SRS: Cranial and Spine

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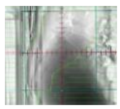
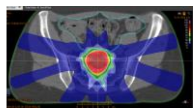
- MGH has received research support from Raysearch

Overview

- Linac SRS
  - Spine
  - Cranial
- Proton SRS

Overview: Spine

- Several treatment options exist for spinal metastases:
  - Surgery: decompression, en bloc resection, stabilization, minimally invasive
  - Augmentation: vertebroplasty or kyphoplasty
  - Radiation therapy: conventional or stereotactic radiosurgery

Spine metastases

- About 40% of cancer patients develop vertebral metastases: serious consequences pain, paralysis, quality of life
  - Common primary sites: breast, melanoma, renal, lung, and prostate
- Palliative low-dose radiotherapy is well established evidence-based treatment
- Limited long-term efficacy of conventional palliative RT

- **Dose-intensified spine radiosurgery / SBRT**
- Practiced by 44% of US Radiation Oncologists (*Pan Cancer 2011*)
- Quicker and more durable pain relief and local tumor control

ASTRO 2013 - Multi-institutional Spine SBRT
Guckenberger M, et. al.

Overview

- Focus on minimizing morbidity of spine care in order to:
  - Improve pain control and quality of life
  - Maximize opportunities for systemic therapy
  - Retain durable local control
- Use of intensity modulated treatment modalities to increase dose to GTV/CTV/PTV while avoiding dose to critical structures: cord, cauda, esophagus

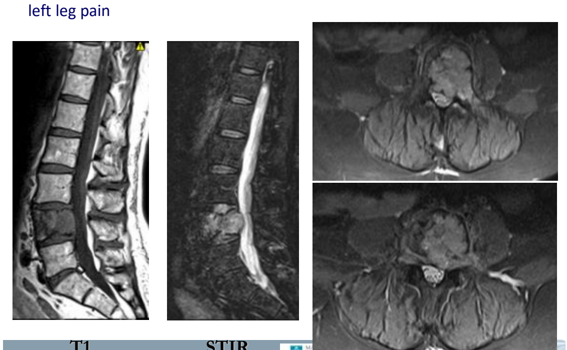
Spine Radiosurgery

- Benefits
  - Single session
  - Higher dose to tumor ("radioresistant")
  - Retreatment after failed conventional RT ("salvage")
  - Multimodality therapy to minimize extent of resection ("separation surgery")
- Potential drawbacks
  - Vertebral body fractures which are dose-dependent
  - Reoccurrence local to the cord

Oh K, et. al.

Case #1: Solitary and radioresistant metastasis

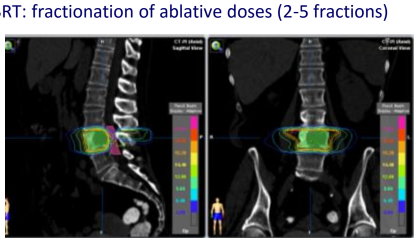
68 yo with metastatic RCC and solitary L4 metastasis causing back and left leg pain



Oh K, et. al.

Stereotactic Body Radiation Therapy "Spine Radiosurgery"

- SRS: Delivery of a high radiation dose (18-24 Gy) in a single fraction with high precision
- SBRT: fractionation of ablative doses (2-5 fractions)



Stereotactic Body Radiation Therapy: Outcomes

Study	Year	N (tumors)	Fractionation (median)	Are salvage RT	pain relief	local control
HFH Detroit	2005	61	10-16 Gy x 1	0%	85%	93%
U Pitt	2007	500	20 Gy x 1	69%	86%	88%
MDACC	2007	74	6 Gy x 5 or 9 Gy x 3	56%	NR	77%
MSKCC	2008	103	24 Gy x1	0%	NR	90%
PMH	2009	60	8 Gy x 3	62%	67%	85%
Taiwan	2009	127	7.75 Gy x 2	22%	88%	97%

Histology	N (tumors)	dose	pain relief	local control
Breast	83	20 Gy x 1	96%	100%
Lung	80	20 Gy x 1	93%	100%
Renal cell	93	20 Gy x 1	94%	87%
Melanoma	38	20 Gy x 1	96%	75%

median follow-up = 21 months
from Gerszten et al. Spine 2007;32: 193-9

Toxicity

Acute toxicity

	Dermatitis	Dysphagia	Pain
Tox assessment	322	324	348
G0	307	290	290
G1	15	31	35
G2	0	3	20
G3	0	0	3

