

# Image-Guidance for SBRT: Technical Challenges and Pitfalls

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## Acknowledgments

- Colleagues and SBRT Teams at Duke
- Research supports from NIH and Varian Medical Systems



## Outline:

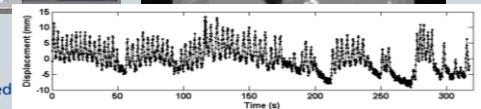
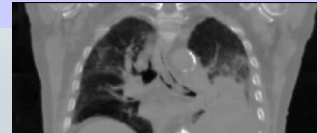
- Imaging: through the process
- Margin: GTV  $\rightarrow$  PTV
- Planning and delivery
- Treatment assessment and process management



## Imaging: 4D CT for Organ Motion

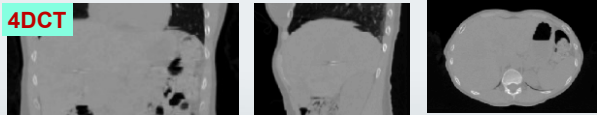
### Challenges:

- Poor soft-tissue contrast
- Only produce one breathing cycle
- Correlation between internal target and external surrogates
- Imaging dose ...

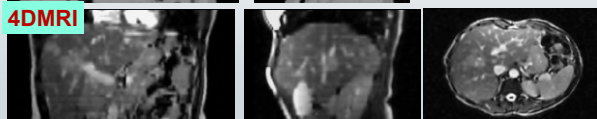


## Imaging: Motion with 4D CT and 4D MRI

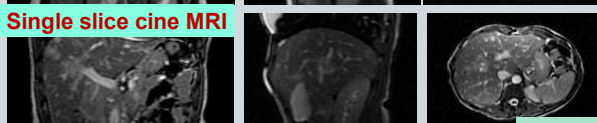
4DCT



4DMRI



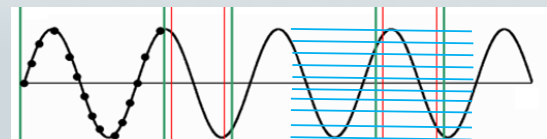
Single slice cine MRI



Cai et al

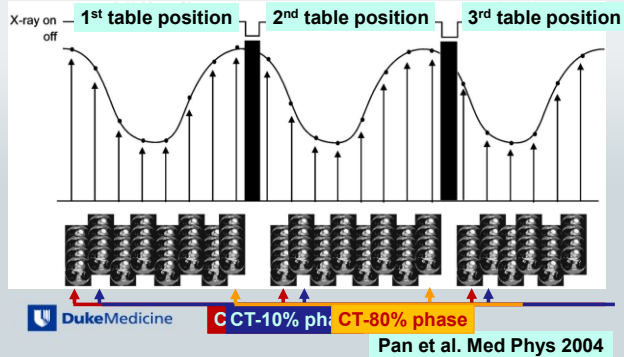
## 4D Imaging: Soring Types

- Retrospective – sorting same phase or amplitude
- Prospective – image at a specific phase or amplitude
- Phase gated – sorting based on phase
- Amplitude gated – sorting based on amplitude



How accurate is 4-D CT?

## 4D Imaging: Retrospective Sorting



## 4D Imaging: Related Images

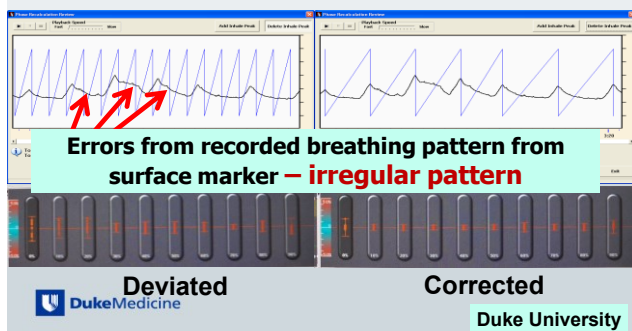


- FB/BH CT
  - 10-phase FB 4DCT
  - Fluoroscopy
- MIP  
AIP  
MinIP
- Treatment Planning System

