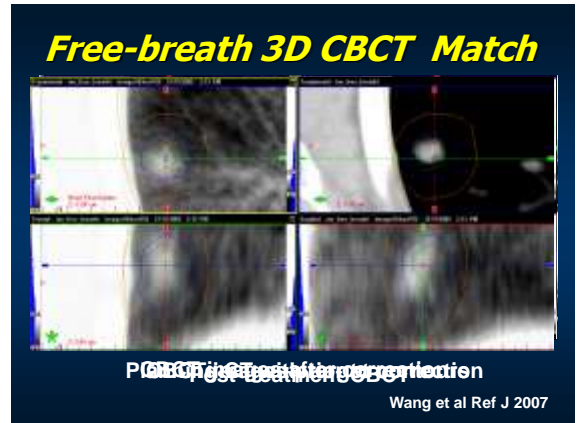
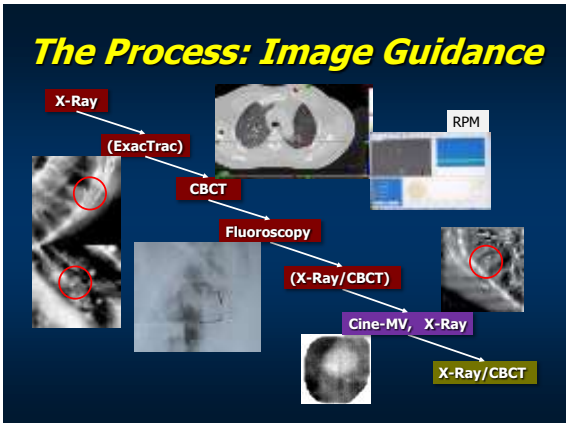
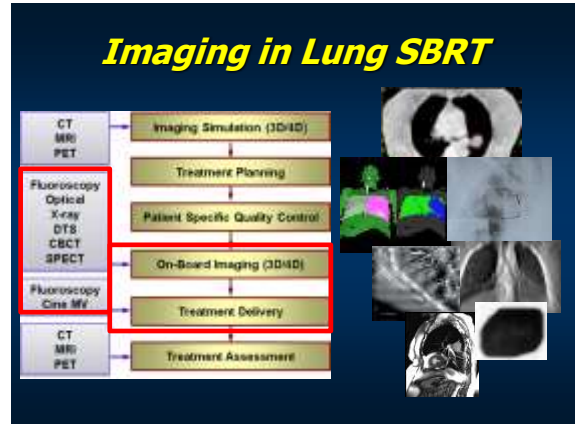


DUKE UNIVERSITY MEDICAL CENTER

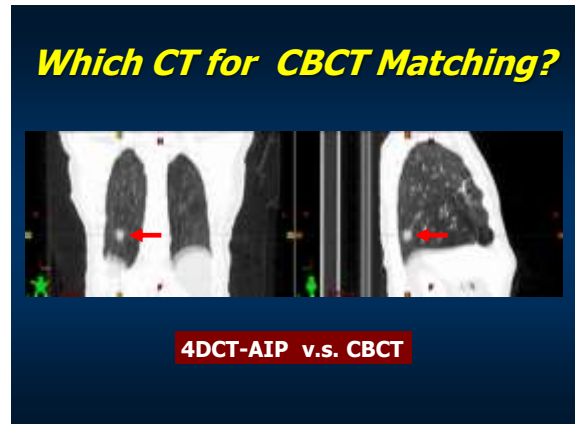
Uncertainties and Quality Assurance of Localization and Treatment in Lung SBRT

Jing Cai, PhD
Duke University Medical Center

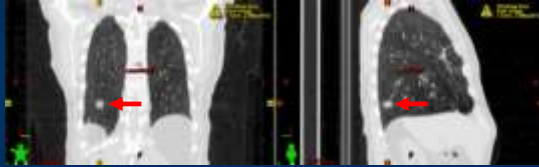
2013 AAPM 59th Annual Meeting, Educational Course, Therapy Track, MOC SAM Program



- ## Uncertainties in lung SBRT IGRT
- Tumor volume in CBCT
 - Soft-tissue contrast
 - Inter-observer variations
 - Reproducibility of tumor location at breath-hold
 - Internal-external motion correlation
 - Changes of tumor size and motion
 - Changes of anatomy
 - Shifts and rotations in matching
 -

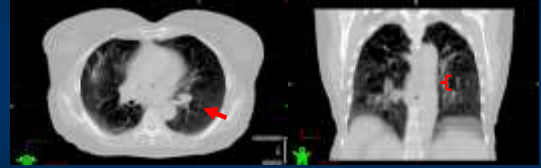


Which CT for CBCT Matching?



