Clinical Use of Respiratory Correlated CT Imaging

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Disclosure

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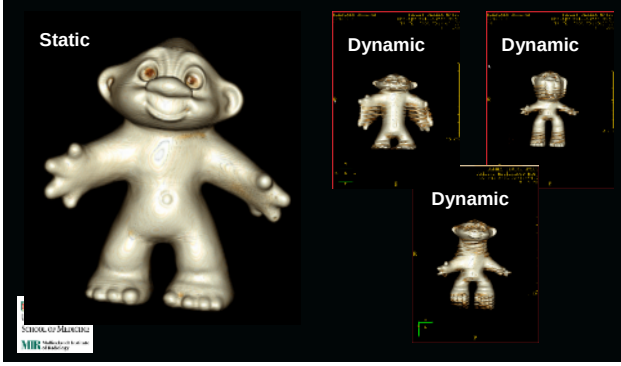
- The presenter is not directly supported by these grants

Learning Objectives

- To demonstrate the need for commissioning and understanding of respiratory correlated CT imaging systems and processes
- Respiratory correlated imaging and treatment delivery can significantly improve accuracy and conformality of dose distributions delivered to moving targets
- While this presentation will mainly demonstrate pitfalls and artifacts associated with respiratory correlated imaging, it is in no way intended to discourage clinical use of this technology
- An purpose of the presentation is to promote safe and accurate use of this technology

The Need to Gate



Terms

CT Imaging

- Axial & Spiral CT
- Single-slice & Multi-slice CT
- Collimation
- Coverage (detector width)
- Pitch
- Temporal resolution

Dynamic CT Imaging

- Waveform
- Tag
- Phase
- Amplitude
- MIP
- MinIP
- AvgIP
- Sub-phase (MIP, MinIP)
- Prospective
- Retrospective

Commissioning and QA

- Three stages of QA/Commissioning
  - CT Scanner Commissioning
  - Treatment Delivery Commissioning
  - Patient Specific QA
    - During Imaging
    - Treatment Planning
    - Daily Treatments

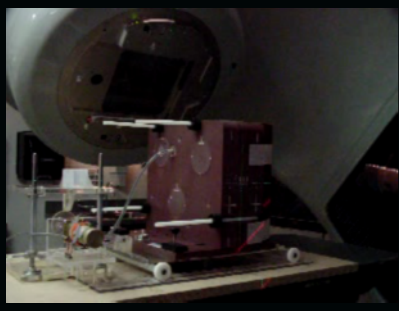
Scanner QA

Gating QA procedure

- Qualitative gating QA (do things look right?)
  - Is motion compensated for?
  - Are inhale and exhale really inhale and exhale?
  - Identify patient breathing characteristics that will cause system failure
- Quantitative gating QA
  - Phases accurate
  - Verify MIP generation

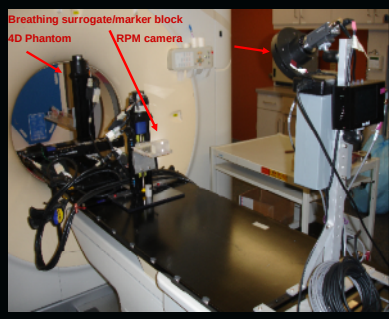
Gating Verification
3D (2D+Time) Phantom

- Motion in one direction
- Simple to use
- Works with different surrogates
- Will accommodate almost any phantom
- Not commercially available



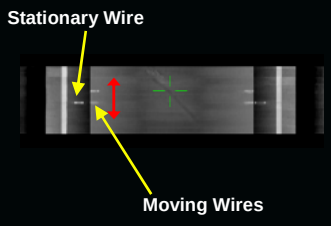
Scanner QA
5D+ Phantom

- Programmable motion in 3D
- Computer controlled
- Sub-millimeter precision
- Not commercially available



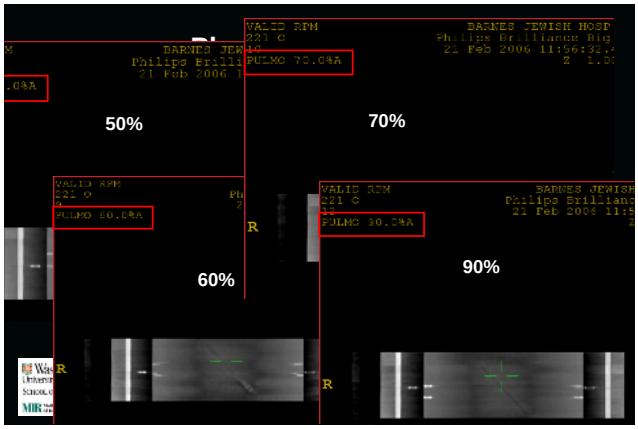
Phase/MIP Phantom

- Moving wires placed next to two stationary wire
- Travel distance known
- Distances measured on generated images used to evaluate reconstruction accuracy