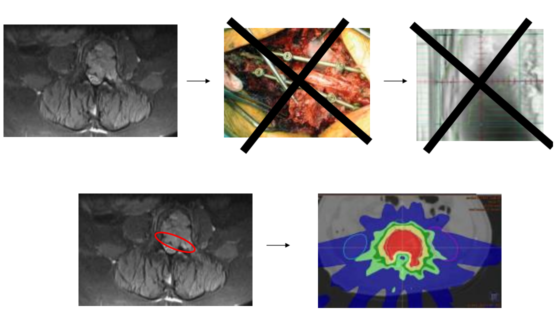
Fracture

	New fracture	Progressive fracture
Tox assessment	403	400
Positive	17 (4.2%)	21 (5.3%)

- Low rates and low grade acute toxicity
- 10% fracture rate, but 50% progressive fracture
- No case of radiation induced myelopathy

ASTRO 2013 - Multi-institutional Spine SBRT
Guckenberger M, et. al.

Case #1 revisted: Solitary and radioresistant metastasis



Oh K, et. al.

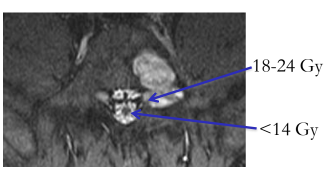
Immobilization and Visualization

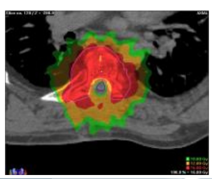
- Rigid immobilization using custom body mold and vacuum bag (BodyFix) or QFix (Mask) for upper T-spine and C-Spine
- Real-time imaging in treatment position with integrated robotic couch



Treatment Planning

- Dose constraints:
  - Spinal cord < 10-14 Gy x 1
  - Cauda equina < 16 Gy x 1
  - Sacral plexus < 18 Gy x 1

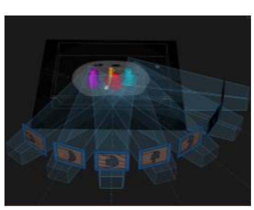




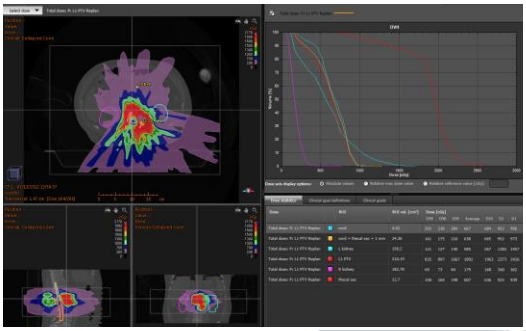
Oh K, et. al.

Planning

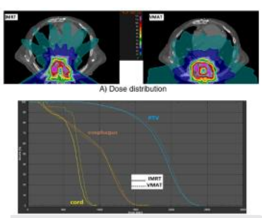
- IMRT or VMAT
- Coplanar 7-9 beams/2-3 arcs
- Posterior (Anterior used for Cervical Vertebral locations)
- ~20 deg separation
- Collimator Rotation Can Reduce MUs



Final Dose



IMRT versus VMAT



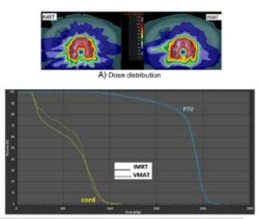


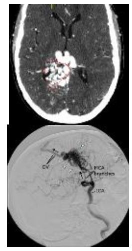
Table 2 Monitor units (MU) and delivery time (average ± SD) comparison for MCO-IMRT and VMAT with or without collimator rotation

Variable	Colli: 0		Colli: Rot	
	MCO-IMRT	VMAT	MCO-IMRT	VMAT
MU	6216 ± 756[a]	5861 ± 896[b]	4681 ± 726[a]	4360 ± 722[b]
Delivery time (min)	–	–	18.3 ± 2.5[c]	14.2 ± 2.0[c]

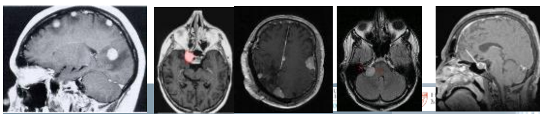
Chen *et al* PRO 2015 "Efficiency Gains for Spine SRS using MCO IMRT guided VMAT Planning"

Linac Cranial SRS

Diseases



- Cranial lesions
  - Mets from Lung, Breast, Melanoma, other sites
  - Gliomas
  - Benign: schwannomas, meningiomas, Acromegaly
  - AVMs



SRS dose

Factors to consider

- histology
- size
- proximity to OARs
- prior radiation therapy
- patient situation
- Typical range of 18-24 Gy with normalizations of 70-90%

Patient care after SRS

Potential Side-Effects

Acute (hours)

- Seizure
- Fatigue
- Hair loss
- Nausea/vomiting (uncommon)
- Edema from pin sites

Late (months-years)

- Radionecrosis requiring steroids and/or surgery

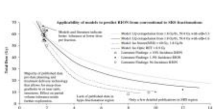


Fig. 2. Isoeffect linear-quadratic model extrapolations and alternative biologically effective threshold models (curves) compared with reported maximum optic nerve/chiasm doses detailing incidence of radiation-induced optic neuropathy (RION) (symbols) for full range of dose per fraction. Linear-quadratic model was unreliable for extrapolating from fractionated (1.8–2.0-Gy/fraction) dose range to single-fraction range. Detailed data needed for low (<1.8 Gy) and hypofractionated regions to better define organ response.

