Robotic and Gimbaled Spine SBRT

A Physicist's Perspective

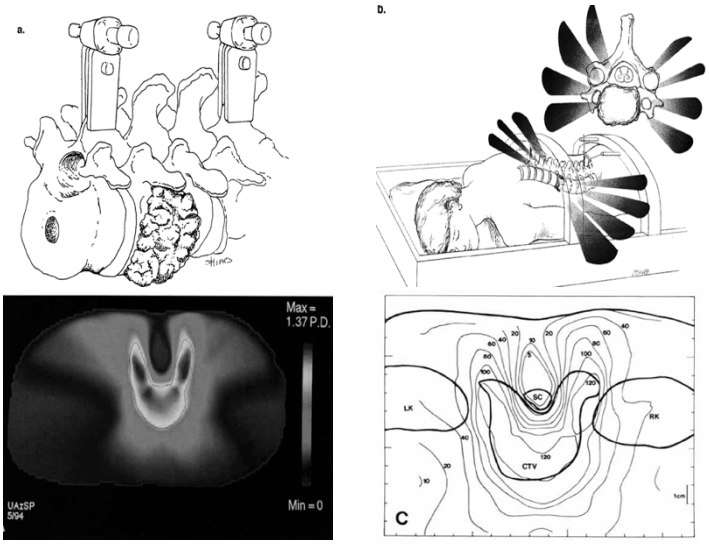
LIJUN MA, PhD, FAAPM
Professor In Residence
CAMPEP Program Director
UCSF Radiation Oncology

Lijun.MA@ucsf.edu

Educational Objectives

- To grasp fundamental imaging and motion management concepts of robotic and gimbaled systems for spine SBRT
- To understand operations of robotic and gimbal system in a clinical setting for spine SBRT treatment delivery
- To define unique features of robotic and gimbaled systems against standard linac-based systems for spine SBRT

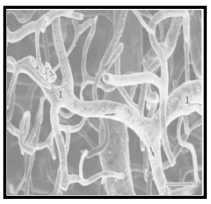
Genesis of Spine SBRT Circa 1995



Radiobiological Rationales

- **Single fraction: ~ 12-24 Gy /fx**

  No 4R; vascular damage observed



- **Hypofractionation: ~ 5-10 Gy /fx**

  Leverage Reoxygenation & Reassortment

Technical Basis of RT ed. S Levitt 2012

Spine SBRT vs Conventional IMRT

Properties	IMRT	SBRT
Dose × Fractions	3 Gy × 10 fx	16-24 Gy x 1 fx 12 Gy x 2 fx 6-9 Gy x 3 fx 6-10 Gy x 5 fx
Margin	10-20 mm	1-2 mm
Target Definitions	PTV	CTV/ITV/PTV
Motion Management	None	Must
Marginal Accuracy	Moderate	High
Radiobiology	Sufficient	Work in Progress

A physician may prescribe which of the following for an spinal metastasis SBRT treatment?

20% 1. 50 Gy in 25 fractions

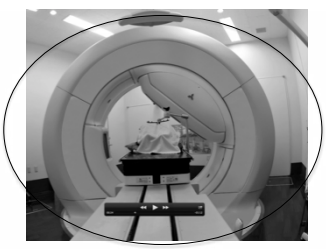
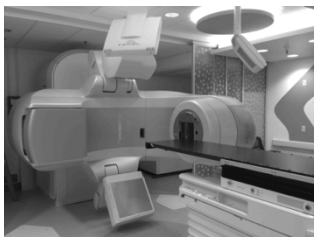
20% 2. 50 Gy in 20 fractions

20% 3. 50 Gy in 10 fractions

20% 4. 50 Gy in 5 fractions

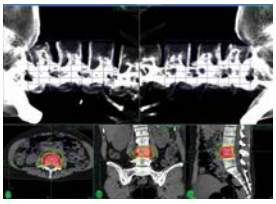
20% 5. 50 Gy in 2 fractions

State-of-the Art Spine SBRT Modalities

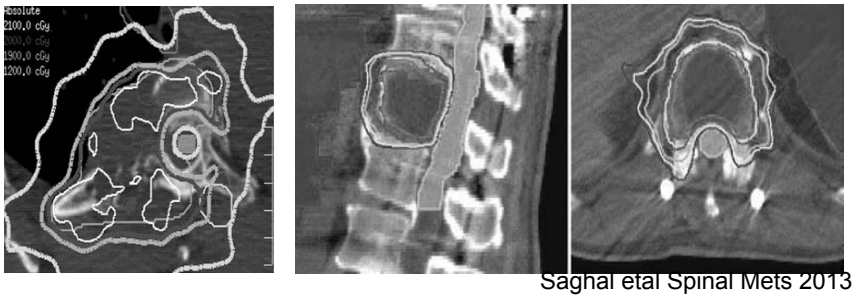

Features of Spine SBRT Delivery

- Speed: 10+ Gy/min
- Adequate field size: ~ 6 - 20 cm
- Fine beam modulation: ~ 5 mm
- Imaging Guidance: 2D/3D
- Motion Management: active/passive

