

HyTEC Spinal Cord Dose Limits for Spine SRS/SBRT

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*A total of ~ 40 spine SBRT papers reviewed

Historical Dose Limits: TD5/5 - TD50/5

Conventional 47 - 50 Gy 60-70 Gy



P Rubin (1974) The radiographic expression of radiotherapeutic injury: An overview, Vol 9, Sem Roentgenology
Emami et al (1991) Tolerance fo Normal Tissue to Therapeutic Irradiation, Vol 21 IJROBP



Clinical Investigation: Central Nervous System Tumor

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

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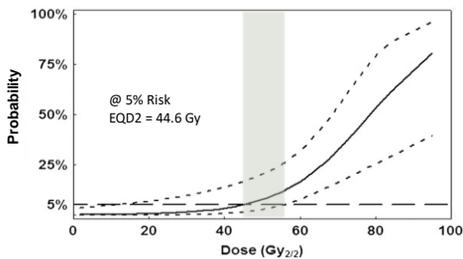
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Dosimetric Data

- Worldwide institutions
- 9 RM cases; 66 random control cases
- RM cases: Thecal Sac $D_{max} = 10.6$ to 16.2 Gy /Fx; 25.6 Gy /2Fx; 30.9 Gy /3Fx
- EQD2 modeled ($\alpha/\beta = 2$ Gy)

Logistic Regression Curve for RM



Int J Radiat Oncol Biol Phys, 2013, 85(2), 341-7

Estimated Dose Limits

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

Int J Radiat Oncol Biol Phys, 2013, 85(2), 341-347

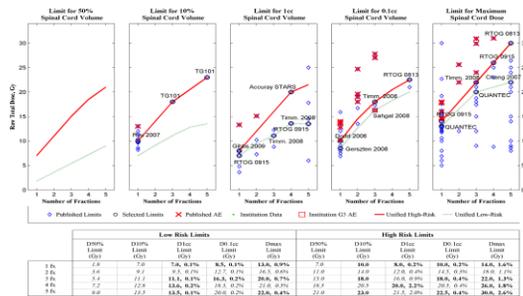


Estimated Risk Level of Unified Stereotactic Body Radiation Therapy Dose Tolerance Limits for Spinal Cord

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Clinical Investigation

A Detailed Dosimetric Analysis of Spinal Cord Tolerance in High-Dose Spine Radiosurgery



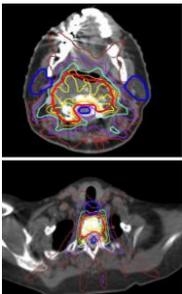
Evangelia Katsoulakis, MD,^{2*} Andrew Jackson, PhD,¹ Brett Cox, MD,¹ Michael Lovelock, PhD,¹ and Yoshiya Yamada, MD^{2*}

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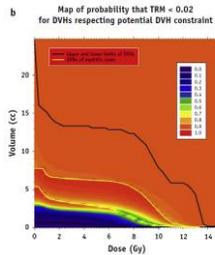
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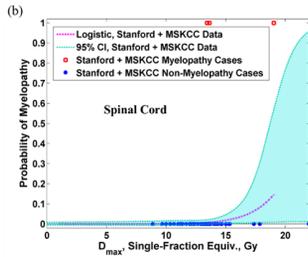
Dosimetric Data

- 2 RM cases; 228 patients; 259 lesions
- All are single fraction delivery
- RM cases: Cord D_{max} = 13.4 Gy and 13.6 Gy
- DVH atlas obtained for all cases published on-line in Supplementary Data



Median Cord Dmax = 13.85 Gy
for 2 RM cases out of 295 cases
Therefore 14 Gy /1Fx appears safe (<1% risk)





The logistic model of Gibbs 2007 (1/19)+ Katsoulakis 2017 (2/259) data in single-fraction equivalent dose (GK model) is shown; since the confidence intervals extend all the way from 1% to 96% at high dose, the model itself was only plotted at lower dose.

Re-Irradiation Dose Limits



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CLINICAL INVESTIGATION **Central Nervous System Tumor**

REIRRADIATION HUMAN SPINAL CORD TOLERANCE FOR STEREOTACTIC BODY RADIOTHERAPY

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Re-Irradiation RM Cases

Patient and tumor	Age	Tumor type	Spine tumor location and target volume (cc)	Prex EBRT (total dose Gy/Prx BED) (nBED)	SBRT Re-irradiation tumor dose (Gy/Prx BED) (nBED) (isodose %)	Time interval to SBRT (months)	Time to RM after re-irradiation (months)	Follow up Post-SBRT (months)	Status last follow up
A	55	Breast	T5 (18.7)	40/22 (76 Gy)	292/80 (38 Gy)	81	6	55	Alive/ Non-plagic
B	59	Breast	T1 (18.8)	25/25 (37 Gy)	212/69 (37 Gy)	70	5	29	Alive/ Chair bound
C*	63	Renal Cell	T11, T12 (319)	21/25 (46 Gy)	143/100 (33 Gy)	11*	3	17	Alive/ Non-plagic
D	42	Chordoma	C1/C2 (31.3)	51/92 (100 Gy)	335/83 (50 Gy)	18	8	11	Alive/ Sensory deficit
E	54	Renal cell	T10 (46.4)	43/215 (52.8 Gy)	161/88 (32.8 Gy)	12	3	3	Dead

Abbreviations: BED = biologically effective doses; C = cervical; EBRT = external beam radiation; Pr = fraction; L = lumbar; nBED = normalized BED; RM, radiation myelopathy; SBRT = stereotactic body radiotherapy; T = thoracic.
* re-irradiation was given 11 months post-SBRT as patient was initially treated with SBRT for the irradiated with conventional EBRT. Tumor location refers to the location of the vertebral treated in the spine. The tumor volume refers to the planning target volume treated in cc.

Challenging Issues

- Cord vs. PRV (e.g. 1-2 mm margin or Thecal Sac)
- LQ formula (e.g. EQD2 to 1Fx dose conversion)
- Dmax Specifications (e.g. Plan vs. Delivered Dose)

Summary

- **De novo Treatment:** Point maximum doses (Dmax) as conservative thresholds for approximate 1-5% risk between 12.4 (Sahgal) - 14.0 Gy (Gibbs/Katsoulakis) @1Fx, via LQ the following limits at higher fx number: 17.0 – 19.3 Gy/2Fx, 20.3- 23.1 Gy/3Fx, 23.0- 26.2 Gy/4Fx, 25.3 – 28.8 Gy/5Fx
- **Re-Irradiation**
 - (1) < 70 Gy in total EQD2
 - (2) < 25 Gy EDQ2 and < 50% for the SBRT portion
 - (3) > 5 months in minimum time interval
