Spine SBRT: Indications, Planning Strategies and Clinical Outcomes

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Introduction

Spine SBRT: Not routine high dose palliation

Precise, high conformal treatment in appropriately selected patients designed to achieve

more durable pain relief	Stronger local tumour control	Lower re-irradiation rates

ASTRO and ESTRO explicitly position SBRT as preferred approach for selected vertebral metastases

Learning Objectives

- Why Spine SBRT can be superior to routine palliative fraction
- Apply NOMS framework together with SINS and Bilsky/ESCC
- Delineate GTV, CTV, PTV, cord/thecal sac and postoperative target volumes as per ISRS guidelines
- Choosing evidence-based dose fractionation schedules and their BED10 implications
- Applying practical cord/thecal sac constraints
- Recognizing major expected toxicities

Why Spine SBRT better?

Conventional RT includes 30 Gy in 10#, 20 Gy in 5# and 8 Gy in 1#

- Both ASTRO and ESTRO notes higher re-RT rates for 8 Gy in 1# with same amount of pain control

Modern metastatic patients tend to live longer thanks to advances in all the fields of Oncology.

Essential to look for metastasis directed RT such as SBRT for durable local control.

Not only to reduce pain, but prevent local progression, future neurologic compromise and repeat reirradiation.

Image guidance is imperative and essential due to OARs.

Practical Question	Routine Palliative RT	Spine SBRT
Main Historical Goal	Pain Palliation	Durable Pain relief, Durable local control
Typical Setup burden	Lower	Higher
Dose Intensity	Lower BED	Higher BED
Imaging/planning	Less demanding	Image guided
Best suited for	Short prognosis, urgent symptom control	Good prognosis, controlled limited disease

The NOMS Framework: Approach to the Treatment of Spinal Metastatic Tumors

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Disclosures of potential conflicts of interest may be found at the end of this article.

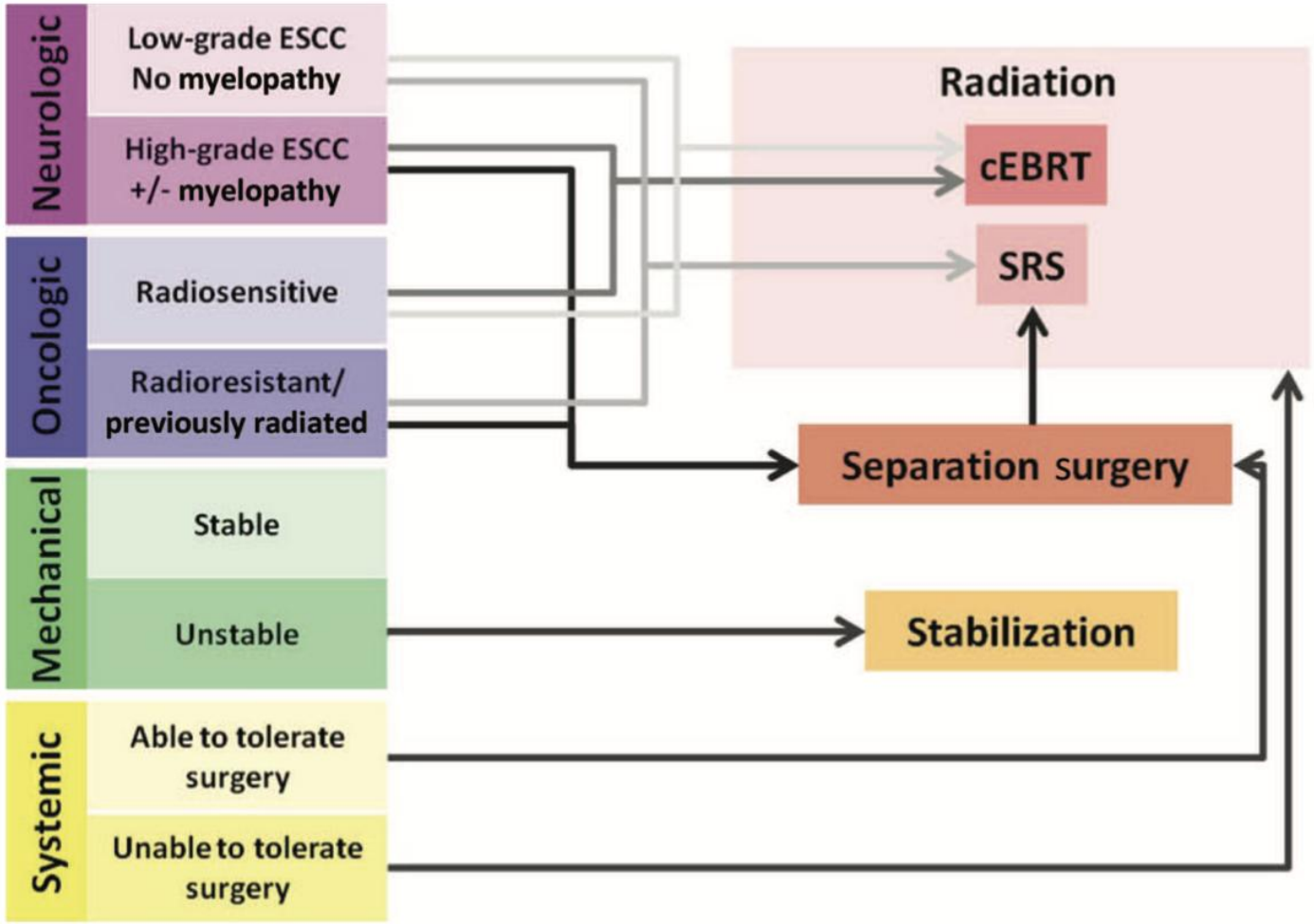


Table 2. Spinal Instability Neoplastic Score

	Score
Location	
Junctional (occiput-C2, C7-T2, T11-L1, L5-S1)	3
Mobile spine (C3-C6, L2-L4)	2
Semirigid (T3-T10)	1
Rigid (S2-S5)	0
Pain	
Yes	3
Occasional pain but not mechanical	1
Pain-free lesion	0
Bone lesion	
Lytic	2
Mixed (lytic/blastic)	1
Blastic	0
Radiographic spinal alignment	
Subluxation/translation present	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
Vertebral body collapse	
>50% collapse	3
<50% collapse	2
No collapse with >50% body involved	1
None of the above	0
Posterolateral involvement of spinal elements	
Bilateral	3
Unilateral	1
None of the above	0
Total score	
Stable	0–6
Indeterminate	7–12
Unstable	13–18

Oncologist, 2013

Table 1. Summary of expected radiation response based on histology

Study	Lymphoma, seminoma, myeloma	Breast	Prostate	Sarcoma	Melanoma	Gastrointestinal	NSCLC	Renal
Gilbert et al. [8]	F	F	U	U	U	U	U	U
Maranzano et al. [9]	F	F	F	U	U	U	U	U
Rades et al. [13]	F	I	I	I	U	I	U	I
Rades et al. [12]	F	F	F	U	U	U	U	U
Katagiri et al. [11]	F	F	F	U	U	U	U	U
Maranzano et al. [10]	F	F	F	U	U	U	U	U
Rades et al. [14]	F	I	I	I	U	I	U	I

Adapted from [7].
Abbreviations: F, favorable; I, intermediate; NSCLC, non-small cell lung cancer; U, unfavorable.

Table 3. Current NOMS decision framework

Neurologic	Oncologic	Mechanical	Systemic	Decision
Low-grade ESCC + no myelopathy	Radiosensitive	Stable		cEBRT
	Radiosensitive	Unstable		Stabilization followed by cEBRT
	Radioresistant	Stable		SRS
	Radioresistant	Unstable		Stabilization followed by SRS
High-grade ESCC ± myelopathy	Radiosensitive	Stable		cEBRT
	Radiosensitive	Unstable		Stabilization followed by cEBRT
	Radioresistant	Stable	Able to tolerate surgery	Decompression/stabilization followed by SRS
	Radioresistant	Stable	Unable to tolerate surgery	cEBRT
	Radioresistant	Unstable	Able to tolerate surgery	Decompression/stabilization followed by SRS
	Radioresistant	Unstable	Unable to tolerate surgery	Stabilization followed by cEBRT

Low-grade ESCC is defined as grade 0 or 1 on Spine Oncology Study Group scoring system [5]. High-grade ESCC is defined as grade 2 or 3 on the ESCC scale [5]. Stabilization options include percutaneous cement augmentation, percutaneous pedicle screw instrumentation, and open instrumentation. For patients with significant systemic comorbidities that affect the ability to tolerate open surgery, stabilization may be limited to cement augmentation and/or percutaneous screw augmentation.

Abbreviations: cEBRT, conventional external beam radiation; ESCC, epidural spinal cord compression; NOMS, neurologic, oncologic, mechanical, and systemic; SRS, stereotactic radiosurgery.

Reliability analysis of the epidural spinal cord compression scale

Clinical article

Mark H. Bilsky, M.D.,[1,2] Ilya Laufer, M.D.,[2] Daryl R. Fourney, M.D., F.R.C.S.C.,[3] Michael Groff, M.D.,[4] Meic H. Schmidt, M.D.,[5] Peter Paul Varga, M.D.,[6] Frank D. Vrionis, M.D., M.P.H., Ph.D.,[7] Yoshiya Yamada, M.D.,[8] Peter C. Gerszten, M.D.,[9] and Timothy R. Kuklo, M.D., J.D.[10]

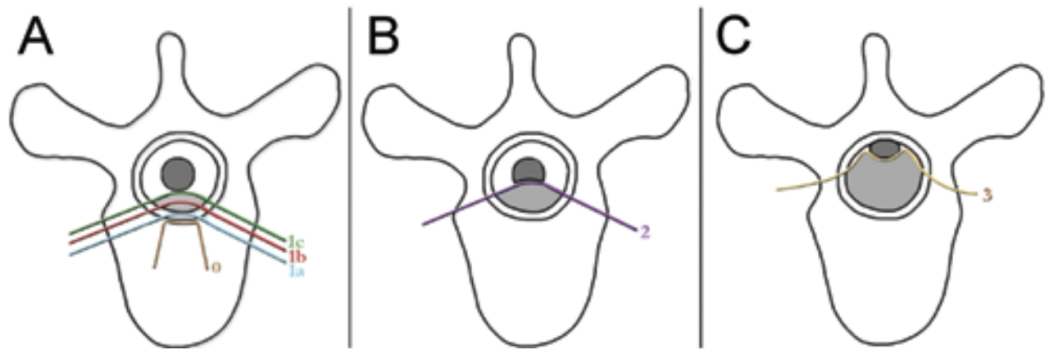
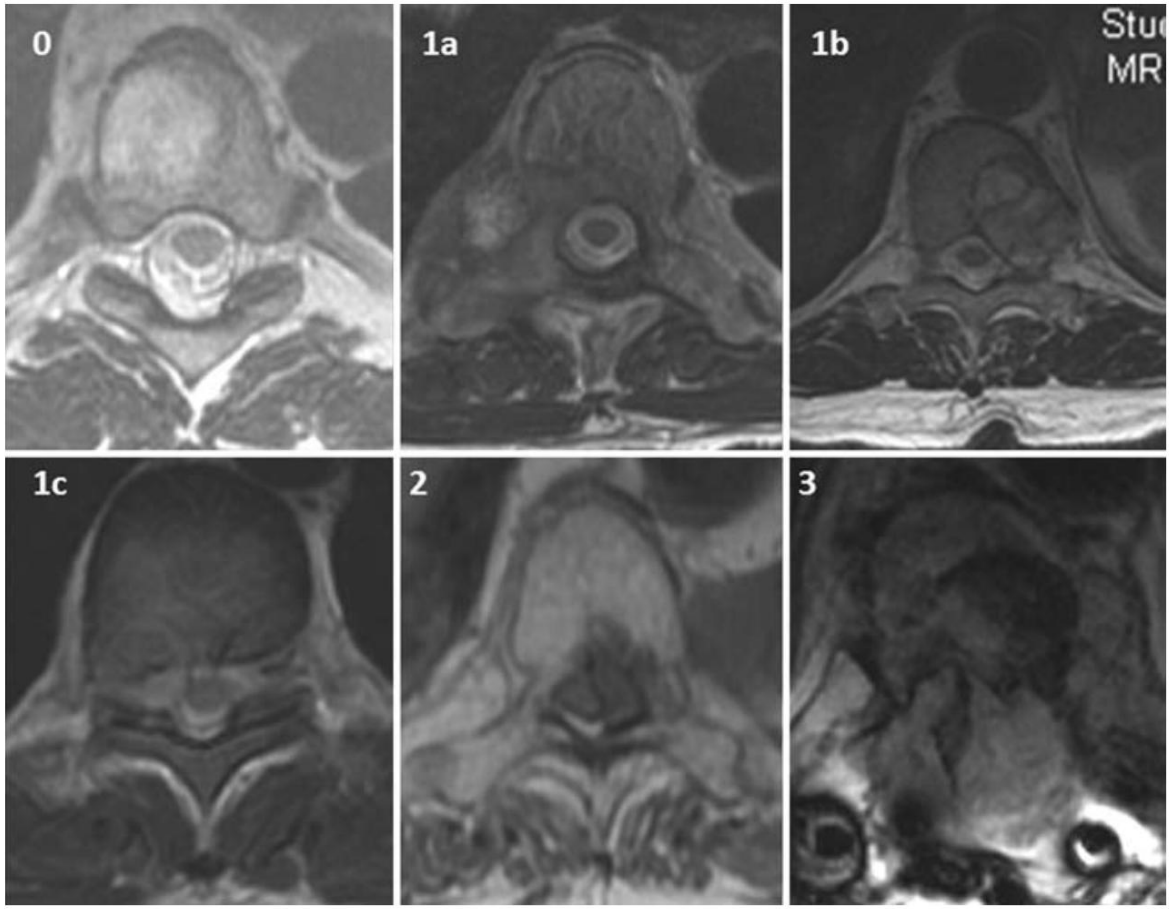


Fig. 1. Schematic representation of the 6-point ESCC grading scale. A grade of 0 indicates bone-only disease; 1a, epidural impingement, without deformation of the thecal sac; 1b, deformation of the thecal sac, without spinal cord abutment; 1c, deformation of the thecal sac with spinal cord abutment, but without cord compression; 2, spinal cord compression, but with CSF visible around the cord; and 3, spinal cord compression, no CSF visible around the cord.



