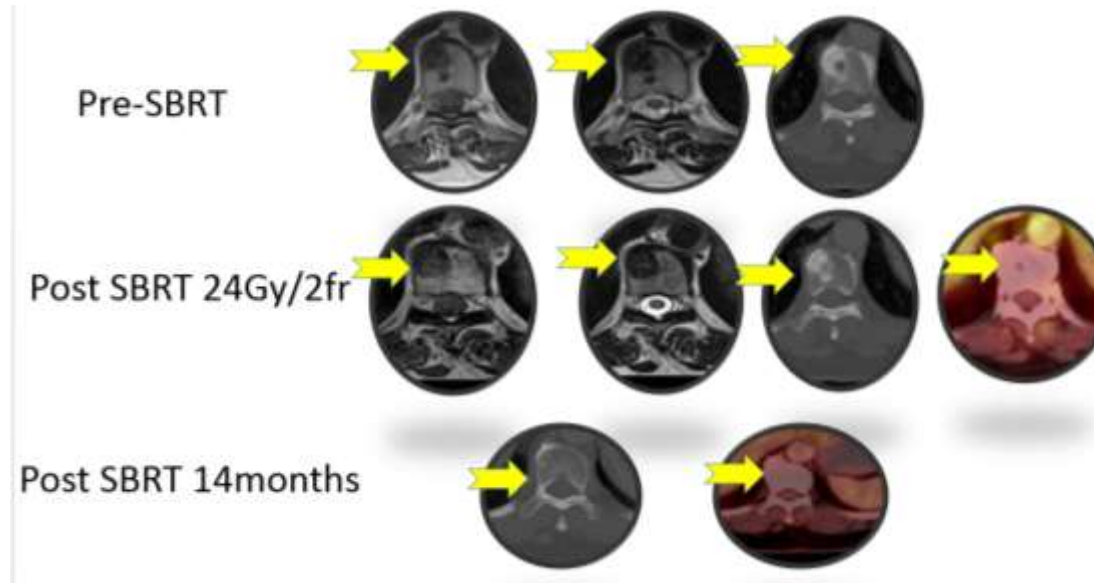
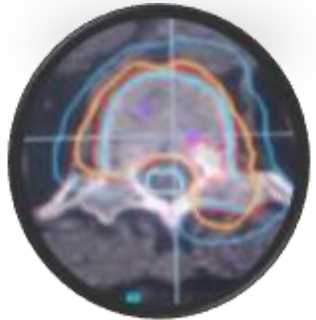
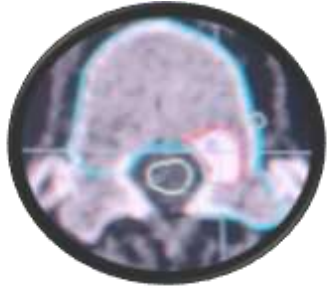


Spine SBRT An Overview



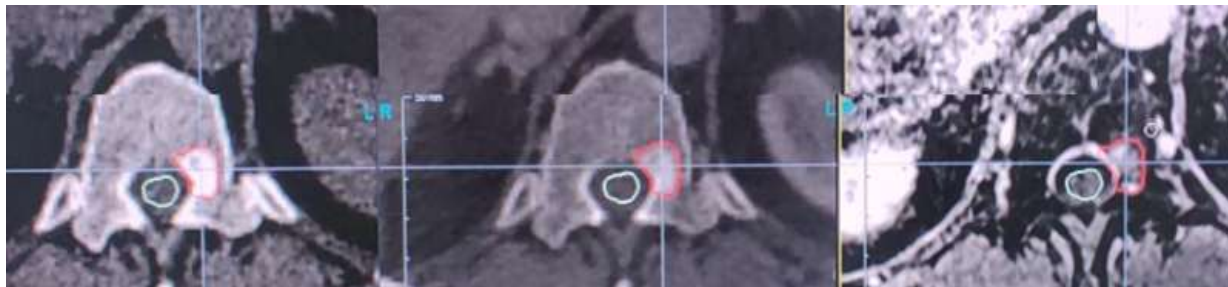
Dr Deepak Gupta
Senior Consultant
Radiation Oncology,
Medanta The Medicity
Email:-deepakonco@gmail.com,
deepak.gupta@medanta.org

Case

- 64 year old male diagnosed case of carcinoma Prostate Post op , Post RT 2013
- Presented with occasional pain in back
- Rising PSA
- PSMA PETCT WB(J,2023)-D12 vertebrae PSMA avid lesion. No other side of metabolic uptake.



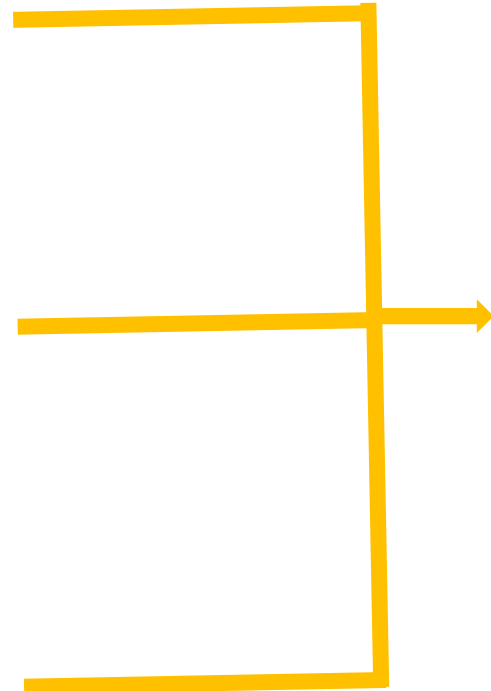
D12 pedicle lesion on PSMA PET



Denovo

Post Op

Re-Radiation



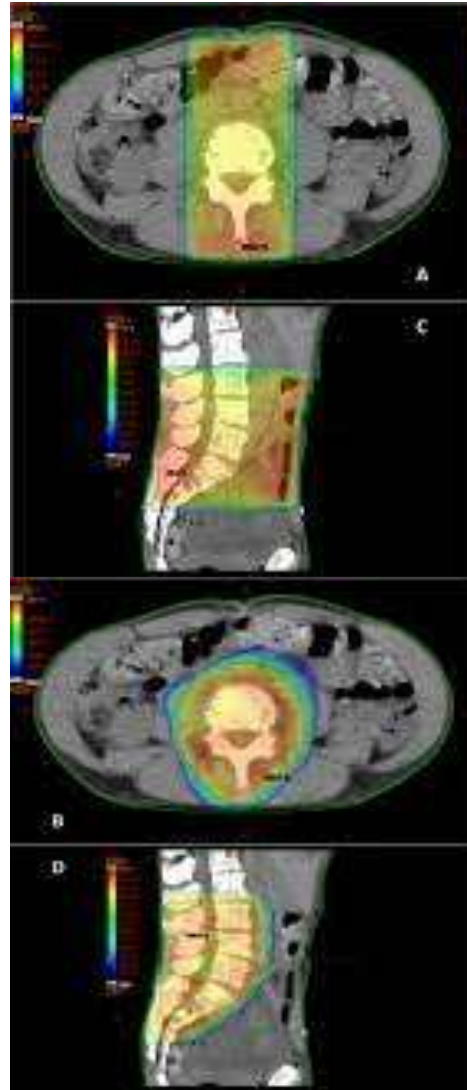
- Background
- Rationale
- Determining eligibility (Patient selection)
- Required imaging
- Simulation
- Target delineation
- Planning, dose selection
- OAR tolerances
- Plan evaluation
- Delivery and IGRT
- Toxicity
- Pattern of failure

Background

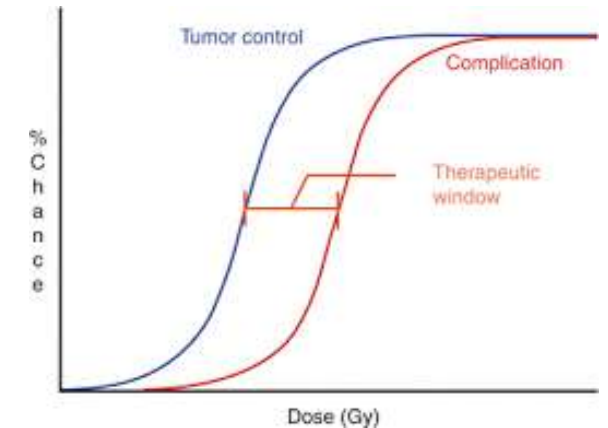
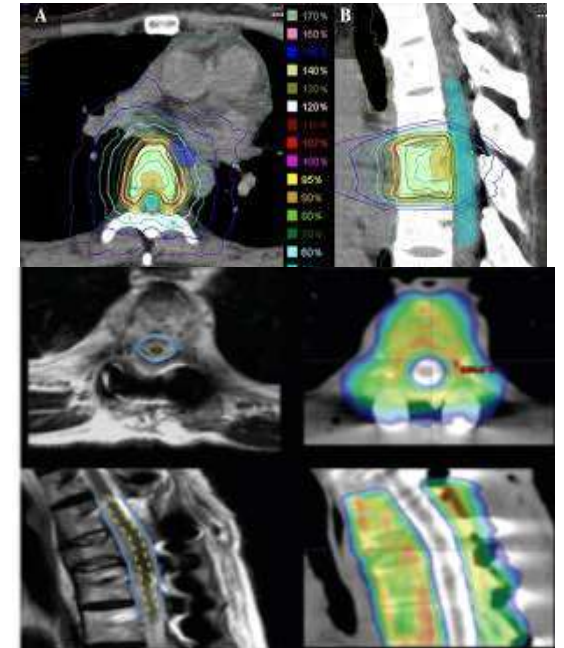
- Metastases are diagnosed in ~40% of cancer patients and are the most common spine tumors.
 - Autopsy studies suggest 30-90% of cancer pts may have metastasis in the spine
- Most common presenting symptom is pain followed by upper/lower extremity weakness, numbness or incontinence of bladder or bowel.
- When left untreated -Vertebral body fracture, radiculopathy and complication of metastatic epidural spinal cord compression (MESCC).

Rationale

- Pre SBRT
 - Role of Radiation
 - Pain Control Only
 - No dose escalation



- High doses to target
- Avoidance of critical structure



Points for Clinician to Focus On

- Clinical symptoms & signs
- Performance Status
- Systemic Disease
- Spine Stability
- Neurological compression
- Histology
- Spinal disease extent
- Challenges of procedure



PROGNOSTICATION

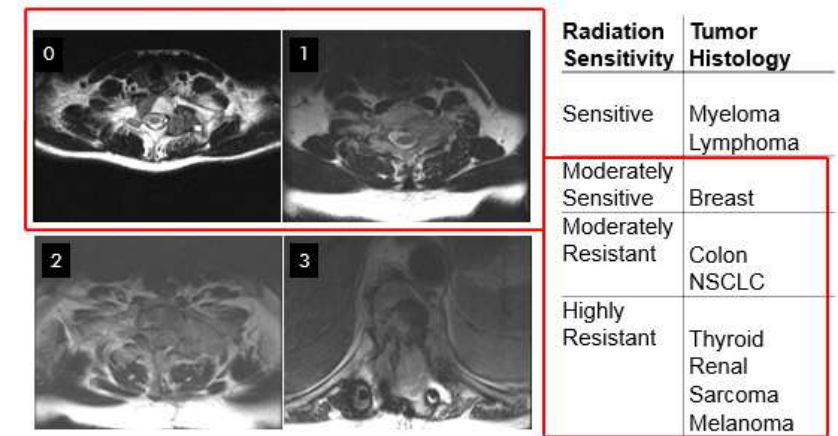
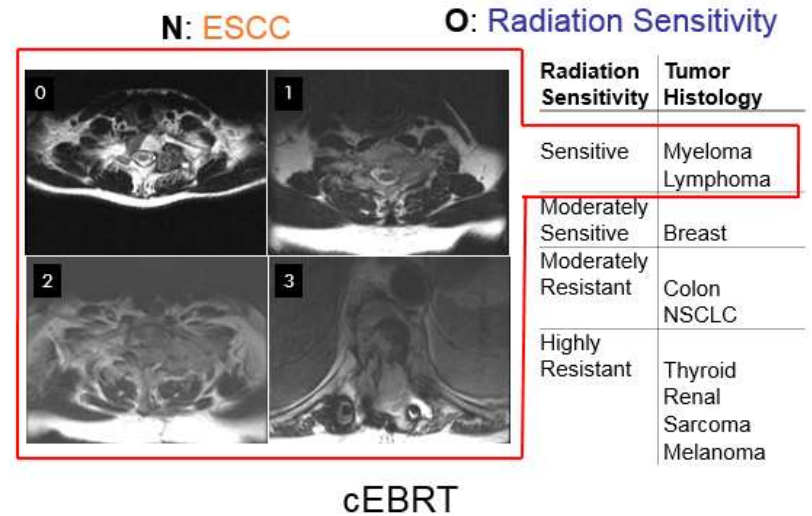
Radical or Palliative

