prescription dose (Gy)	15.6 ± 2.7	15.3 ± 2.1	0.10	0.46
Maximum dose (Gy)	18.2 ± 3.6	17.6 ± 2.7	0.13	0.24
Minimum dose (Gy)	10.2 ± 2.4	10.0 ± 1.9	0.07	0.93
PTV coverage (%)	94.0 ± 2.5	93.9 ± 2.7	0.03	0.82
PTV (cm ³)	115.9 ± 112.2	101.5 ± 114.8	0.13	0.22
Maximum diam (cm)	7.7 ± 2.6	7.1 ± 2.7	0.15	0.28

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TABLE 1. Baseline characteristics of matched populations of patients with spinal metastases

Characteristic	Instrumentation Group	Control Group	Standardized Diff	p Value
Dosimetric characteristics (<i>continued</i>)				
Conformality index	1.3 ± 0.2	1.4 ± 0.4	-0.15	0.11
Heterogeneity index	1.2 ± 0.1	1.2 ± 0.1	0.00	0.93
Radiographic follow-up (mos)	14.9 ± 17.8	14.0 ± 19.2	0.05	0.18

BMI = body mass index; chemo = chemotherapy; diam = diameter; diff = difference.

Values are presented as the mean ± SD, median [range], or number (%).

* Melanoma, sarcoma, or renal cell carcinoma.

9.5% (SRS + surgery), without consideration of competing risks. The authors concluded that SRS with or without epidural decompression represents an effective alternative to radical oncological resection. However, this conclusion was an extrapolation, because no comparison cohort of radical oncological resection was included. Given the small sample size and lack of adjustment for confounding, it is difficult to draw meaningful conclusions from these data.

Beyond these concerns for LF, there is some evidence suggesting that SRS may decrease the rate of instrumentation failure relative to conventional radiotherapy. In a small retrospective cohort study of 15 patients, Harel and Zach reported that the risk of instrumentation failure was 43% among patients undergoing conventional radiotherapy, compared with 0% among patients undergoing SRS ($p = 0.08$).¹³ This small sample was not matched or adjusted to account for confounding. Furthermore, patients in the conventionally fractionated radiotherapy cohort received doses usually reserved for definitive courses (> 30 Gy). In general, patients undergoing conventional radiotherapy probably represent a dissimilar population relative to patients undergoing SRS. Future studies might compare these 2 techniques at instrumented sites in an effort to determine the risk-benefit profile of dose escalation and greater conformality. Since this publication, a larger multi-institutional series of 318 patients reported a low inci-

dence (2.8%) of instrumentation failure following spine SRS.¹ Without a matched comparator arm, it is unknown whether a similarly low incidence would be observed following conventional radiotherapy.

Our findings must be carefully interpreted in the context of competing risks, because median survival was non-significantly greater in the instrumentation cohort (18 vs 12 months, $p = 0.17$, Fig. 1). This could be interpreted as evidence of a survival benefit with the use of decompression and fixation, analogous to the survival benefit reported by Patchell et al. in a randomized trial of circumferential decompression with radiotherapy versus radiotherapy alone.¹⁸ Alternatively, the observed survival difference may be evidence of unmeasured confounding despite propensity matching across more than 30 covariates. Certainly, patients must be medically fit to undergo surgery, thereby biasing survival in favor of the instrumentation cohort. Although the 12-month cumulative incidence of LF was not statistically significantly different (22.8% vs 15.8%, $p = 0.25$, Fig. 2), a larger multi-institutional investigation might detect a significant difference. This difference in LF may be due to differences in survival; the 12-month cumulative incidence of either LF or death was 47.4% (95% CI 36.1%–58.6%) in the instrumentation cohort, compared with 58.4% (95% CI 50.6%–66.2%, $p = 0.10$) among patients in the control cohort. Therefore, extended survival among patients with instrumentation may be responsible

FIG. 1. Graph showing OS following SRS with and without in-field spinal instrumentation.

FIG. 2. Graph showing the cumulative incidence of LF following SRS with and without in-field spinal instrumentation.

for the absolute (albeit small) difference in LF, rather than the effect of decompression with instrumentation itself. Similarly, patients with controlled systemic disease were at greater risk for LF (HR 1.72, 95% CI 1.06–2.78, $p = 0.03$), probably due to extended survival in this population. Randomizing patients with spinal instability to SRS alone versus SRS with instrumentation would be unethical, and therefore this retrospective comparative investigation with rigorous matching is necessary to control for sources of confounding.

Strengths and Limitations

Several limitations must be considered when interpreting the results of this study. Patients undergoing spinal decompression with instrumentation are inherently different from patients whose disease is managed with SRS alone, introducing selection bias. These patients are more likely

to have extensive epidural disease, cord compression, or bony retropulsion compared with patients undergoing SRS alone; although the extent of epidural disease is not explicitly graded at our institution, it is encouraging that similar rates of LF were observed between cohorts despite a greater expected degree of epidural disease in the instrumentation cohort. This may reflect superior dosimetric coverage of the epidural space following surgical decompression. Although cohorts were propensity matched across more than 30 covariates, unmeasured confounding potentially limits the internal validity of this investigation. However, randomization would be necessary to discern the independent effect of spinal fixation on survival and LF. A further limitation is the precision (or lack thereof) of MRI at instrumented sites, which may have increased the time to detection of LF. Alternatively, patients with instrumentation may undergo imaging more frequently, increasing the

