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MEDICINE
RADIATION ONCOLOGY &
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Optimizing Tumor Outcomes While Minimizing Toxicity Following Spine SBRT

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Disclosures

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- Data Safety Monitoring Board: BioMimetix
- Honorarium for educational seminar: Accuray

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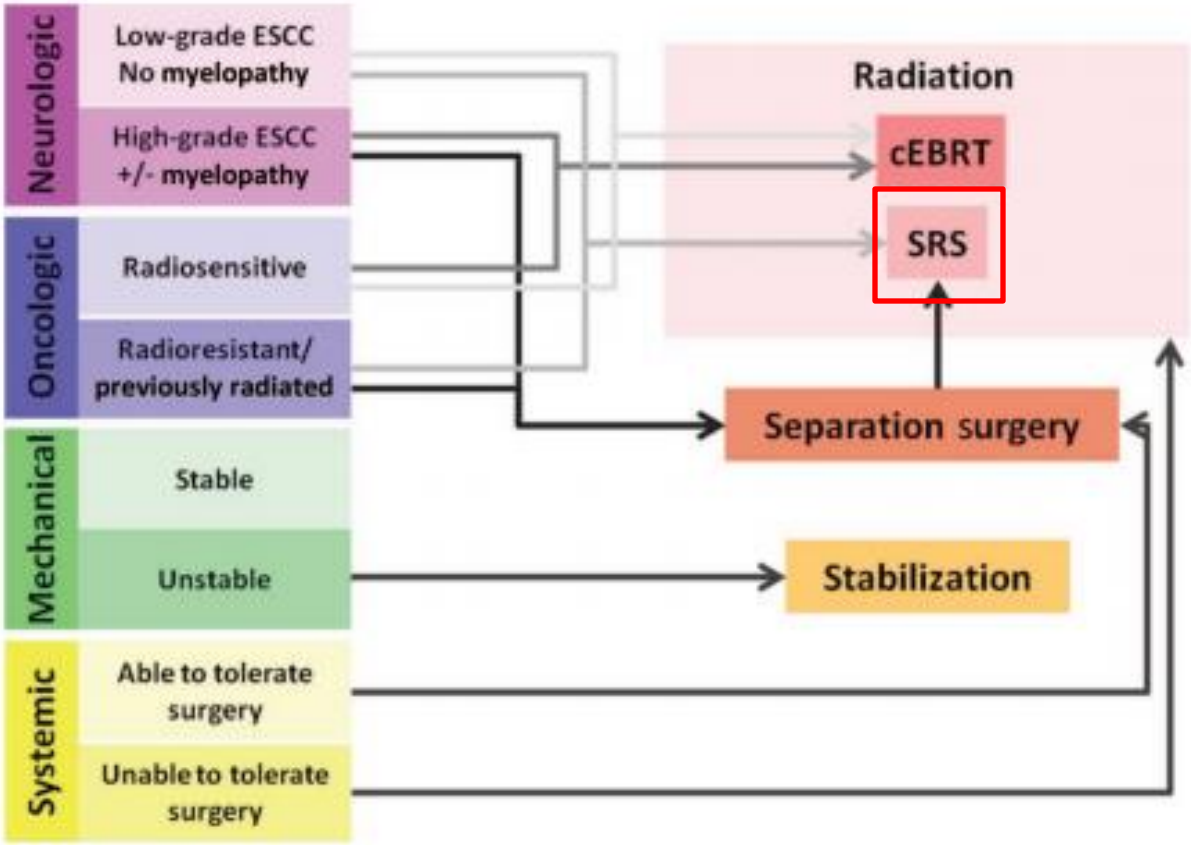
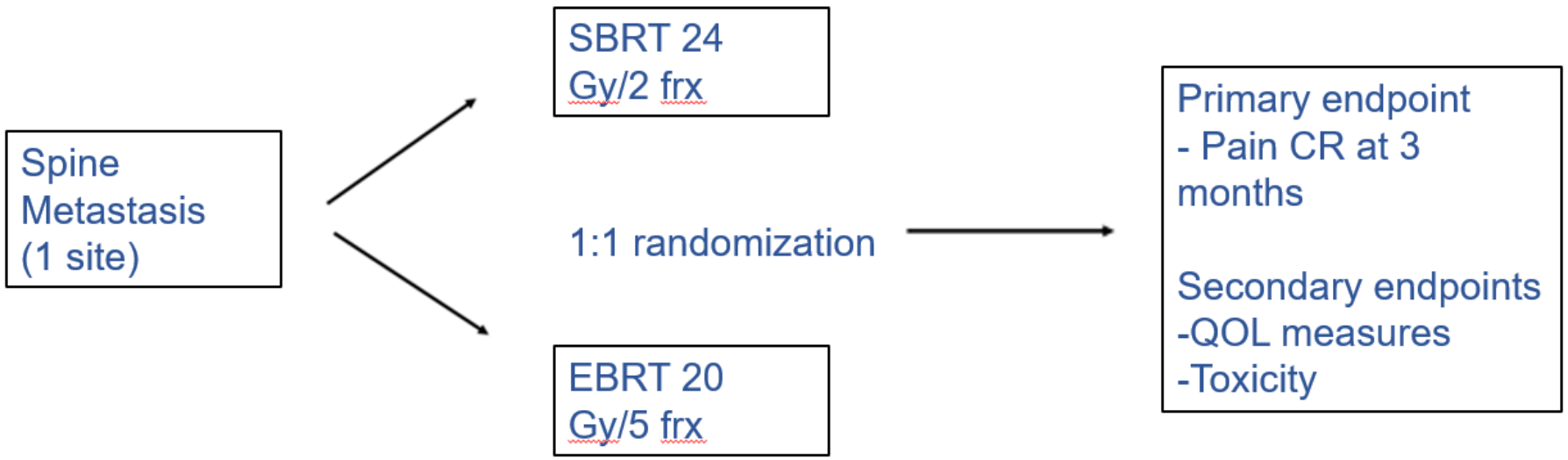
SBRT is Critical Advancement



Randomized Data: SC24



Sahgal Lancet Oncology 2021

SC24 Pain Response

	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*
3-month assessment			
Complete response	16 (14%)	40 (35%)	0·0002*
6-month assessment			
Complete response	18 (16%)	37 (32%)	0·0036*

Sahgal Lancet Oncology 2021

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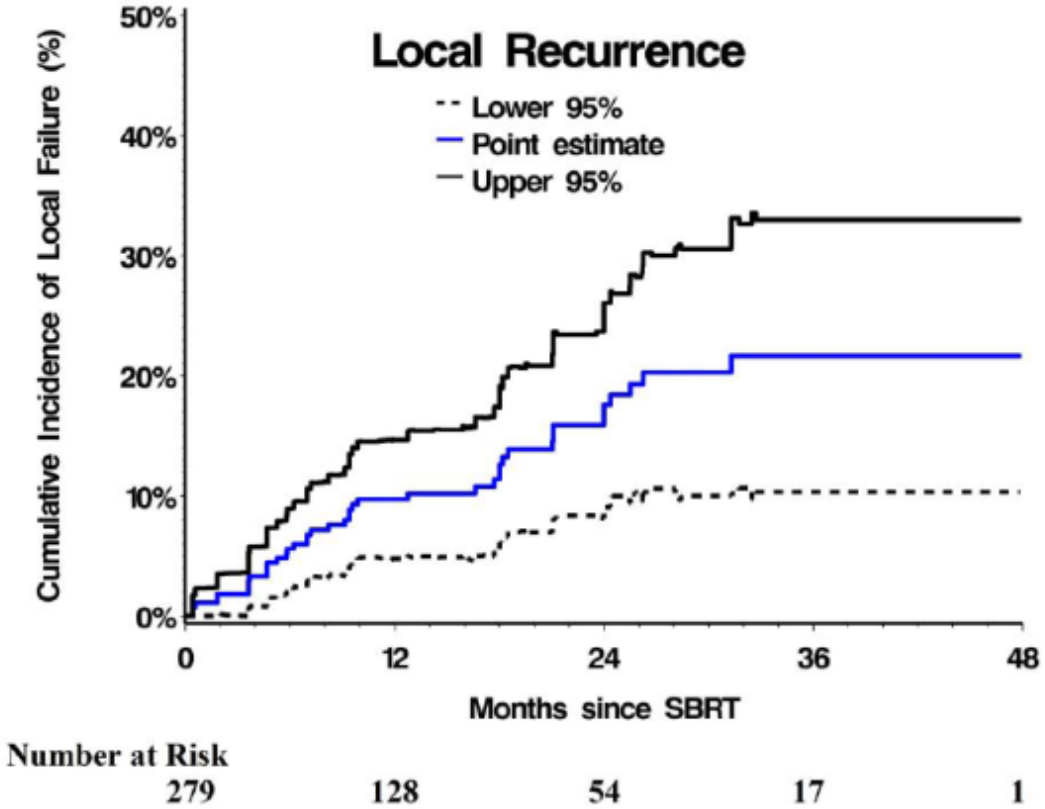
Sahgal Lancet Oncology 2021