Axial T2-weighted MR images representing progressive grades of ESCC.

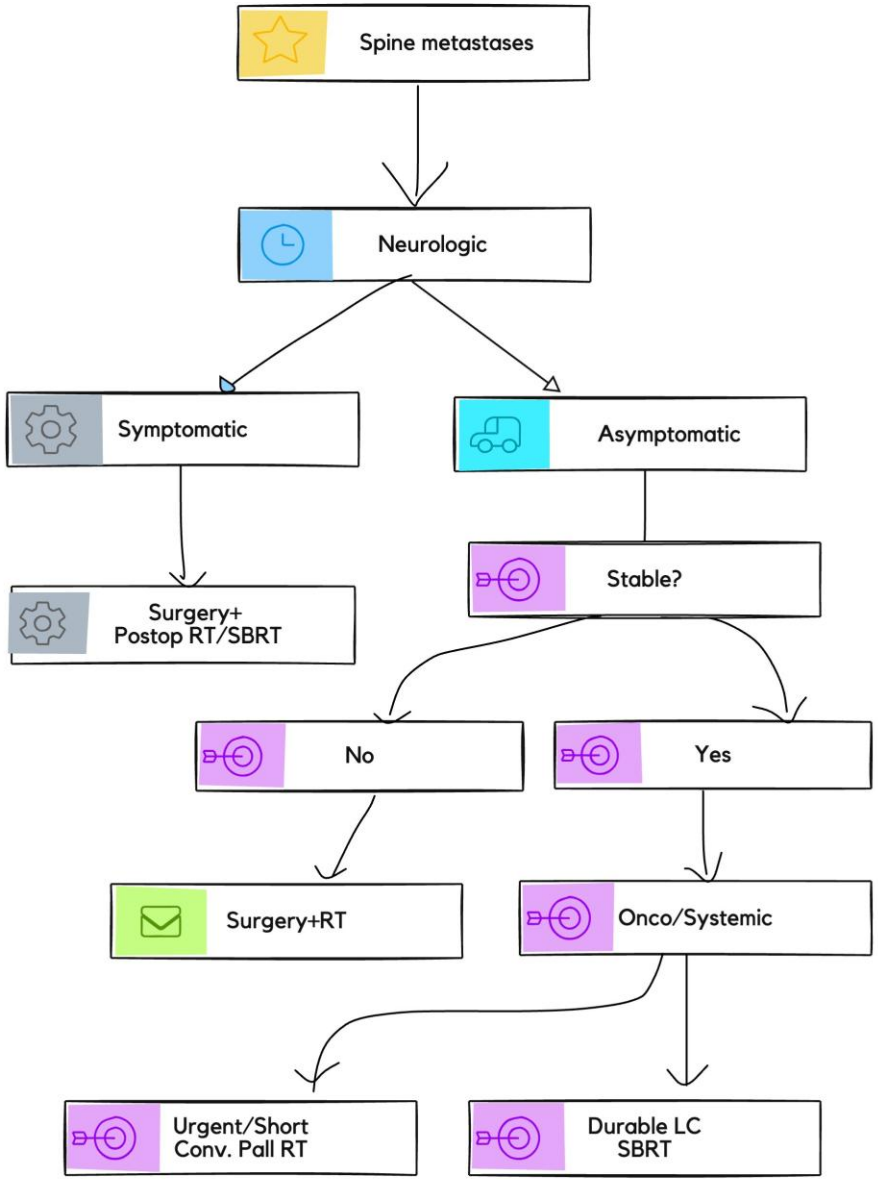
JNS, 2010

Common Indications

- Oligometastatic disease
- Radioresistant histologies
- Painful de-novo spine metastasis in ECOG 0-2 (Conditional recommendation)
- Re-irradiation
- Postop after decompression/separation surgery especially in Oligometastatic disease, radioresistant/paraspinal mass/prior RT

Important Contraindications

- Symptomatic metastatic spinal cord or cauda equina compression.
- Frank instability (SINS scores of 13-18 are unstable)
- Very short life expectancy
- Unable to tolerate MRI/rigid immobilization
- >3 consecutive vertebral body spread


Spine metastases
Neurologic
Symptomatic
Asymptomatic
Surgery+
Postop RT/SBRT
Stable?
No
Yes
Surgery+RT
Onco/Systemic
Urgent/Short
Conv. Pall RT
Durable LC
SBRT

Planning, Imaging, Contouring and Delivery

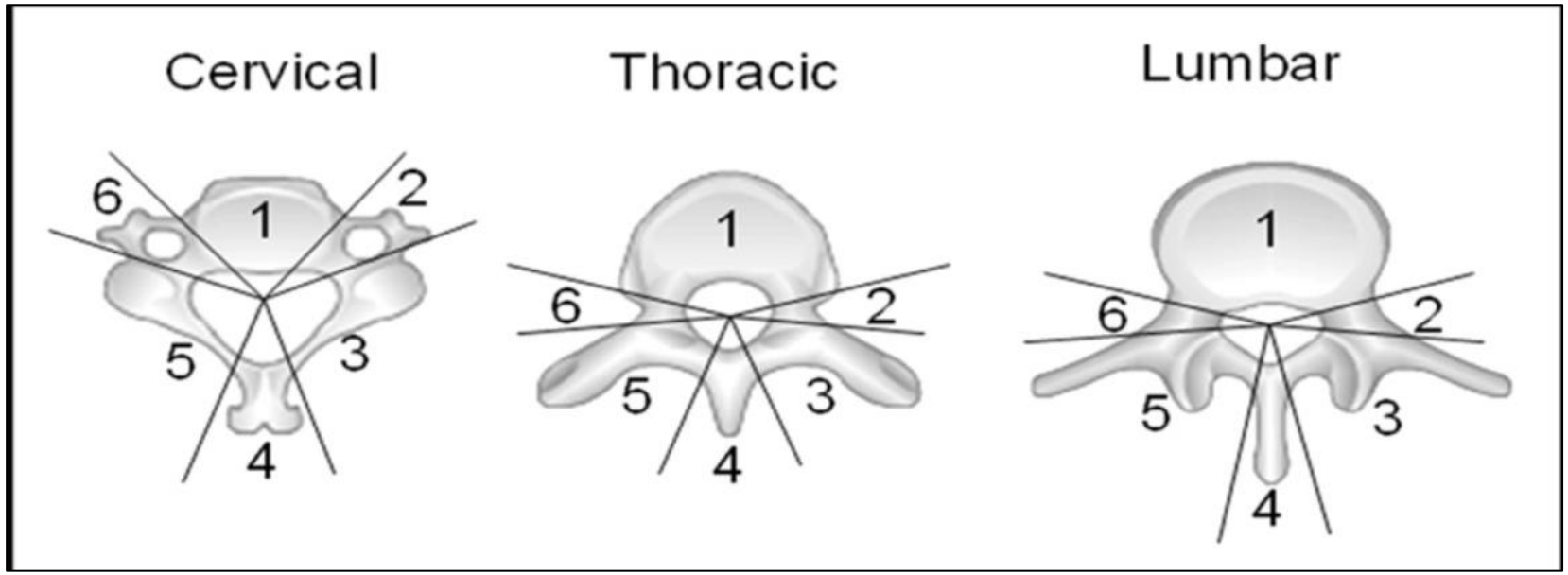
</= 1.5 mm cuts and fused with T1 and T2 sequences MRI

CT myelography useful when metal artefacts present

Based on ISRS guidelines

International Spine Radiosurgery Consortium Consensus Guidelines for Target Volume Definition in Spinal Stereotactic Radiosurgery

Brett W. Cox, MD,[*,1] Daniel E. Spratt, MD,[*,1] Michael Lovelock, PhD,[†] Mark H. Bilsky, MD,[‡] Eric Lis, MD,[§] Samuel Ryu, MD,[‖] Jason Sheehan, MD,[¶] Peter C. Gerszten, MD, MPH,[**] Eric Chang, MD,[††] Iris Gibbs, MD,[‡‡] Scott Soltys, MD,[‡‡] Arjun Sahgal, MD,[§§] Joe Deasy, PhD,[†] John Flickinger, MD,[‖‖] Mubina Quader, PhD,[‖‖] Stefan Mindea, MD,[¶¶] and Yoshiya Yamada, MD[‡‡]



IJROBP, 2012

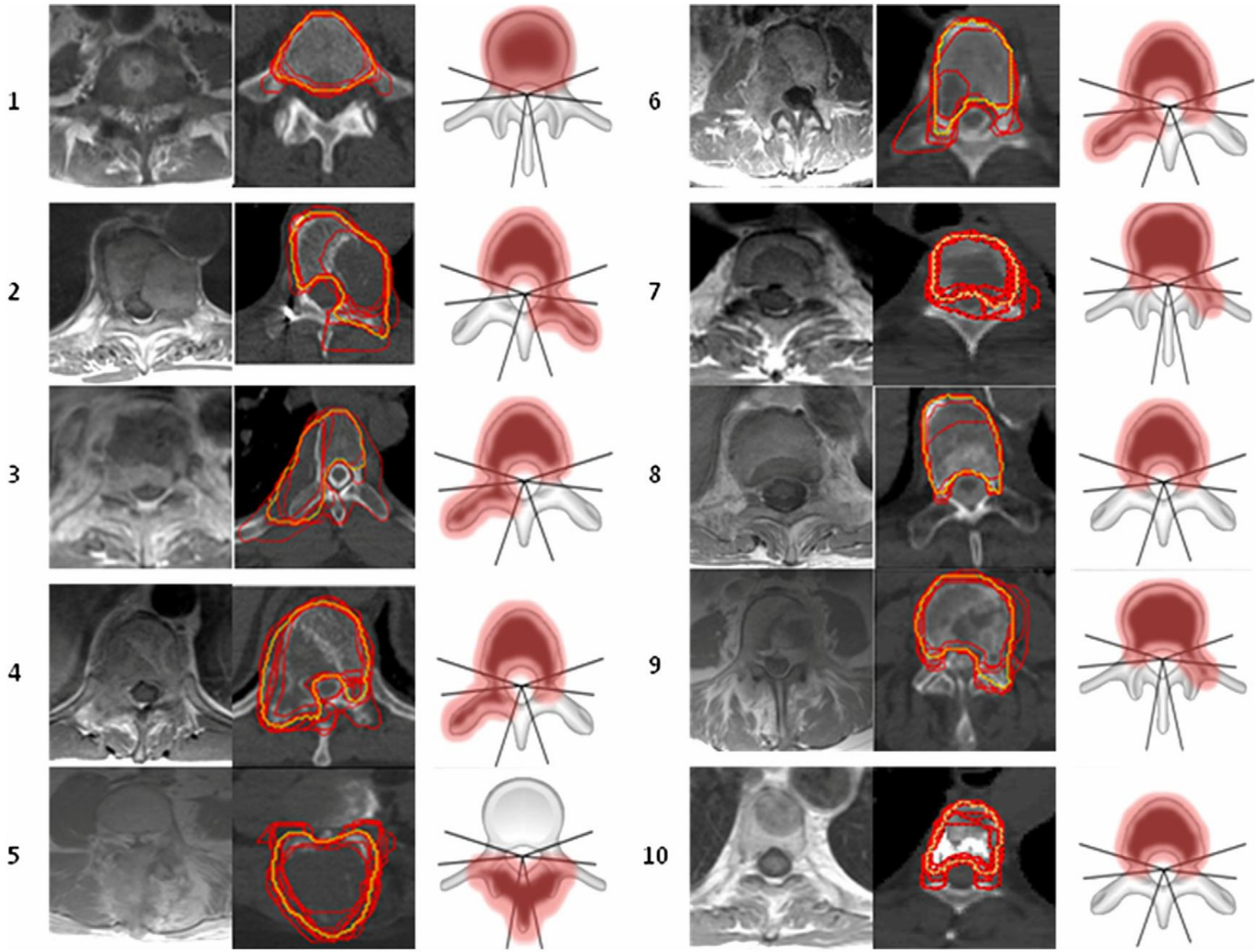


Fig. 2. Consensus clinical target volume contours for spinal stereotactic radiosurgery. Red indicates individual contours and orange indicates consensus contours.

