Robotic and Gimbaled Spine SBRT

A Physicist's Perspective

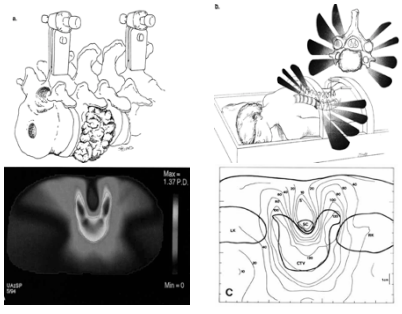
LIJUN MA, PhD, FAAPM
Professor In Residence
CAMPEP Program Director
UCSF Radiation Oncology

Lijun.MA@ucsf.edu

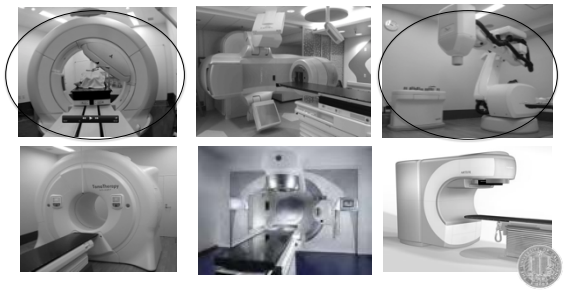
Educational Objectives

- To grasp fundamental imaging and motion management principles of robotic and gimbaled systems for spine SBRT
- To understand operation 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



State-of-the Art Spine SBRT Modalities



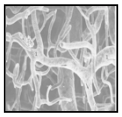
Spine SBRT vs Conventional IMRT

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	Good	Work in Progress

Radiobiological Rationale

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

  No 4R: vascular damage noted



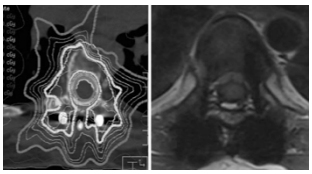
- **Hypofractionation: 5-10 Gy /fx**

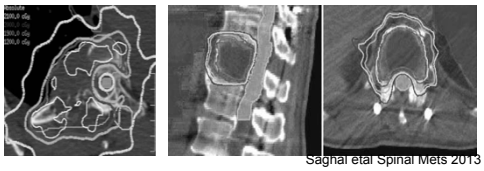
  Reoxygenation & Reassortment

Technical Basis of RT ed. S Levitt 2012

Sharp Dose Gradient

10-15% per mm dose fall-off





Saghal etal Spinal Mets 2013

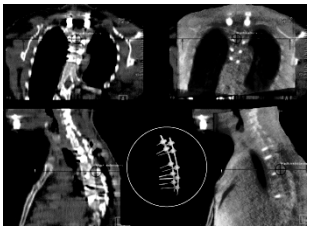
Features of Spine SBRT Delivery

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

Motion Management Techniques

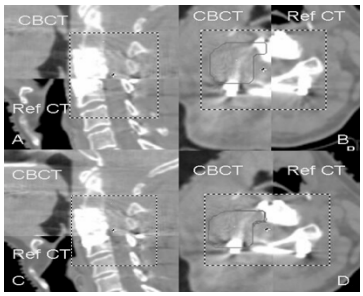
System	Method
Elekta	kV CBCT +/- 2D kV +/- BodyFrame
Artiste	MV CBCT
Varian/Novalis	kV CBCT +/- 2D kV +/- Surface markers
Cyberknife	2D kV +/- Feedback Beam Correction
Vero 4DRT	kV CBCT +/- 2D kV+/- Surface markers +/- Feedback Beam Correction

MV CBCT for Spine Hardware



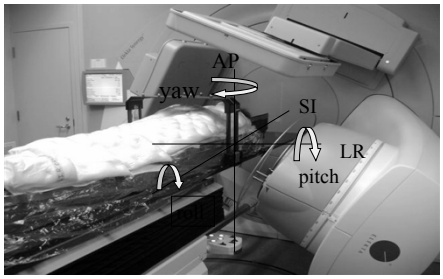
Alignment despite presence of hardware
(E Hansen and D Larson etal UCSF)

kV CBCT-Based Alignment



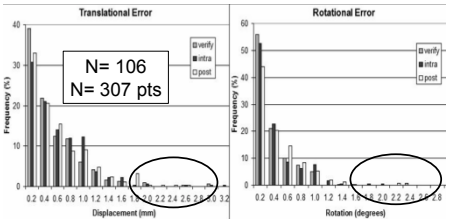
Sahgal, Bilsky, Chang et al. JNS Spine (2011)