Sharp Dose Gradient

10-15% per mm dose fall-off

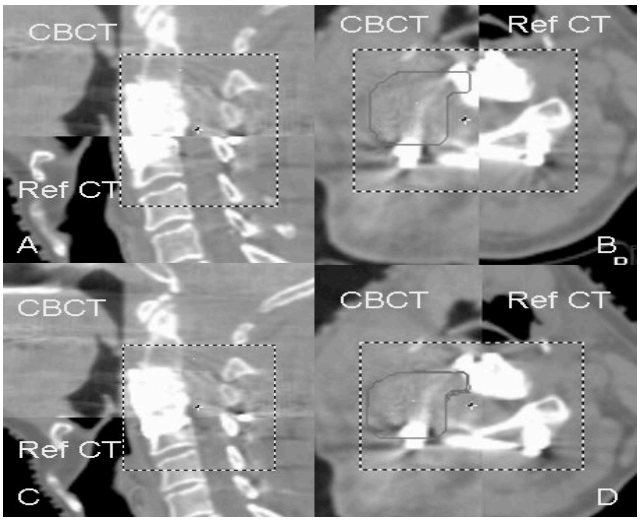


Saghal etal Spinal Mets 2013

Motion Management Techniques

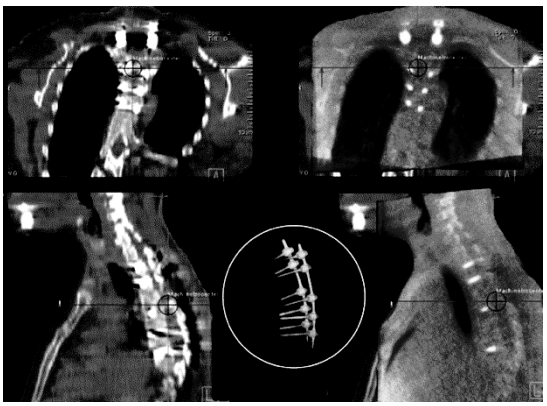
System	Method
Elekta	kV CBCT +/- 2D kV +/- BodyFrame
Artiste	MV CBCT
Varian/Novalis	kV CBCT +/- 2D kV +/- Surface markers
Cyberknife	2D kV +/- Feedback Beam Correction
Vero 4DRT	kV CBCT +/- 2D kV+/- Surface markers +/- Feedback Beam Correction

kV CBCT-Based Alignment



Sahgal, Bilsky, Chang et al. JNS Spine (2011)

MV CBCT Overcoming Spine Hardware



Alignment despite presence of hardware
(E Hansen and D Larson etal UCSF)

In the presence of extensive heavy-metal hardware for a spine SBRT treatment, the most appropriate imaging for patient setup would be

20% 1. kV Tomosynthesis

20% 2. MV Cone-beam CT

20% 3. kV Fluoroscopy

20% 4. MV Cerenkov scanning

20% 5. kV Portal imaging

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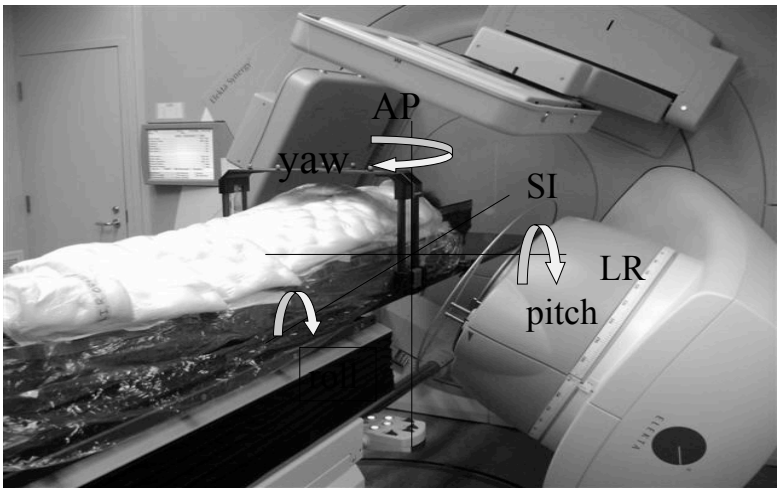
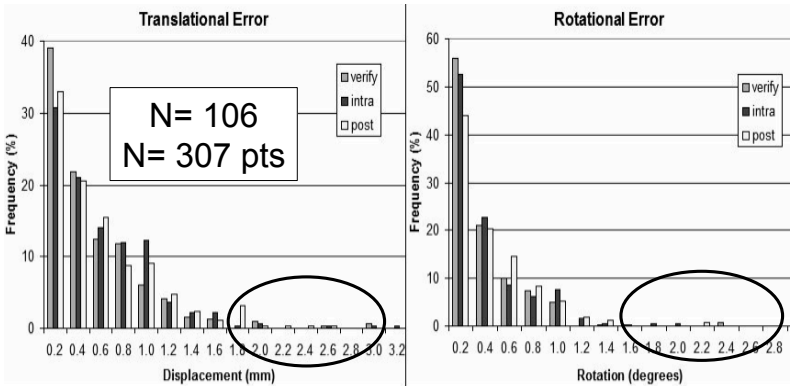
Combining BodyFrame and IG