Table 3 Guidelines for spinal SRS bony CTV delineation

GTV involvement	ISRC GTV anatomic classification	ISRC bony CTV recommendation	CTV description
Any portion of the vertebral body	1	1	Include the entire vertebral body
Lateralized within the vertebral body	1	1, 2	Include the entire vertebral body and the ipsilateral pedicle/transverse process
Diffusely involves the vertebral body	1	1, 2, 6	Include the entire vertebral body and the bilateral pedicles/transverse processes
GTV involves vertebral body and	1, 2	1, 2, 3	Include entire vertebral body,

Table 4 Summary of contouring guidelines for GTV, CTV, and PTV in spinal stereotactic radiosurgery

Target volume	Guidelines
GTV	• Contour gross tumor using all available imaging • Include epidural and paraspinal components of tumor
CTV	• Include abnormal marrow signal suspicious for microscopic invasion • Include bony CTV expansion to account for subclinical spread • Should contain GTV • Circumferential CTVs encircling the cord should be avoided except in rare instances where the vertebral body, bilateral pedicles/lamina, and spinous process are all involved or when there is extensive metastatic disease along the circumference of the epidural space without spinal cord compression
PTV	• Uniform expansion around CTV • CTV to PTV margin $\leq$3 mm • Modified at dural margin and adjacent critical structures to allow spacing at discretion of the treating physician unless GTV compromised • Never overlaps with cord • Should contain entire GTV and CTV

Consensus Contouring Guidelines for Postoperative Stereotactic Body Radiation Therapy for Metastatic Solid Tumor Malignancies to the Spine

Kristin J. Redmond, MD, MPH,* Scott Robertson, PhD,*
Simon S. Lo, MD, FAC
Todd McNutt, PhD,* S
Amol Ghia, MD,# Eric
and Arjun Sahgal, MD

Table 5 Summary of GTV, CTV, and PTV contouring guidelines for postoperative spine SBRT for spinal metastases

Target volume	Guidelines
GTV	• Gross tumor based on postoperative CT and MRI with attention to residual epidural or paraspinal disease • Include postoperative residual epidural and paraspinal components of tumor
CTV	• Include the postoperative region and entire anatomic compartment corresponding to all preoperative MRI abnormalities suspicious for tumor involvement • Include entire GTV • Surgical instrumentation and incision not included unless involved • Judicious use of circumferential CTVs limited to cases of preoperative circumferential osseous and/or epidural involvement; however, can be considered for near-circumferential epidural disease involvement • Modified at reconstructed dural space and to account for changes in anatomy after surgery at discretion of treating physician • Consider additional anatomic expansions of up to 5 mm beyond paraspinal extension and cranio-caudally for epidural disease
PTV	• Uniform CTV to PTV expansion of up to 2.5 mm • Treating physician may modify expansion at the interface with critical organs at risk • May subtract cord avoidance structure from PTV as a modified PTV for planning and dose reporting purposes • Include entire GTV and CTV

Table 4 Gui
both preoperat

Preoperati			
Circumferentia			
Anterior epidu central body			
Anterior epidu region of bo			
Epidural involv region of the region of pe			
Epidural involvement anteriorly in the region of the body, unilaterally in the region of pedicle, and posteriorly in the region of the spinous process	1, 4-6	1, 3-6, ±2	Preoperative body plus ipsilateral pedicle, bilateral transverse process, bilateral laminae, and spinous process
Posterior epidural involvement in region of spinous process	4	3-5	Preoperative spinous process, bilateral laminae and bilateral transverse processes
Any of the above plus extensive paraspinal extension	As above	As above	As above plus coverage of the entire preoperative extent of paraspinal extension

IJROBP, 2016

Table 3 Consensus clinical target volume contours for postoperative stereotactic body radiation therapy for spine metastases

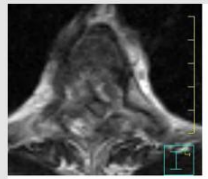
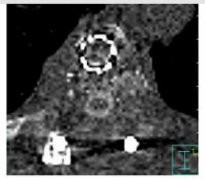
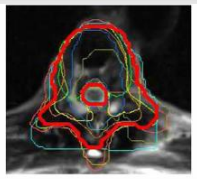
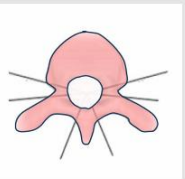
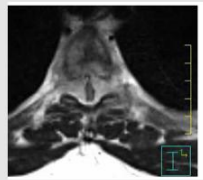
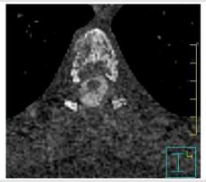
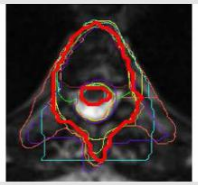
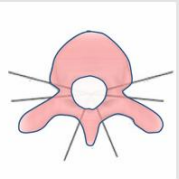
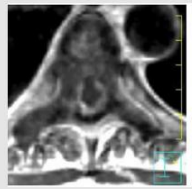
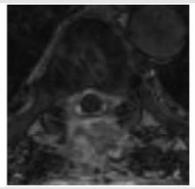
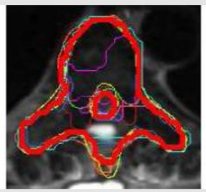
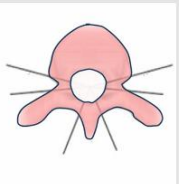
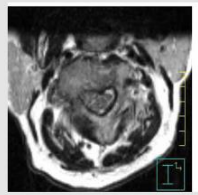
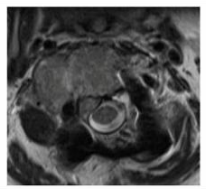
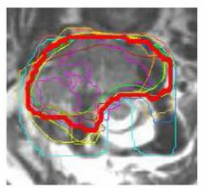
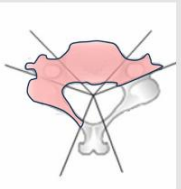
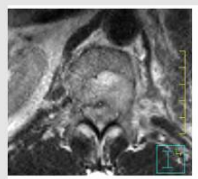
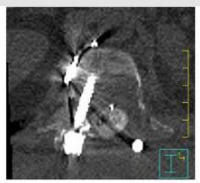
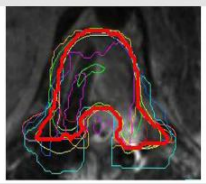
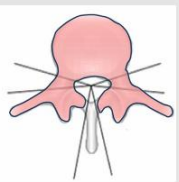
Patient no.	Preoperative axial MRI	Postoperative axial CT myelogram or T2 MRI	Simulation MRI with individual and consensus CTV contour	Schematic diagram
1				
2				
3				
4				
5				

Table 3 (*continued*)

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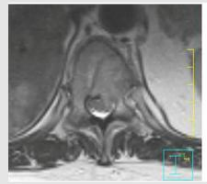
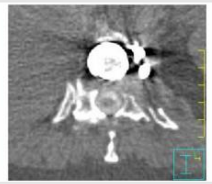
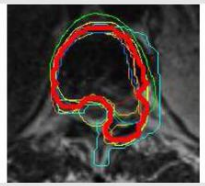
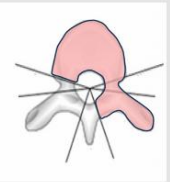
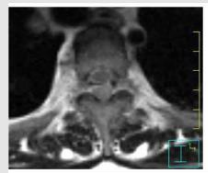
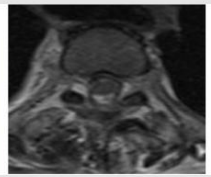
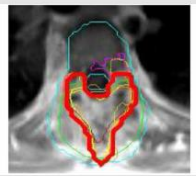
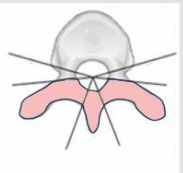
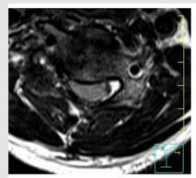
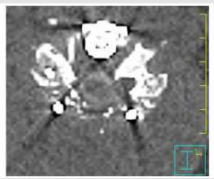
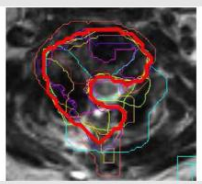
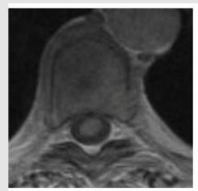
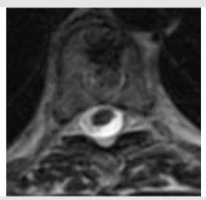
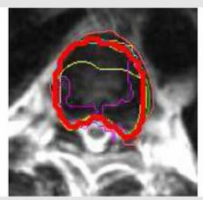
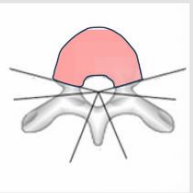
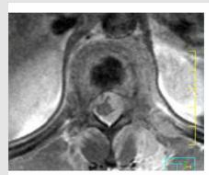
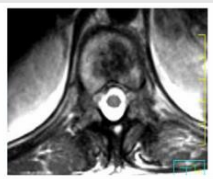
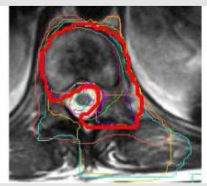
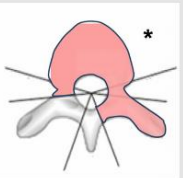
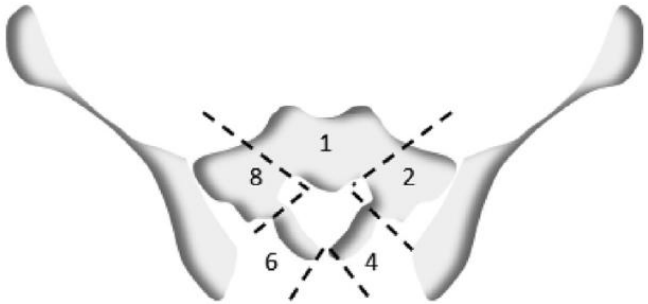
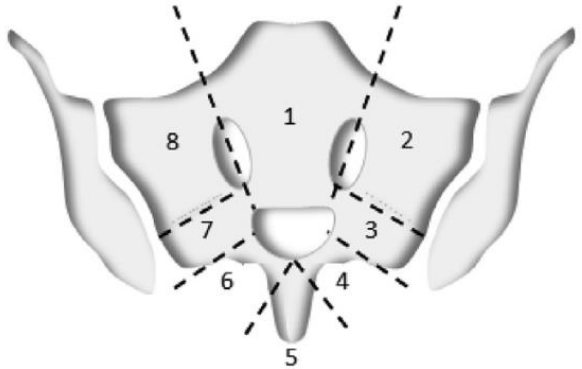
6				
7				
8				
9				
10				 *

International consensus recommendations for target volume delineation specific to sacral metastases and spinal stereotactic body radiation therapy (SBRT)

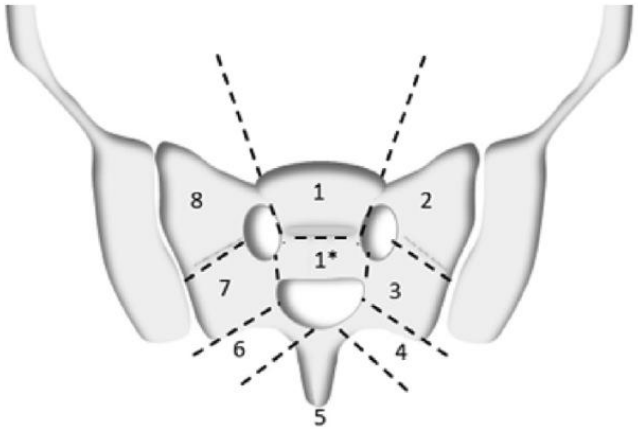
Emma M. Dunne [a,*], Arjun Sahgal [b], Simon S. Lo [c], Alanah Bergman [a], Robert Kosztyla [a], Nicolas Dea [d], Eric L. Chang [e], Ung-Kyu Chang [f], Samuel T. Chao [g], Salman Faruqi [h], Amol J. Ghia [i], Kristin J. Redmond [j], Scott G. Soltys [k], Mitchell C. Liu [a]