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Cover, et al, Red J, 2006

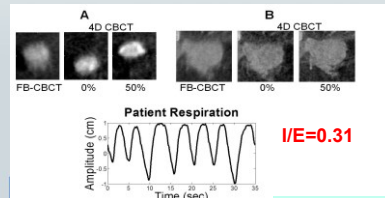
## Imaging: 4DCT Sorting Artifact



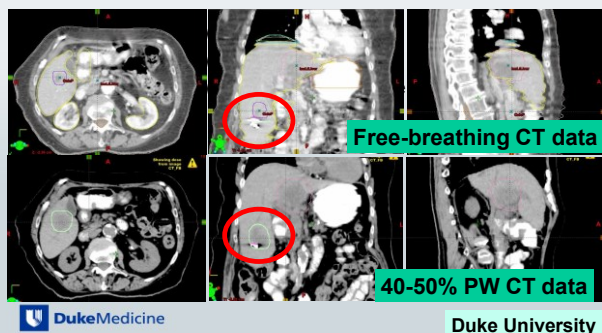
## Imaging: Irregular Breathing CBCT

### ITV from irregular breathing patient

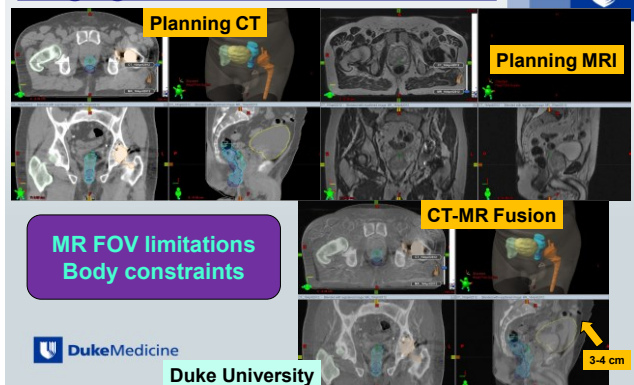
Tumor	Free-Breathing ITV (cm <sup>3</sup> )	4D ITV (cm <sup>3</sup> )	Volume Underestimation (%)
A	1.78	2.97	40.1
B	35.62	46.98	24.2



## Imaging: Volumes in Gated CT



## Imaging: Position Effect on Fusion



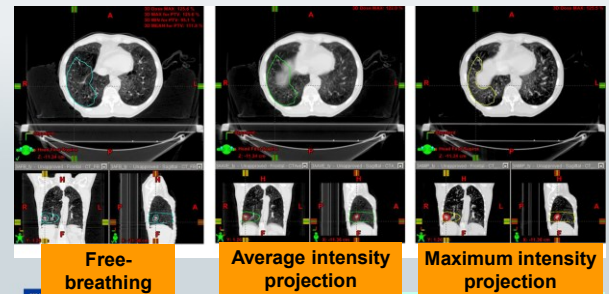
## Imaging: Treatment Planning

Often, we have CTs for lung/liver SBRT:

- FB, 4DTC, AIP, MIP, and BH CT data sets
- **Handling of Motion Images**
  - For contouring
  - For dose calculation
  - For localization (prior treat)
  - For verification (during treat)
  - For assessment (post treat)

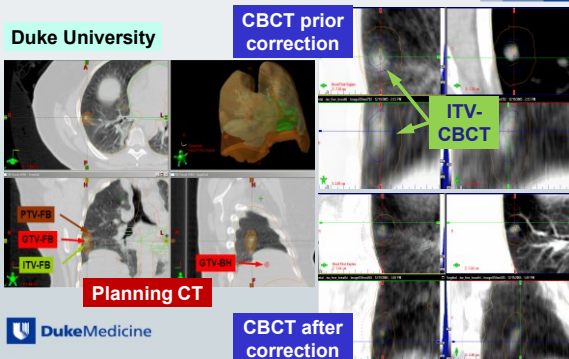


## Imaging: CT for Dose Calculation?



Yuan Tian et al, Med Phys 2012

## Lung - Pretreatment Localization



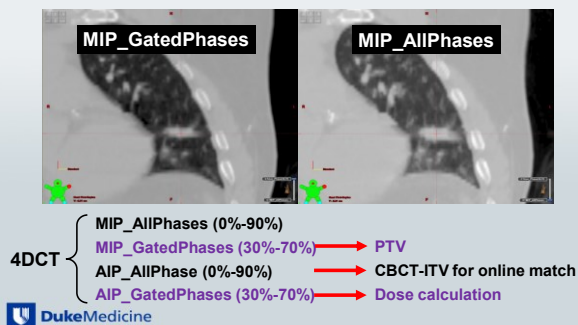
## Imaging: Overall Assessment

- A spinal SRS/SBRT was imaged three times
  - Prior to correction A
  - After correction before treat B
  - After treatment C
- Factors determining the margin
  - PTV
  - Setup uncertainty
  - Organ motion uncertainty
  - CTV motion trajectories
  - IGRT system errors