Surgery or RT

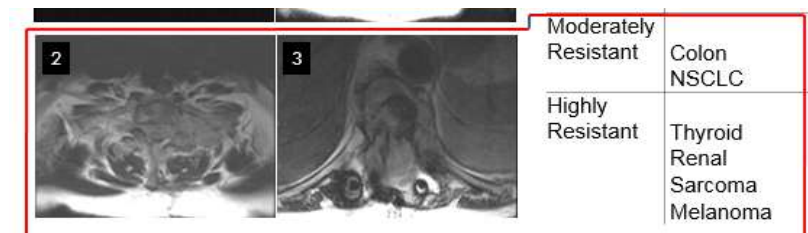
Conventional or SBRT

NOMS Assessment

- **N**eurologic
 - Myelopathy
 - Functional Radiculopathy
 - Degree of epidural spinal cord compression
- **O**ncologic
 - Tumor Histology
 - Radiation or Chemosensitivity
- **M**echanical Instability
- **S**ystemic Disease and Medical Co-morbidity



SRS



Surgery + SRS

American Spinal Injury Association international classification system

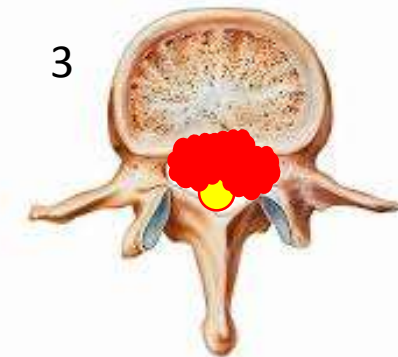
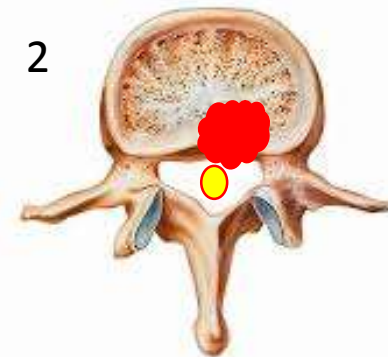
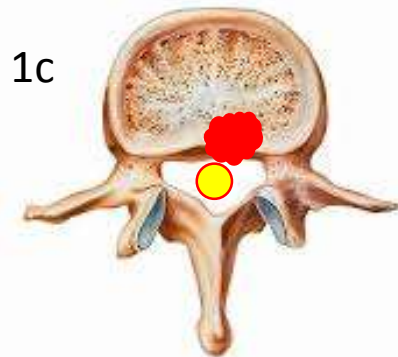
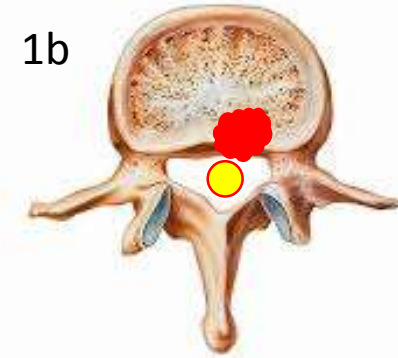
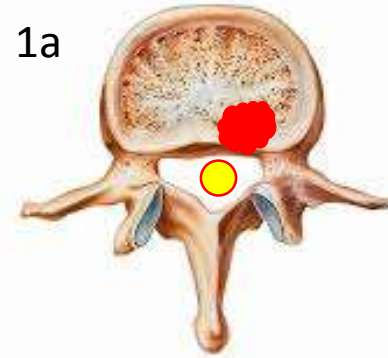
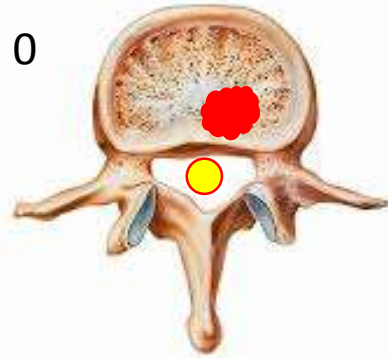
- Objective grading of neurologic function
- Effective communication between radiation oncologists and surgeons

Category	Description
A	Complete: no motor or sensory function preserved
B	Sensory incomplete: sensory but not motor function preserved below neurologic level
C	Motor incomplete: motor function preserved below neurologic level and more than one-half of muscles below level have grade <3
D	Motor incomplete: motor function preserved below neurologic level and more than one-half of muscles below level have grade ≥ 3
E	Normal neurologic function

The diagram illustrates the relationship between the ASIA classification categories and treatment options. A blue bracket groups categories A, B, C, and D, with an arrow pointing to a box labeled "Surgery". An arrow points from category E to a box labeled "RT".

Neurological Compression

BILSKY GRADING for degree of epidural spinal cord compression



Grade 0 : Bone involvement alone

Grade 1 : Epidural impingement

1a : Epidural impingement without deformation of the thecal sac

1b : Deformation of thecal sac without spinal cord abutment

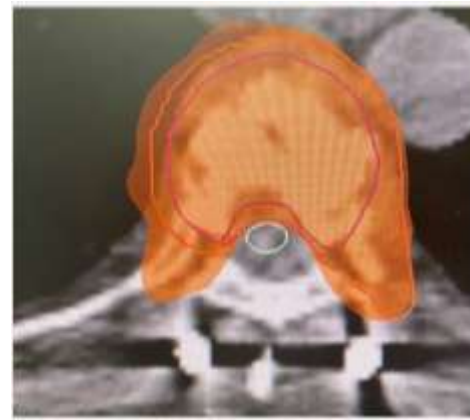
1c : Deformation of thecal sac with spinal cord abutment, but no compression

Grade 2 : Spinal cord compression, but with visible CSF around the cord

Grade 3 : Spinal cord compression, without visible CSF around the cord



Separation surgery should be performed before Stereotactic Body Radiation Therapy (SBRT) in Bilsky's high grade epidural vertebral metastases:



VS

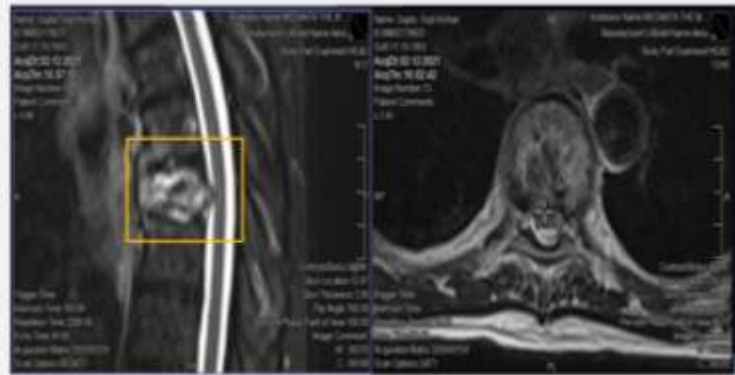


Fig: Post separation Surgery MRI showing Bilsky 1c epidural compression

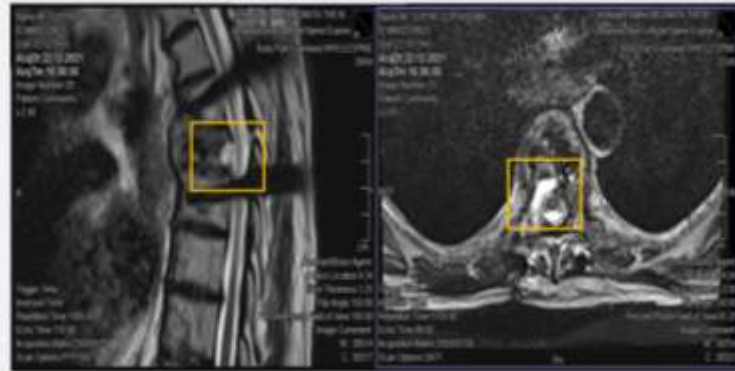


Fig: Post separation Surgery showing spacer in situ

Case 1

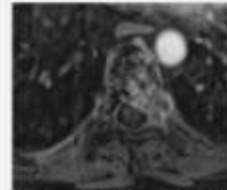


Fig: Pre separation Surgery MRI

Dose/Frac	No. of Fractions*	Total dose*
6 Gy	5	30 Gy to CTV

Dose/ Fractionation scheme

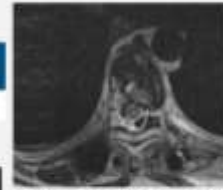
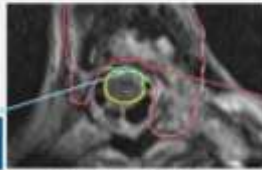


Fig: Post Separation Surgery MRI



D6 vertebrae lesion

Spinal cord dose	Volume %	Dose (Gy)
Pre Surgery	Max dose 0.35 cc 1.2 cc	32 20 16.3

Spinal cord dose	Volume %	Dose (Gy)
Post Surgery	Max dose 0.35 cc	<u>28.1</u> 17.45

Better Spinal Cord Sparing with same dose and coverage

Case	Dose	Pre Spinal Cord Dmax (Gy)	Post Spinal Cord Dmax (Gy)	Difference (Gy)	% Reduction
Case 1	30 Gy in 5 fractions	32 Gy	28.1 Gy	<u>3.90 Gy</u>	12.18%
Case 2	24 Gy in 2 fractions	24.5 Gy	17.45 Gy	<u>7.05 Gy</u>	28.7%

Case 2

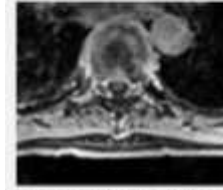


Fig: Pre separation Surgery MRI

Dose/Frac	No. of Fractions*	Total dose*
12 Gy	2	24 Gy to CTV

Dose/ Fractionation scheme

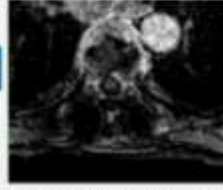
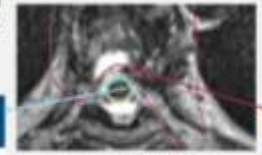


Fig: Post Separation Surgery MRI



D8 vertebrae lesion

Spinal cord dose	Volume %	Dose (Gy)
Pre Surgery	Max dose 0.35 cc	24.5 17.49

Spinal cord dose	Volume %	Dose (Gy)
Post Surgery	Max dose 0.35 cc 1.2 cc	<u>17.45</u> 13.93 10.98

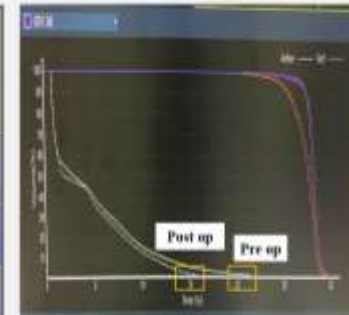
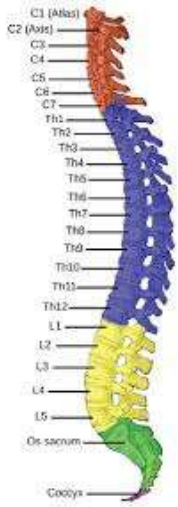


Fig: DVH comparing spinal cord doses

Spinal Instability



- 3 (C0-2)
- 2 (C3-6)
- 3 (C7-Th2)
- 1 (Th3-10)
- 3 (Th11-L1)
- 2 (L2-4)
- 3 (L5-S1)
- 0 (S2-5)

1 - Occasional

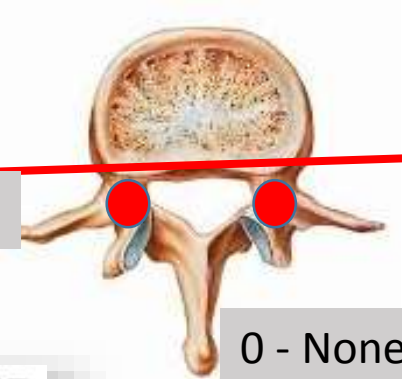
0 - No

3 - Yes

Pain
0,1,3

Location
0-3

Posterolateral involvement of spinal element

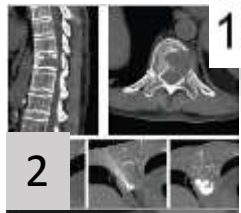


1 - UNI

2 - B/L

0 - None

SCORE	SPINE STATUS	ACTION NEEDED
0-6	Stable	None
7-12	Potentially unstable	Surgery
13-18	Unstable	Surgery