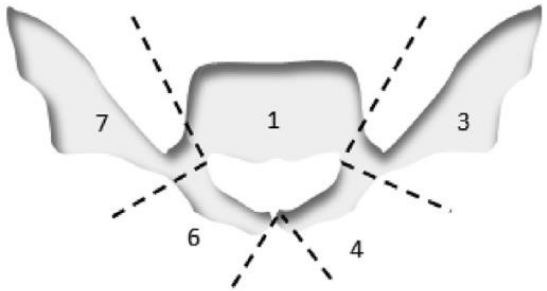
L5/S1 Junction



S1 Level



S1/S2 Level



S3 – S5 Level

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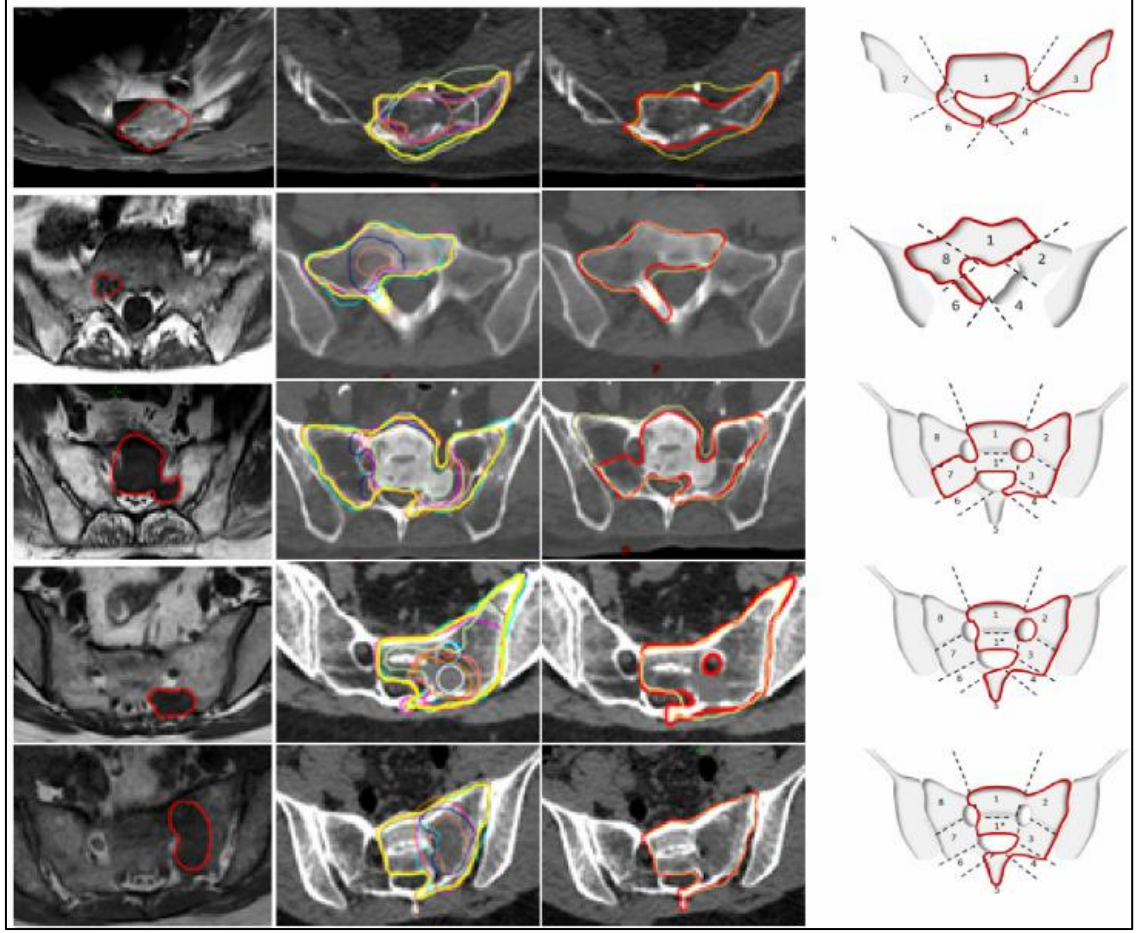
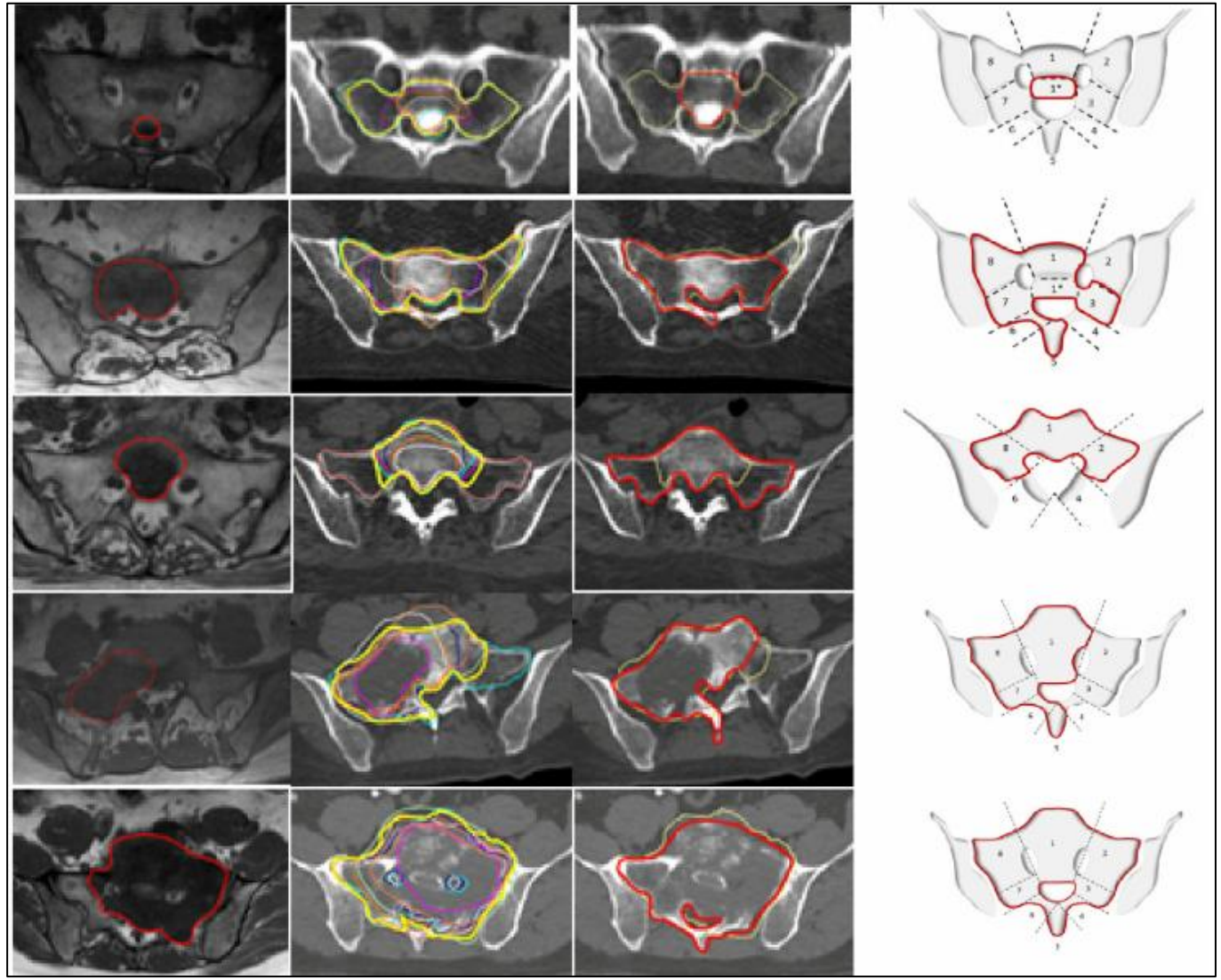
Axial T1 MRI with GTV contour	STAPLE CTV contour	Modified STAPLE CTV contour	Schematic diagram





Recommendations for target volume definition of the sacrum in spinal stereotactic body radiation therapy/stereotactic radiosurgery (SBRT/SRS).

GTV involvement	Sacrum anatomic Map classification	Sacrum bony CTV recommendation	CTV description
Any portion of the VB	1	1	Entire VB
Lateralised within the VB (S1–S2)*	1	1, 2, 3	Entire VB and the ipsilateral ala. When contouring the ala, use the ossification line if visible to limit the extent of the CTV. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB†
Lateralised within the VB (S3–S5)*	1	1, 3	Entire VB and the ipsilateral posterior ala. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB
Diffusely involves the VB (S1–S2)*	1	1, 2, 3, 7, 8	Entire VB and bilateral alae. When contouring the ala, use the ossification line if visible to limit the extent of the CTV. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB†
Diffusely involves the VB (S3–S5)*	1	1, 3, 7	Entire VB, bilateral posterior ala. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB.
GTV involves VB and unilateral ala (S1–S2)*	1, 2, 3	1, 2, 3, 4	Entire VB, ipsilateral ala and ipsilateral lamina. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB†
GTV involves VB and unilateral ala (S3–S5)*	1, 3	1, 3, 4	Entire VB, ipsilateral posterior ala and ipsilateral lamina. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB.
GTV involves VB and bilateral ala (S1–S2)*	1, 2, 3, 7, 8	1, 2, 3, 4, 6, 7, 8	Entire VB, bilateral alae and bilateral laminae. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB†
GTV involves VB and bilateral ala (S3–S5)*	1, 3, 7	1, 3, 4, 6, 7	Entire VB, bilateral posterior alae and bilateral laminae. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB.
GTV involves the unilateral ala (S1–S2)*	2, 3	2, 3, ±1	Entire ipsilateral ala ± the entire adjacent VB. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB†
GTV involves unilateral lamina	4	4, 5, ±1	Ipsilateral lamina, spinous process ± VB
GTV involves bilateral laminae	4, 6	4, 5, 6, ±1	Bilateral laminae, spinous process ± VB
GTV involves spinous process	5	4, 5, 6	Spinous process and bilateral laminae

Organs at Risk

Spinal Cord Dose Tolerance to Stereotactic Body Radiation Therapy

Arjun Sahgal, MD,* Joe H. Chang, MBChB, PhD,* Lijun Ma, PhD,† Lawrence B. Marks, MD,‡ Michael T. Milano, MD, PhD,§ Paul Medin, PhD,‖ Andrzej Niemierko, PhD,¶ Scott G. Soltys, MD,# Wolfgang A. Tomé, PhD, C. Shun Wong, MD,* Ellen Yorke, PhD,†† Jimm Grimm, PhD,‡‡ and Andrew Jackson, PhD††**

- MRI fusion with CT or
- CT Myelogram

Table 3 Spinal cord and thecal sac D_{max} values recommended in previous publications compared with model-derived limits

	Existing expert-based recommendations for D_{max}		Model-based limits for D_{max} derived from clinical data		
	AAPM TG101[5]	Kim et al 2017[56]	Sahgal 2013*	Katsoulakis–Gibbs model*	Approximate
			LQ, $\alpha/\beta = 2$ Gy	LQ, $\alpha/\beta = 2$ Gy	Risk
No. fractions	Gy	Gy	Gy	Gy	of RM, %
1	14	14	12.4	14	1-5
2		18.3	*17*	*19.3*	1-5
3	21.9	22.5	*20.3*	*23.1*	1-5
4		25.6	*23*	*26.2*	1-5
5	30	28	*25.3*	*28.8*	1-5

IJROBP, 2019

Table 4 Maximal spinal cord doses for reirradiation associated with a low risk of RM according to Sahgal et al 2012[43]

Prior RT		Recommended spinal cord* D^{max} in 1-5 fractions (Gy)				
Dose, Gy/fractions	$EQD2_2$, Gy	1 fraction	2 fractions	3 fractions	4 fractions	5 fractions
20/5	30	9	12.2	14.5	16.2	18
30/10	37.5	9	12.2	14.5	16.2	18
40/20	40	N/A	12.2	14.5	16.2	18
45/25	43	N/A	12.2	14.5	16.2	18
50/25	50	N/A	11	12.5	14	15.5

Abbreviations: D_{max} = maximum dose; $EQD2_2$ = equivalent dose in 2 Gy fractions (α/β = 2 Gy); RT = radiation therapy.
* The thecal sac was used as a surrogate structure for the spinal cord in this study.[43]

- For Reirradiation SBRT:
  - Cumulative Thecal sac EQD2 Dmax should not exceed 70 Gy
  - Reirradiation SBRT thecal sac EQD2 Dmax should not exceed 25 Gy
  - Reirradiation SBRT thecal sac EQD2 Dmax to cumulative EQD2 Dmax ratio should not exceed 0.5
  - Minimum time interval to reirradiation should be atleast 5 months

OARs	Dmax	Volume	Notes
Brachial Plexus • 1 Fx • 3 Fx • 5 Fx	• 17.5 Gy / 14 Gy • 24 Gy / 20.4 Gy • 32 Gy / 30 Gy	Max Point/ <3cc	• RTOG 0631 • RTOG 1021 • RTOG 0813
Cauda Equina • 1 Fx • 3 Fx • 5 Fx	• 16 Gy / 14 Gy • 24 Gy / 20.4 Gy • 32 Gy / 30 Gy	Max Point/ <3cc	• RTOG 0631 • RTOG 1021 (E) • RTOG 0813 (E)
Esophagus • 1 Fx • 3 Fx • 5 Fx	• 16 Gy / 11.9 Gy • 25.2 Gy / 17.7 Gy • 105% of PTV prescription / 27.5 Gy	Max Point/ <3cc	• RTOG 0631 • RTOG 1021 • RTOG 0813

Review

Dose–Volume Constraints fOr oRganS At risk In Radiotherapy (CORSAIR): An "All-in-One" Multicenter–Multidisciplinary Practical Summary

Silvia Bisello [1,2,*,†], Savino Cilla [3,†], Anna Benini [1,2], Raffaele Cardano [1,2], Nam P. Nguyen [4], Francesco Deodato [5], Gabriella Macchia [5], Milly Buwenge [1], Silvia Cammelli [1,2], Tigeneh Wondemagegnehu [6], A. F. M. Kamal Uddin [7], Stefania Rizzo [8], Alberto Bazzocchi [9], Lidia Strigari [10] and Alessio G. Morganti [1,2]

Organ	Constraints (Conventional Fractionation) *	Constraints (Hypofractionation)			
		1 Fraction	3 Fractions	5 Fractions	8 Fractions
Esophagus	D_{MEAN} < 34 Gy; $V_{35\ Gy}$ < 50%; $V_{50\ Gy}$ < 40%; $V_{70\ Gy}$ < 20% [5] (A);	$D_{MAX(0.1\ cm^3)}$ < 15.4 $Gy_{(mandatory)}$ [6,25] (A); $D_{5\ cm^3}$ < 11.9 $Gy_{(optimal)}$; [8] (A)	$D_{MAX(0.1\ cm^3)}$ < 25.2 $Gy_{(mandatory)}$ [6] (A); $D_{MAX(0.1\ cm^3)}$ < 27 Gy [25] (A); $D_{0.5\ cm^3}$ < 17.7 $Gy_{(optimal)}$; [7,8] (A) $V_{21\ Gy}$ < 5 cm^3 [10] (B)	$D_{MAX(0.1\ cm^3)}$ <35 $Gy_{(mandatory)}$ [6] (A); $D_{MAX(0.5\ cm^3)}$ <32 $Gy_{(optimal)}$; [7,8] (A) $V_{27.5\ Gy}$ < 5 cm^3; $V_{19.5\ Gy}$ < 10 cm^3 [10] (B); Avoid 105% of PTV prescription [25] (A)	$D_{MAX(0.1\ cm^3)}$ < 40 $Gy_{(mandatory)}$ [6] (A)
Heart	D_{MEAN} < 26–30 Gy $V_{25\ Gy}$ < 10%; $V_{30\ Gy} \leq$ 30%; [5,26] (A)	$D_{MAX(0.03\ cm^3)}$ < 22 $Gy_{(mandatory)}$ [8,25]; $D_{15\ cm^3}$ < 16 $Gy_{(optimal)}$; [8] (A)	$D_{MAX(0.5\ cm^3)}$ < 26 $Gy_{(mandatory)}$; $D_{MAX(0.5\ cm^3)}$ < 24 $Gy_{(optimal)}$; [7] (A) D_{MAX} < 30 $Gy_{(mandatory)}$ [25] (A); $D_{15\ cm^3}$ < 24 Gy [8] (A); $V_{21\ Gy}$ < 5 cm^3 [10] (B)	$D_{MAX(0.5\ cm^3)}$ < 29 $Gy_{(mandatory)}$; $D_{MAX(0.5\ cm^3)}$ < 27 $Gy_{(optimal)}$; [7] (A) $D_{15\ cm^3}$ < 32 Gy [8] (A) Avoid 105% of PTV prescription [25] (A)	$D_{MAX(0.5\ cm^3)}$ <60 $Gy_{(mandatory)}$; $D_{MAX(0.5\ cm^3)}$ < 50 $Gy_{(optimal)}$; [7] (A)
Lung	$V_{40\ Gy} \leq$ 10%; $V_{30\ Gy} \leq$ 15%; $V_{20\ Gy} \leq$ 20%; $V_{10\ Gy} \leq$ 40%; $V_{5\ Gy} \leq$ 50%; D_{MEAN} < 20 Gy [26] (A)	Lungs and Lungs–ITV: $V_{20\ Gy}$ < 15% (mandatory); D_{MEAN} < 8 Gy (optimal); $V_{20\ Gy}$ < 10% (optimal); [6] (A) $D_{1500\ cm^3}$ < 7 Gy; $D_{1000\ cm^3}$ < 7.4 Gy; [8] (A)	Lungs and Lungs–ITV: $V_{20\ Gy}$ < 15% (mandatory); D_{MEAN} < 8 Gy (optimal); $V_{20\ Gy}$ < 10% (optimal); [6] (A) $D_{1500\ cm^3}$ < 11.6 Gy; $D_{1000\ cm^3}$ < 12.4 Gy; [8] (A)	Lungs and Lungs–ITV: $V_{20\ Gy}$ < 15% (mandatory); D_{MEAN} < 8 Gy (optimal); $V_{20\ Gy}$ < 10% (optimal); [6] (A) $D_{1500\ cm^3}$ < 12.5 Gy; $D_{1000\ cm^3}$ < 13.5 Gy; [8] (A)	Lungs and Lungs–ITV: $V_{20\ Gy}$ < 15% (mandatory); D_{MEAN} < 8 Gy (optimal); $V_{20\ Gy}$ < 10% (optimal); [6] (A)