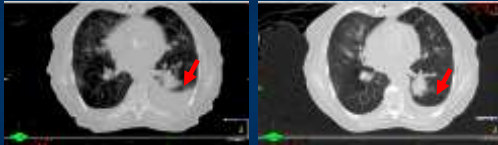
3D FB-CT v.s. CBCT

CBCT Matching: Tiny Tumor



Tumor Size ~ 5 mm; Tumor Motion ~ 20 mm

CBCT Matching: Large Anatomical Change

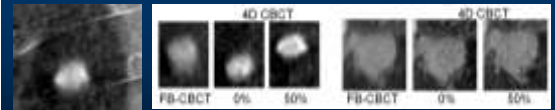
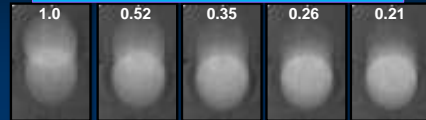


Pleural effusion at Sim
Largely disappeared at 1 fx

Re-simed, Re-planned

CBCT ITV Uncertainty

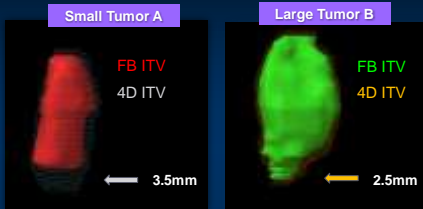
ITV at different Inspiration/Expiration (I/E) Ratio



4D CBCT

Vergalaso, et al, Med Phys. 2011

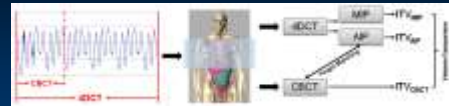
CBCT ITV Uncertainty



Tumor	Free-Breathing ITV (cm ³)	4D ITV (cm ³)	Volume Underestimation (%)
A	1.78	2.97	40.1
B	35.62	46.98	24.2

Vergalaso et al, Med Phys 2011

Target Matching Uncertainty



Turner et al
2013 AAPM

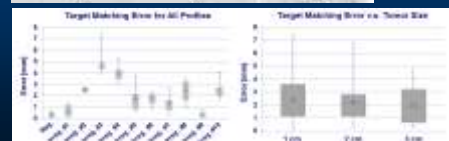
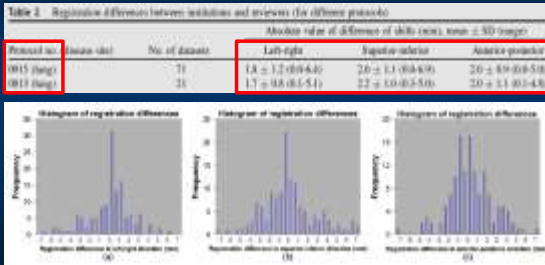


Image Registration Uncertainty: Inter-observer Variation

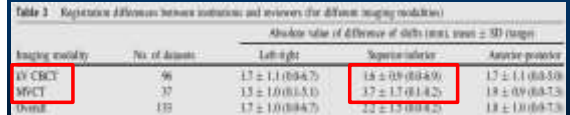


Cui et al, Red J, 2011; 81:305-312.

MVCT for Lung SBRT IGRT

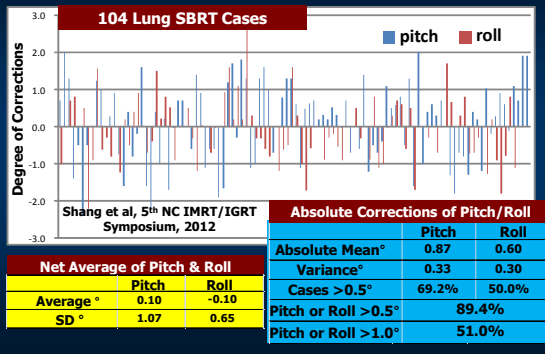


Siker et al, Red J, 2006

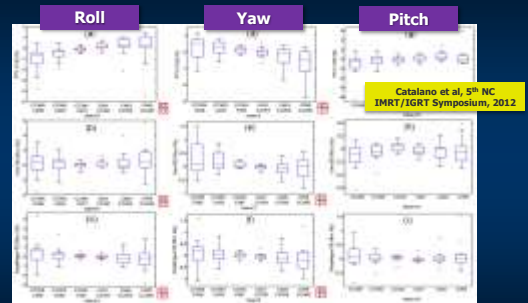


Cui et al, Red J, 2011; 81:305-312.

Rotational Shifts in Lung SBRT

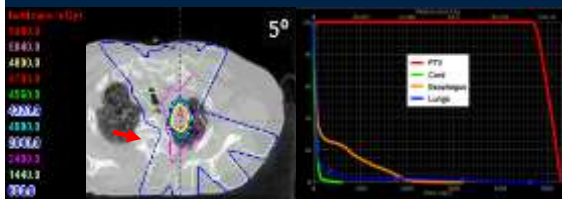


Dosimetric Effects of Rotations



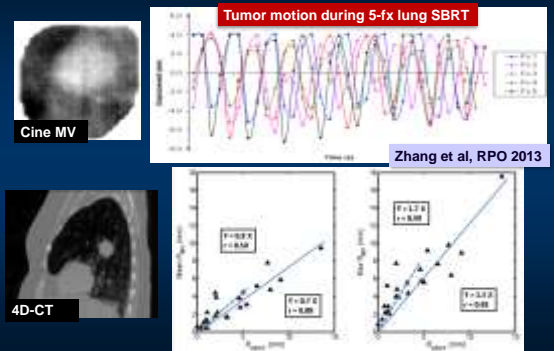
- 95.6% of all differences were <1% or <1Gy.
- Overall small dosimetric effects of uncorrected rotations.