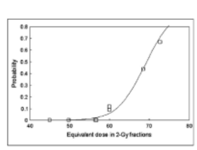
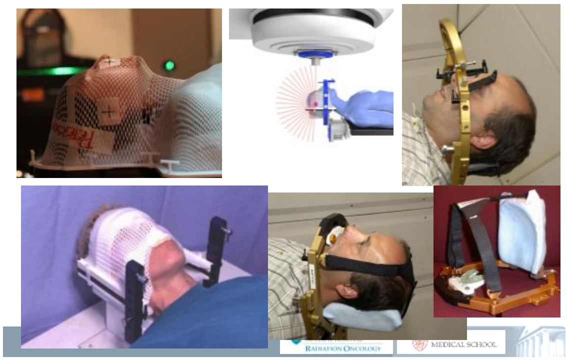
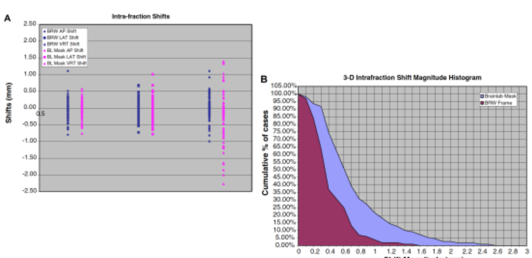


Fig. 1. The dose–response function for the myelopathy of the cervical spinal cord and data points (□) derived from Table 1. The probability of myelopathy was calculated from the data in Table 1, adjusted for estimated overall survival per (18).

Immobilizations



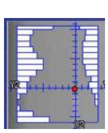
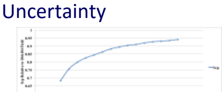
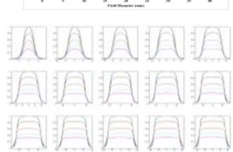
Mask and Frame

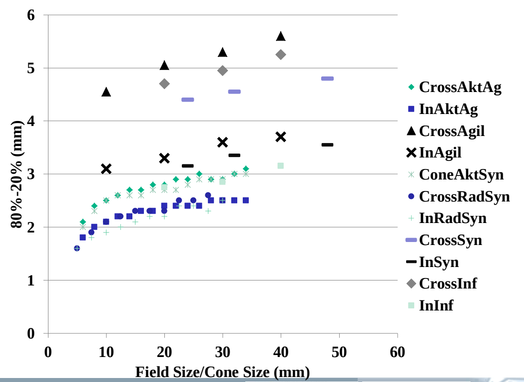


Ramakrishna, et al 2010 *Radioth and Onc*

Photon Planning

- Photons planning questions
  - MLC versus Cones
  - Field Size Effects: Dosimetric Uncertainty
  - MLC field size uncertainty
  - Penumbra