Bone lesion
0-2

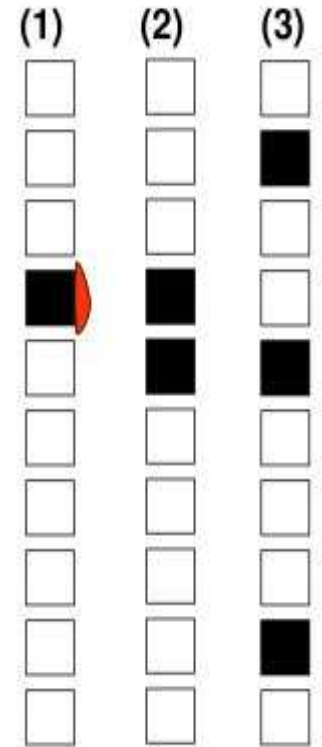
VB collapse
0-3

Spinal alignment
4,2,0

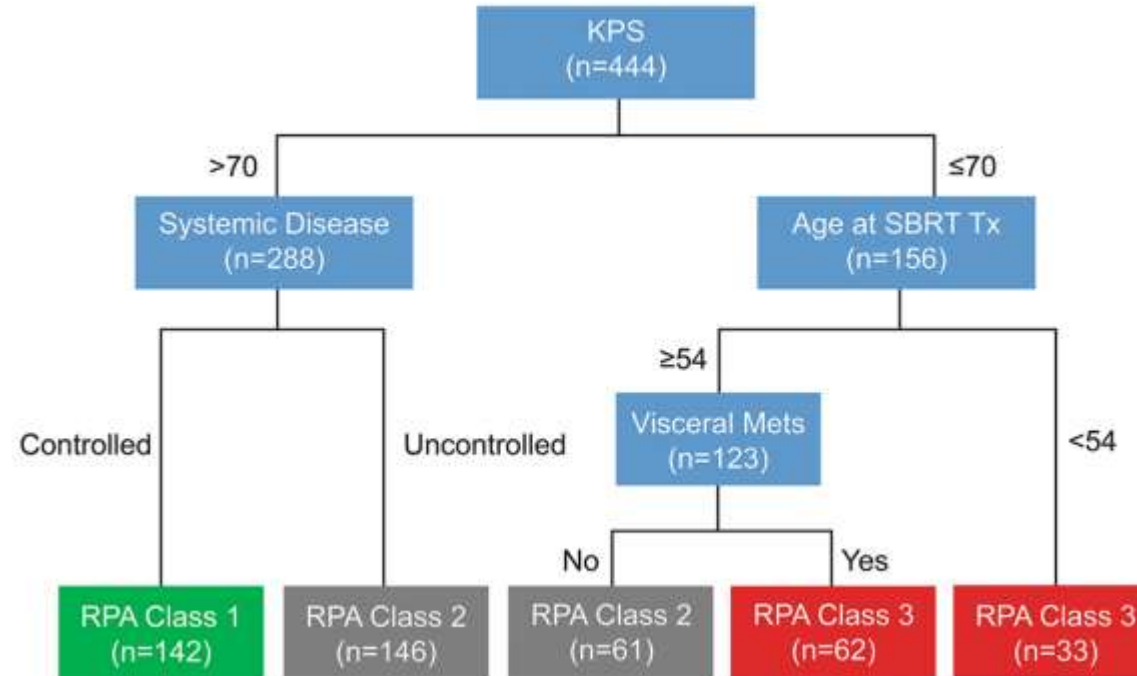


Spinal Disease Extent

- Disease burden : single, multiple, disseminated
 - If metastasis involves multiple bony structures with no canal compromise or associated bone fracture, these patients can be managed without surgery, provided the spine stability is not compromised.
 - If metastasis involves **1-3 vertebrae without collapse or compression**, SRS / SBRT preferred
- Which vertebra(e) affected ? (Spinal cord or Theca)
- Which part(s) of vertebra affected ?
- Degree of Cord / Thecal compression



Prognostic Scoring Systems



RPA Class

I

II

III

OS

26.7 months

13.4 months

4.5 months



candidate for intensive procedure

best suited for conventional RT and/or palliative care

Who should get spine SBRT?

ASTRO International Bone Mets Consensus Guidelines

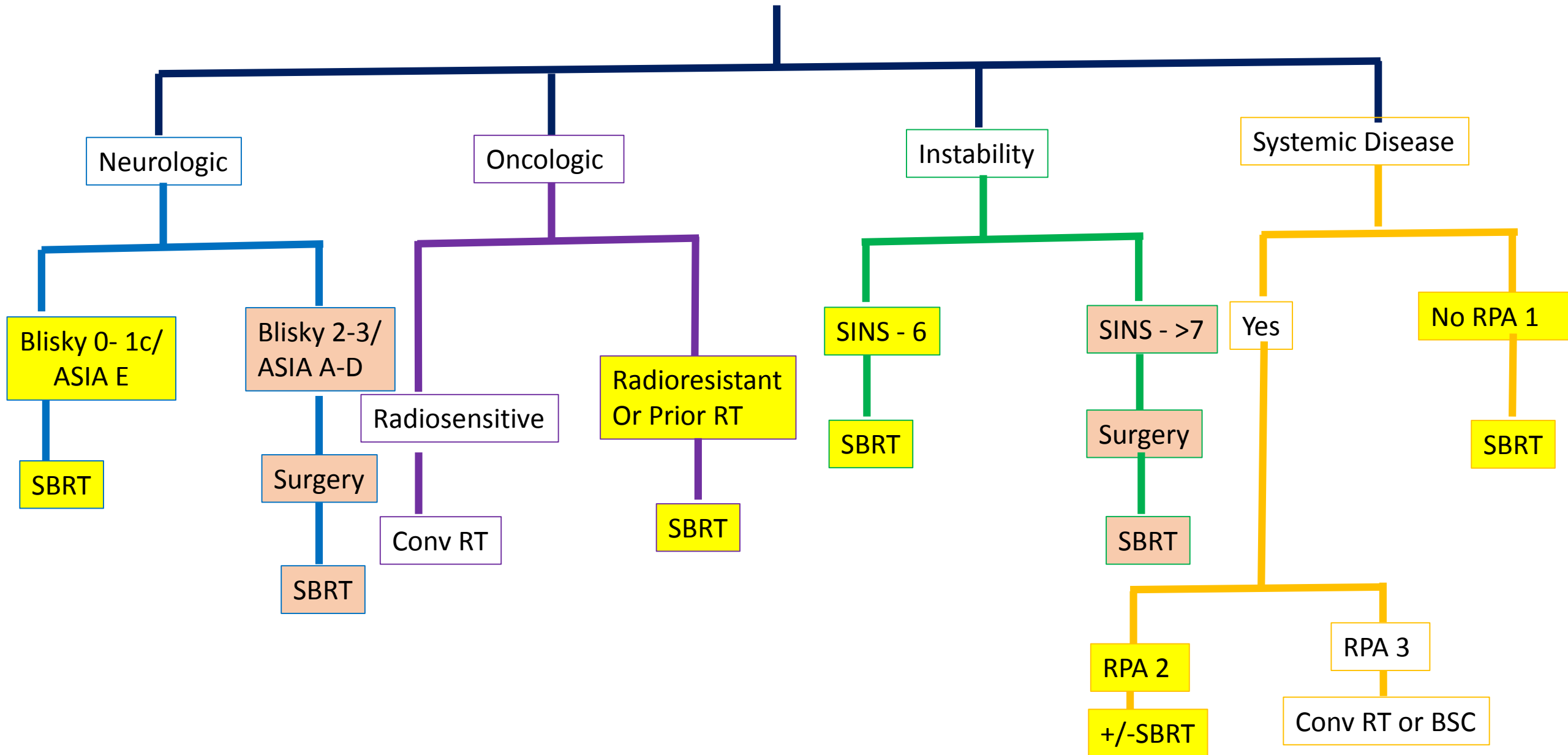
INCLUSION CRITERIA

- **Radiographic-**
 1. spinal / paraspinal metastasis by MRI,
 2. no more than 2 consecutive or 3 noncontiguous spine segments involved.
- **Patient—**
 1. Age ≥ 18 yrs,
 2. KPS $\geq 40-50$,
 3. medically inoperable or refusing Sx
- **Tumor-**
 1. Histologic proof of malignancy,
 2. biopsy of spine lesion if first suspected malignancy
 3. oligometastatic or bone only metastatic disease
- **Previous t/t-**
 1. Previous EBRT < 45 Gy,
 2. failure of previous surgery to that spinal level,
 3. presence of gross residual after surgery

EXCLUSION CRITERIA

- **Radiographic-**
 1. spine MRI could not be completed for any reason
 2. Epidural compression of cord or cauda equina,
 3. Spinal cord compression $>25\%$,
 4. unstable spine requiring surgical stabilisation
 5. Tumor location within 5mm of spinal cord or cauda.
- **Patient-**
 1. Active connective tissue disease,
 2. worsening or progressive neurologic deficit,
 3. inability to lie flat,
 4. patient in hospice or with life expectancy < 3 months
- **Tumor-**
 1. Radiosensitive histology,
 2. extraspinal disease not eligible for further treatment
- **Previous t/t-**
 1. EBRT within 90 days,
 2. chemotherapy within 30 days

Algorithm



Simulation

- Immobilisation:-
 - Prerequisite
 - Accurate and reproducible
 - Reduce/minimise patient voluntary and involuntary motion.
 - Reduce/minimise/target motion
 - Long treatment – patient should be comfortable
 - Compatible with IGRT

Translational accuracy of <1 mm and a rotational accuracy of <2°

Thermoplastic mask for lesion above T4



Body Fix for vertebra T4 and below



Imaging

- CT scan with slice thickness **1-1.5mm**.
- Intravenous Contrast.
- Scanning preferably should be done in treatment position- MRI/PET.
- In patients with **metal artifact** from hardware obscuring critical neural structures, **CT myelogram should be obtained**.
- In rare situations, the metal artifact may be so significant **that neither CT myelogram nor MRI is reliable and, in these cases, SBRT should be avoided**.

Imaging

- MRI sequences
 - T1W and T2W axial **non-contrast** sequences.
 - T2W axial especially helpful in paraspinal disease extension and delineation of the **spinal cord or thecal sac**.
 - Slice thickness of 1–2 mm and no skip acquisition.
 - Gadolinium contrast (Controversial) - **Paraspinal disease, epidural disease** or both



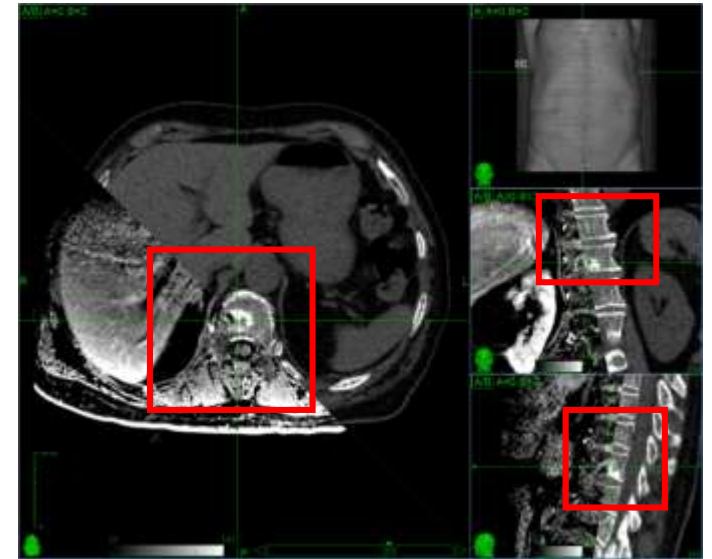
Figure 1: (A) Axial-T1, (B) Axial-T2, (C) Post-contrast T1 weighted images showing metastatic bone marrow infiltration in the right portion and peduncle of fifth lumbar vertebra.