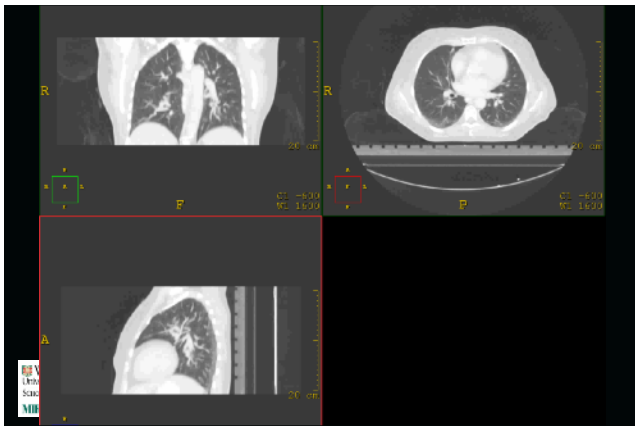


Quantative MIP

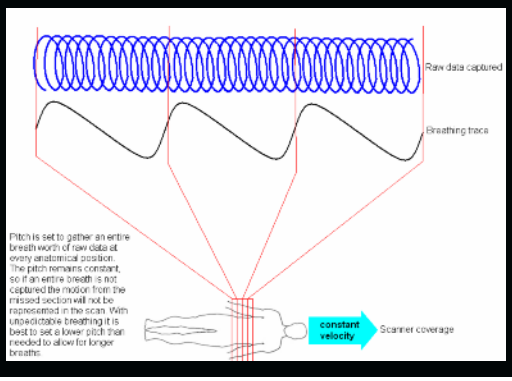
Wire separation measured on MIP should agree with the traveled distance



Patient Specific QA - Imaging



Pitch



Choosing optimal pitch based on breathing rate

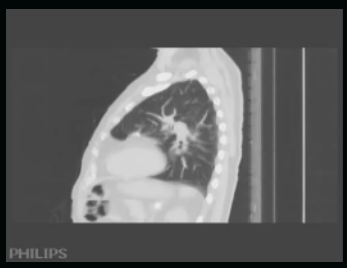
Breath Rate (in breaths per minute)	For 0.5 sec Rotation Time, use a pitch no higher than:	For 0.44 sec Rotation Time, use a pitch no higher than:
20	0.15	0.12
15	0.11	0.1
14	0.105	0.09
13	0.09	0.085
12	0.09	0.08
11	0.08	0.07
10	0.075	0.065

$$\frac{\text{Rotation Time(secs)} \times \text{Breath Rate(breaths/min)}}{60\ (\text{seconds/min})}$$

Image review and artifacts
Wrong Pitch

Mid-Scan Breathing Rate Slows

Breathing rate slows during scan acquisition



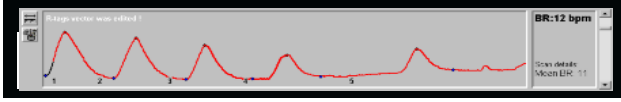
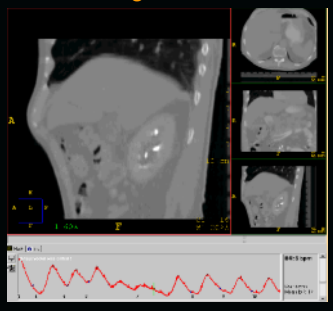
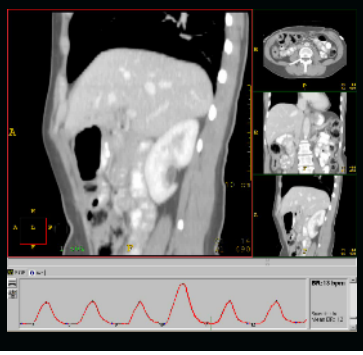


Image review and artifacts
Big Pause



Mid-Scan Amplitude Change



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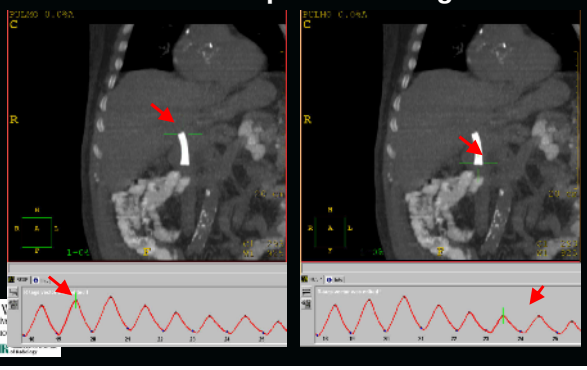

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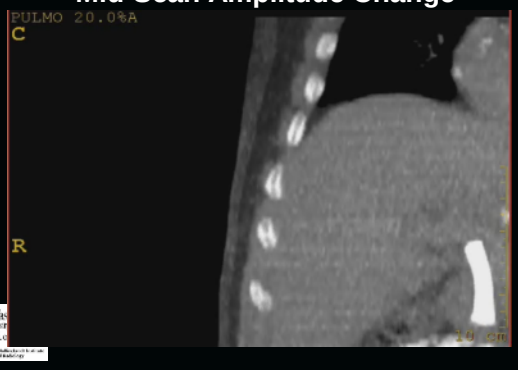