Delivery and planning tips

- Modern acceptable planning techniques
- Online Image guidance before each fraction
- Preferable 6-degree-of-freedom correction
- Rigid immobilization and supine position
- MRI fusion or CT myelogram
- Maintenance of sharp dose fall-off
- Modulated inverse planning techniques
- In postop scenario, for preop volume than only residual volume

KEY TRIALS

Stereotactic body radiotherapy versus conventional external beam radiotherapy in patients with painful spinal metastases: an open-label, multicentre, randomised, controlled, phase 2/3 trial

*Arjun Sahgal, Sten D Myrehaug, Shankar Siva, Giuseppina L Masucci, Pejman J Maralani, Michael Brundage, James Butler, Edward Chow, Michael G Fehlings, Mathew Foote, Zsolt Gabos, Jeffrey Greenspoon, Marc Kerba, Young Lee, Mitchell Liu, Stanley K Liu, Isabelle Thibault, Rebecca K Wong, Maaike Hum, Keyue Ding, Wendy R Parulekar, on behalf of the trial investigators**

	Conventional external beam radiotherapy group (n=115)	Stereotactic body radiotherapy group (n=114)	p value
1-month assessment			
Complete response	20 (17%)	30 (26%)	0·10*
Partial response	33 (29%)	34 (30%)	..
Stable pain	38 (33%)	26 (23%)	..
Progressive pain	14 (12%)	9 (8%)	..
Indeterminant	10 (9%)	15 (13%)	..
Mean daily OME consumption, mg	44 (122)	27 (95)	0·26
3-month assessment			
Complete response	16 (14%)	40 (35%)	0·0002*
Partial response	29 (25%)	20 (18%)	..
Stable pain	34 (30%)	27 (24%)	..
Progressive pain	14 (12%)	7 (6%)	..
Indeterminant	22 (19%)	20 (18%)	..
Mean daily OME consumption, mg	43 (106)	37 (97)	0·70
Mean change in SINS from baseline	−0·49 (1·61)	−0·94 (1·69)	0·034
6-month assessment			
Complete response	18 (16%)	37 (32%)	0·0036*
Partial response	18 (16%)	10 (9%)	..
Stable pain	32 (28%)	26 (23%)	..
Progressive pain	8 (7%)	5 (4%)	..
Indeterminant	39 (34%)	36 (32%)	..
Mean daily OME consumption, mg	36 (126)	36 (84)	1·00
Mean change in SINS from baseline	−0·74 (1·99)	−0·73 (1·86)	0·88

	Conventional external beam radiotherapy group (n=115)	Stereotactic body radiotherapy group (n=114)
Sex		
Female	54 (47%)	55 (48%)
Male	61 (53%)	59 (52%)
Age, years		
18–59	36 (31%)	47 (41%)
60–69	36 (31%)	25 (22%)
≥70	43 (37%)	42 (37%)
Median age, years	65 (55–73)	63 (56–72)
Primary malignancy		
Breast	27 (23%)	23 (20%)
Genitourinary (excluding renal cell carcinoma)	25 (22%)	21 (18%)
Lung	26 (23%)	35 (31%)
Gastrointestinal	15 (13%)	14 (12%)
Renal cell	7 (6%)	13 (11%)
Head and neck	3 (3%)	5 (4%)
Melanoma	5 (4%)	2 (2%)
Other	7 (6%)	1 (1%)
Spinal location of target vertebrae		
Cervical	8 (7%)	11 (10%)
Thoracic	61 (53%)	50 (44%)
Lumbar	42 (37%)	41 (36%)
Sacral	4 (3%)	8 (7%)
Number of consecutive spinal segments in target volume		
1	46 (40%)	63 (55%)
2	37 (32%)	32 (28%)
3	32 (28%)	18 (16%)
>3	0	1 (1%)
Worst pain score		
2–4	43 (37%)	46 (40%)
5–7	45 (39%)	42 (37%)
8–10	27 (23%)	26 (23%)
Median pain score	5 (4–7)	5 (4–7)
SINS score		
0–6	46 (40%)	57 (50%)
7–12	69 (60%)	57 (50%)
Median SINS score†	7 (6–8)	7 (5–8)

LANCET ONCOLOGY, 2021

	Conventional external beam radiotherapy group (n=115)			Stereotactic body radiotherapy group (n=110)		
	Grade 2	Grade 3	Grade 4	Grade 2	Grade 3	Grade 4
Dysphagia	0	0	0	1 (1%)	1 (1%)	0
Oesophagitis*	2 (2%)	0	0	2 (2%)	0	0
Nausea	2 (2%)	1 (1%)	0	1 (1%)	0	0
Pain†	4 (3%)	5 (4%)	0	2 (2%)	5 (5%)	0
Fatigue	0	1 (1%)	0	0	0	0
Vertebral compression fracture	0	0	1 (1%)	0	1 (1%)	0

Data are n (%). Adverse events were graded according to the Common Terminology Criteria for Adverse Events version 4.0. No grade 5 adverse events were reported. *Oesophagitis events are presented as an aggregate of oesophageal pain, oesophagitis, and pharyngeal mucositis. †Pain events are presented as an aggregate of general disorders pain, neoplasm-related tumour pain, and musculoskeletal and connective tissue disorders.

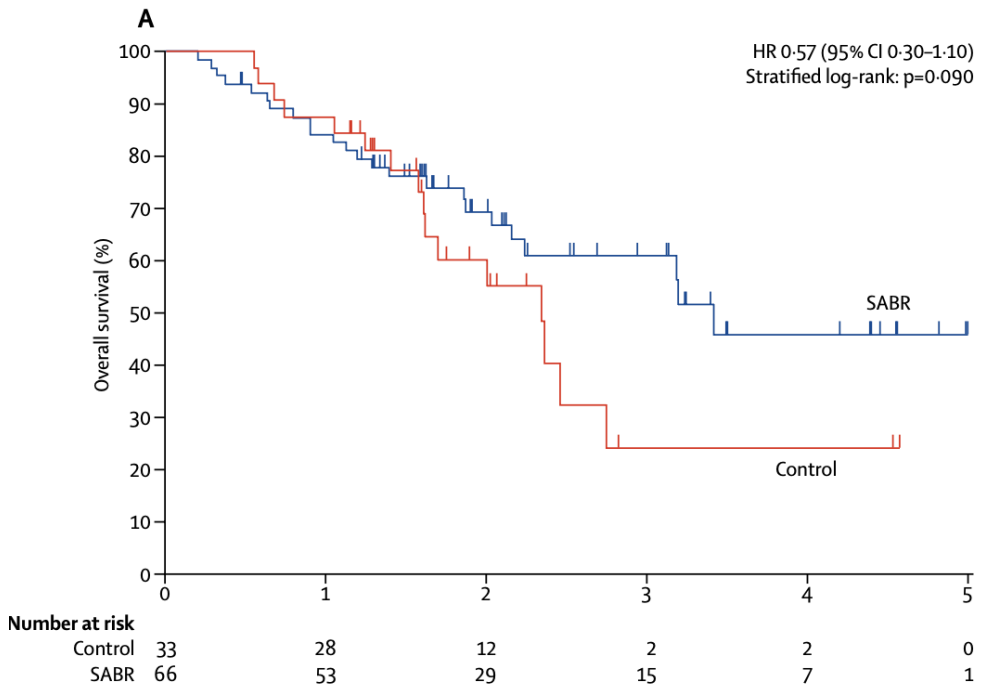
Table 5: **Incidence of grade 2 or higher treatment-related adverse events in the safety analysis population**

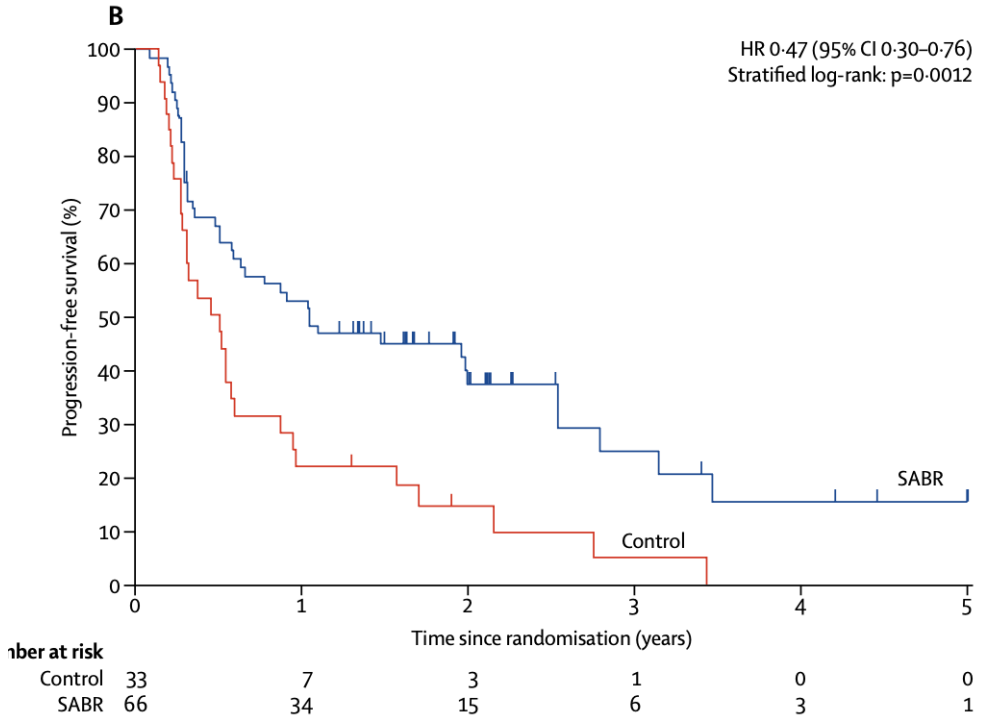
Stereotactic body radiotherapy at a dose of 24 Gy in two daily fractions was superior to conventional external beam radiotherapy at a dose of 20 Gy in five daily fractions in improving the complete response rate for pain.

Stereotactic ablative radiotherapy versus standard of care palliative treatment in patients with oligometastatic cancers (SABR-COMET): a randomised, phase 2, open-label trial

David A Palma, Robert Olson, Stephen Harrow, Stewart Gaede, Alexander V Louie, Cornelis Haasbeek, Liam Mulroy, Michael Lock, George B Rodrigues, Brian P Yaremko, Devin Schellenberg, Belal Ahmad, Gwendolyn Griffioen, Sashendra Senthi, Anand Swaminath, Neil Kopek, Mitchell Liu, Karen Moore, Suzanne Currie, Glenn S Bauman, Andrew Warner, Suresh Senan

Stereotactic Radiation for the Comprehensive Treatment of Oligometastases (SABR-COMET): Extended Long-Term Outcomes