Lesion:- Hypointense to fatty bone marrow on T1

Hyperintense - Gadolinium enhanced or T2

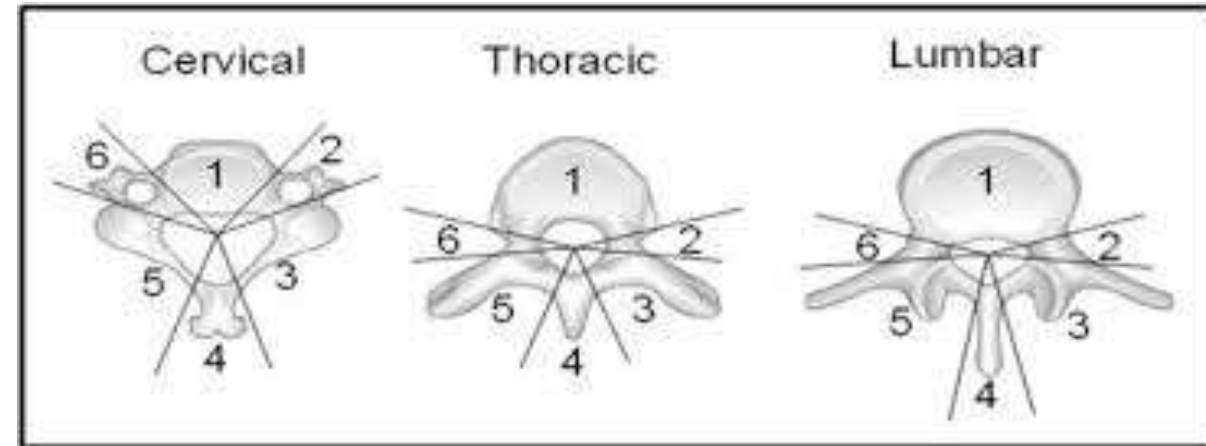
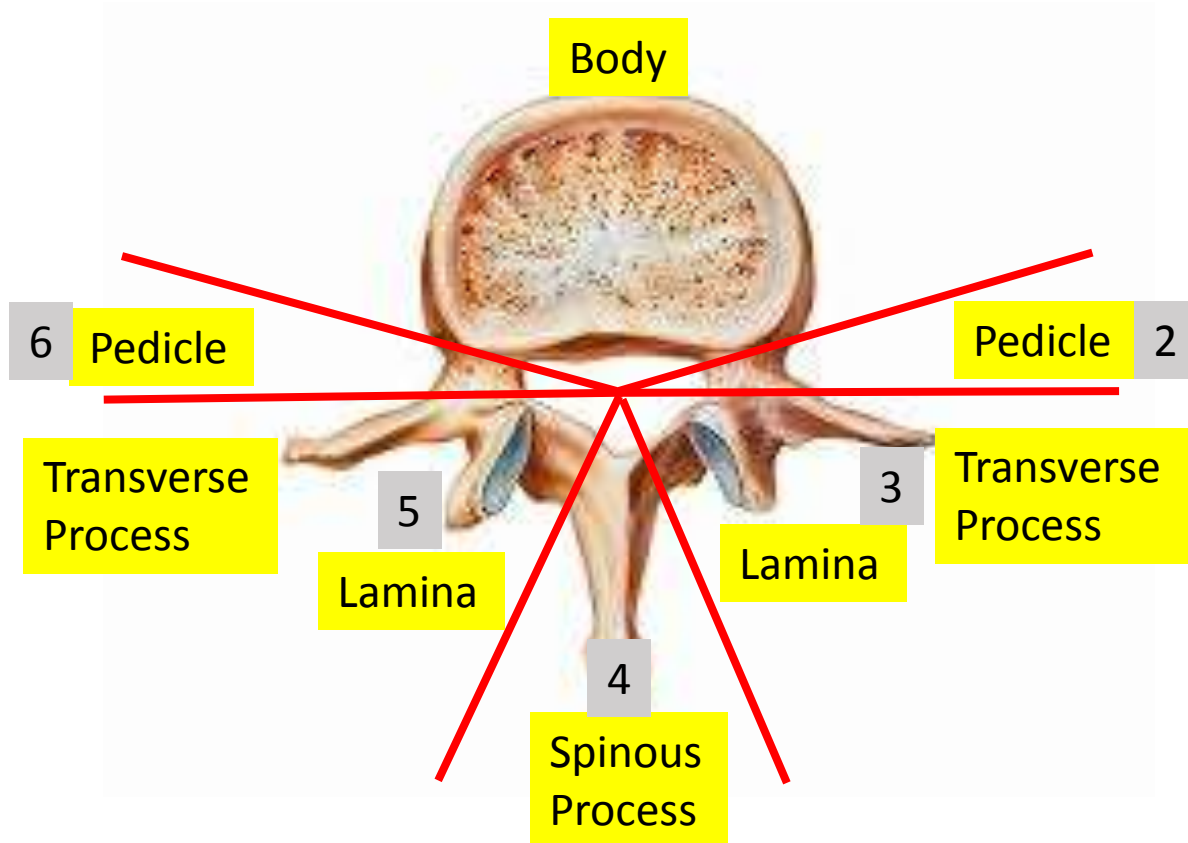
Volume delineation

- GTV (Tumour alone) – Use diagnostic MRI (T1c, T2) and PET.
- Fusion:-
 - Area of interest
 - Rigid image registration.
- In Post OP case uses preop MRI and also involve operation surgeon.
- Problems with delineation of target due to artifacts → May include addl MVCT images (if available)/MRI/Myelogram
- **CTV Exist in spine SBRT** (As per guidelines)



Volume delineation

1



Modified Weinstein-Boriani-Biagini

Contouring guidelines



2012

International Journal of
Radiation Oncology
biology • physics

www.redjournal.org

Clinical Investigation: Central Nervous System Tumor

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

Brett W. Cox, MD,^{*,1} Daniel E. Spratt, M
Mark H. Bilsky, MD,[‡] Eric Lis, MD,[§] Samu
Peter C. Gerszten, MD, MPH,^{**} Eric Chan
Arjun Sahgal, MD,^{§§} Joe Deasy, PhD,[†] Jol
Stefan Mindea, MD,^{¶¶} and Yoshiya Yama

2017

International Journal of
Radiation Oncology
biology • physics

www.redjournal.org

Clinical Investigation

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, FACR,[†] Scott G. Soltys, MD,[‡] Samuel Ryu, MD,
Todd McNutt, PhD,^{*} Samuel T. Chao, MD,^{||} Yoshiya Yamada, M
Amol Ghia, MD,[#] Eric L. Chang, MD,^{**} Jason Sheehan, MD, Ph
and Arjun Sahgal, MD, FRCPC^{††}

2020

Radiotherapy and Oncology 145 (2020) 21–29

Contents lists available at ScienceDirect

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journal homepage: www.thegreenjournal.com



Original Article

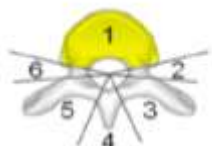
International consensus recommendations for target volume delineation specific to sacral metastases and spinal stereotactic body radiation therapy (SBRT)

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. Ghiaⁱ, Kristin J. Redmond^j, Scott G. Soltys^k, Mitchell C. Liu^a

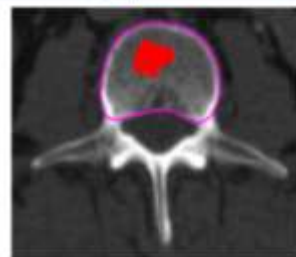


Guidelines for bony CTV delineation

GTV	Anatomic classification	CTV recommendation	CTV description
Any portion of vertebral body	1	1	Include entire vertebral body

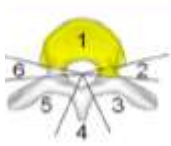


GTV: Any portion of the vertebral body



CTV Recommendation: Entire Body

GTV	Anatomic classification	CTV recommendation	CTV description
lateralized within the vertebral body	1	1,2	Include entire vertebral body and ipsilateral pedicle/ transverse process

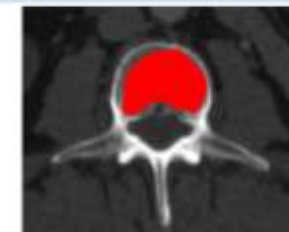
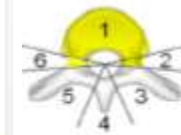


GTV: vertebral body+ Unilateral Pedicle

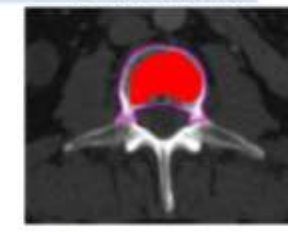


CTV: Vertebral body+ Unilateral Pedicle+ (Next station) I/L Transverse process & Lamina

GTV	Anatomic classification	CTV recommendation	CTV description
Diffusely involves the vertebral body	1	1,2,5	Include entire vertebral body and bilateral pedicles/transverse process

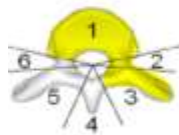


GTV: Diffusely involves the vertebral body

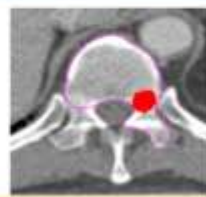


CTV: Vertebral body and the bilateral pedicles/transverse processes

GTV	Anatomic classification	CTV recommendation	CTV description
Vertebral body and unilateral pedicle	1,2	1,2,3	Include entire vertebral body, pedicle, ipsilateral transverse process and lamina

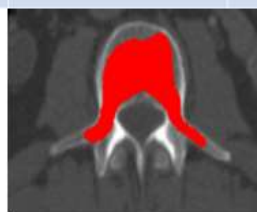
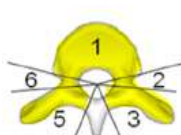


GTV: vertebral body+ Unilateral Pedicle



CTV: Vertebral body+ Unilateral Pedicle+ (Next station) I/L Transverse process & Lamina

GTV	Anatomic classification	CTV recommendation	CTV description
Vertebral body and bilateral pedicles/ transverse process	6,1,2 (±3, ±5)	1,2,3,5,6	Include entire vertebral body, bilateral pedicles, bilateral transverse processes and laminae

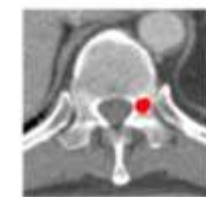
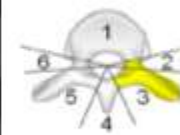


GTV involves vertebral body and bilateral pedicles/transverse processes



CTV:-Include entire vertebral body, bilateral pedicles/transverse processes and bilateral laminae

GTV	Anatomic classification	CTV recommendation	CTV description
Unilateral pedicle	2	2,3,1	Include ipsilateral pedicle, transverse process and laminae; Vertebral body

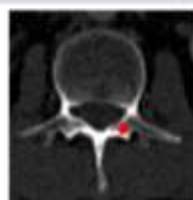
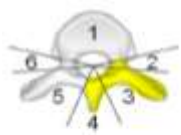


GTV involves unilateral pedicle



CTV:-Include pedicle, ipsilateral transverse process, and ipsilateral laminae, vertebral body

GTV	Anatomic classification	CTV recommendation	CTV description
Unilateral lamina	3	2,3,4	Include lamina, ipsilateral pedicle/transverse process and spinous process

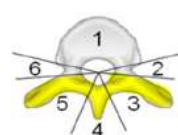


GTV involves unilateral lamina



CTV:-Include lamina, ipsilateral pedicle/transverse process, and spinous process

GTV	Anatomic classification	CTV recommendation	CTV description
Spinous process	4	3,4,5	Include spinous process and bilateral laminae



GTV involves spinous process



CTV:-Include entire spinous process and bilateral laminae

Postop SBRT - CTV

Target volume	Guidelines
GTV	<ul style="list-style-type: none">• Gross tumor based on postoperative CT and MRI with attention to residual epidural or paraspinal disease
CTV	<ul style="list-style-type: none">• Include entire GTV• Include the postoperative region and entire anatomic compartment corresponding to all preoperative MRI abnormalities suspicious for tumor involvement• 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.• 5 mm margin beyond paraspinal extension and cranio-caudally for epidural Disease.
PTV	<p>Uniform CTV to PTV expansion of up to 2.5 mm</p> <p>Treating physician may modify expansion at the interface with critical organs at risk</p> <p>May subtract cord avoidance structure from PTV as a modified PTV for planning and dose reporting purposes</p> <p>Include entire GTV and CTV</p>

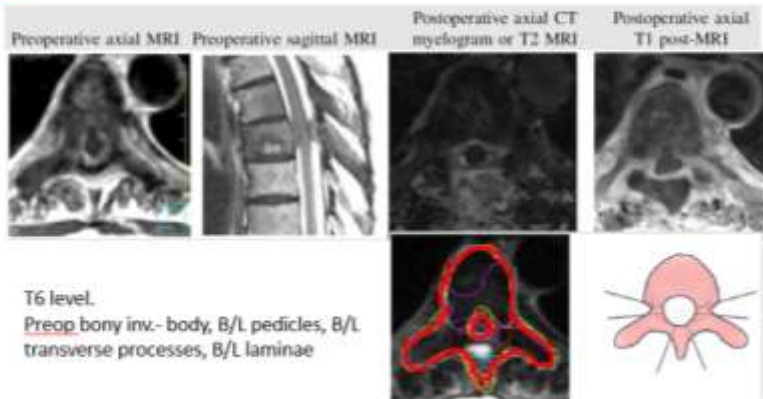
Postop SBRT - CTV

Postop SBRT: Case 1 (a)

Circumferential epidural ds preop

Residual near circumferential epidural ds postop

Preop bony inv.: Sectors 1-6



Postop SBRT: Case 2 (a)