Radiographic Outcomes

24 Gy in 2 fractions



Tseng IJROBP 2018

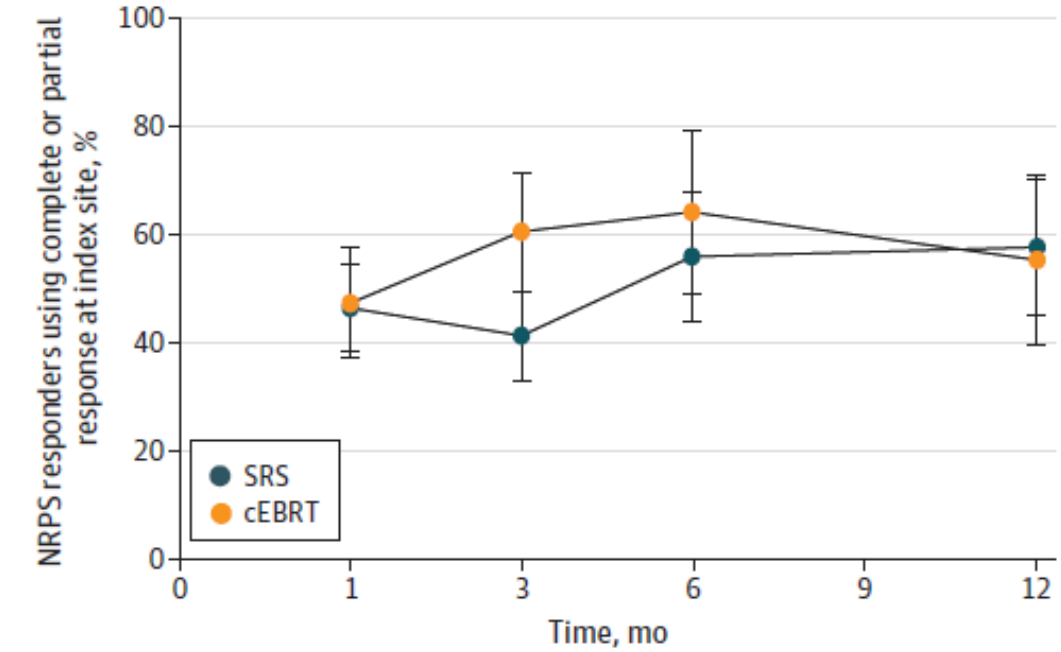
Toxicities SC24

	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

Sahgal Lancet Oncology 2021

Outcomes from RTOG 0631

- 339 patients randomized conventional RT 8 Gy/1 fx vs. SBRT 16-18 Gy/ 1fx



No. at risk				
SRS	153	138	68	59
cEBRT	93	76	39	38

Ryu JAMA Oncology 2023

Outcomes from RTOG 0631

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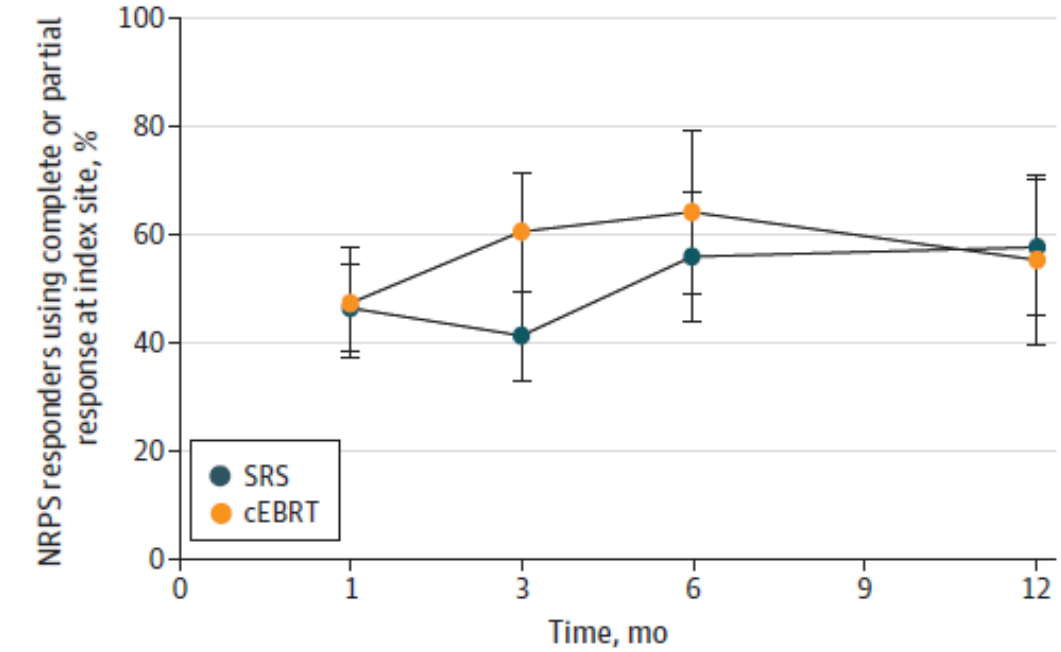

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SRS	153	138	68	59
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No evidence of improved pain response with SBRT!

Ryu JAMA Oncology 2023

Outcomes from RTOG 0631

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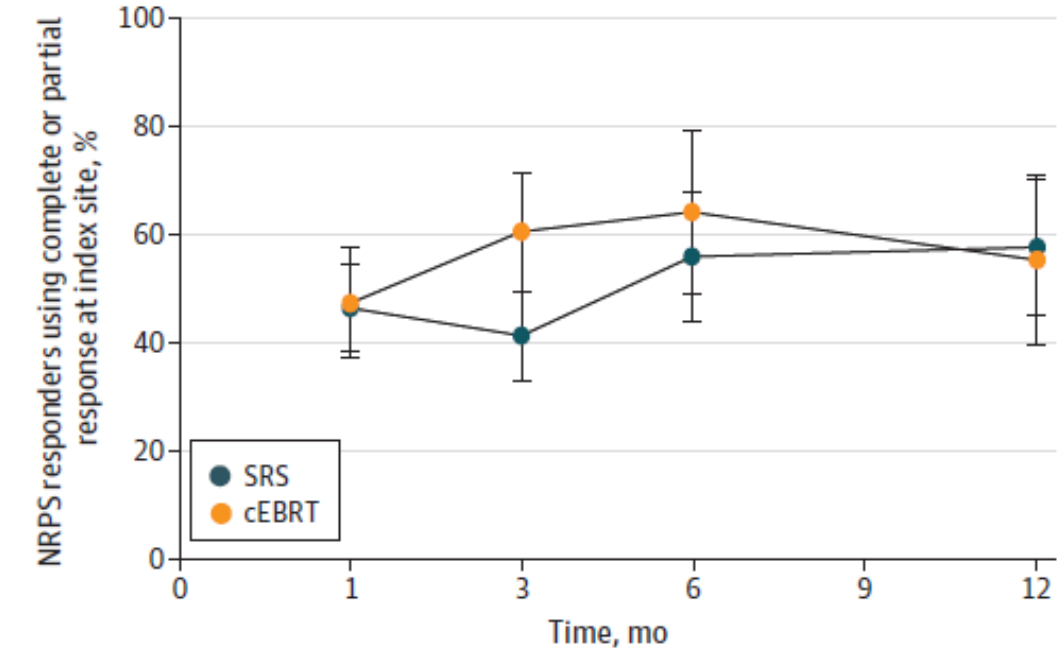


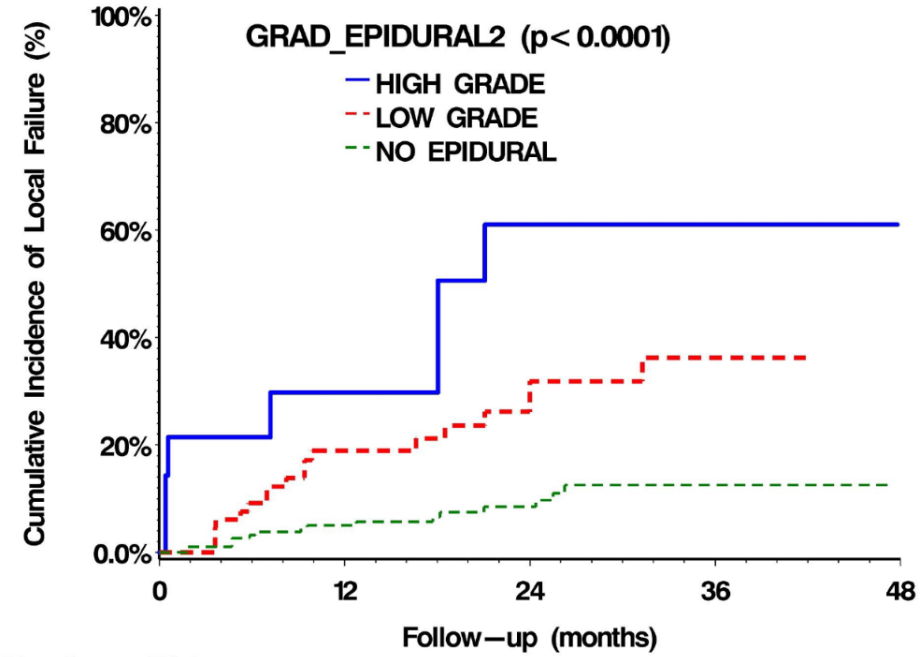
No. at risk				
SRS	153	138	68	59
cEBRT	93	76	39	38

Partial (3 point improvement) or complete pain response at 3 months 41.3% for SBRT and 60.5% cEBRT

Ryu JAMA Oncology 2023

Epidural Disease Impacts LR

24 Gy in 2 fractions

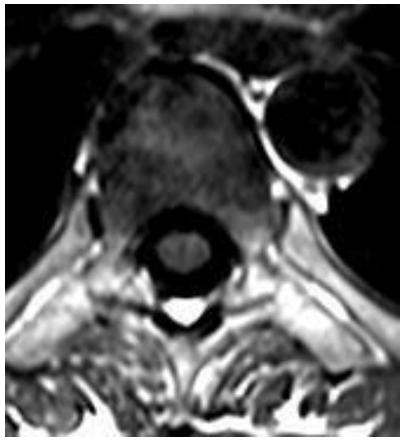


Number at Risk					
HIGH GRADE	14	5	1	1	0
LOW GRADE	70	23	9	2	0
NO EPIDURAL	195	100	44	14	1