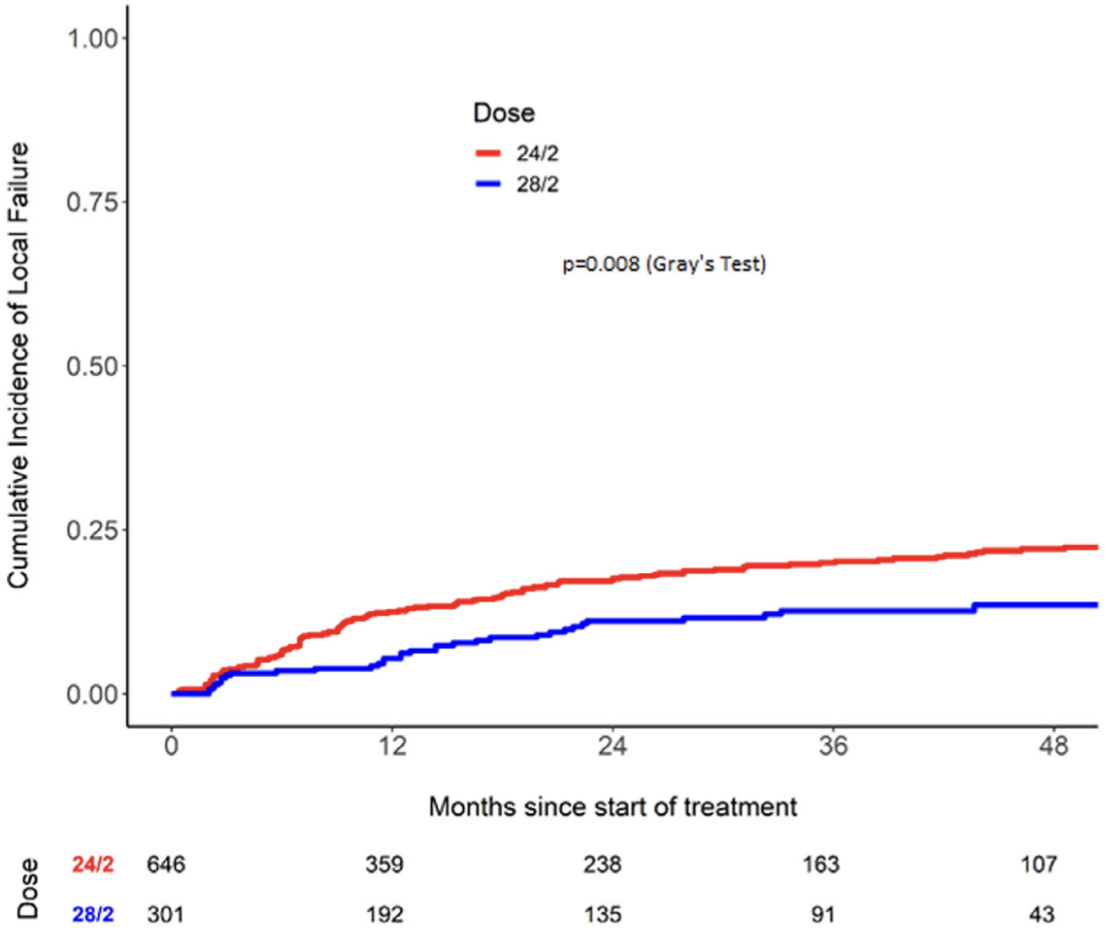
- Eight-year OS 27.2% vs 13.6%
- Eight-year PFS 21.3% vs 0%
- Toxicities ≧ 2: 30.3% vs 9.1%

LANCET, 2021
IJROBP, 2022

Dose-Escalated 2-Fraction Spine Stereotactic Body Radiation Therapy: 28 Gy Versus 24 Gy in 2 Daily Fractions

K. Liang Zeng, MD,* Ahmed Abugarib, MD,*,† Hany Soliman, MD,* Sten Myrehaug, MD,* Zain A. Husain, MD,* Jay Detsky, MD, PhD,* Mark Ruschin, PhD,* Aliaksandr Karotki, PhD,* Eshetu G. Atenafu, MSc,‡ Jeremie Larouche, MD,§ Mikki Campbell, BSc,* Pejman Maralani, MD,‖ Arjun Sahgal, MD,* and Chia-Lin Tseng, MDCM*

- 28 Gy cohort, the 6-, 12-, and 24-month cumulative incidences of LF were 3.5%, 5.4%, and 11.1%
- 24 Gy cohort: 6.0%, 12.5%, and 17.6%
- Risk of VCF was 5.5%, 7.6%, and 10.7% at 6, 12, and 24 months, respectively, and was similar between cohorts
- Dose escalation to 28 Gy in 2 daily fractions was associated with improved local control without increasing the risk of VCF.



IJROBP, 2023

External Beam Radiation Therapy for Palliation of Symptomatic Bone Metastases: An ASTRO Clinical Practice Guideline

Sara Alcorn, MD, PhD,[a,*] Ángel Artal Cortés, MD, PhD,[b] Lisa Bradfield, BA,[c] Margaret Brennan, MD,[d] Kristopher Dennis, MD, PhD,[e] Dayssy A. Diaz, MD,[f] Yee-Cheen Doung, MD,[g] Shekinah Elmore, MD,[h] Lauren Hertan, MD,[i] Candice Johnstone, MD,[j] Joshua Jones, MD,[k] Nicole Larrier, MD,[l] Simon S. Lo, MbChB,[m] Quynh-Nhu Nguyen, MD,[n] Yolanda D. Tseng, MD,[m] Divya Yerramilli, MD,[o] Sandra Zaky, MD,[p] and Tracy Balboni, MD, MPH[q]

4. For patients with symptomatic bone metastases treated with SBRT, 1200 to 1600 cGy in 1 fraction (nonspine) and 2400 cGy in 2 fractions (spine) are recommended. Implementation remark: Other established SBRT dose and fractionation regimens (eg, 3-5 fraction) with similar BEDs may be an option based on patient tumor and normal tissue factors, and physician experience.	Strong	Moderate 10,75-77
5. For patients with symptomatic bone metastases with ECOG PS 0-2, receiving no surgical intervention, and absent neurological symptoms, SBRT is conditionally recommended over conventional palliative RT. Implementation remark: Other factors to consider include life expectancy, tumor radiosensitivity, and metastatic disease burden.	Conditional	Moderate 10,75-77

PRO, 2021

ESTRO clinical practice guideline: Stereotactic body radiotherapy for spine metastases

M Guckenberger [a,*], N Andratschke [a], C Belka [b,c,d], D Bellut [e], F Cuccia [f], M Dahele [g], RS Guninski [a], M Josipovic [h,i], P Mancosu [j], G Minniti [k,s], M Niyazi [t], U Ricardi [l], P Munck af Rosenschold [m], A Sahgal [n], Y Tsang [o], WFAR Verbakel [p], F Alongi [q,r]

	KQ 1 Recommendations	Strength of Recommendation	Level of Evidence (Refs)
1.	For patients who are candidates to receive SBRT for painful vertebral metastases from solid malignancies, a baseline and post-SBRT pain assessment is recommended using either Brief Pain Inventory Index (BPI), Visual Analog Score (VAS) or Numeric Rating Scale (NRS).	Strong	High [4–9]
2.	For patients with painful vertebral metastases from solid malignancies, SBRT should be considered due to higher complete pain response rates in carefully selected patients who are not frankly unstable (SINS>12), who have no or minimal epidural disease (Bilsky 0–1), up to 3 contiguous vertebral segments in the radiation treatment volume and a prolonged life expectancy where durable local and control is also intended.	Conditional	Moderate [4–9]

	KQ 2 Recommendations	Strength of Recommendation	Level of Evidence (Refs)
1.	For patients with vertebral metastases from solid malignancies, SBRT should be practiced with a prescription dose higher than the equivalent of 1x18Gy ($BED_{10} = 50\ Gy_{10}$). For de novo spine metastases, high dose spine SBRT practice includes 1x20Gy, 1x24Gy, 2x12Gy, 3x10Gy, and 5x7Gy. Based on these schemes there is an expectation of local control (LC) ranging from 80 to 90% at 1–2 years.	Strong	Moderate/expert opinion [6,10–13]
2.	For patients with painful vertebral metastases from solid malignancies meeting the eligibility criteria for spine SBRT, a fractionated approach using 2x12Gy is conditionally recommended as the preferred palliative SBRT dose and fractionation.	Conditional	Moderate [6]
3.	For patients with vertebral metastases from solid malignancies, single fraction SBRT with 16 or 18 Gy is not recommended as an alternative to conventional low-dose palliative radiotherapy (1x8Gy) if pain relief and/or quality of life are the primary treatment goals.	Strong	Moderate [10]
4.	For patients with vertebral metastases from solid malignancies, where local therapy for OMD is supported by disease-specific guidelines and/or the tumor board, then spine SBRT is recommended for the majority of eligible patients. In selected patients, more aggressive combined modality approaches involving (separation) surgery and SBRT may be needed to optimize LC and functional outcomes.	Strong	Expert opinion/ moderate [11,14–19]
5.	For patients with vertebral metastases from solid malignancies, when SBRT is performed in the context of concomitant targeted/immuno-therapy, a potential risk for unexpected and/or increased toxicity should be discussed between spine SBRT practitioners and medical oncologists.	Strong	Expert opinion [20,21]

RADIOTHERAPY AND ONCOLOGY, 2024

ESTRO-ISRS clinical practice recommendations for re-irradiation of spinal metastases with Stereotactic Body Radiotherapy: Delphi consensus supported by a systematic review and *meta*-analysis

Filippo A
Alexande
Simon Lo
Jason She

ESTRO-ISRS Consensus Statements for spine SBRT re-irradiation.

1) Is SBRT re-irradiation effective in pain control for painful vertebral metastases?

A. Spine SBRT re-irradiation results in effective pain control in patients with prior cEBRT. (**Level III**)

B. Pain assessment before SBRT re-irradiation and after treatment is strongly recommended using a standardized instrument such as the Brief Pain Inventory index (BPI), Visual Analog Scale (VAS), or Numeric Rating Scale (NRS). (**Level III**)

2) Is SBRT re-irradiation effective in local control for vertebral metastases?

A. Spine SBRT re-irradiation results in effective local control with 1- and 2-year pooled LC rates of 81 % and 70 %, respectively.

B. Spine re-irradiation with SBRT is associated with favorable local control and can be considered after prior cEBRT or SBRT. **(Level III)**

3) What is the toxicity profile of spine SBRT re-irradiation?

A. Re-irradiation with SBRT results in low serious adverse event rates with the caveat of carefully considering SBRT in the elderly. (**Level III**)

B. Repeated SBRT to the same spine level is not associated with a higher risk of adverse events, when compared to SBRT after first course cEBRT. (**Level III**)

Joint ESTRO ISRS Clinical Practice Recommendations

Patient selection for SBRT re-irradiation of vertebral metastases:

For patients with recurrent vertebral metastasis after prior radiotherapy, SBRT for re-irradiation should be considered in carefully selected patients with longer-term overall survival expectancy if a more durable pain response as compared to conventional radiotherapy is intended. **(Level III, strong consensus)**

For patients with recurrent vertebral metastasis after prior radiotherapy, SBRT for re-irradiation is recommended in carefully selected oligometastatic patients if a durable local metastasis control is intended. **(Level III, strong consensus)**

For patients with recurrent vertebral metastasis after prior radiotherapy and with an indication for re-irradiation, SBRT is recommended only if the interval to the first radiotherapy course is > 12 months and SBRT can be considered in carefully selected patients if the interval is between 6 – 12 months. (**Level III, strong consensus**)

For patients with recurrent vertebral metastasis after prior radiotherapy and with an indication for re-irradiation, it is strongly recommended to perform a baseline SINS assessment of spinal stability. (**Level III, strong consensus**)

For patients with recurrent vertebral metastasis after prior radiotherapy and with an indication for reirradiation, SBRT is recommended only for stable or potentially unstable vertebral metastases. (SINS 0–12) **(Level III, strong consensus)**

For patients with recurrent vertebral metastasis after prior radiotherapy and with an indication for re-irradiation, prior surgery should not be considered as an exclusion criteria to SBRT. (**Level V, strong consensus**)

Imaging and treatment planning for SBRT reirradiation of vertebral metastases:

For SBRT re-irradiation of vertebral metastasis after prior radiotherapy, the use of previously reported ESTRO technical guidelines [15] is recommended.**(Level V, strong consensus)**

For SBRT re-irradiation of vertebral metastasis after prior radiotherapy, the use of MRI for target volume and organs-at-risk delineation is strongly recommended. If MRI imaging is not possible, it is recommended using CT myelography for spinal cord/thecal sac delineation and additional functional imaging such as PET to confirm target volume delineation.(**Level V, strong consensus**)

For SBRT re-irradiation of vertebral metastasis after prior radiotherapy, the use of highly-conformal intensity-modulated image-guided techniques (IMRT, VMAT, robotic radiotherapy) is strongly recommended. (**Level III, strong consensus**)

Target and organ-at-risk doses for SBRT reirradiation of vertebral metastases:

For SBRT re-irradiation of vertebral metastasis after prior radiotherapy, the use of the following dose fractionations is recommended: 24 Gy/2 fx, 30 Gy/4 fx, 30 Gy/5 fx, or 16 Gy/1 fx. (**Level III, strong consensus**)

For SBRT re-irradiation of vertebral metastasis after prior radiotherapy, the use of the Hytec 2021 spinal cord dose-constraints [19] is recommended. (**Level V**)

RADIOTHERAPY & ONCOLOGY, 2026

Review Article

Separation surgery followed by stereotactic ablative radiotherapy for metastatic epidural spinal cord compression: A systematic review and meta-analys