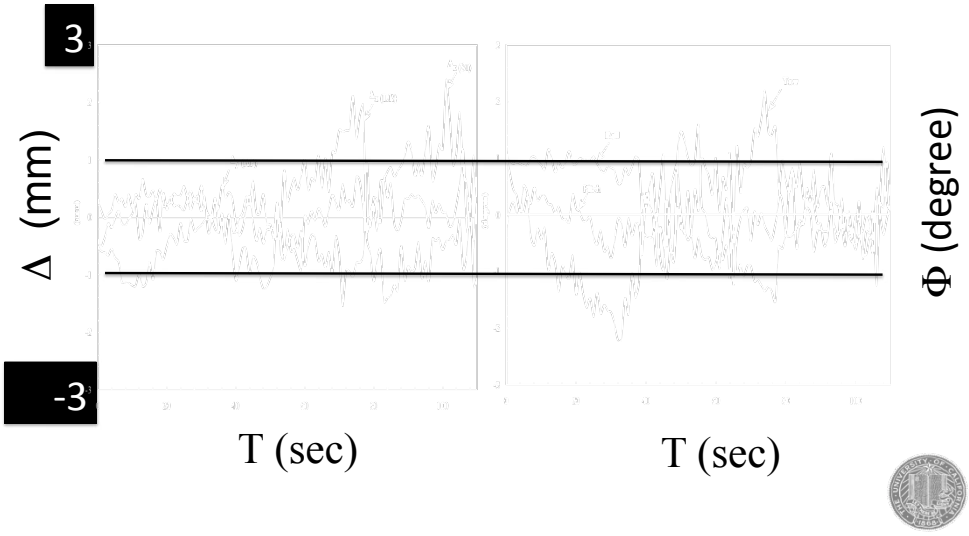
A Sahgal et al 2012 (Univ of Toronto)

Online Detection/Correction Results



Mean Shifts of 1.2 mm and 0.9 deg (CI = 95%)

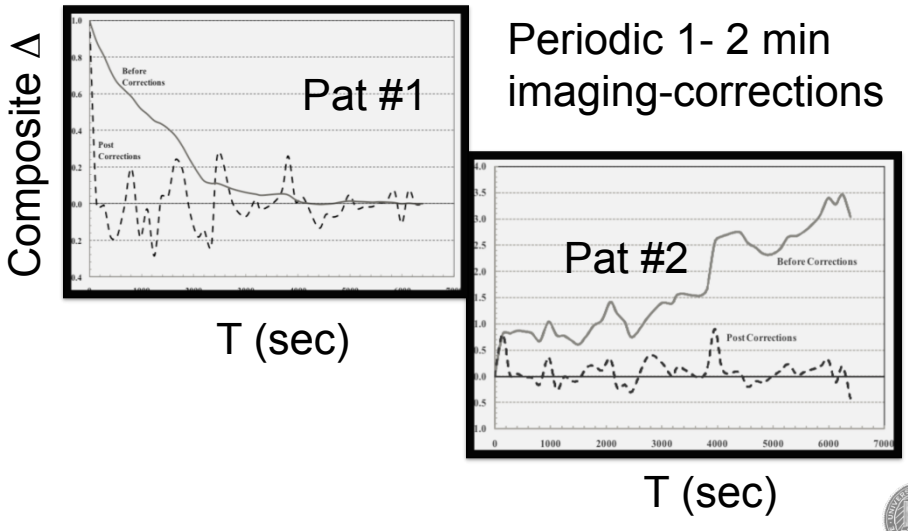
On-line Spine Target Motion Patterns



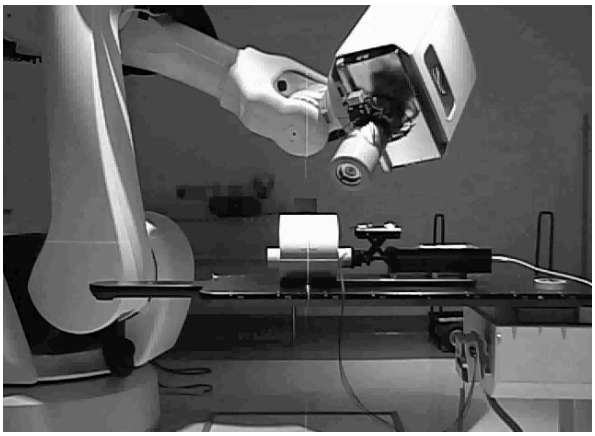
Non-rigid Setup Spine Motions

Site	Required Treatment T(min)	Non-Random DOF	Required Correction T(min)
T (n=20)	48-170	3.1±1.3	5.9 (1.1-14.3)
C (n=20)	30-138	5.5±0.7	5.5 (1.3-16.7)
LS (n=24)	44-150	4.1±1.3	7.1 (1.6-30.7)