Tseng IJROBP 2018

Paraspinal Extension Impacts LC

Mass vs. non-mass lesions



- 1 year LC: 45.7% vs. 86.3%
- 2 year LC: 38.9% vs. 75.9%

Mizumoto IJROBP 2011

Paraspinal Extension Impacts LC

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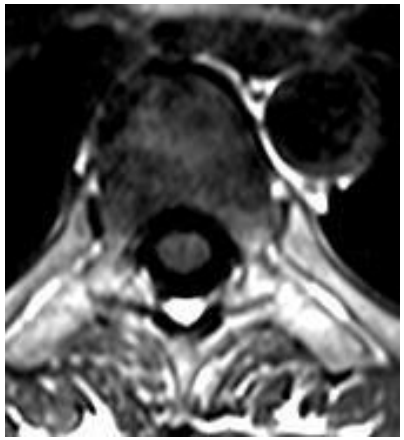

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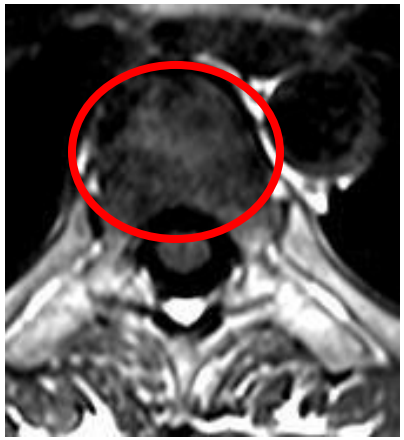


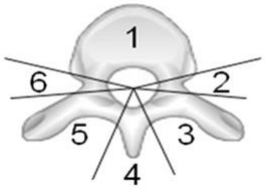
- 1 year LC: 45.7% vs. 86.3%
- 2 year LC: 38.9% vs. 75.9%

Mizumoto IJROBP 2011

Target Delineation

Consensus CTV for Intact Vertebrae

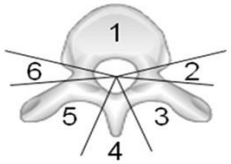
GTV involvement	CTV description
Any portion of the vertebral body	Include the entire vertebral body
Lateralized within the vertebral body	Include the entire vertebral body and the ipsilateral pedicle/transverse process
Diffusely involves the vertebral body	Include the entire vertebral body and the bilateral pedicles/transverse processes
GTV involves vertebral body and unilateral pedicle	Include entire vertebral body, pedicle, ipsilateral transverse process, and ipsilateral lamina
GTV involves vertebral body and bilateral pedicles/transverse processes	Include entire vertebral body, bilateral pedicles/transverse processes, and bilateral laminae
GTV involves unilateral pedicle	Include pedicle, ipsilateral transverse process, and ipsilateral lamina, ± vertebral body
GTV involves unilateral lamina	Include lamina, ipsilateral pedicle/transverse process, and spinous process
GTV involves spinous process	Include entire spinous process and bilateral laminae



Cox IJORBP 2012

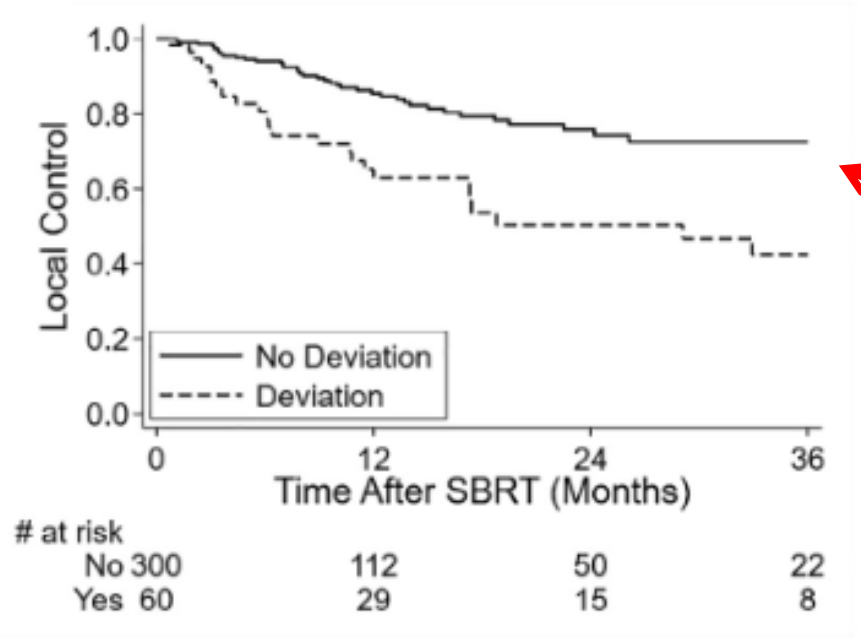
Post-Op CTV based on Pre-Operative Extent

Preoperative epidural involvement	Postoperative CTV description
Circumferential epidural disease	Circumferential treatment including the preoperative body, bilateral pedicles, bilateral transverse processes, bilateral laminae, and spinous process
Anterior epidural involvement in region of central body	Preoperative body
Anterior epidural involvement in lateral region of body	Preoperative body plus ipsilateral pedicle ± lamina
Epidural involvement anteriorly in the region of the body and unilaterally in the region of pedicle	Preoperative body plus ipsilateral pedicle, ipsilateral transverse process and ipsilateral lamina
Epidural involvement anteriorly in the region of the body, unilaterally in the region of pedicle, and posteriorly in the region of the spinous process	Preoperative body plus ipsilateral pedicle, bilateral transverse process, bilateral laminae, and spinous process
Posterior epidural involvement in region of spinous process	Preoperative spinous process, bilateral laminae and bilateral transverse processes
Any of the above plus extensive paraspinal extension	As above plus coverage of the entire preoperative extent of paraspinal extension



Redmond IJROBP 2016

Patterns of Failure

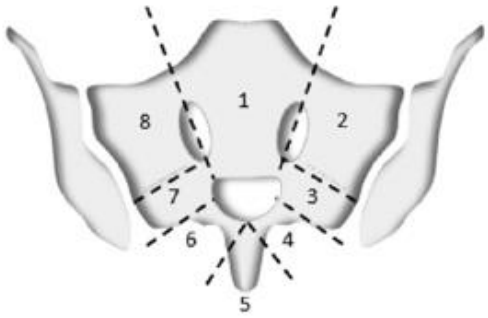


1 year LC 63% in patients with deviation from guidelines vs. 85.5% when adherent ($p<0.001$)

Chen Radiother & Oncol 2022

Sacral Consensus CTV

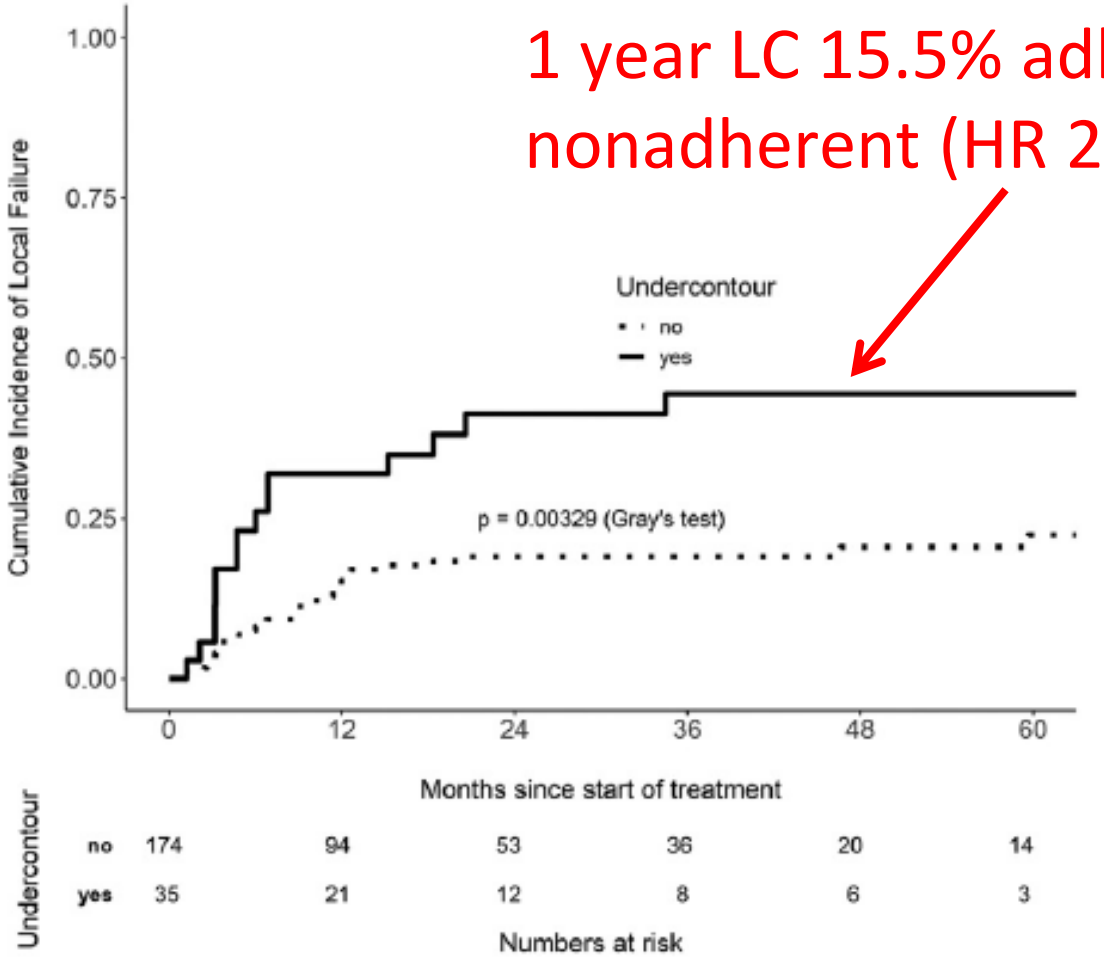
GTV involvement	CTV description
Any portion of the VB	Entire VB
Lateralised within the VB (S1–S2)*	Entire VB and the ipsilateral ala. When contouring the ala, use the ossification line if visible to limit the extent of the CTV. The superior and inferior extent of the CTV is determined by the superior and inferior extent of the adjacent VB†
Lateralised within the VB (S3–S5)*	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)*	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)*	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)*	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)*	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)*	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)*	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)*	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	Ipsilateral lamina, spinous process ± VB
GTV involves bilateral laminae	Bilateral laminae, spinous process ± VB
GTV involves spinous process	Spinous process and bilateral laminae