Dong-Ho Kang,

Rui-feng
Rong-xi

Giuseppe Di Perna
, Nicola Marengo [a]
Tartara [d], Francesc

Separation Surgery in the Treatment of Spinal Metastasis

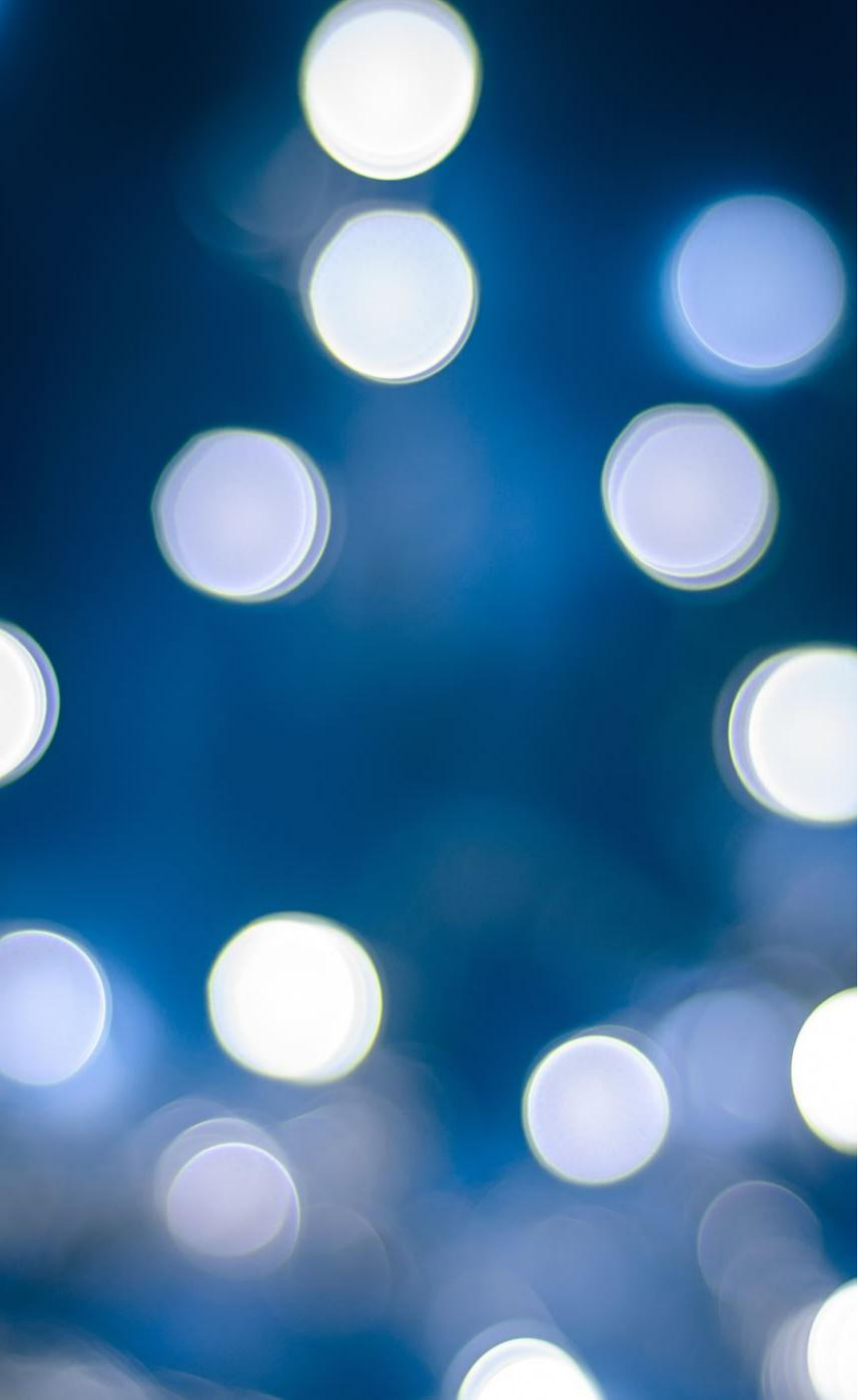
Separation surgery for metastatic epidural spinal cord compression: A qualitative review

Phase 2 Clinical Trial of Separation Surgery Followed by Stereotactic Body Radiation Therapy for Metastatic Epidural Spinal Cord Compression

Kei Ito, MD, PhD,* Shurei Sugita, MD, PhD,† Yujiro Nakajima, PhD,* Tomohisa Furuya, PhD,* Ogawa Hiroaki, MD,* Sara Hayakawa, MD,* Takahiro Hozumi, MD,† Makoto Saito, MSc,‡ and Katsuyuki Karasawa, MD, PhD*

Preferred Dosing Regimens in a Nutshell

Regimen	BED 10	Context
18 Gy/1	50.4	BED10 threshold level; **not** the preferred palliative spine-SBRT schedule per ESTRO
20 Gy/1	60	Ablative single-fraction intact-disease practice at some centers
24 Gy/1	81.6	Very-high-dose OMD/intact disease; higher VCF concern
24 Gy/2	52.8	Preferred Palliative RT regimen
28 Gy/2	67.2	Alternate Regimen with better LC
27 Gy/3	51.3	Durable regimen, used when avoiding single fraction
30 Gy/3	60	High dose regimen for durable LC in selected patients
30 Gy/4	52.5	Used postop/Re-RT
30 Gy/5	48	Very conservative, near critical OARs
35 Gy/5	59.5	Higher dose regimen for durable LC



Toxicity Profile

Vertebral compression fracture: 6-14%, especially with single fraction and reduces with fractionation

Radiation induced myelopathy: 0.4% (1-5%)

Pain flare: 43% (SBRT) vs 33% (conv) (Treat with steroids)

Vertebral Compression Fracture After Spine Stereotactic Body Radiation Therapy: A Review of the Pathophysiology and Risk Factors

TABLE 1. Risk Factors for VCF After Spine SBRT

Study, year	No. of patients (no. segments)	Median SBRT dose/fraction (range)	VBs with baseline lytic tumor (%)	VBs with baseline VCF (%)	Post-SBRT VCF (De novo/progressed)	Median time to VCF (mo)	Risk factors on MVA (HR)	Risk factors on UVA (HR)	% of VCF salvaged	Median follow-up (mo)
Boehling et al, 2012[19]	93 (123)	27Gy/3fx (18-30Gy/1-5fx)	58%	28%	20% (11%/9%)	3	Age > 55 (5.67) Preexisting fracture (4.12) Lytic appearance (2.76)	Age > 55 (6.05) Preexisting fracture (5.05) Baseline pain (1.31) and narcotic use (2.98) After SBRT pain (1.34) and narcotic use (3.63).	60%	16
Boyce-Fappiano et al, 2017[20]	448 (1070)	18Gy/1fx (10-60Gy/1-5fx)	27%	42%	11.9%[a] (4.2%/4.1%)	2.7	<3 vs 3+ treated levels (4-4.3) Lytic lesion (2.49-3.04) Prior VCF (1.69)	Lytic lesion (2.85-3.07) Hematologic malignancies (2.68) Prior VCF (1.99) <3 vs 3+ treated levels (4.17-5.26) Female sex (1.54) Thoracic spine (1.54)	29%	17.7
Cunha et al, 2012[21]	90 (167)	20-27Gy/3fx (8-35Gy/1-5fx)	48%	17%	11.4% (7.2%/4.2%)	2	HCC histology (34) Lytic (12.2) Kyphosis/scoliosis (11.1) Dose/fx ≥ 20 Gy (6.82) Lung histology (4.3)	Kyphosis/scoliosis Lytic lesion Prior VCF Histology Dose/fx ≥ 20 Gy	47%	7.4
Germano et al, 2016[22]	79 (143)	18Gy/1fx (10-18Gy/1fx)	39%	42%	21% (6.3%/14.7%)	5 (mean)	None significant	Histology SINS VB collapse Pre-existing VCF Baseline pain	30%	16 (mean)
Jawad et al, 2016[23]	(594)	20Gy/1fx (8-40Gy/1-5fx)	71%	24%	5.7% (3%/2.7%)	3	Solitary metastasis (OR 3.46) Preexisting VCF (OR 2.82) Prescription dose to target volume dose ≥ 38.4 Gy EQD_2 (OR 2.28)	Short interval from diagnosis to SBRT (<37 d) Solitary metastasis No additional bony metastases No prior chemo Preexisting VCF No MRI for target delineation EQD_2 tumor ≥ 41.8 Gy Max dose to spinal cord > 46.1 Gy EQD_2 Tumor volume > 37.3cm[3]	NR	10.1

TABLE 1 Continued

Study, year	No. of patients (no. segments)	Median SBRT dose/fraction (range)	VBs with baseline lytic tumor (%)	VBs with baseline VCF (%)	Post-SBRT VCF (De novo/progressed)	Median time to VCF (mo)	Risk factors on MVA (HR)	Risk factors on UVA (HR)	% of VCF salvaged	Median follow-up (mo)
Lee et al, 2016[24]	79 (100)	24-27Gy/3fx (16-27Gy/1-3fx)	NR	22%	32% (20%/12%)	3.3	SINS 0-6 vs 7-12 (5.63) Age < 65 vs ≥65 (2.15)	SINS Score (6.01) ESCC classification (3.91) Dose/fraction < 20 Gy vs 24 Gy (2.91) Age < 65 vs ≥65 (2.47) XRT failure (2.19)	47%	21.2
Rose et al, 2009[17]	62 (71)	24Gy/1fx (18-24Gy/1fx)	65%	28%	39% (NR)	25	Lesions occupying 41% to 60% of VB (3.9) Lytic (3.8)	NR	11%	13
Sahgal et al, 2013[18]	252 (410)	18-26Gy/1fx (8-35Gy/1-5fx)	62%	20%	13.9% (6.6%/7.3%)	2.5	Dose/fx compared to ≤19 Gy: ≥24 Gy (5.25) and 20-23 Gy (4.91) Baseline VCF: <50% (8.98) and >50% (6.92) >50% VB involved by Tumor (4.46) (Lytic) bone lesion type (3.53) Spinal misalignment (2.99)	Dose/fx Vertebral body collapse >50% VB involved by tumor Bone lesion type Spinal misalignment Paraspinal/epidural extension	43%	11.5
Sung et al, 2014[25]	72 (72)	(18-45Gy/1-5fx)	NR	NR	36% (NR)	1.5 (mean)	VB osteolysis rate ≤ 60% vs >60% (8.5)	Pre-SBRT deformity (15.4) VB osteolysis rate (11.5) SINS (10.9) Whole VB involvement (4)	58%	11 (mean)
Thibault et al, 2014[9]	37 (61)	24Gy/2fx (18-30Gy/1-5fx)	95%	21%	16% (5%/11.5%)	1.6	Baseline VCF (9.25) Single fraction SBRT (5.03)	NR	40%	12.3
Thibault et al, 2016[26]	55 (100)	24Gy/2fx (12-35Gy/1-5fx)	56%	24%	17% (5%/12%)	1.68	≥11.6% lytic (OR 51.7) Baseline VCF (OR 37) Dose ≥ 20 Gy/fx (OR 11.8)	Baseline VCF (OR 14.2) SINS lytic classification (OR 7.68) Dose ≥ 20Gy (2.6)	NR	7.3

CRUDE VCF RATE OF 13.9%

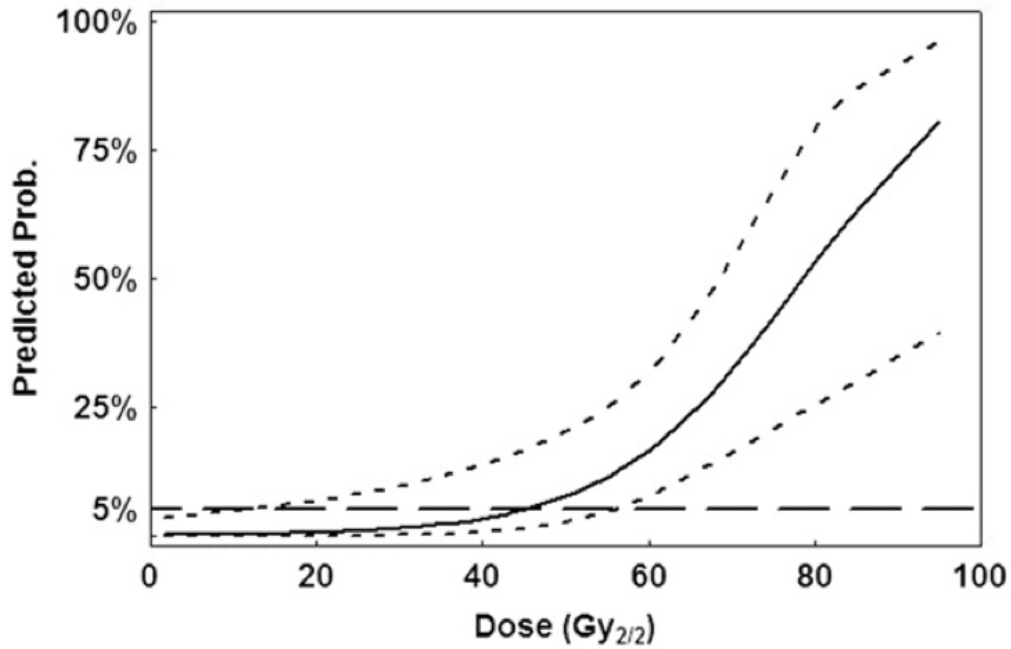
NEUROSURGERY ONLINE, 2017

Probabilities of Radiation Myelopathy Specific to Stereotactic Body Radiation Therapy to Guide Safe Practice

Arjun Sahgal, MD,*,† Vivian Weinberg, PhD,‡ Lijun Ma, PhD,‖‖ Eric Chang, MD,§ Sam Chao, MD,‖ Alexander Muacevic, MD,¶ Alessandra Gorgulho, MD,** Scott Soltys, MD,†† Peter C. Gerszten, MD,‡‡ Sam Ryu, MD,§§ Lilyana Angelov, MD,‖ Iris Gibbs, MD,†† C. Shun Wong, MD,† and David A. Larson, MD, PhD‖‖

Table 5 Predicted Pmax volume absolute doses in Gy for 1 to 5 SBRT that result in 1%-5% probability of radiation myelopathy (RM)

	1 fraction Pmax limit (Gy)	2 fractions Pmax limit (Gy)	3 fractions Pmax limit (Gy)	4 fractions Pmax limit (Gy)	5 fractions Pmax limit (Gy)
1% probability	9.2	12.5	14.8	16.7	18.2
2% probability	10.7	14.6	17.4	19.6	21.5
3% probability	11.5	15.7	18.8	21.2	23.1
4% probability	12.0	16.4	19.6	22.2	24.4
5% probability	12.4	17.0	20.3	23.0	25.3



IJROBP, 2013

Single and Multifraction Spine Stereotactic Body Radiation Therapy and the Risk of Radiation Induced Myelopathy

Table 3 Planning target volume coverage based on distance from spinal cord

Distance from cord		<1 mm	1-2 mm	2-3 mm
PTV_High	Dmin [%]	54.4 ± 1.5	64.8 ±1.6*	74.8 ± 2.2*
	D90% [%]	96.3 ±1.0	98.8 ± 5.6*	100.4 ± 0.5*
	D80% [%]	101.3 ±7.5	102.4 ± 3.2	103.2 ± 0.3*
PTV_Low	Dmin [%]	57.0 ± 0.9	72.6 ± 1.7*	77.9 ± 3.9*
	D90% [%]	102.3 ± 0.4	103.2 ± 4.8	104.4 ± 0.7*
	D80% [%]	106.7 ± 0.3	106.8 ± 0.5	109.2 ± 1.6