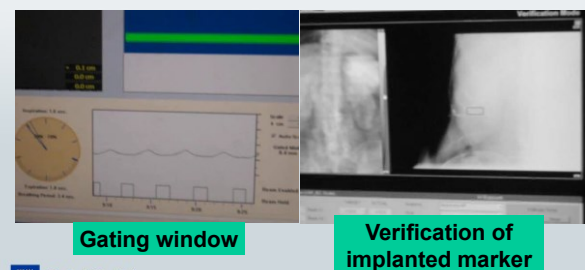
RTOG0631

## Imaging: Gated Treatment Volumes



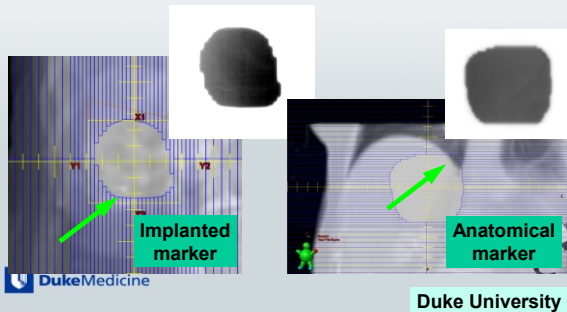
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## Imaging: Treatment Verification

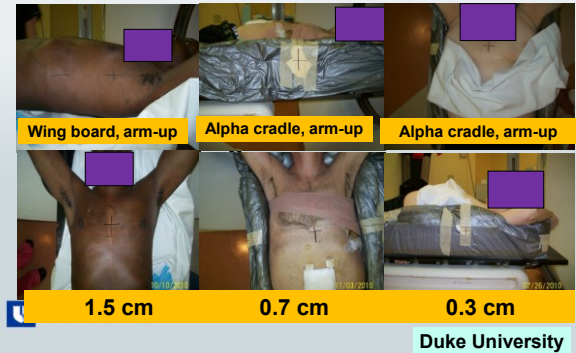


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## Imaging: Real-time Treat Verification



## Margin: Setup Uncertainty



## Margin: Organ Motion Uncertainty



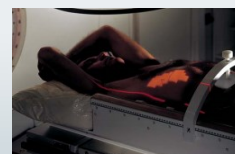
Active breath control:  
The residual errors of GTV  
ML:  $0.3 \pm 1.8$  mm  
AP:  $1.2 \pm 2.3$  mm  
SI:  $1.1 \pm 3.5$  mm

Cheung, et al, Red J 2003

- Remains some inter-breath hold variability in peripheral lung
- Limited reduction of PTV margin

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## Margin: Motion Uncertainty



### Abdominal Compression

Mean motion reduction:

3.5 mm for lower lobe tumors

0.8 mm for upper/middle lobe

Sometime, compression increased tumor motion

Mean ITV reduction:

3.6 cc for lower lobe lesions

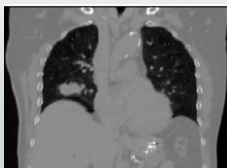
0.2 cc for upper/middle lobe lesions

Dosimetric gain for lung sparing was not clinically relevant

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Bouilhol et al, 2012, Phys Med

## Margin: Organ Motion Uncertainty



Total intravenous anesthesia (TIVA)

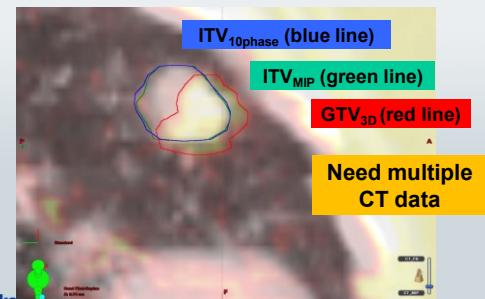
High-frequency jet ventilation (HFJV)

Animal study:  
Motion range:  $< 3$  mm

Yin et al 2001 IJROBP:  
"Extracranial radiosurgery:  
Immobilizing liver motion using  
high-frequency jet ventilation and  
total intravenous anesthesia"

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## Margin: Volume Uncertainty

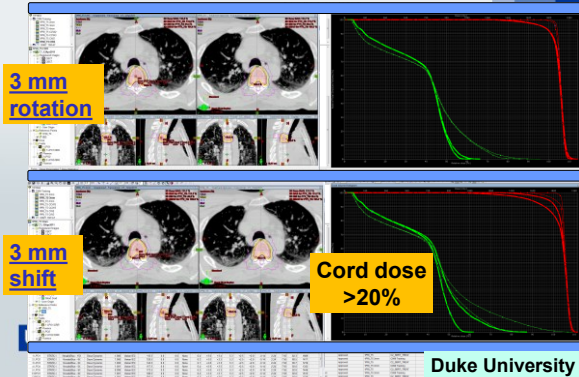


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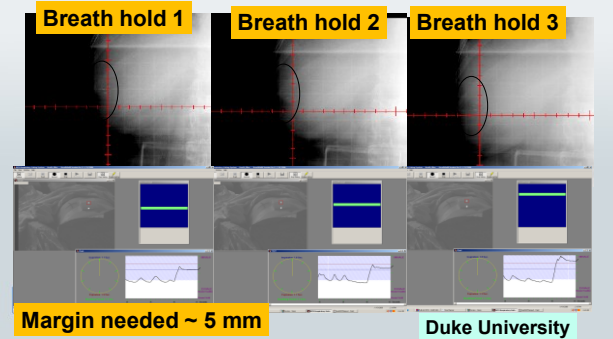
Ge et al, Red J 2012