Dunne Radiother & Oncol 2020

Patterns of Failure

1 year LC 15.5% adherent vs. 31.4% nonadherent (HR 2.5; p=0.003)



Moore-Palhares IJROBP 2024

Data Regarding Prescription Dose

HyTEC Tumor Control Probability

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‡

Soltys IJROBP 2021

HyTEC Tumor Control Probability

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Soltys IJROBP 2021

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Soltys IJROBP 2021

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Soltys IJROBP 2021

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22*	94*	28†	90†	33†	90†	33*	85*	35*	83*
24*	96*	30‡	95‡	36‡	95‡	40‡	95‡	45‡	95‡

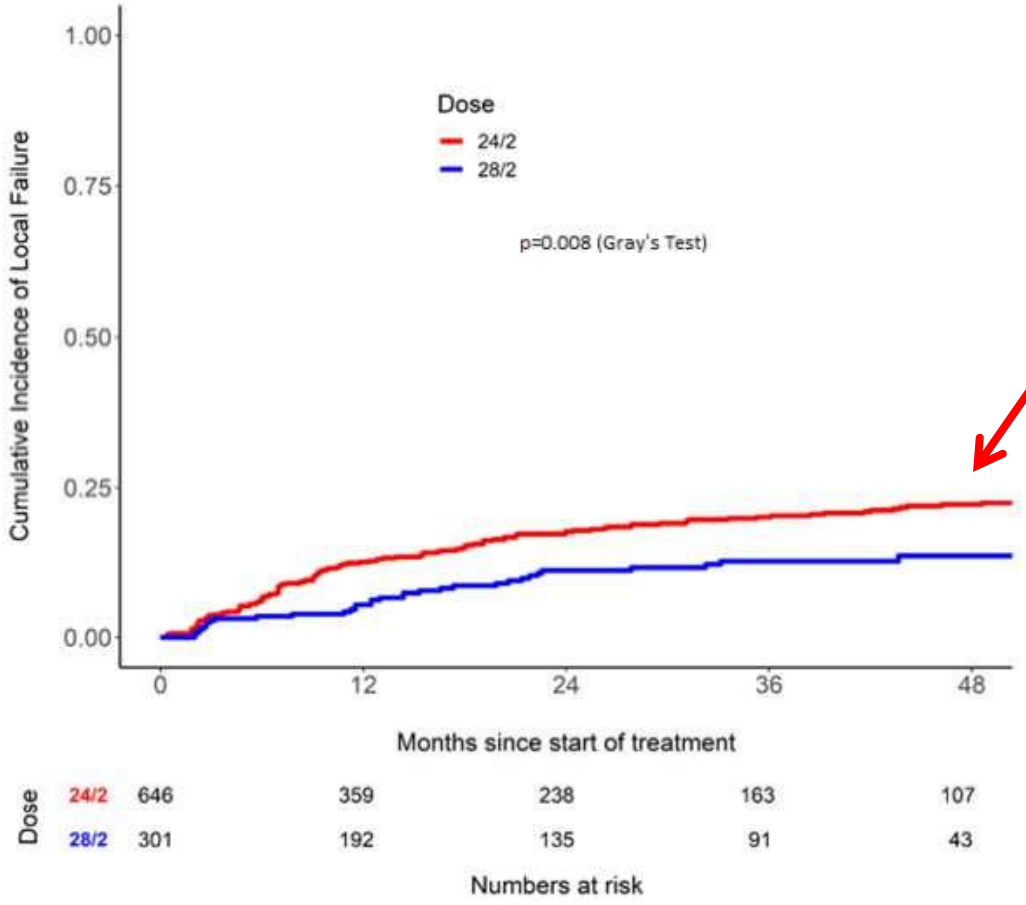
Soltys IJROBP 2021

Dose Escalation Improves LC!

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‡

Soltys IJROBP 2021

24 Gy/2 fx vs. 28 Gy/2 fx

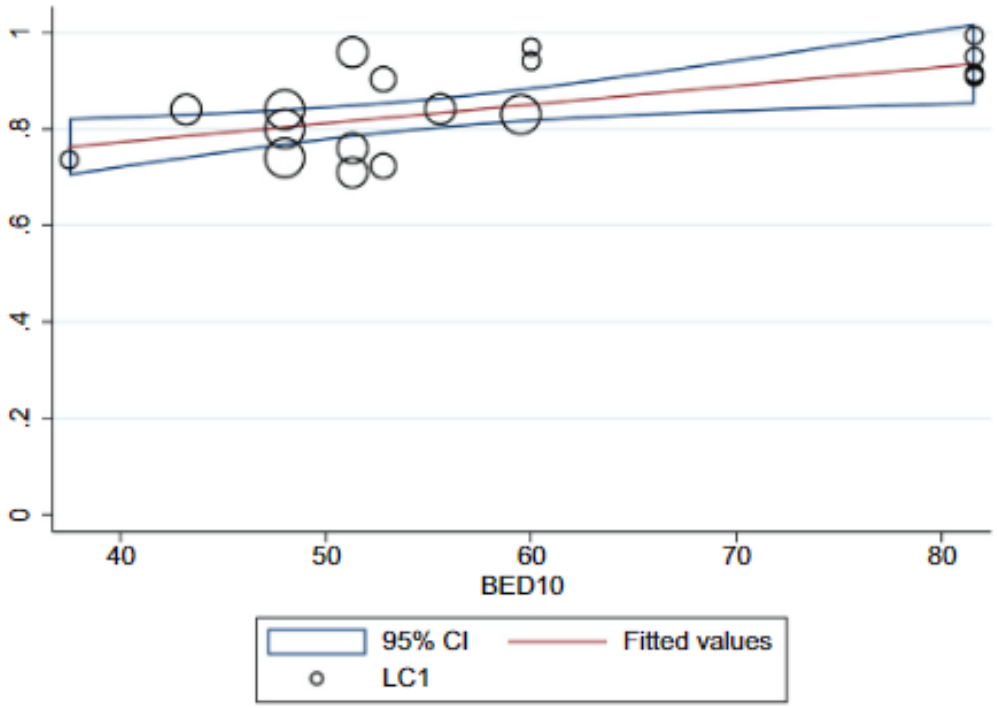


Superior LC with 28 Gy!

Zeng IJROBP 2023

SAFFRON Meta-Analysis

- 1 year LC based on BED_{10}

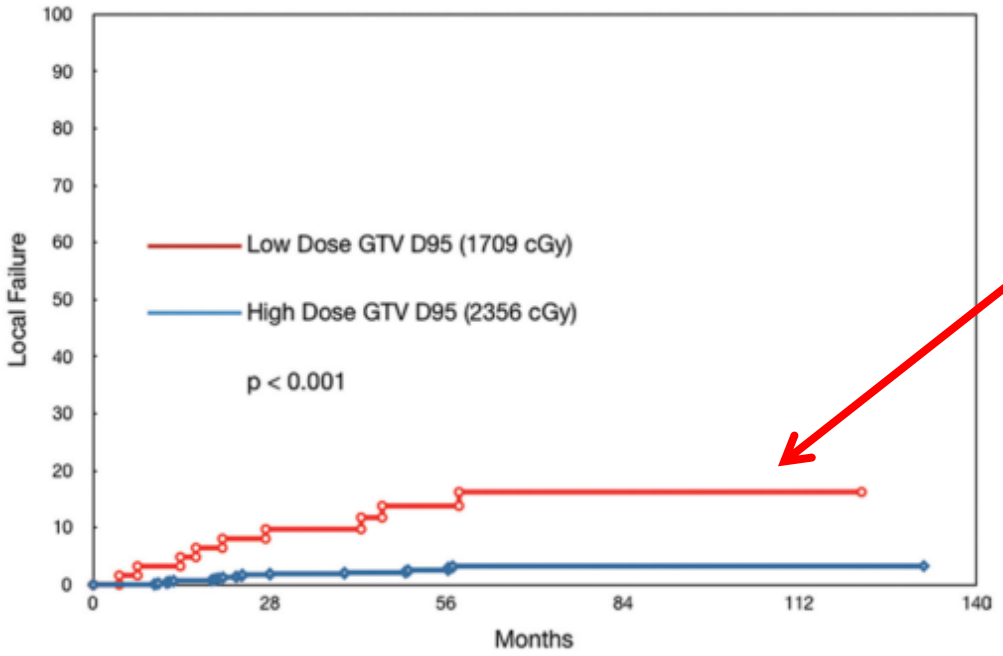


4.7% increase in LC for each 10 Gy BED_{10}!