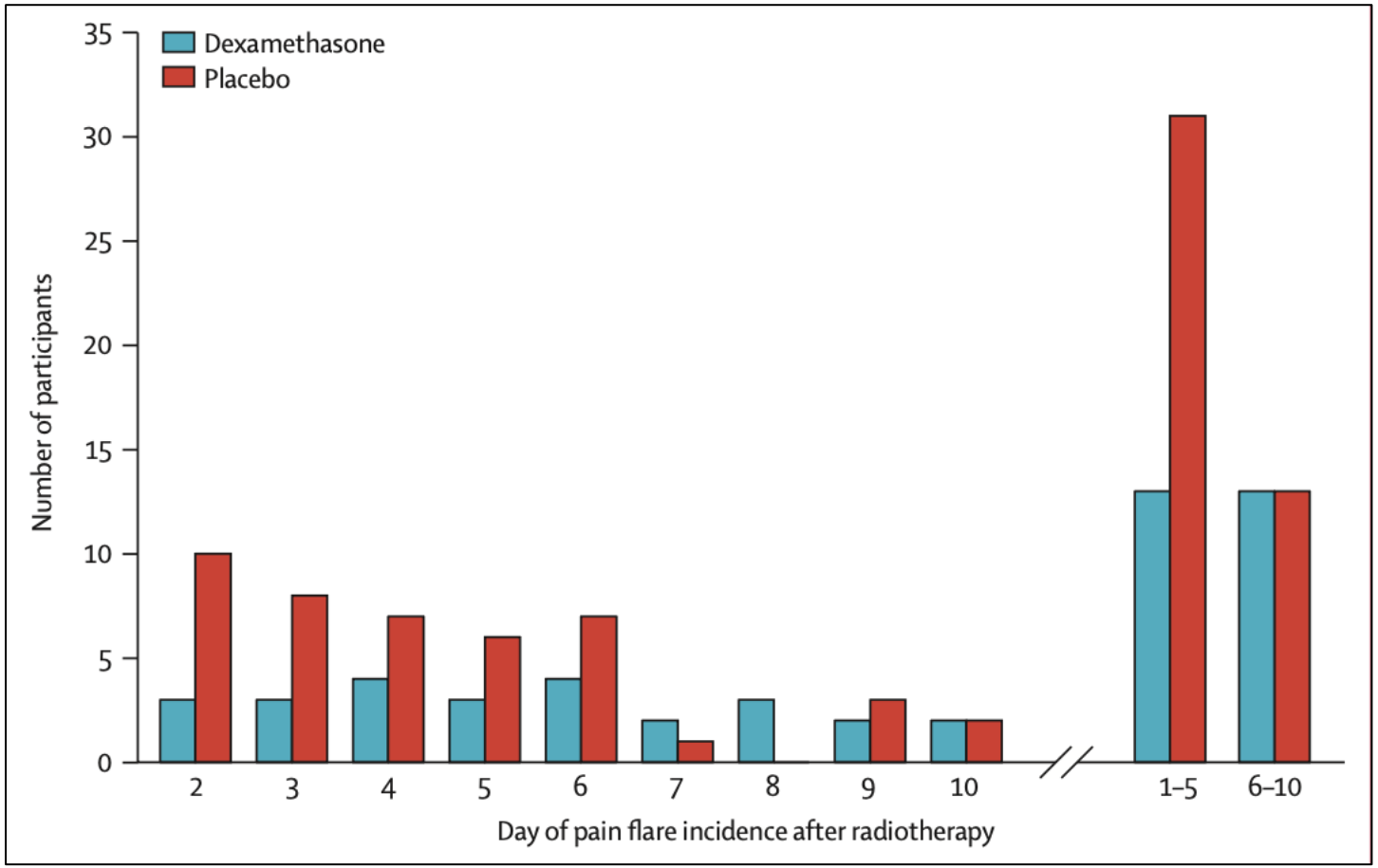
Abbreviations: D80% = minimum dose delivered to 80% of the PTV; D90% = minimum dose delivered to 90% of the PTV; Dmin = minimum dose received by the PTV; PTV_high = high-risk planning-target volume; PTV_low = low-risk planning target volume.

* Statistically significant differences between the mean of either the 1 to 2 mm or 2 to 3 mm group and the mean of the <1 mm.

gure 3 Select dose-volume statistics for the spinal cord doses for (A) single-fraction, (B) 3-fraction, (C) 5-fraction spine ereotactic body radiation therapy, and (D) the normalized biological equivalent doses ($nBED_{2/2}$) and (E) the single-fraction equivalent doses ($SFED_2$) for all treatment plans in the cohort. The box-and-whisker plots show the median, inner iartiles, and 10 to 90 percentile ranges.

Dexamethasone in the prophylaxis of radiation-induced pain flare after palliative radiotherapy for bone metastases: a double-blind, randomised placebo-controlled, phase 3 trial

Edward Chow, Ralph M Meyer, Keyue Ding, Abdenour Nabid, Pierre Chabot, Philip Wong, Shahida Ahmed, Joda Kuk, A Rashid Dar, Aamer Mahmud, Alysa Fairchild, Carolyn F Wilson, Jackson S Y Wu, Kristopher Dennis, Michael Brundage, Carlo DeAngelis, Rebecca K S Wong



2x4 mg Dexa tablets 1 hr before RT and continued for 5 days (8 Gy in 1)

LANCET, 2015

Planning Criteria

Dose prescription and coverage

- Dmax ideally inside PTV.
- Prescription isodose ~80–90% (allows inhomogeneous high dose inside PTV).
- Aim for PTV V100% ≥95% and V90% >99% whenever cord/thecal constraints permit.

Conformity

- Conformity index (CI) ≈ V100% / PTV volume; ideal CI ≤1.2 (tight conformal coverage)

Planning Criteria- Continued

High-dose spillage

- V105% (volume receiving ≥105% of prescription) should be <15% of PTV volume to avoid large hot lobes.

Intermediate-dose spillage (R50 and D2cm)

- R50% = V50% / PTV volume; keep as low as possible (e.g., R50% <4.6 as a useful target in many SBRT series).
- D2cm = maximum % dose at 2 cm beyond PTV in any direction – aim <52–55% of prescription

Spine stereotactic body radiation therapy plans: Achieving dose coverage, conformity, and dose falloff

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[*]*Department of Radiation Oncology, Montefiore Medical Center, Bronx, NY;* [†]*Department of Radiation Oncology, Albert Einstein College of Medicine, Bronx, NY; and* [‡]*Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, NY*

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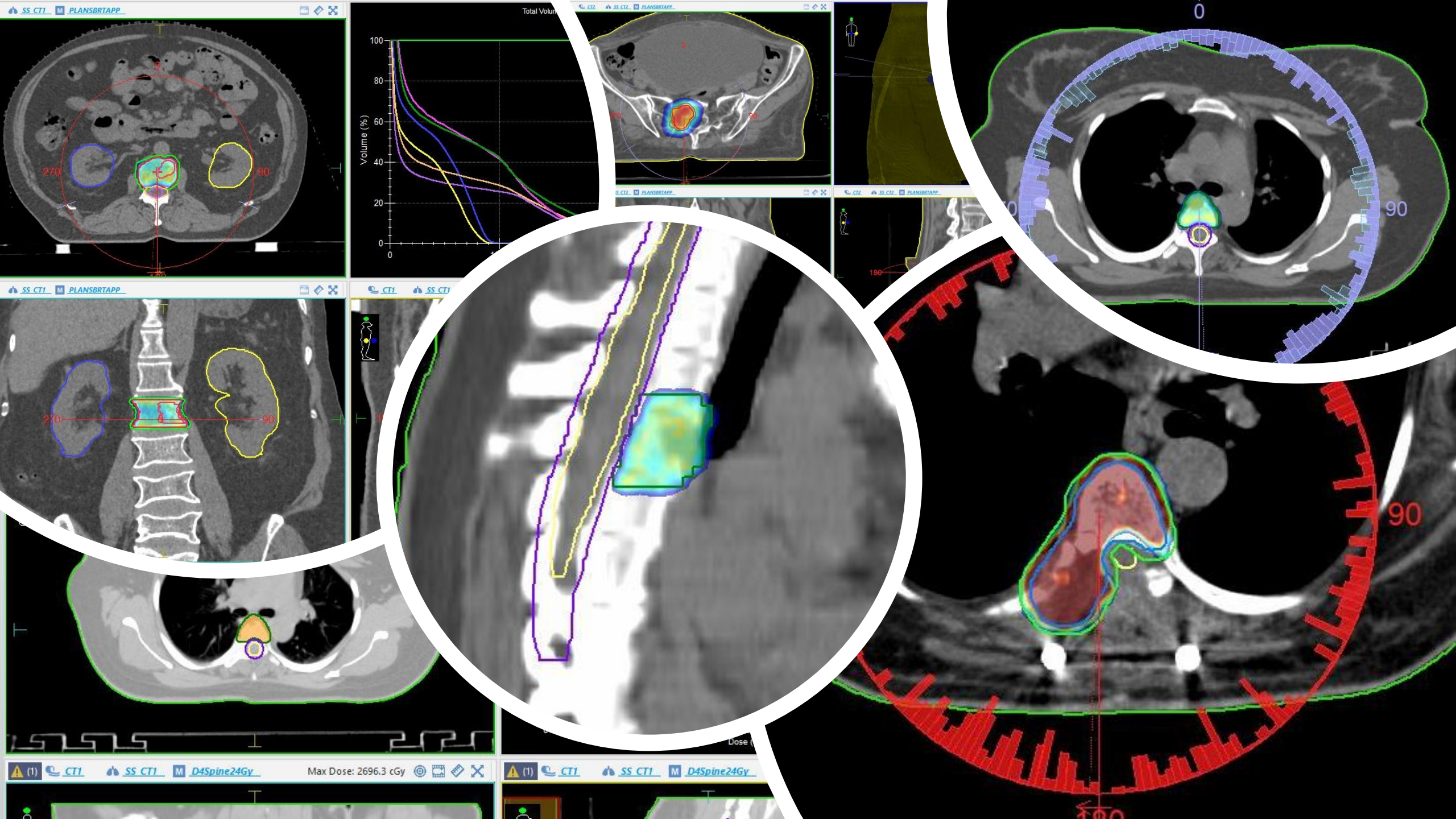
ABSTRACT

We report our experience of establishing planning objectives to achieve dose coverage, conformity, and dose falloff for spine stereotactic body radiation therapy (SBRT) plans. Patients with spine lesions were treated using SBRT in our institution since September 2009. Since September 2011, we established the following planning objectives for our SBRT spine plans in addition to the cord dose constraints: (1) dose coverage—prescription dose (PD) to cover at least 95% planning target volume (PTV) and 90% PD to cover at least 99% PTV; (2) conformity index (CI)—ratio of prescription isodose volume (PIV) to the PTV < 1.2; (3) dose falloff—ratio of 50% PIV to the PTV ($R_{50\%}$); (4) and maximum dose in percentage of PD at 2 cm from PTV in any direction (D_{2cm}) to follow Radiation Therapy Oncology Group (RTOG) 0915. We have retrospectively reviewed 66 separate spine lesions treated between September 2009 and December 2012 (31 treated before September 2011 [group 1] and 35 treated after [group 2]). The χ^2 test was used to examine the difference in parameters between groups. The PTV $V_{100\%\ PD} \geq 95\%$ objective was met in 29.0% of group 1 *vs* 91.4% of group 2 ($p < 0.01$) plans. The PTV $V_{90\%\ PD} \geq 99\%$ objective was met in 38.7% of group 1 *vs* 88.6% of group 2 ($p < 0.01$) plans. Overall, 4 plans in group 1 had CI > 1.2 *vs* none in group 2 ($p = 0.04$). For D_{2cm}, 48.3% plans yielded a minor violation of the objectives and 16.1% a major violation for group 1, whereas 17.1% exhibited a minor violation and 2.9% a major violation for group 2 ($p < 0.01$). Spine SBRT plans can be improved on dose coverage, conformity, and dose falloff employing a combination of RTOG spine and lung SBRT protocol planning objectives.

My Experience


SS CT1
PLANSBRTAPP
Total Volu
Volume (%)
100
80
60
40
20
0
270
90
180
CT1
SS CT1
D4Spine24Gy
Max Dose: 2696.3 cGy

Conclusion

- **First, pick the right patient.** Spine SBRT is not “fancy 20 Gy/5”; it is for patients with reasonable prognosis, limited disease, and lesions where durable local control actually matters (oligomets, radioresistant primaries).
- **Always think NOMS + SINS + Bilsky before opening the planning system.** Low-grade ESCC (Bilsky 0–1) with stable spine → SBRT works well; high-grade ESCC (Bilsky 2–3) or mechanical instability → talk to your spine surgeon about separation surgery/stabilisation first, then postop SBRT.
- **Respect the cord and thecal sac, even if it costs PTV coverage.** Use MRI/CT-myelogram fusion, contour cord/thecal sac PRV properly, and keep within modern D0.03cc limits for 1–5 fractions – this is why radiation myelopathy is now extremely rare.
- **Demand good plans.** For every case, check: PTV coverage (~95% V100), conformity (CI ≤1.2), limited hotspots (V105 <15%), tight R50/D2cm, and a steep gradient away from cord.
- **Anticipate toxicity and counsel patients.** Remember VCF (≈10–15% overall, higher with lytic/high single-fraction dose) and pain flare; use SINS and prophylactic steroids wisely, and follow these patients long term.

Remember only three things

Check	Check Bilsky
Contour	Contour carefully
Compromise	Never compromise the cord for coverage.