Anterior & Left lateral epidural ds preop

Residual anterolateral epidural ds postop

Preop bony inv.: Sectors 1,2

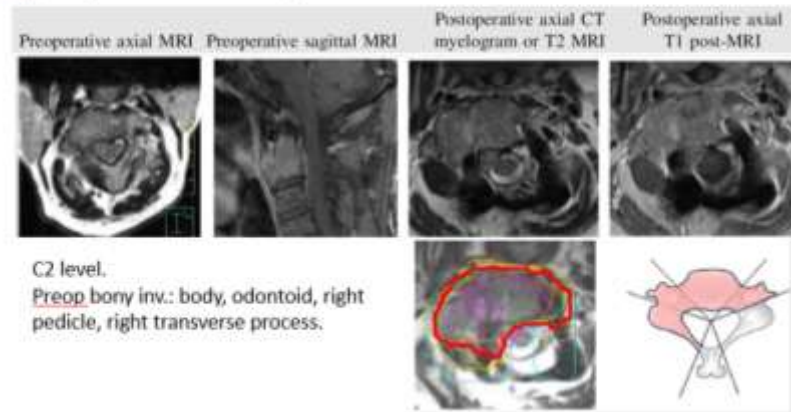


Postop SBRT: Case 2 (b)

Rt lateral and anterior epidural ds preop

Residual anterolateral epidural ds postop

Preop bony inv.: Sectors 1,5,6

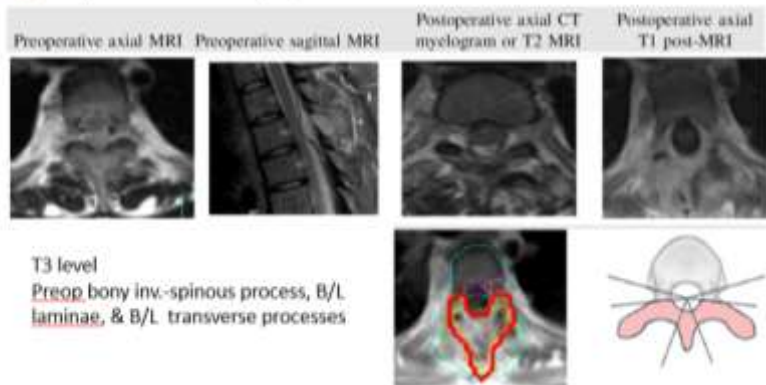


Postop SBRT: Case 3 (a)

Posterior epidural ds preop

No residual epidural ds postop

Preop bony inv.: Sectors 3,4,5



Postop SBRT: Case 3 (c)

Anterior, rt lateral and posterior epidural ds preop

No residual epidural ds postop

Preop bony inv.: Sectors 1,4,5,6

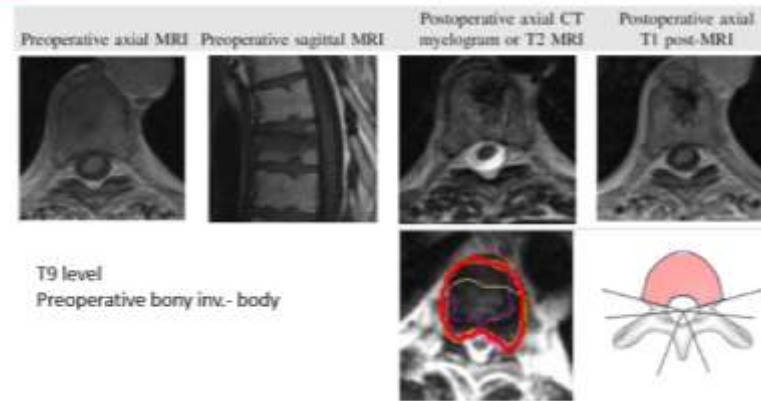


Postop SBRT: Case 4

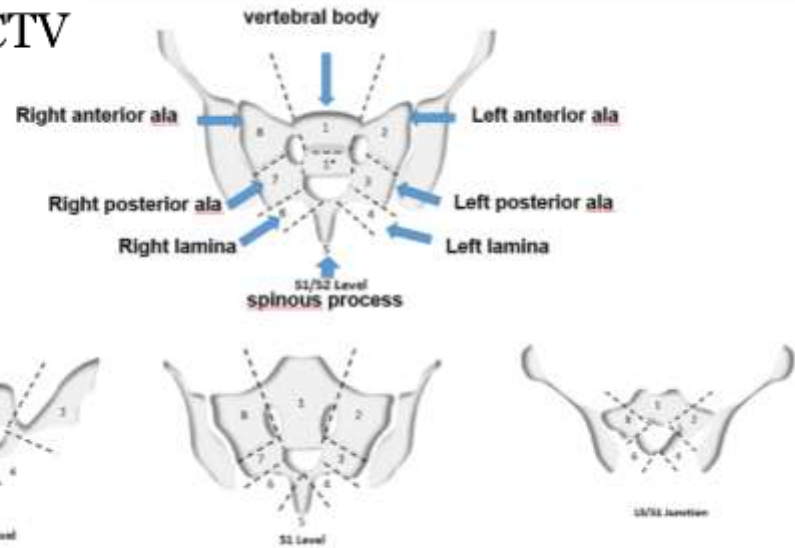
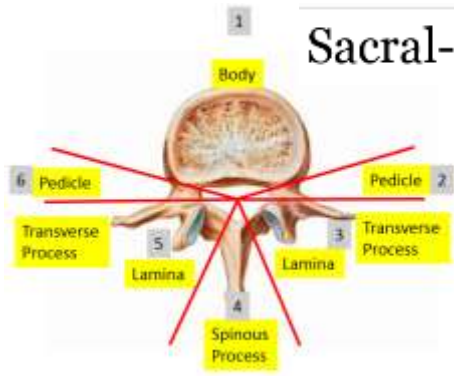
V body #, post vertebroplasty, no epidural ds preop

No residual epidural ds postop

Preop bony inv.: Sector 1



Sacral- CTV



Dunne EM et al. Radiother Oncol 2

GTV GTV Lateralised within vertebral body (S1-S2)		CTV description CTV includes • Vertebral body • Left Anterior ala • Left Posterior ala
GTV GTV diffusely involves vertebral body (S1-S2)		CTV description CTV includes • Vertebral body • B/L anterior and posterior ala
GTV GTV lateralised to vertebral body (S3-S5)		CTV description CTV includes • Vertebral body • Left ala

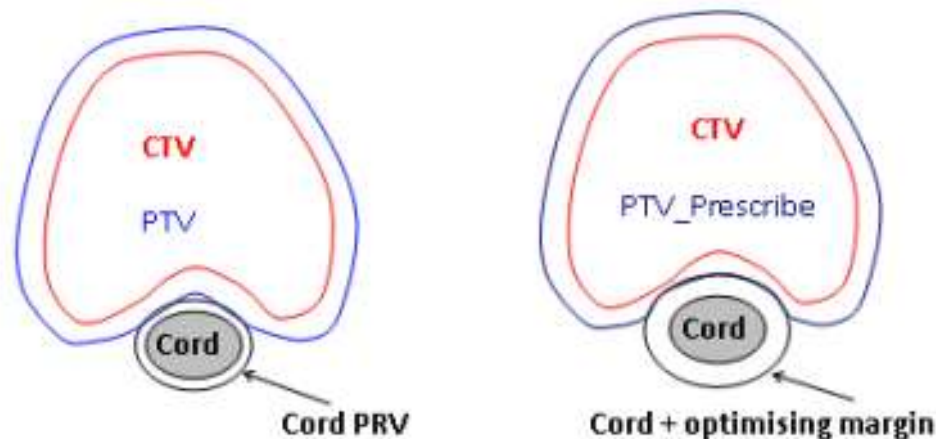
GTV GTV diffusely involves the vertebral body (S3-S5)		CTV description CTV includes • Vertebral body • Left ala • Left lamina
GTV GTV involves vertebral body and unilateral ala (S1-S2)		CTV description CTV includes • Vertebral body • Left anterior ala • Left posterior ala • Left lamina
GTV GTV involves vertebral body and unilateral ala (S3-S5)		CTV description CTV includes • Vertebral body • Left anterior ala • Left posterior ala • Left lamina

GTV GTV involves vertebral body and bilateral ala (S1-S2)		CTV description CTV includes • Vertebral body • Bilateral anterior and posterior ala • Bilateral lamina • Spinous process
GTV GTV involves vertebral body and bilateral ala (S3-S5)		CTV description CTV includes • Vertebral body • Bilateral ala • Bilateral lamina
GTV GTV involves unilateral ala (S1-S2)		CTV description CTV includes • Anterior ala • Posterior ala • +/- vertebral body

GTV GTV involves unilateral lamina		CTV description CTV includes • Right lamina • Spinous process • +/- vertebral body
GTV GTV involves spinous process		CTV description CTV includes • Spinous process • Bilateral lamina
GTV GTV involves bilateral lamina		CTV description CTV includes • Bilateral lamina • Spinous process • +/- vertebral body

Volume delineation: PTV

- Uniform expansion around the CTV (1.5-2.5 mm margin)
- Should contain entire GTV and CTV
- PTV margin adjacent to critical structures may be modified to allow spacing at discretion of treating physician unless GTV compromised
 - Never overlaps with cord/ cord avoidance structure
- **PTV_prescribe = PTV – Cord PRV:**
 - To allow for unavoidable underdosing of PTV in close proximity to spinal cord, while maintaining consistency in treatment prescription



PTV_Prescribe volume may be generated or edited appropriately in treatment situations where GTV extends beyond this volume

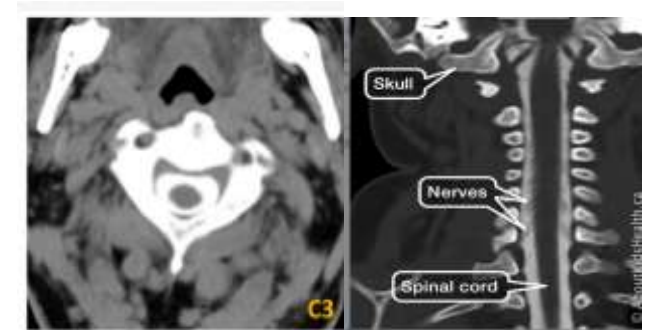
OARs

Adjacent OARs should be contoured 1 vertebral level above and below the PTV

- Spinal cord/ Cauda equina: fused T1/T2 MRI or CT myelogram
- Esophagus
- Ribs/Chest wall
- Skin
- Aorta
- Lungs/ Heart/ Kidneys/ Bowel as per site