Image review and artifacts

Heart

Intensity-Projection-over-phases

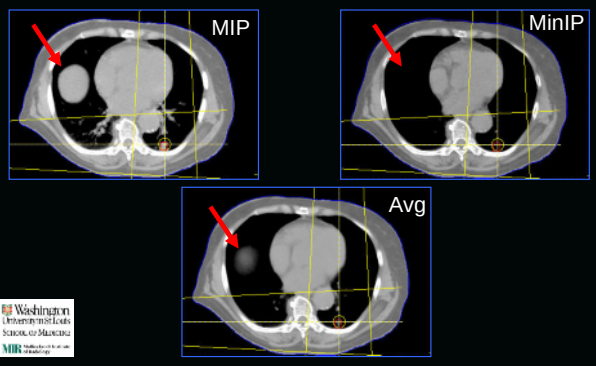
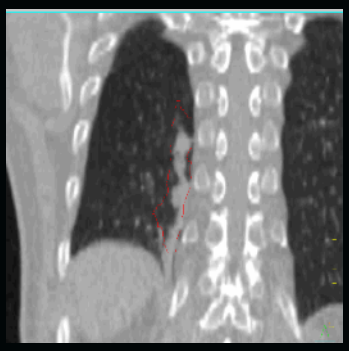
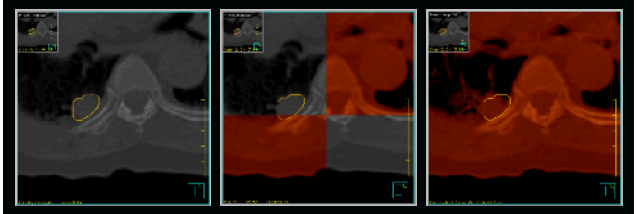


Image review and artifacts
Dangers of MIP

Image review and artifacts
Dangers of MIP

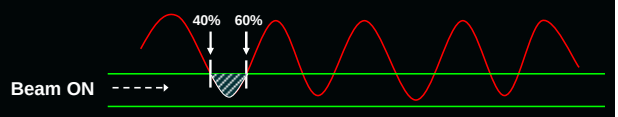


Data Set Registration
Patient movement – between scans

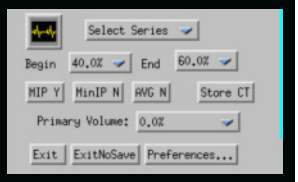


Free Breathing | Fused | MIP

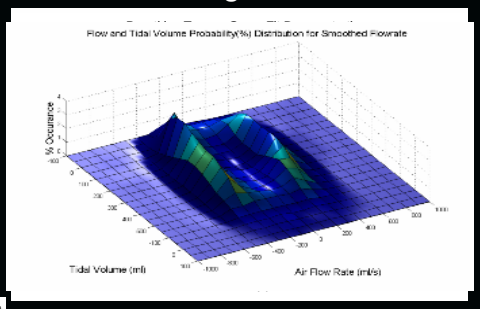
Image Reconstruction – Subset-MIP



- RPM gating on linac is performed during portion of breathing cycle
- Reconstruct ITV (MIP) that best represents portion of breathing cycle when beam is on



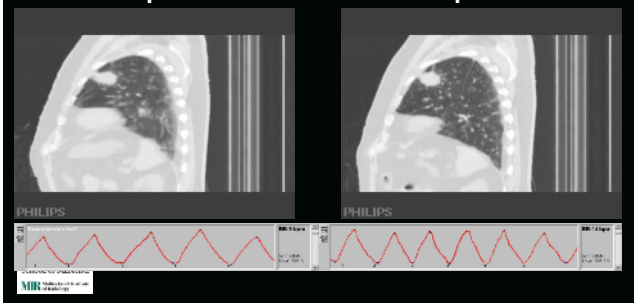
Breathing Traces



Courtesy D.A. Low

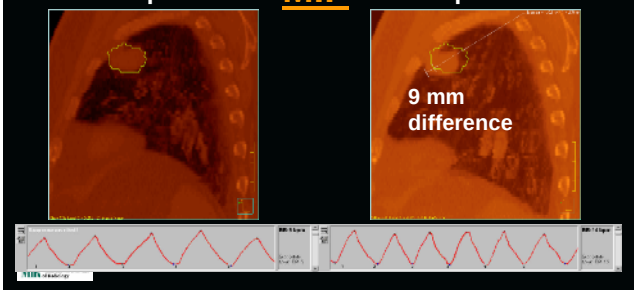
Breathing Rate Difference (Coaching Effects)

9 bpm 14 bpm



Breathing Rate Difference (Coaching Effects)

9 bpm **MIP** 14 bpm



Conclusions

- Respiration correlated imaging and delivery hardware and software relatively robust
- Inadequate processes and understanding main source of concerns
- Individual patient data sets review imperative
- Respiration correlated delivery only with daily validation of gating window
- We only gate patients who have targets, stents, or fiducial markers visible on fluoroscopic imaging

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