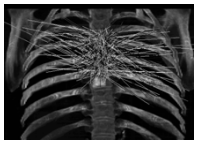
Frequent Intervention Results



Fiducial Based Robotic Tracking



Robotic SRT/SBRT Plan Delivery



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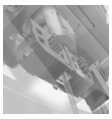
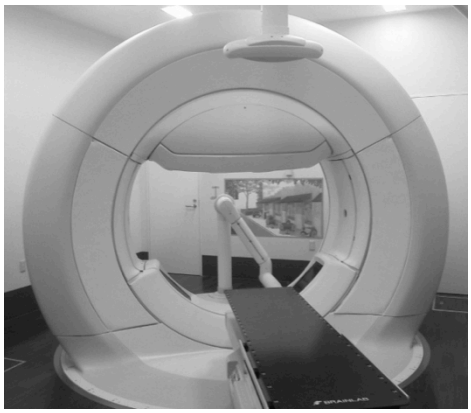
Cancer Hospital



Gimbaled (± 2.5^{o}) X-ray SBRT



± 60^{o} gantry twist ✈ ±185^{o} gantry rotation
5D robotic couch ✈ ExacTRAC system

Gimbaled X-ray Spine SBRT

Tokyo Kamagome
Radiation Oncology

Cyberknife spine SBRT typically employs a large number of which of the following?

20% 1. beam orientations

20% 2. collimator rotations

20% 3. couch corrections

20% 4. gantry angles

20% 5. cone shuffles

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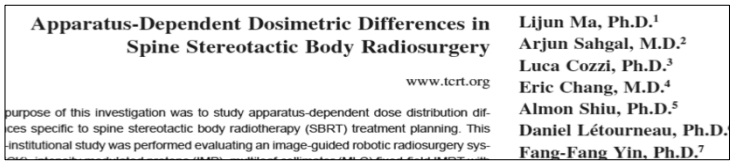
Apparatus Dependence for Spine SBRT

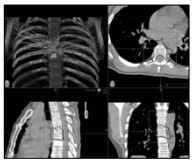


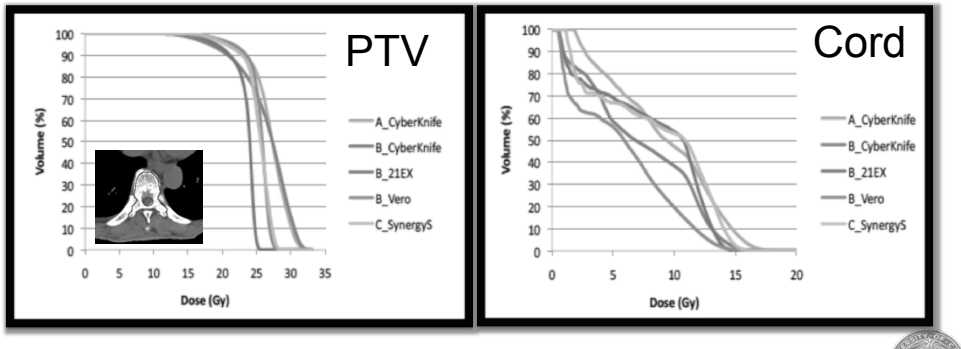
Apparatus-Dependent Dosimetric Differences in Spine Stereotactic Body Radiosurgery

www.tcrt.org

purpose of this investigation was to study apparatus-dependent dose distribution dif-ces specific to spine stereotactic body radiotherapy (SBRT) treatment planning. This -institutional study was performed evaluating an image-guided robotic radiosurgery sys-

Lijun Ma, Ph.D.[1]
Arjun Sahgal, M.D.[2]
Luca Cozzi, Ph.D.[3]
Eric Chang, M.D.[4]
Almon Shiu, Ph.D.[5]
Daniel Létourneau, Ph.D.
Fang-Fang Yin, Ph.D.[7]





Noticeable differences for complex cases

Summary

- Millimeter-level accuracy achievable for current Spine SBRT treatments.
- Future trend is for ***faster***, more ***adaptive***, and more ***integrated*** spine SBRT treatments

Acknowdgement

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