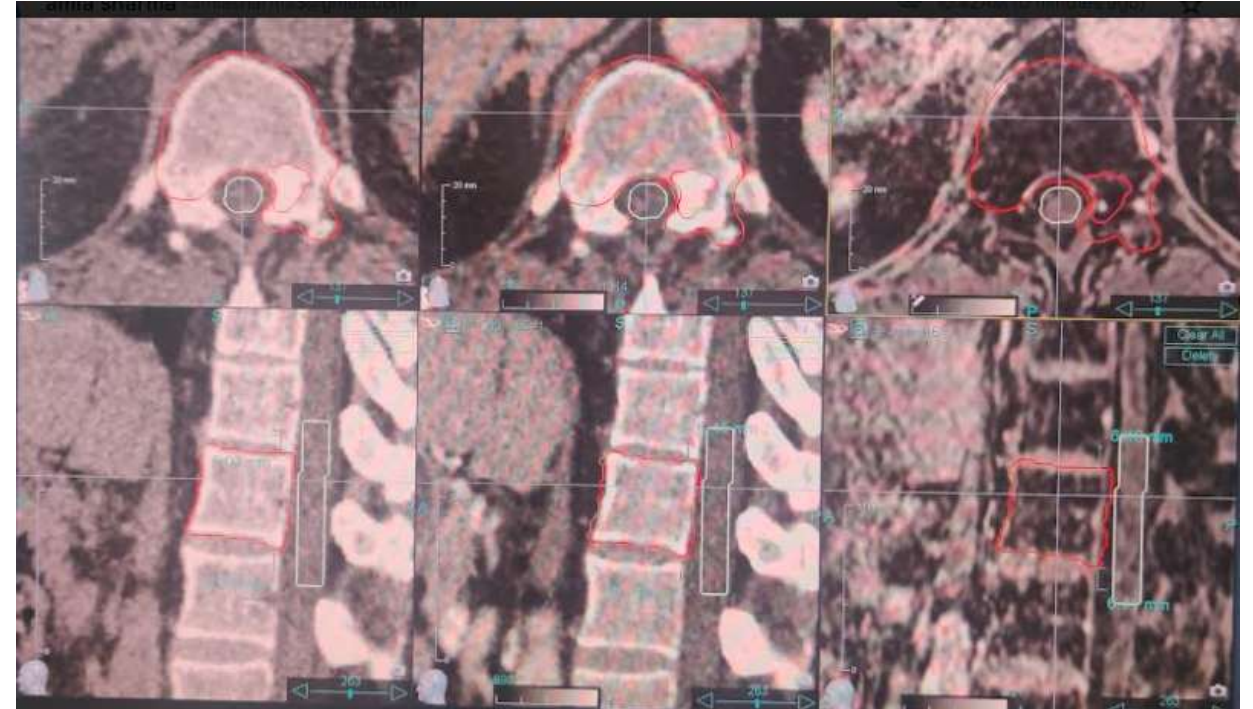
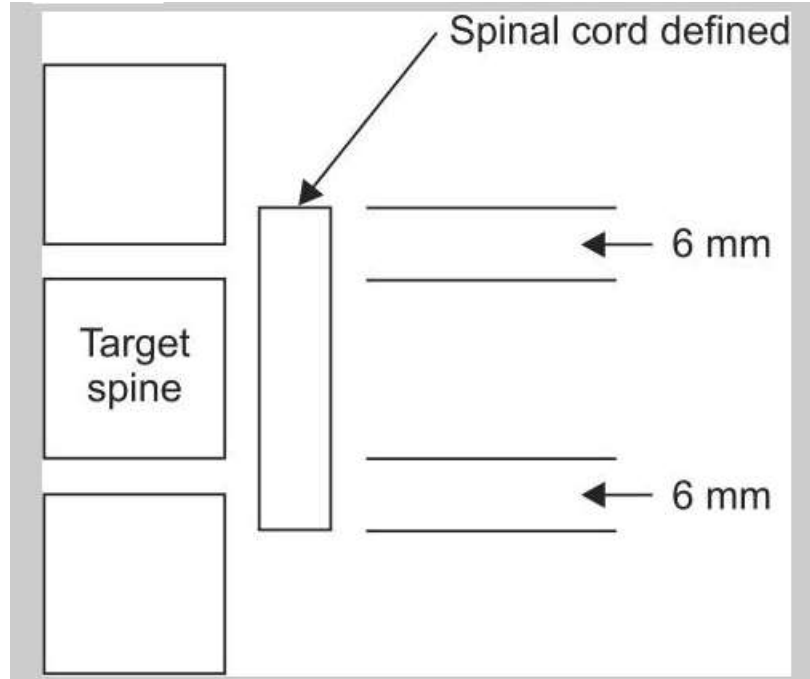
Spinal cord delineation

- Challenging, but critical for safe practice.
- Double edge sword:-
 - Contouring generously – **Under dosing tumor in epidural space.**
 - Contouring inaccurately – **Higher dose to true spinal cord .**
- Thin-slice T1 and T2 axial volumetric MR images fused to the treatment planning CT and/or a **CT myelogram** – closest way to contour what is “true cord”.
- **Caution:-** Simple window levelling by itself can alter what is contoured as the “true” cord.



- PRV: 1.5-2 mm margin around cord
- Thecal sac (surrogate for cord/cauda) is equivalent to **1.5mm PRV margin** to cord

Extent of spinal cord contouring for SBRT Spine



- Spinal cord to be contoured 6mm above and 6mm below the target volume
- Rationale- distance of dose fall-off (90% to 50% isodose line) being 5 mm, and that the radiosurgical beam arrangement is co-planar.

HyTEC Organ-Specific Paper: Spinal Cord

Stereotactic Body Radiation Therapy for Spinal Metastases: Tumor Control Probability Analyses and Recommended Reporting Standards

1 Fraction		2 Fractions		3 Fractions		4 Fractions		5 Fractions	
Dose (Gy)	LC (%)	Dose (Gy)	LC (%)	Dose (Gy)	LC (%)	Dose (Gy)	LC (%)	Dose (Gy)	LC (%)
16 [†]	72 [†]	20 [†]	66 [†]	24 [*]	70 [*]	20 [†]	45 [†]	20 [*]	41 [*]
18 [*]	82 [*]	22 [†]	74 [†]	27 [*]	78 [*]	28 [†]	73 [†]	25 [*]	57 [*]
20 [*]	90 [*]	24 [*]	82 [*]	30 [*]	85 [*]	30 [*]	78 [*]	30 [*]	72 [*]
22 [*]	94 [*]	28 [†]	90 [†]	33 [†]	90 [†]	33 [*]	85 [*]	35 [*]	83 [*]
24 [*]	96 [*]	30 [†]	95 [†]	36 [†]	95 [†]	40 [†]	95 [†]	45 [†]	95 [†]

Fractions	80% LC	90% LC	95% LC
1fxED:	18 [*]	20 [*]	23 [†]
2fxED:	23 [†]	28 [†]	30 [†]
3fxED:	27 [*]	33 [†]	36 [†]
4fxED:	32 [†]	36 [†]	40 [†]
5fxED:	33 [†]	40 [†]	45 [†]

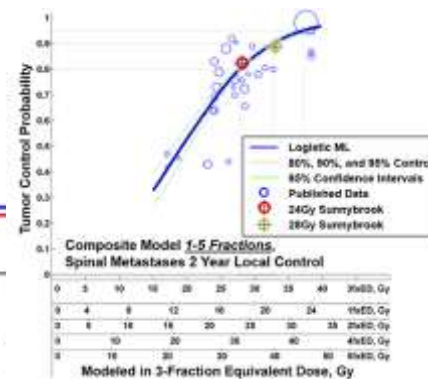
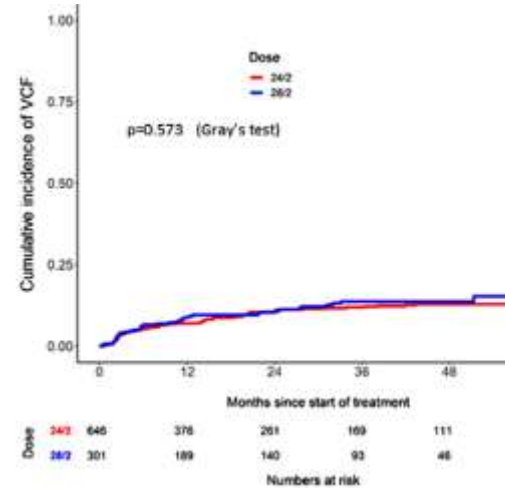
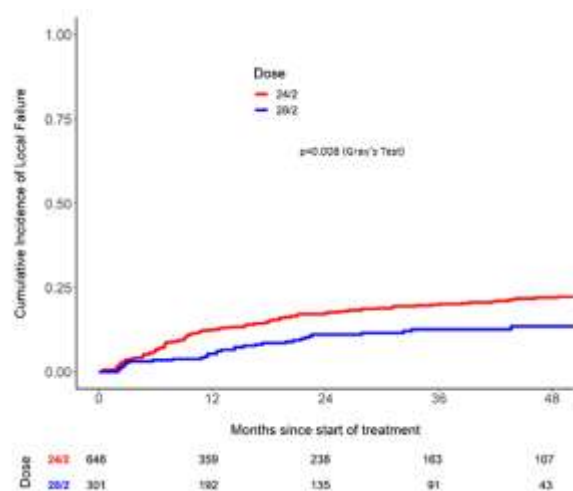
Stereotactic body radiotherapy versus conventional external beam radiotherapy in patients with painful spinal metastases: an open-label, multicentre, randomised, controlled, phase 2/3 trial



Arjun Sahgal, Sten D Myrehaug, Shankar Siva, Giuseppina L Masucci, Pejman J Maralani, Michael Brundage, James Butler, Edward Chow, Michael G Fehlings, Matthew Foote, Zsolt Gabos, Jeffrey Greenspoon, Marc Kerba, Young Lee, Mitchell Liu, Stanley K Liu, Isabelle Thibault, Rebecca K Wong, Maaiké 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

Data are n (%) or mean (SD). Pain responses at 1, 3, and 6 months after treatment relative to baseline assessments were based on International Consensus on Palliative Radiotherapy Endpoints. OME=oral morphine equivalent. SINS=Spinal Instability in Neoplasia Score. *Adjusted for stratification factors of histology (radioresistant vs radiosensitive), and the the presence or absence of mass-type tumour (extraosseous or epidural disease extension, or both) on imaging.



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*

INTERNATIONAL JOURNAL OF RADIATION ONCOLOGY • BIOLOGY • PHYSICS

- Stereotactic body radiotherapy is superior to conventional external beam radiotherapy in achieving complete pain relief at the treatment site.
- Stereotactic body radiotherapy significantly improved the complete response rate for pain compared with conventional external beam radiotherapy, and had a durable effect at the 6-month and final follow-up assessment.

Conclusions: Dose escalation to 28 Gy in 2 daily fractions was associated with improved local control without increasing the risk of VCF. The 2-year local control rates are consistent with those predicted by the Hypofractionated Treatment Effects in the Clinic spine tumor control probability model, and these data will inform a proposed dose escalation randomized trial. © 2022 Elsevier Inc. All rights reserved.

Tolerance to SBRT-Thecal sac Dmax

Clinical Investigation: Central Nervous System Tumor

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^{|||}

^{*}Department of Radiation Oncology, Princess Margaret Hospital, University of Toronto, Toronto, ON, Canada; [†]Department of Radiation Oncology, Sunnybrook Health Sciences Centre, University of Toronto, Toronto, ON, Canada; [‡]University of California San Francisco Helen Diller Family Comprehensive Cancer Center Biostatistics Core, San Francisco, California; [§]Department of Radiation Oncology, University of Southern California and The University of Texas MD Anderson Cancer Center, University of Texas, Houston, Texas; [¶]Department of Radiation Oncology and Neurosurgery, Cleveland Clinic, Cleveland, Ohio; ^{|||}European Cyberknife Center Munich in affiliation with the University Hospitals of Munich, Munich, Germany; ^{**}Department of Neurosurgery, University of California at Los Angeles, Los Angeles, California; ^{††}Department of Radiation Oncology, Stanford University, Stanford, California; ^{‡‡}Departments of Neurological Surgery and Radiation Oncology, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania; ^{§§}Department of Radiation Oncology, Henry Ford Hospital, Detroit, Michigan; and ^{||}Department of Radiation Oncology, University of California at San Francisco, San Francisco, California

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10gy/1fx= 60BED= 30-35 EQD2

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

For 2% probability of RM: Theca Dmax EQD2 OF 30Gy-single fx; 35Gy upto 5Fx is supported as safe

Estimated Risk Level of Unified SBRT Dose Tolerance Limits for Spinal Cord

Jimm Grimm, PhD^a, Arjun Sahgal, MD^b, Scott G. Soltys, MD^c, Gary Luxton, PhD^c, Ashish Patel, MD^d, Scott Herbert, MD^e, Jinyu Xue, PhD^d, Lijun Ma, PhD^f, Ellen Yorke, PhD^g, John R. Adler, MD^c, and Iris C. Gibbs, MD^c

	Low Risk Limits					High Risk Limits				
	D50% Limit (Gy)	D10% Limit (Gy)	D1cc Limit (Gy)	D0.1cc Limit (Gy)	Dmax Limit (Gy)	D50% Limit (Gy)	D10% Limit (Gy)	D1cc Limit (Gy)	D0.1cc Limit (Gy)	Dmax Limit (Gy)
1 fx	1.8	7.0	7.0, 0.1%	8.5, 0.1%	13.0, 0.9%	7.0	10.0	8.0, 0.2%	10.0, 0.2%	14.0, 1.6%
2 fx	3.6	9.1	9.5, 0.1%	12.7, 0.1%	16.5, 0.6%	11.0	14.0	12.0, 0.4%	14.5, 0.3%	18.0, 1.1%
3 fx	5.4	11.1	11.1, 0.1%	16.3, 0.2%	20.0, 0.7%	15.0	18.0	16.0, 0.9%	18.0, 0.4%	22.0, 1.3%
4 fx	7.2	12.8	13.6, 0.2%	18.3, 0.2%	21.0, 0.5%	18.5	20.5	20.0, 2.2%	20.5, 0.4%	26.0, 1.8%
5 fx	9.0	13.5	13.5, 0.1%	20.0, 0.2%	22.0, 0.4%	21.0	23.0	21.5, 2.0%	22.5, 0.4%	30.0, 2.6%

Tolerance to salvage SBRT- Spine

- Take into account previous radiation dose.
- Previous RT: 20/5, 30/10, 40/20, 50/25
= **30-50 EQD2** (above/below this recommendations N/A)
- Recommendations based on thecal sac Dmax.
- Total **EQD2 of thecal sac Dmax upto 70Gy2/2** is **SAFE** as this was within 95% CI for norm group, and no overlap with RM group.
- Sbrt theca Dmax reirradiation BED upto **EQD2 OF 25Gy2/2** is supported as safe



PRIOR CONVENTIONAL RADIOTHERAPY FRACTIONATIONS	PRIOR CONVENTIONAL RADIOTHERAPY nBED (Gy _{2/2})	1-fx SBRT (Gy)	2-fx SBRT (Gy)	3-fx SBRT (Gy)	4-fx SBRT (Gy)	5-fx SBRT (Gy)
20 Gy/5 fx	30	9	12.2	14.5	16.2	18
30 Gy/10 fx	37.5	9	12.2	14.5	16.2	18
40 Gy/20 fx	40	N/A	12.2	14.5	16.2	18
45 Gy/25 fx	43	N/A	12.2	14.5	16.2	18
50 Gy/25 fx	50	N/A	11	12.5	14	15.5

Planning

- Principles:-
 - ✓ Sharp fall off outside PTV
 - ✓ Inhomogeneous dose inside PTV
 - ✓ Multiple non co-planner beam or arc are needed to create conformal dose distributions.