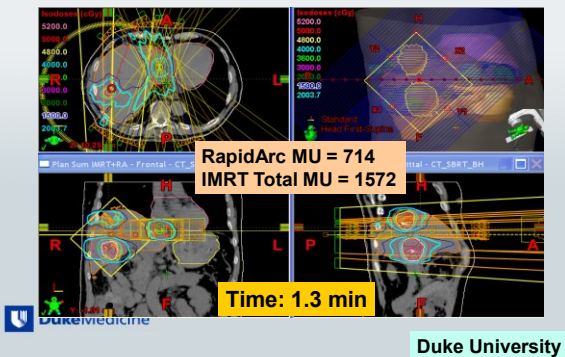
## Margin: Imaging System Uncertainty



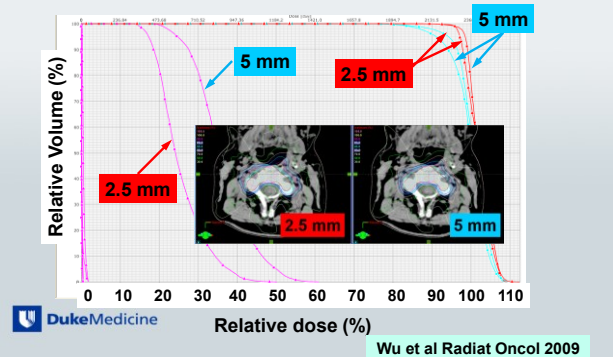
## Margin: Breathhold Uncertainty



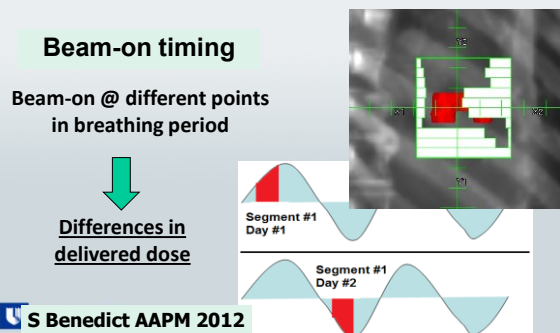
## Delivery: Smart Choice of VMAT/IMRT



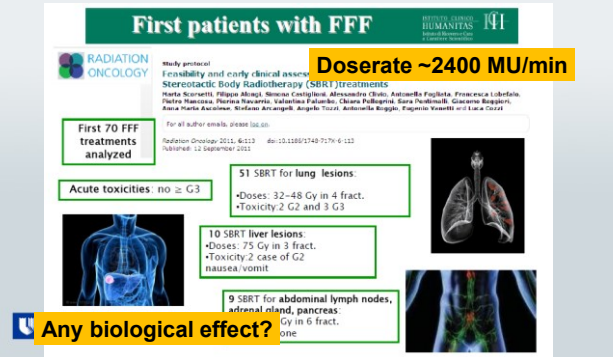
## Delivery: MLC Leaf Width



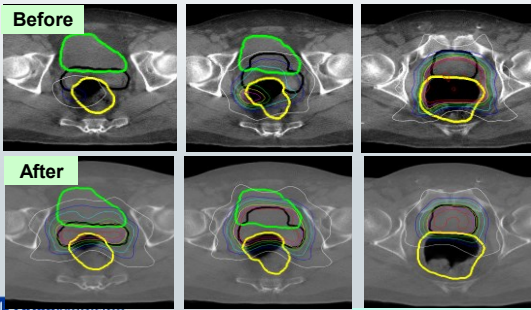
## Delivery: MLC Interplay Effect



## Delivery: High Doserate (FFF)



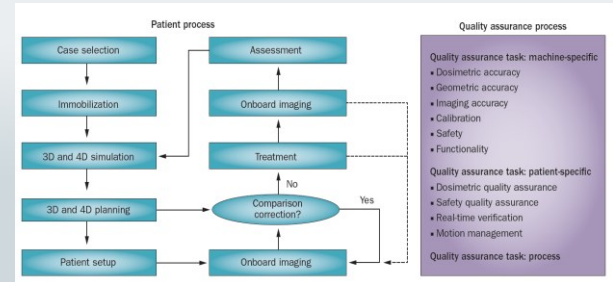
## Assessment: Adaptive Volume Changes



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Wu et al PMB 2008

## Process Management for SBRT



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Salama, Kirkpatrick, and Yin  
Nature Reviews|Clinical Oncology 2012

*Thank you for your attention*

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