Sing Radiother & Oncol 2020

Minimum Dose Contributes to LC

- D95 to GTV for single fraction SBRT

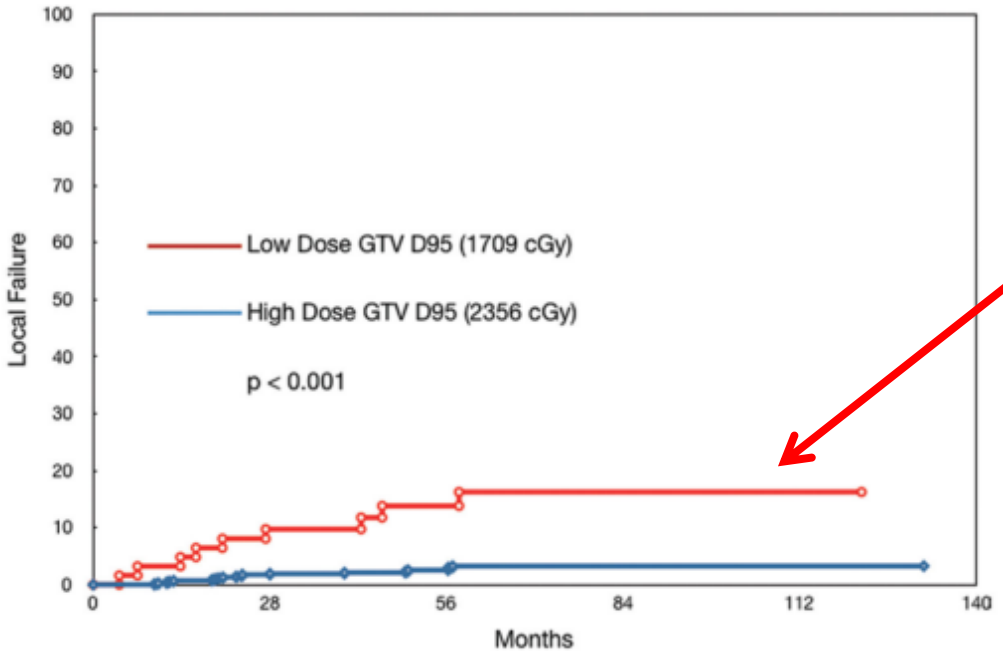


Increased local failure with D95 to GTV <18.3 Gy

Yamada Neurosurg Focus 2017

Minimum Dose Contributes to LC

- D95 to PTV for single fraction SBRT

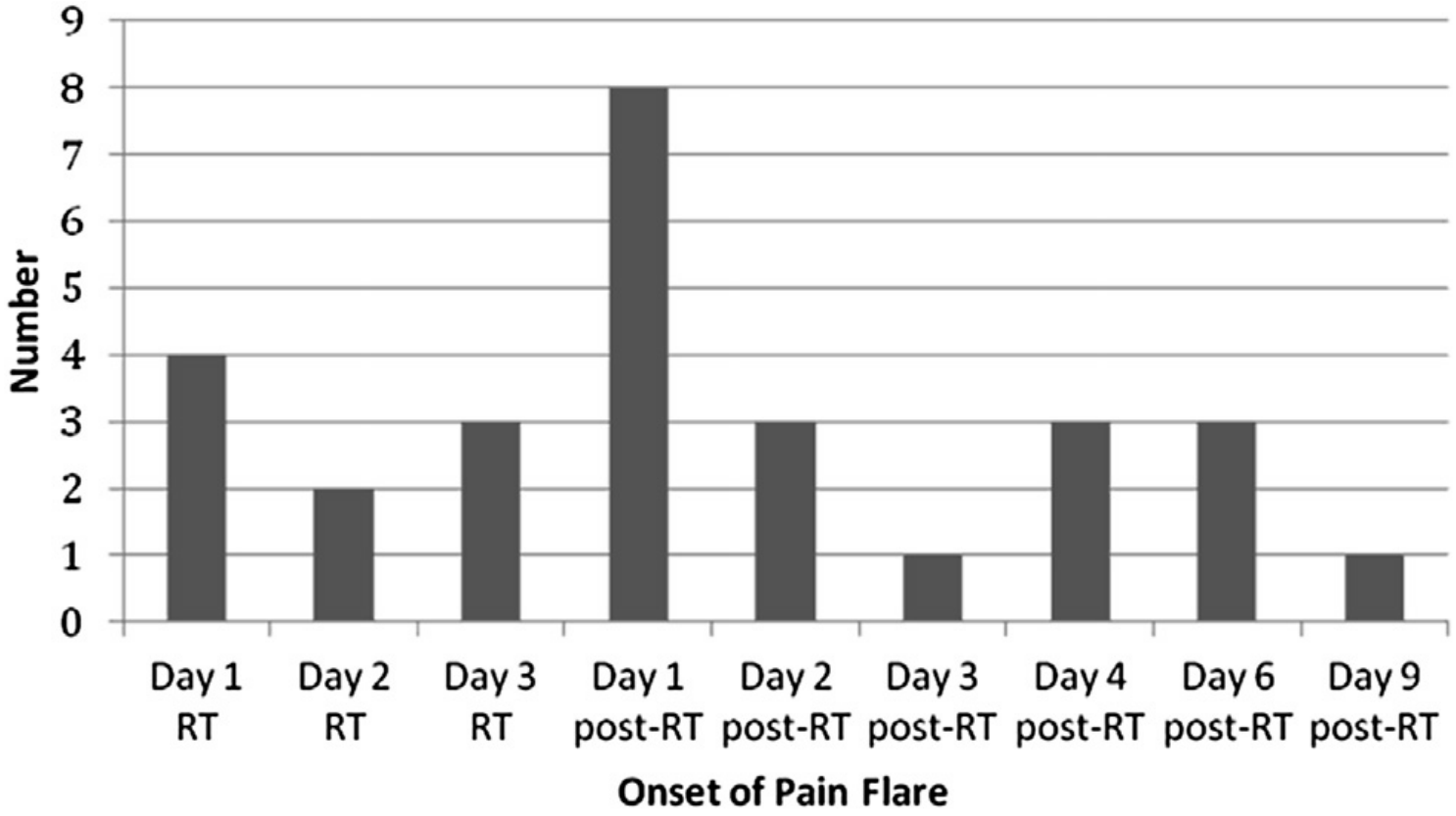


Increased local failure with D95 to PTV <17.4 Gy

Yamada Neurosurg Focus 2017

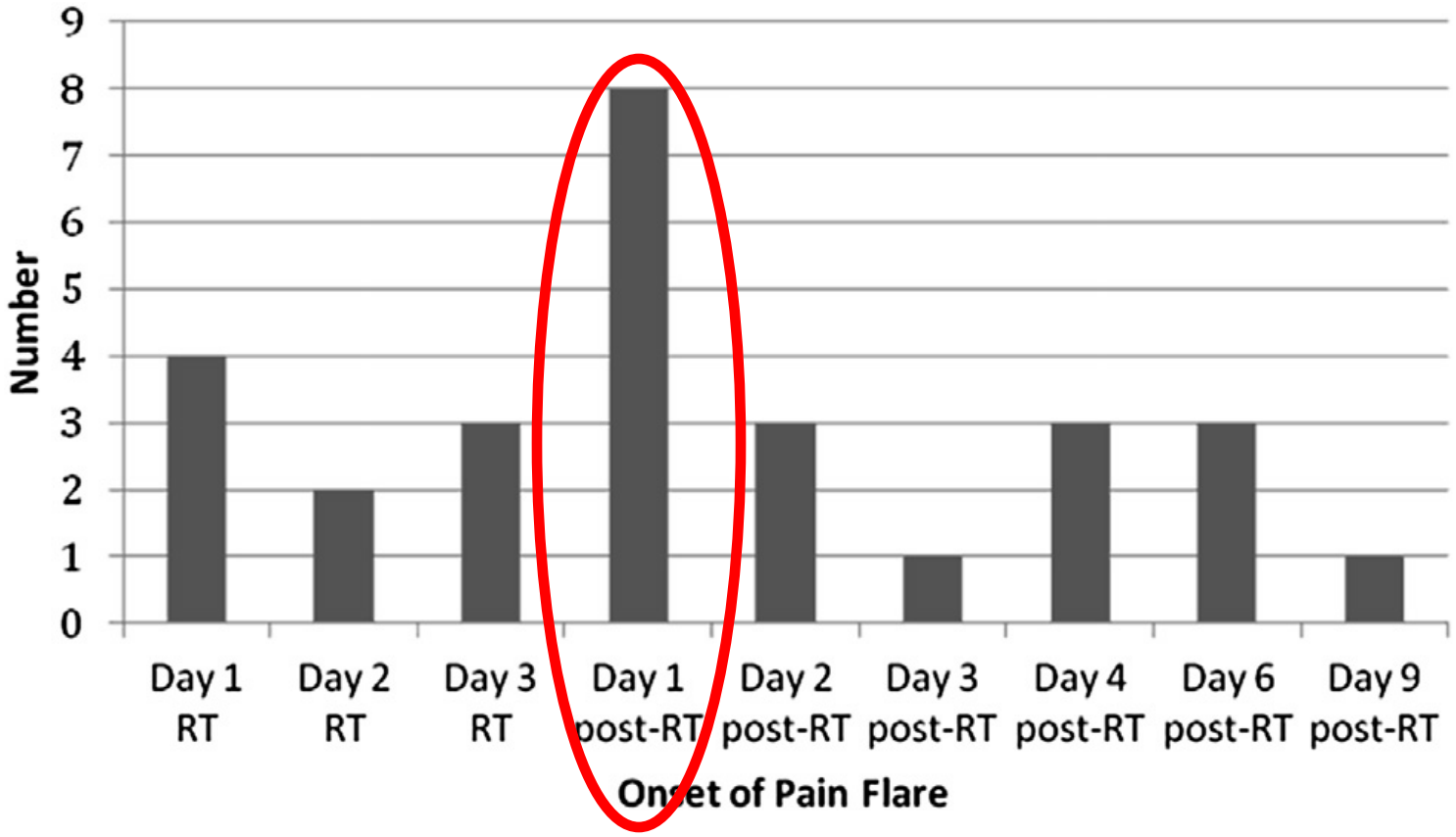
Toxicity

Acute toxicity: Pain Flare