Impact of Hardware

- Because of **electron backscatter**, the high density of titanium hardware may **underestimate** the radiation dose to structures in **front** of it by approximately **6%**.
- Similarly, tissues **behind** the hardware may receive a dose approximately **7% lower** than the anticipated dose due to photon attenuation .

Planning Criteria

- Dmax – Inside the PTV
- PD = 100%
- Prescription isodose: 80% to 90%.

Dose Coverage

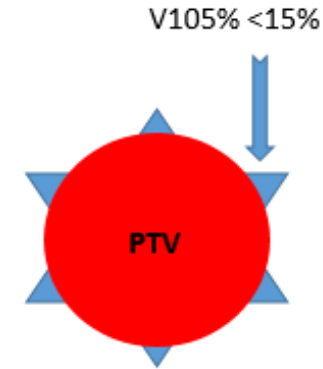
- Ideal PTV $V_{100\%} \geq 95\%$ and $V_{90\%} > 99\%$

CONFIRMITY

- Defined by the conformity index --- $V_{100\%}$ /PTV volume.
- Ideal value ≤ 1.2

HIGH DOSE SPILLAGE

- $V_{105\%}$ should ideally be **< 15% of PTV volume.**



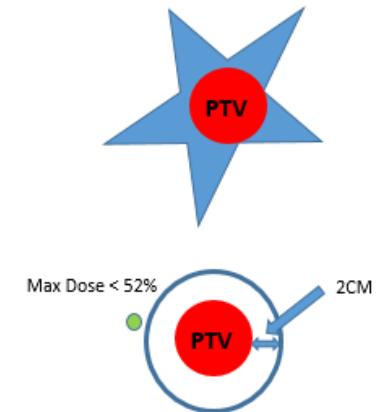
INTERMEDIATE DOSE SPILLAGE

- $R_{50\%} = V_{50\%}/\text{PTV volume.}$

Ideal value < 4.6

- $D_{2\text{cm}}$ = maximum dose in % of prescribed dose at 2 cm beyond the PTV in any direction.

Ideal value < 52.7%



Set verification and delivery

- CBCT

- Pre-treatment
- Mid Treatment
- Post Treatment



- Cyberknife

- Real time tracking
- Imaging every 5 to 150 sec



Toxicity- Pain Flare

- Defined as **temporary worsening of bone pain** at the treated site.
- Incidence higher as compare to conventional RT (68% Vs 28%).
- Mostly on day **1(Median time to pain flare was 5 days)**.
- Responds readily to steroids
- Higher KPS and cervical or lumbar spine locations were associated with higher incidence of pain flare.

Toxicity - Radiation myelopathy

- **Diagnosis of exclusion**, based on neurologic signs and symptoms.
- **Demyelination and necrosis** of the spinal cord, typically confined to **white matter**, are the main histologic features
- Characteristic MRI changes in the cord include areas of low signals on T1-weighted images, **high signals on T2**, and **focal contrast enhancement**.



Spinal Cord Radiation Injury

Type	Timing after XRT	Clinical Findings	Pathogenesis	Outcome
Acute	During XRT	None	--	--
Early-Delayed	2-37 Weeks	Lhermitte's	Demyelination	Recovery
Late Delayed	Months-Years			
Transverse myelopathy		Para/Quadriplegia Brown-Sequard Spastic paraparesis	Necrosis	Irreversible
Motor Neuron Dysfunction		Leg Weakness	Ventral roots	Irreversible
Hemorrhagic myelopathy	8-30 years	Acute paraparesis	Telangiectasia	Reversible

Toxicity - Vertebral compression fracture

- VCF is defined as a collapse of the vertebral body (VB).
- Incidence is 14% to 39%.
- The median and mean time to VCF was 2.46 and 6.33 months with two-thirds of VCFs developing within the first 4 months post-SBRT.
- The pathophysiology - complex (M/c-Osteoradionecrosis)

Predictive factor

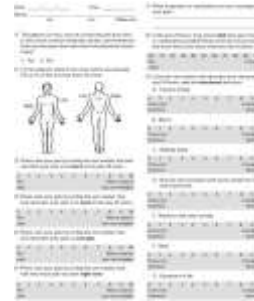
- Dose > 20 Gy/1fr
- Osteolytic tumor
- Preexisting fracture 36.1% Vs 8.3%
- Spinal Malalignment
- Tumor Histology - ? Lung/liver/renal.
- paraspinal tumor extension, and single versus multiple



Response Assessment: SPINO

Committee of RANO working group

- Pain assessment tools → BPI



Post RT 1 or 3 months --???

- Timing. →
- Attrition rates are around 20% per month.
- Confounding effects of additional treatments after SBRT.
- Challenges of collecting data due to questionnaire fatigue or shift in priorities.

- Meaningful pain response. →

ICPRE ^{11*}	
Complete response	Score of 0 at the treated site in patients with baseline pain, and no increase in analgesic requirements (converted to OMED)
Partial response	Pain reduction of ≥ 2 at the treated site without increase in OMED, or analgesic reduction of $\geq 25\%$ from baseline without pain increase
Pain progression	Pain score increase of ≥ 2 above baseline with stable OMED, or analgesic increase of $\geq 25\%$ in OMED with a stable pain score or 1 point above baseline
Indeterminate response	Any response other than complete or partial response and pain progression



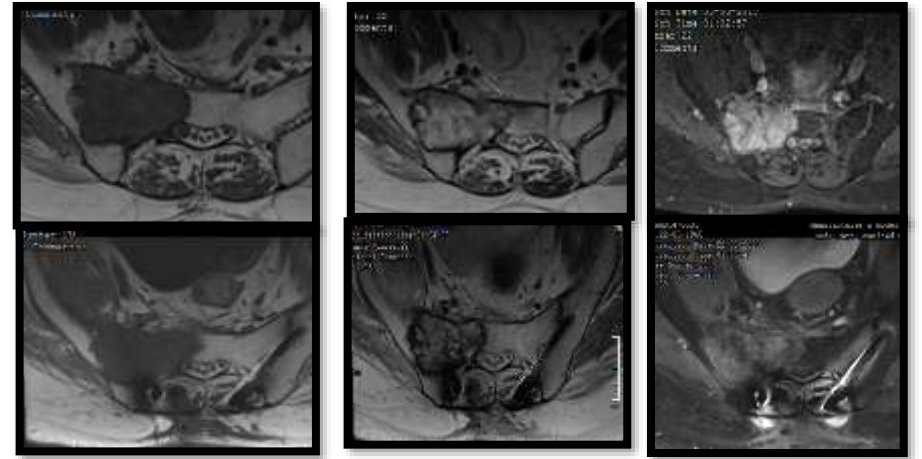
- Multiple spinal lesions.
- Adjustments in opioid and other analgesics.

Response Assessment: SPINO

- *Committee of RANO working group*

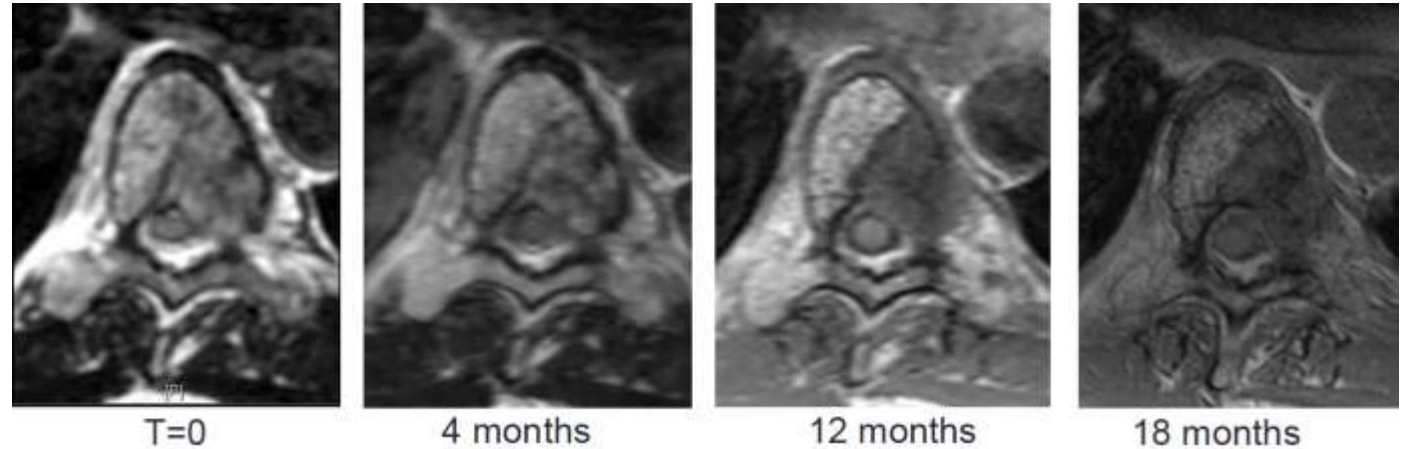
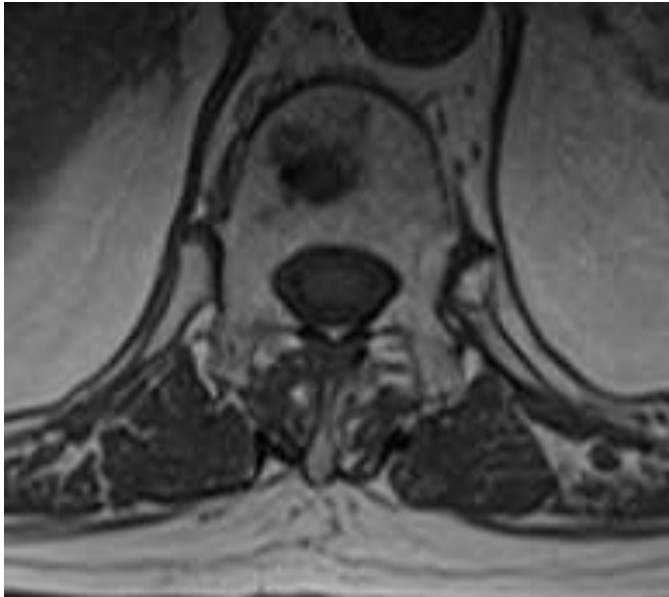
Imaging-based local tumour response

- **MRI** preferred
- Images should be interpreted by a **radiation oncologist and radiologist.**
- Time of assessment: Spine MRI **every 2–3 months** after SBRT for the first **12–18 months**, and every 3–6 months thereafter.