TABLE 2. Unadjusted clinical outcomes in patients with spinal metastases

Characteristic	Instrumentation	Control	p Value
No. of treatments	83	166	
Median OS in mos	18 [12–29]	12 [9–19]	0.17
Cumulative incidence of LF			0.25
6 mos	18.8% [10.1–27.5%]	13.8% [9.2–18.9%]	
12 mos	22.8% [13.4–32.1%]	15.8% [10.0–21.5%]	
Failure requiring surgery	6 (7)	7 (4)	0.37
Failure requiring reirradiation	13 (16)	20 (12)	0.43
Adverse events			
Pain flare	9 (11)	23 (14)	0.55
Vertebral fracture	10 (12)	37 (22)	0.04
Grade ≥ 3 toxicity	1 (1)	1 (1)	1.00
Esophagitis	1 (1)	0 (0)	0.33
Myelopathy	0 (0)	1 (1)	1.00
Instrumentation failure	0 (0)	NA	NA

NA = not applicable.

Values are presented as estimate [95% CI] or number (%).

TABLE 3. Multivariate competing-risks regression for LF in patients with spinal metastases

Covariate	Univariate, p Value	Multivariate		
		HR	95% CI	p Value
Spinal instrumentation	0.30	1.21	0.74–1.98	0.45
Patient characteristics				
Age (yrs)	0.90	—	—	—
Prior smoker	0.29	—	—	—
Current smoker	0.90	—	—	—
KPS score	0.98	—	—	—
NFS score	0.12	0.73	0.56–1.06	0.06
Diabetes	0.03	1.59	0.87–2.91	0.13
No. of prior chemo regimens	0.26	—	—	—
Disease characteristics				
Primary pathology				
Radioresistant*	0.04	2.41	0.94–6.13	0.07
Other	0.03	2.95	0.93–7.69	0.07
Lung	Reference	1.00	Reference	Reference
Breast	0.55	1.40	0.41–4.77	0.70
Prostate	0.45	1.49	0.41–5.47	0.55
Radiosensitive	0.83	0.79	0.16–3.80	0.76
Controlled primary disease	0.83	—	—	—
Controlled systemic disease	0.11	1.72	1.06–2.78	0.03
Visceral metastases	0.41	—	—	—
Extraspinal bone metastases	0.54	—	—	—
Spinal disease burden				
Single level	Reference	—	—	—
Multilevel (2–5 vertebrae)	0.36	—	—	—
Diffuse (>5 vertebrae)	0.87	—	—	—
Treatment site characteristics				
Location				
Cervical	Reference	1.00	Reference	Reference
Thoracic	0.11	1.49	0.58–3.34	0.30
Lumbosacral	0.22	1.40	0.71–3.14	0.45
No. of treated vertebrae	0.02	1.11	0.88–1.40	0.39
Vertebral body	0.80	—	—	—
Epidural disease	0.15	1.39	0.59–3.25	0.45
Neural foramen disease	0.17	1.22	0.66–2.27	0.52
Paraspinal disease	0.43	—	—	—
Posterior elements disease	0.85	—	—	—
Prior radiotherapy	0.50	—	—	—
Dosimetric characteristics				
Prescription dose (Gy)	0.16	1.03	0.92–1.15	0.61
Maximum dose (Gy)	0.06	1.03	0.96–1.11	0.40
Minimum dose (Gy)	0.19	0.92	0.79–1.07	0.25
PTV coverage (%)	0.04	0.89	0.81–0.99	0.03
PTV (cm ³)*	<0.01	1.01	1.01–1.03	0.02
Maximum diam (cm)	0.09	0.91	0.76–1.08	0.27
Conformality index	0.28	—	—	—
Heterogeneity index	0.41	—	—	—

— = not calculated (variables did not meet the univariate p value threshold and are not included in the final multivariate model).

* Per 10-unit increase.

likelihood of earlier detection of LF. Moreover, titanium implants decrease the accuracy of dosimetry at instrumented sites.^{9,20} Use of propensity-matched controls and competing-risks analysis distinguishes the present study from prior investigations, which have generally been non-comparative or unmatched retrospective studies evaluating local control without consideration of competing risks.

Conclusions

In this propensity-matched analysis, LF and toxicity were similar among cohorts, suggesting that decompression with instrumentation does not significantly impact the efficacy or safety of spine SRS. Accordingly, spinal instrumentation may not be a contraindication to SRS. Future studies comparing SRS to conventional radiotherapy at instrumented sites in matched populations are warranted.

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Disclosures

Dr. Suh is a consultant for and received research support from Varian Medical Systems, and he received travel and speaker's fees from Elekta and Philips. Dr. Benzel has the following disclosures: royalties from Elsevier Publications and Thieme Publications; stock ownership in AxioMed, DePuy, OrthoMEMS, and Turning Point; consulting for AxioMed; and research support from OREF and Rawlings. Dr. Chao received an honorarium from Varian Medical Systems.

Author Contributions

Conception and design: Miller, Balagamwala. Acquisition of data: Miller. Analysis and interpretation of data: Miller. Drafting the article: Miller, Balagamwala. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chao. Statistical analysis: Miller. Study supervision: Suh.

Supplemental Information

Previous Presentations

Portions of this work were presented in abstract form at the 2016 Annual Meeting of the American Society for Radiation Oncology, September 25–28, 2016.

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