Chiang IJROBP 2013

Acute toxicity: Pain Flare



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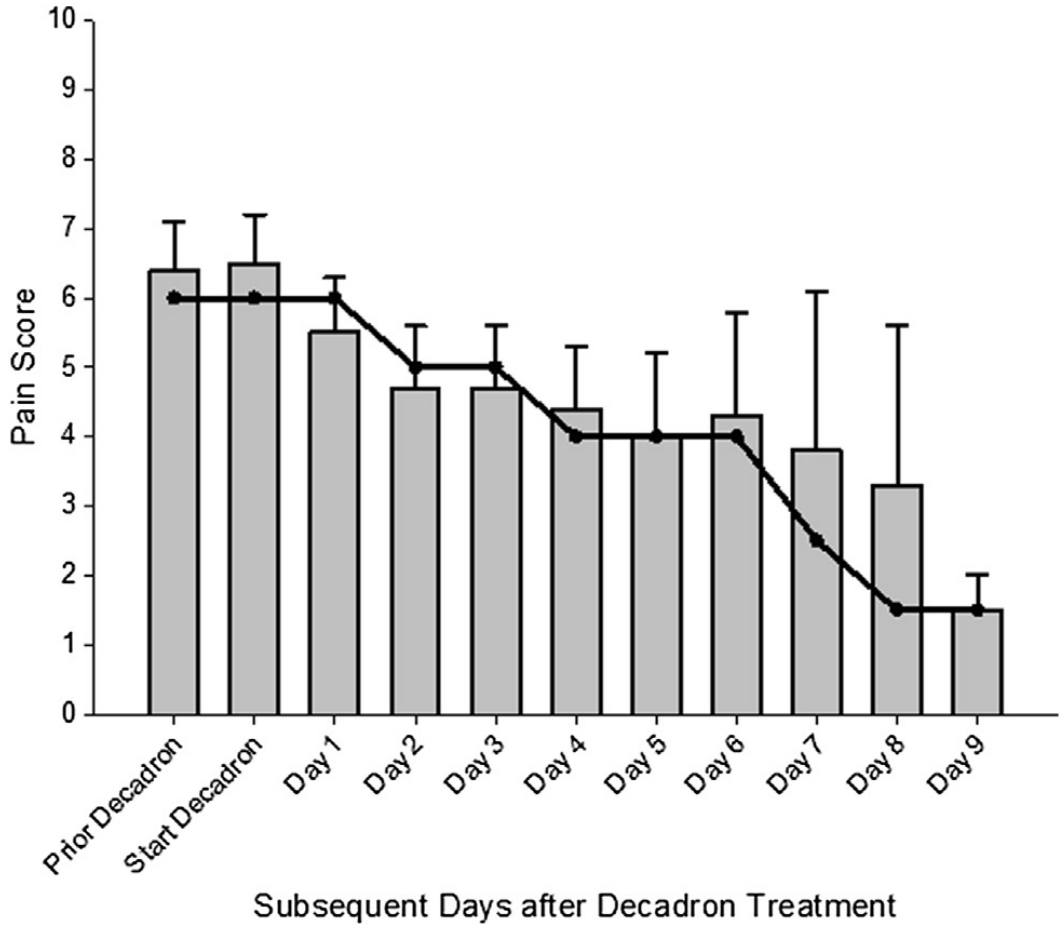

Chiang IJROBP 2013

Vertebral Compression Fracture: 24 Gy in 2 fraction to T7

Pre-RT

Treatment plan

3 months post SBRT

Chen Radiother Oncol 2020

Vertebral Compression Fracture: 24 Gy in 2 fraction to T7

Pre-RT

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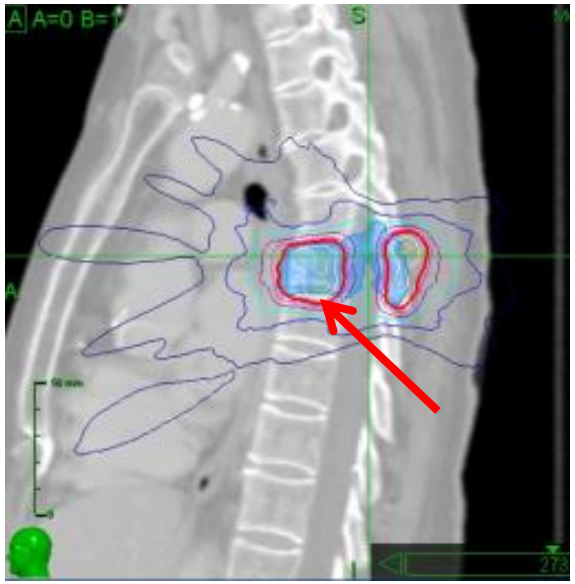
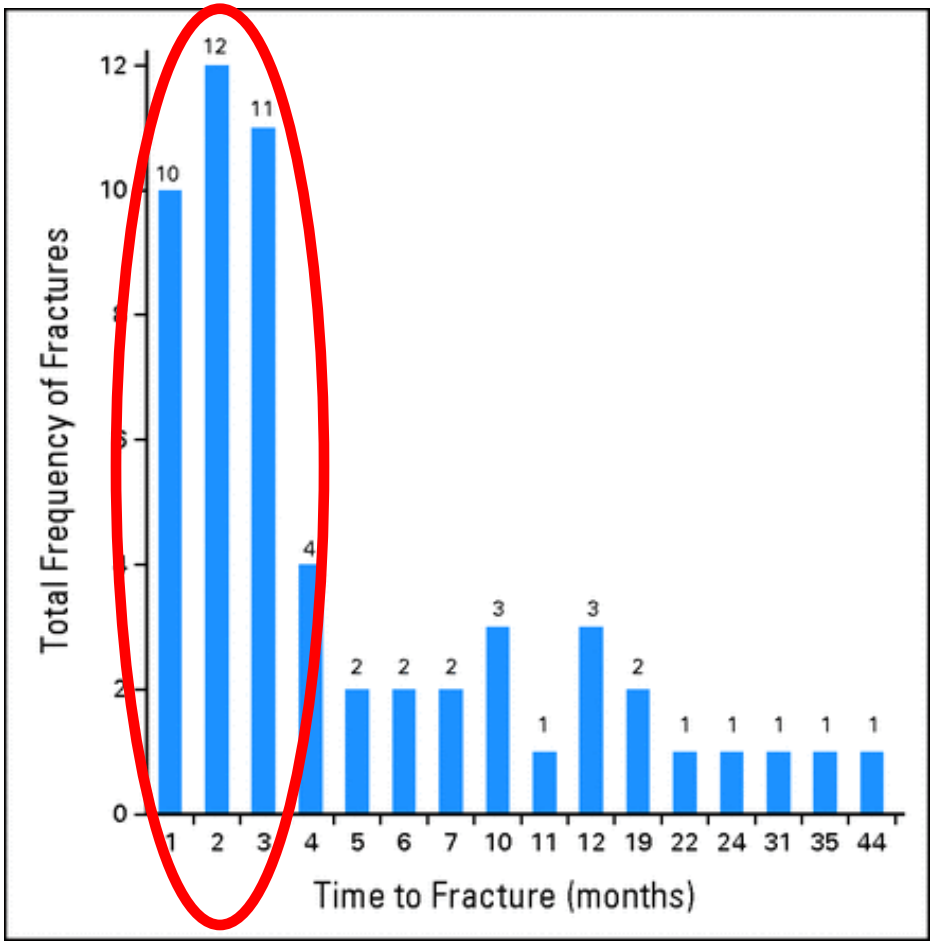