Response assessment: SPINO

Local control be defined as the **absence of progression** within the treated area on serial imaging (two or three consecutive MRI scans 6–8 weeks apart)*

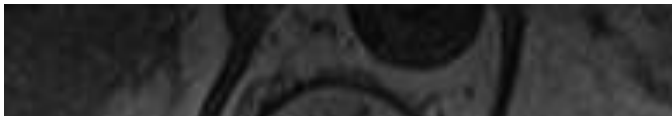
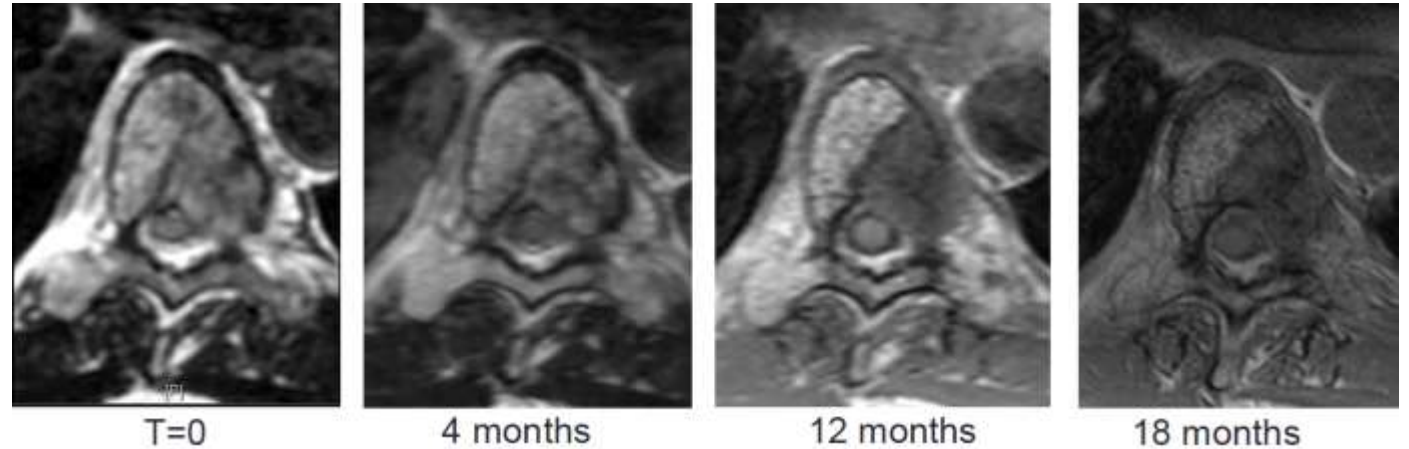


Local progression may be defined as*

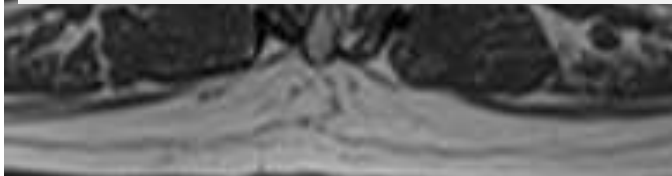
- Gross **unequivocal increase** in tumour volume or linear dimension
- Any **new or progressive** tumour within the epidural space
- **Neurological deterioration** attributable to pre-existing epidural disease with equivocal increased epidural disease dimensions on MRI

Response assessment: SPINO

Local control be defined as the **absence of progression** within the treated area on serial imaging (two or three consecutive MRI scans 6–8 weeks apart)*



CAUTION: T1 and T2 signal changes, rather than being representative of true tumor progression, might be due to **osteoradionecrosis, fibrosis or both, as well as non tumor-related vertebral compression** fracture or secondary to radiation effects when seen in the paraspinal muscles.



epidural disease with equivocal increased epidural disease dimensions on MRI

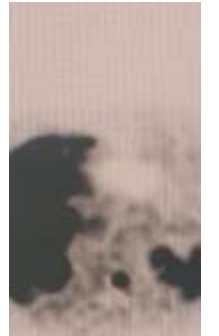
Pattern of failure

- The steep dose fall off necessary in proximity of the spinal cord may result in treatment failures.
- **Two primary patterns of failure :**
 - (1) Recurrence in the bone adjacent to the site of previous treatment
 - (2) Recurrence in the epidural space adjacent to the spinal cord.
- Epidural space failures are the commonest, which is attributed to an underdosing of this region to maintain spinal cord constraints.
- Emphasizes the necessity of combined surgical and radiosurgical treatment.

- 64 year old male diagnosed case of carcinoma Prostate Post op , Post RT 2013
- Presented with occasional pain in back
- Rising PSA
- PSMA PETCT WB(J,2023)-D12 vertebrae PSMA avid lesion. No other side of metabolic uptake.



D12 pedicle lesion on PSMA PET



- | | |
|--|-----|
| 1. Location, Junctional-D12 | - 3 |
| 2. Pain occasional lesion | - 1 |
| 3. Bone lesion, Blastic | - 0 |
| 4. Radiographic spinal alignment Normal | - 0 |
| 5. No vertebral collapse | - 0 |
| 6. Unilateral Posterolateral involvement | - 1 |

Total SINS score- 5 Stable spine

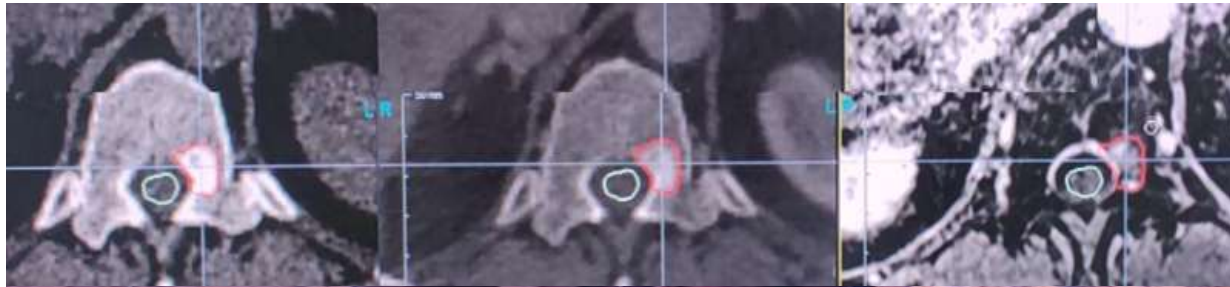
Blisky Gr:- 1

ASIA – 0

RPA 1



GTV



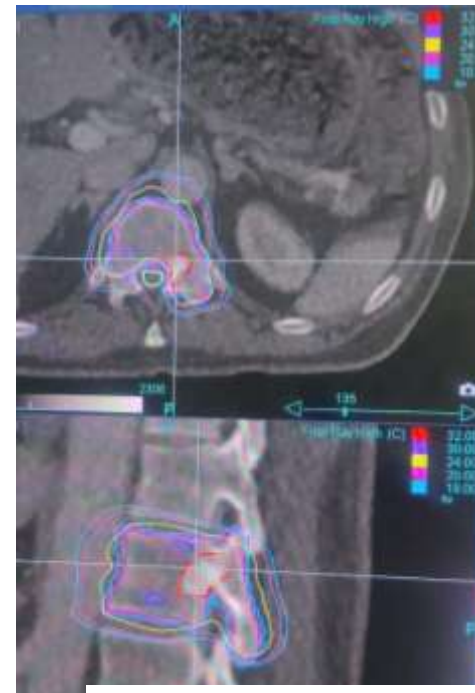
CTV



PTV



Plan



Dose Statistics Table		Dx Vx Values		Plan Information		Dose Points	
Name	Dose (Gy)	Dose (%)	Volume (cm ³)	Volume (%)			
GTV	24.00	77.0	1.26	100.0			
CTV	24.00	77.0	30.86	96.0			
PTV	24.00	77.0	36.78	91.1			
Spinal cord	16.67	53.5	0.00	0.0			
Cord PRV	12.50	40.1	1.20	9.8			
Bowel bag	11.45	36.7	0.00	0.0			
Stomach	10.29	33.0	0.00	0.0			
Kidney Lt	8.60	27.6	16.27	10.0			
Kidney Rt	6.80	21.8	14.73	10.0			
Spleen	9.35	30.0	0.00	0.0			

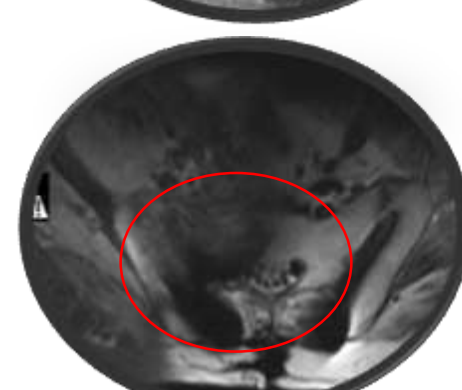
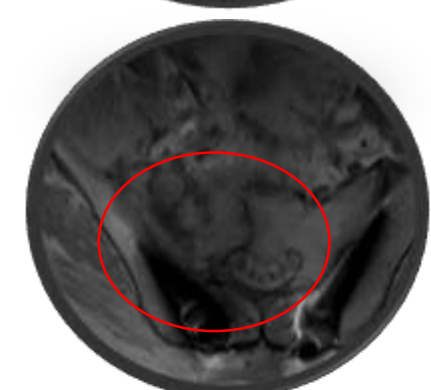
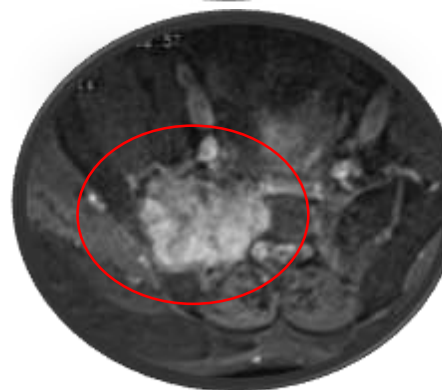
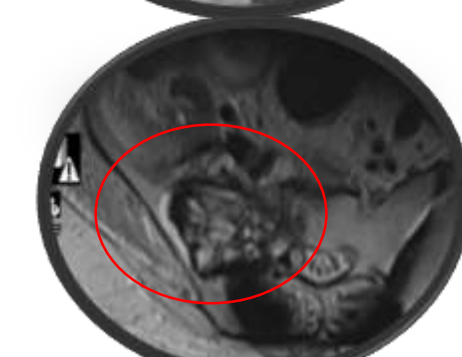
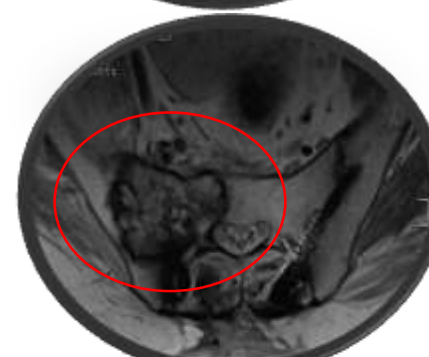
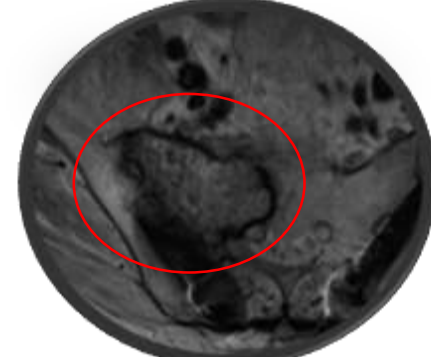
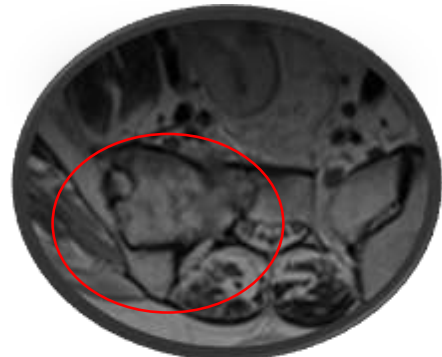
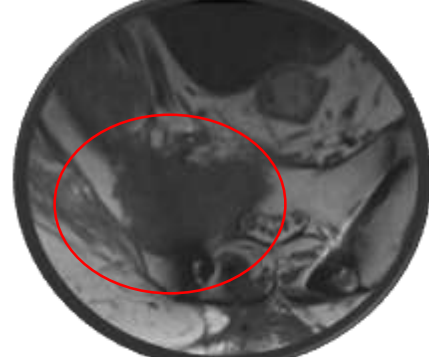
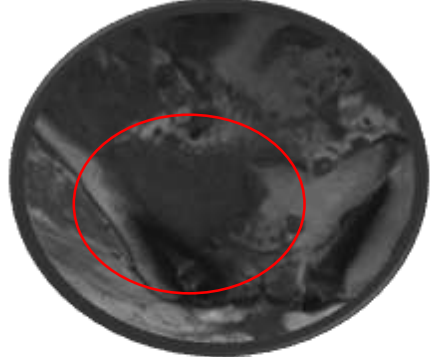
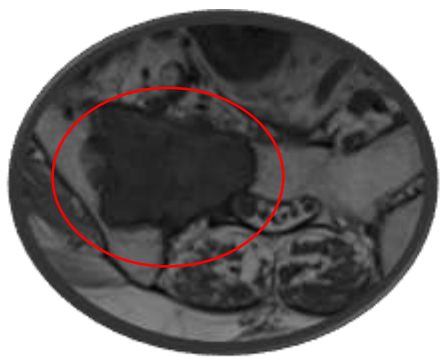
ISODOSE – 80%
 Conformity Index – 1.18

To conclude...

- SBRT : When ? Limited spinal disease, upfront or after decompressive surgery
- SBRT : When Not ? Unstable spine, compression
- SBRT : Why ? More effective palliation, tumour control
- SBRT : Why not ? Complications



Thankyou!!



Pre SBRT

**Post SBRT
3 months**

**Post SBRT
1 year**

**Post SBRT
18 months**