Combining BodyFrame and IG



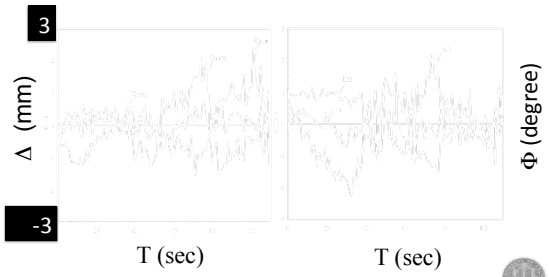
A Sahgal et al 2012 (Univ of Toronto)

Online Detection/Correction Results



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

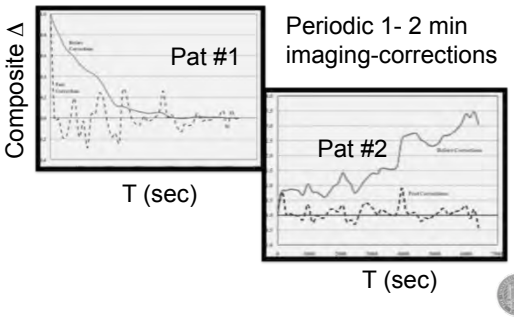
On-line Spine Target Motion Patterns



Non-rigid Setup Spine Motions

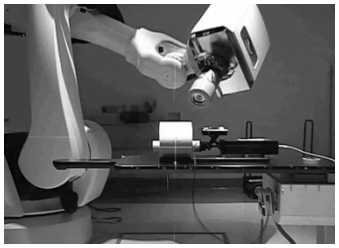
Site	Required Treatment T(min)	Non-Random DOF	Required Correction T(min)
T (n=20)	48-170	3.1±1.3	5.9 (1.1-14.3)
C (n=20)	30-138	5.5±0.7	5.5 (1.3-16.7)
LS (n=24)	44-150	4.1±1.3	7.1 (1.6-30.7)

Frequent Intervention Results

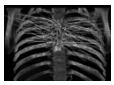


Periodic 1- 2 min
imaging-corrections

Fiducial Based Robotic Tracking

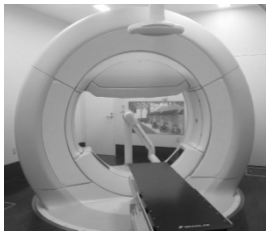


Robotic SRT/SBRT Plan Delivery



Tokyo Kamagome
Cancer Hospital

Gimbaled (± 2.5º) X-ray SBRT

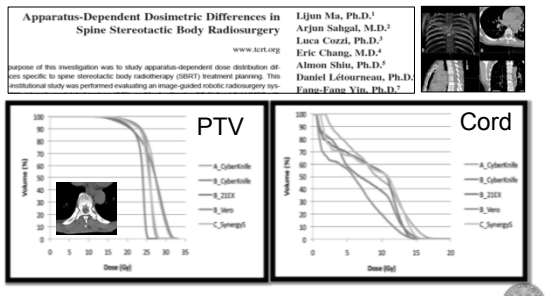


± 60º gantry twist ✈ ±185º gantry rotation
5D robotic couch ✈ ExacTRAC system

Gimbaled X-ray Spine SBRT

Tokyo Kamagome
Radiation Oncology

Apparatus Dependence for Spine SBRT



Apparatus-Dependent Dosimetric Differences in Spine Stereotactic Body Radiosurgery

www.tcrt.org

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.[2]
Fang-Fang Yin, Ph.D.[1]

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

Notable differences for challenging cases

Summary

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

Acknowdgement

Drs. H Tanaka, T Furuya, K Karasawa
Tokyo Kamagome Hospital