Treatment plan

3 months post SBRT

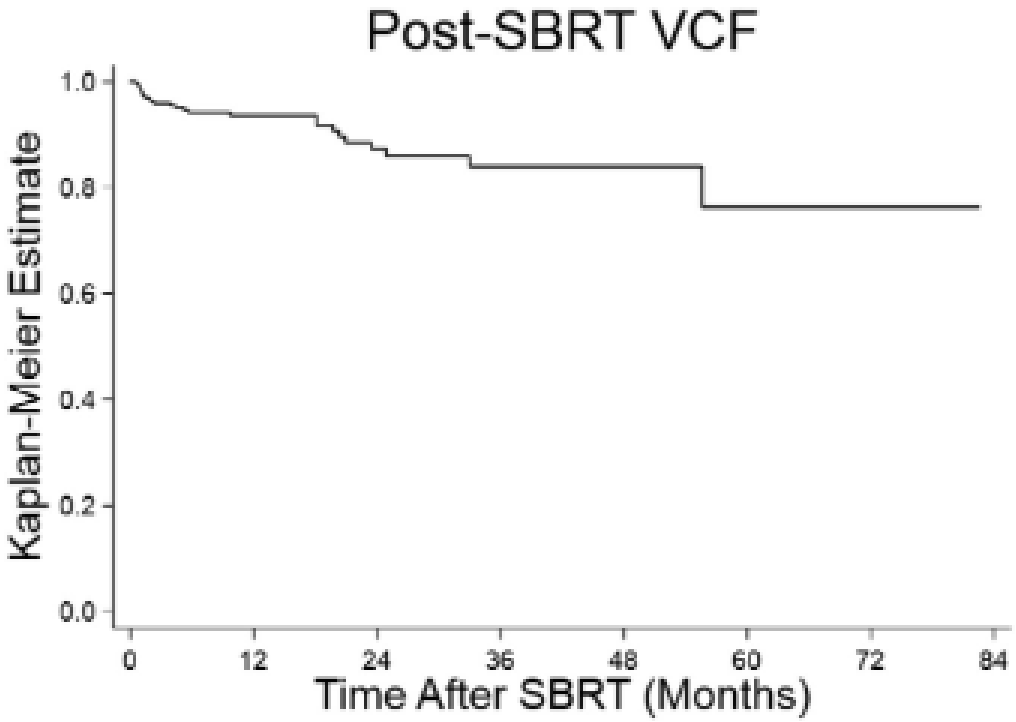
Chen Radiother Oncol 2020

Toxicity: Vertebral Compression Fracture



Saghal JCO 2013

Toxicity: Vertebral Compression Fracture



Chen Radiother Oncol 2020

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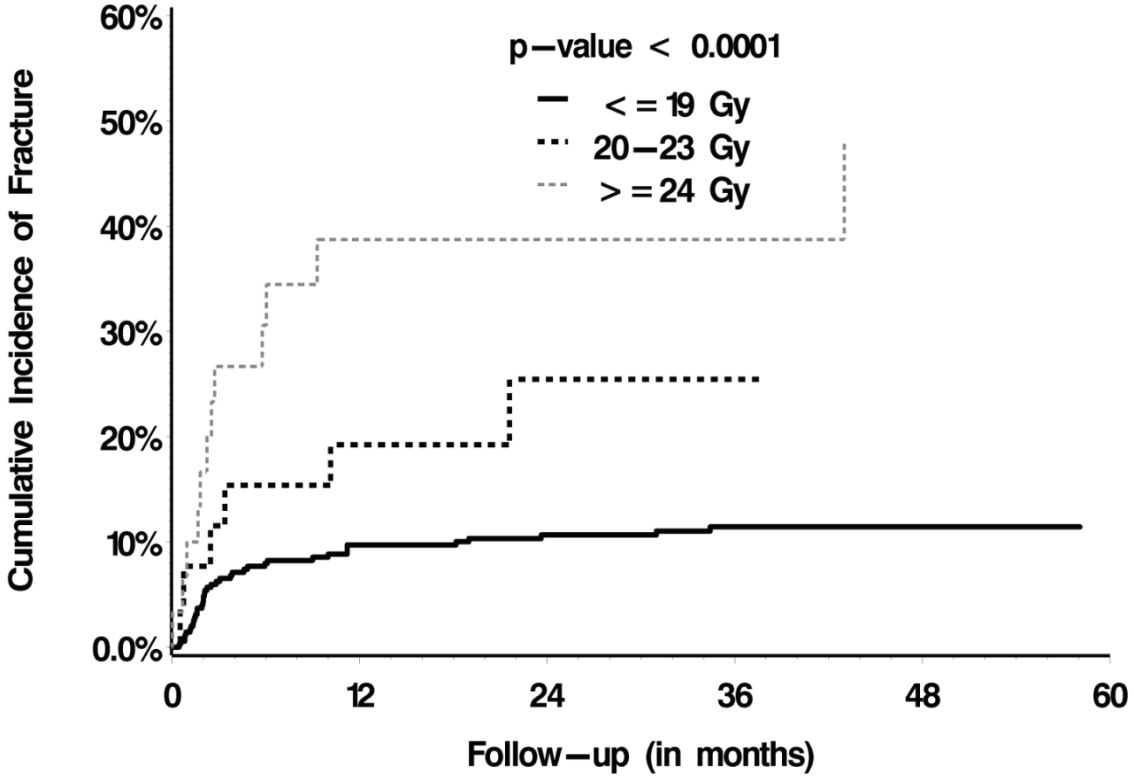
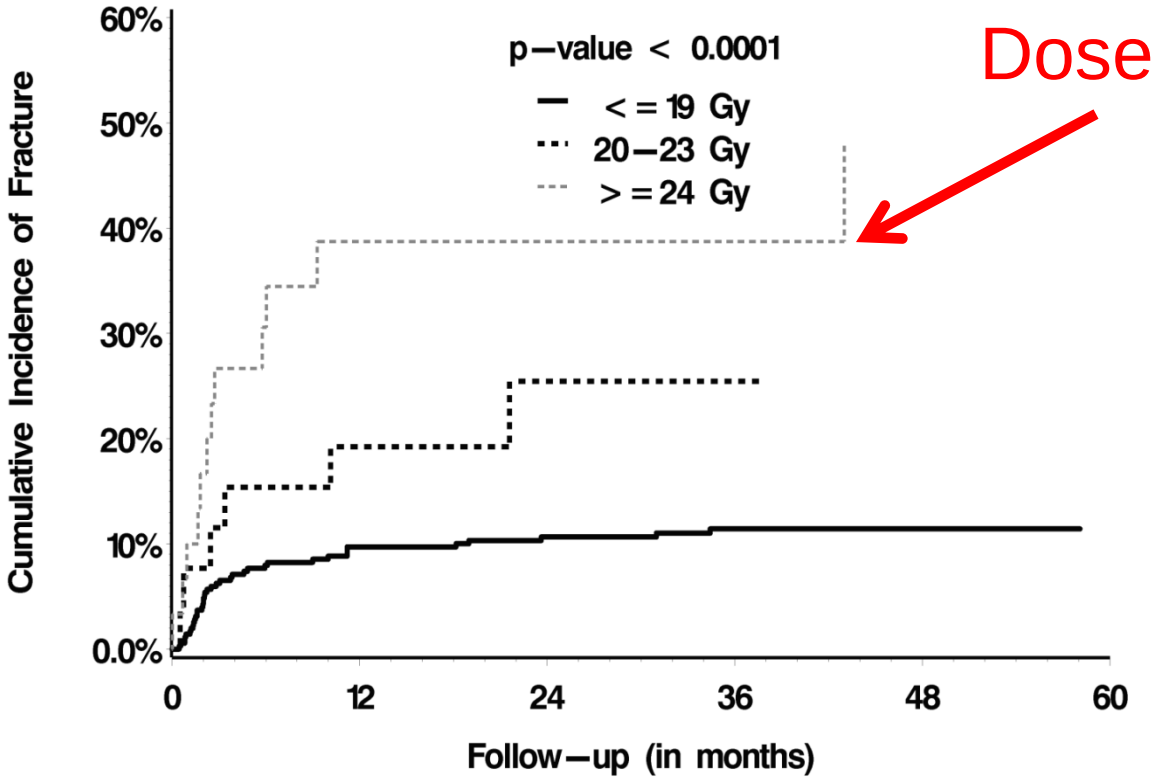


Saghal JCO 2013

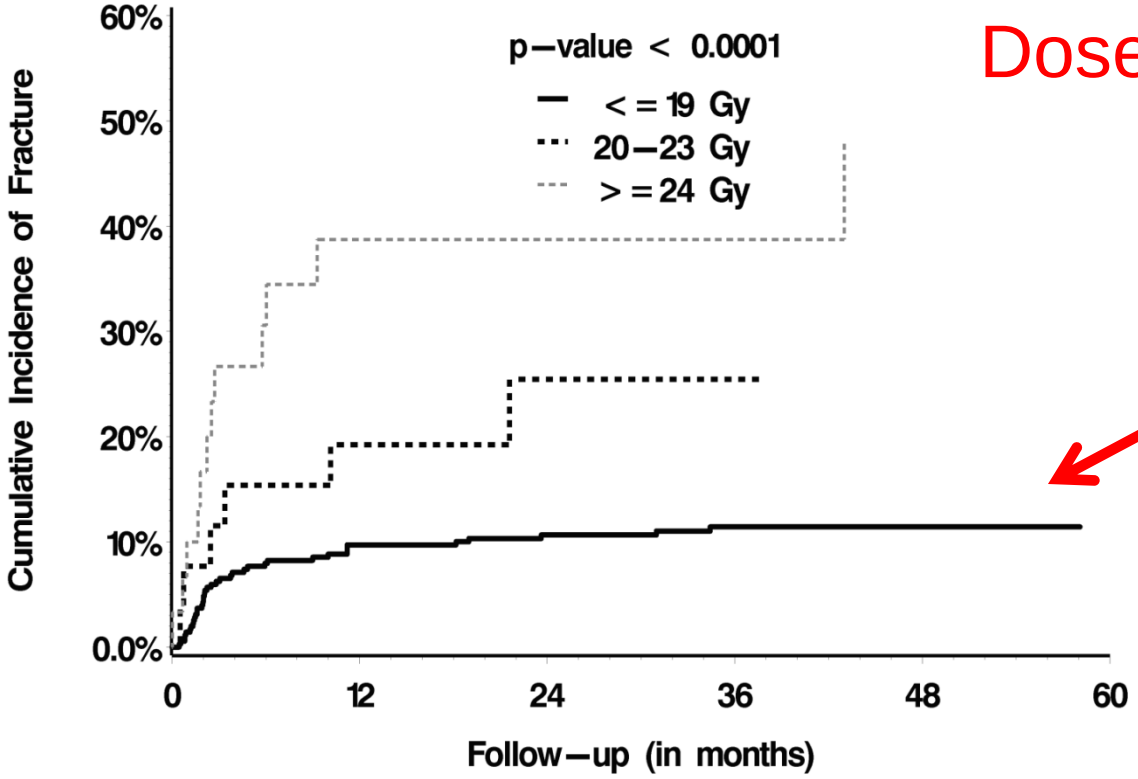
Toxicity: Vertebral Compression Fracture



Dose related!