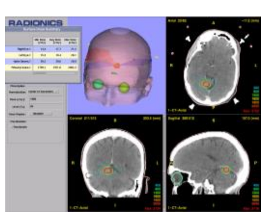


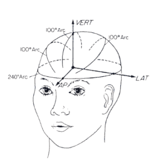
Linac SRS Photon Planning

- Cones
- 3D CRT
- IMRT
- Dynamic Conformal Arcs
- VMAT

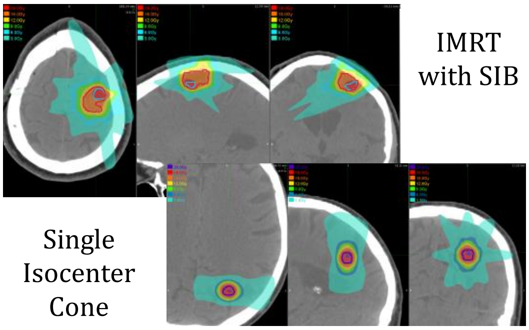
Photon Planning: Cranial

- Classic Planning
- Considerations: OAR and other lesion proximity





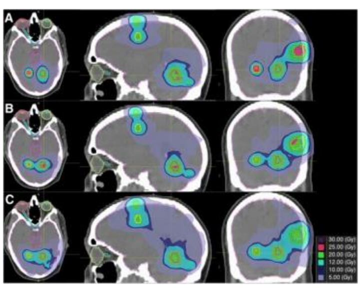
Linac Plans



IMRT with SIB

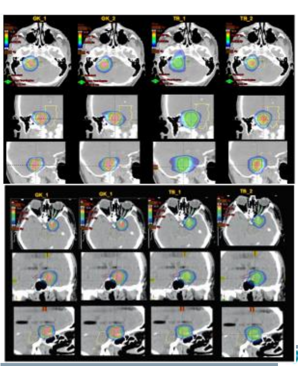
Single Isocenter Cone

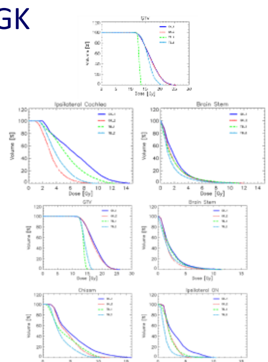
DCA versus VMAT



Gavaert, et al 2016 *Rad Onc*

Linac versus GK



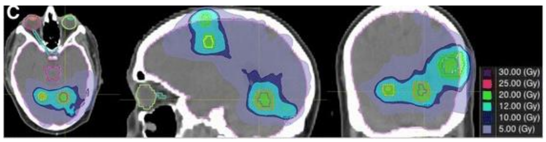


Abraciogl u, et al 2014 *Rad Onc*

VMAT for multiple lesions

- <u>BENEFITS</u>
- Efficient
- Increase patient comfort
- Machines capable

- <u>CHALLENGES</u>
- QA Difficult
- Setup uncertainty
- Margins
- TPS Beam Model

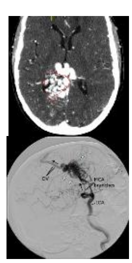


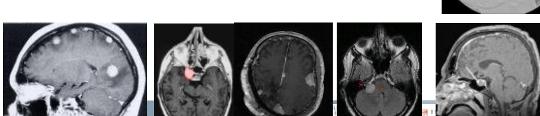
Gavaert, et al 2016 *Rad Onc*

Proton Cranial SRS

Diseases

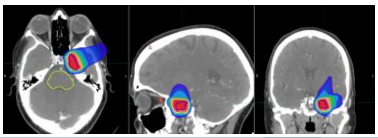
- Cranial lesions
  - **Benign: schwannomas, meningiomas, Acromegaly**
  - **AVMs**
  - **Gliomas**
  - Some mets



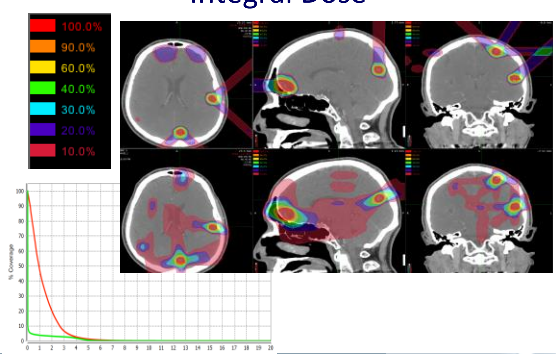


Protons

- No distal dose
- Sharper Penumbra (many caveats)
- Less Integral Dose
- Lower NTCP, especial late effects

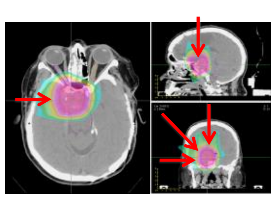


Integral Dose

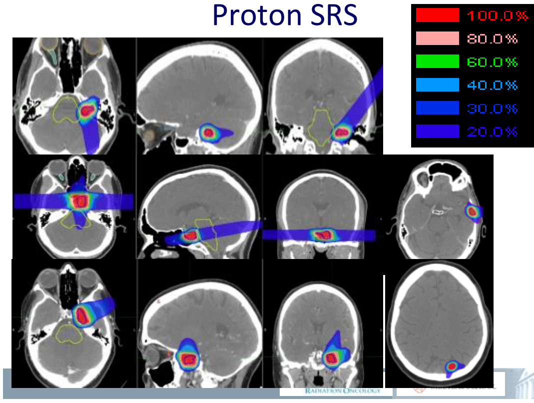


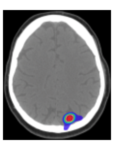
Proton SRS Treatment Planning Overview

- Field Size/MCS
- Beam positions
- Heterogeneities
- Penumbra Regions
- Distal Positions
- LET/RBE
- More beams → More Conformal/Less Uncertainties from single beam



Proton SRS





Thank You!