Dosimetric Effects of Rotations

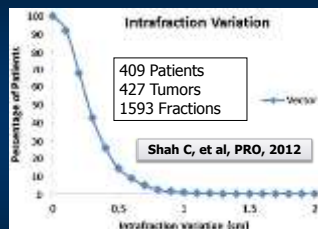


- Large inter-subject variations at large rotation angles.
- Up to 4% reduction in PTV coverage, 6 Gy increase in cord D0.35cc, and 4 Gy in Esophagus D0.35cc observed.

Cine MV: tumor motion during TX



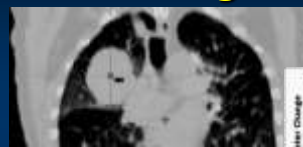
Intra-fractional Mean Tumor Position Shift



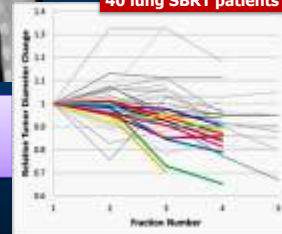
- Intra-fractional variation:
 - AP: 0.0 ± 1.7 mm
 - ML: 0.6 ± 2.2 mm
 - SI: -1.0 ± 2.0 mm
 - 3D: 3.1 ± 2.0 mm
- 3D vector variation:
 - > 2mm in 67.8%
 - > 5mm in 14.3%

- Depending on immobilization (Range: 2.3 – 3.3 mm)
- Body Frame < Alpha Cradle < Body Fix < Wing Board

Change of Tumor Size During Lung SBRT



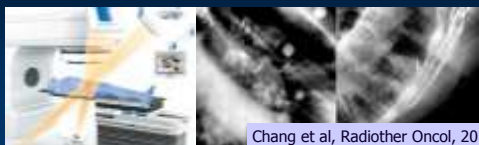
40 lung SBRT patients



- Initial tumor size: 0.7-7.3 cm
- Change of tumor diameter:
 - Range: -34.2% to 33.0%
 - Mean: $-7.9 \pm 11.45\%$

Qin et al, Red J, 2013

ExacTrac



Chang et al, Radiother Oncol, 2010

ExacTrac 6D v.s. CBCT 6D

ML: 1.06 mm	Pitch: 1.22°
AP: 1.43 mm	Row: 0.64°
SI: 1.43 mm	Yaw: 1.66°

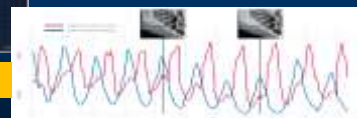
- Small but maybe clinically significant discrepancies between ExacTrac X-ray 6D and CBCT 6D match

Cyberknife



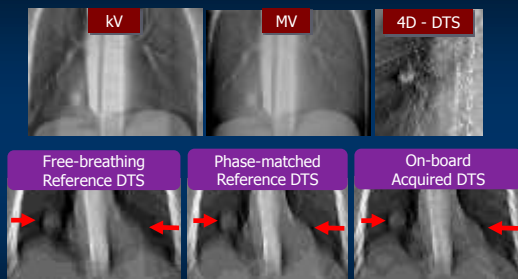
- Targeting error: 0.1 – 0.3 mm
- Correlation error: 0.3 – 2.5 mm
- Prediction error: 1.5 ± 0.8 mm
- Total error: 0.7 – 5.0 mm

Synchrony Respiratory Tracking System (RTS)



Pepin et al, Med Phys. 2011

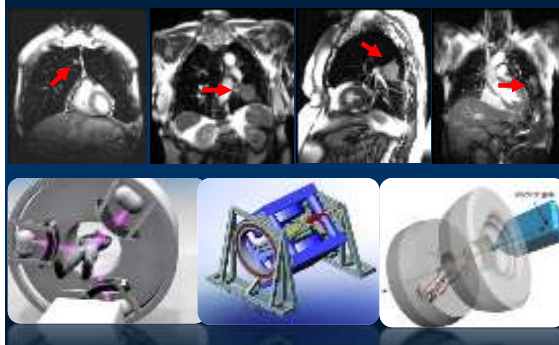
Onboard DTS Imaging



Better Match

Courtesy from Dr. Ren of Duke University

MRI for Image Guidance

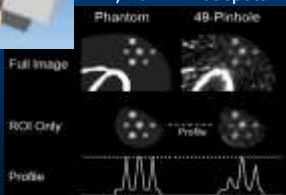


On-Board SPECT



Courtesy from Dr. Bowsher
of Duke University

- 4-min scans
- 7, 10 mm hot spots



- SPECT on robotic arm
- Molecular targeting
- Multi-Pinhole collimation

Summary

- Uncertainties exist in each step of image guidance of lung SBRT
- Understanding root causes and characteristics of these uncertainties is important for successful implementation of lung SBRT
- Next generation of on board imaging techniques has the potential to minimize uncertainties of image guidance of lung SBRT