Saghal JCO 2013

Toxicity: Vertebral Compression Fracture

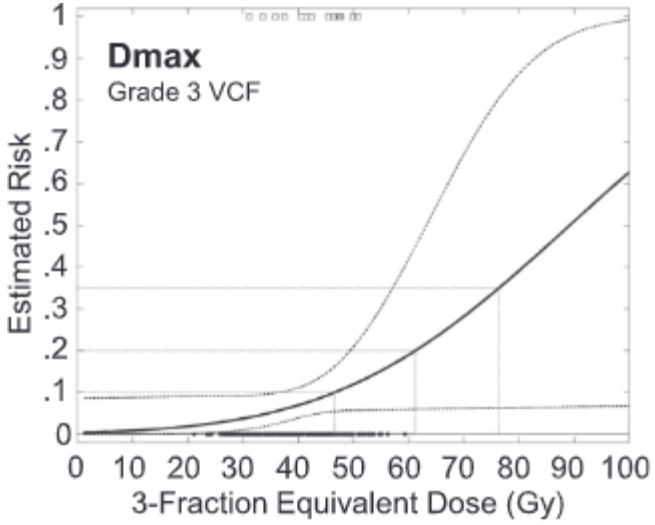


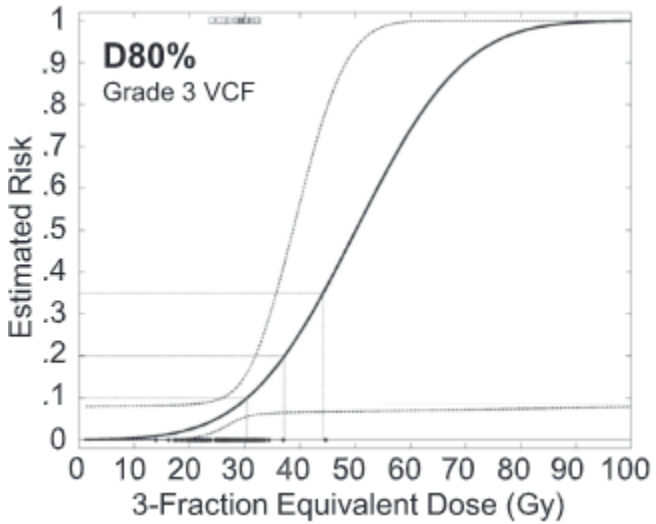
Dose related!

Saghal JCO 2013

Toxicity: Vertebral Compression Fracture

- Driven both by max dose and also low dose bath

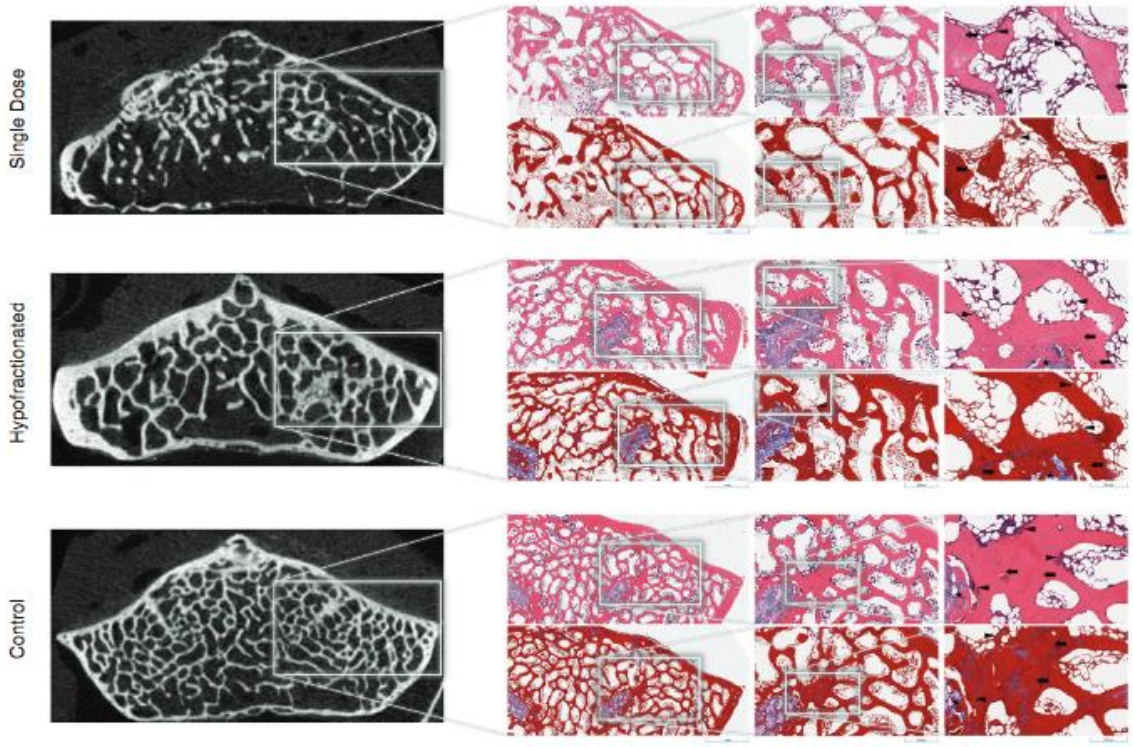




Chen Radiother Oncol 2020

Toxicity: Vertebral Compression Fracture

- Rabbits treated with 24 Gy/1 fx, 24 Gy/3 fx, sham RT

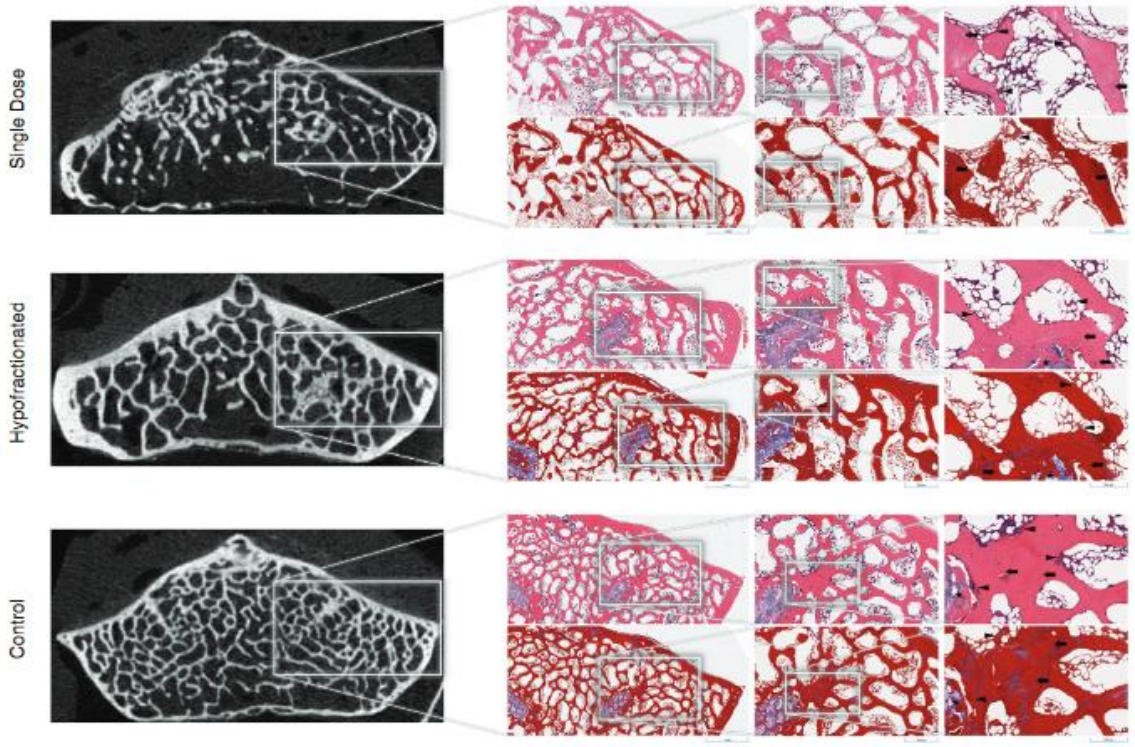


Single fraction increased porosity and decreased trabecular struts associated with reduced fracture loads and stiffness

Perdomo-Pantoja IJROBP 2021

Toxicity: Vertebral Compression Fracture

- Rabbits treated with 24 Gy/1 fx, 24 Gy/3 fx, sham RT

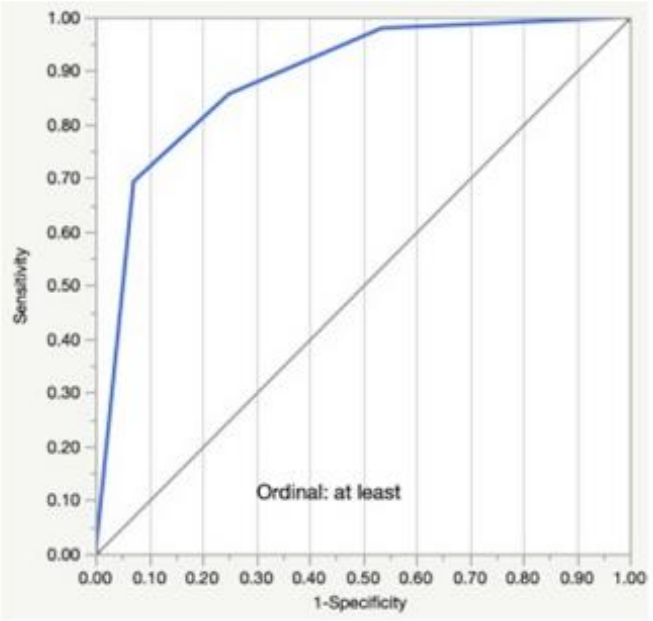


Hypofractionation reduced trabecular number but preserved trabecular cellularity and increased thickness associated with similar fracture load and stiffness as control group

Perdomo-Pantoja IJROBP 2021

Toxicity: Vertebral Compression Fracture

- Pre-SBRT score to assess trabecular bone quality based on T1 pre MRI predicts VCF



Ehresman JNS 2020

Toxicity: Spinal Cord Myelopathy

	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

Abbreviations: AAPM TG101 = American Association of Physicists in Medicine Task Group 101; CT = computed tomography; D_{max} = maximum

Saghal IJROBP 2021

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Saghal IJROBP 2021

Conclusions

- Improvements in RT technology allowing increasingly precise stereotactic techniques
- Excellent tumor control outcomes
- Low toxicity
- Future direction: minimally invasive techniques to stabilize and decompress followed by SBRT