Clinical Use of Respiratory Correlated CT Imaging

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Disclosure

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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 conformity 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

Static

Dynamic

Dynamic

Dynamic
**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 wires
- Travel distance known
- Distances measured on generated images used to evaluate reconstruction accuracy

Quantitative MIP

Wire separation measured on MIP should agree with the traveled distance
Choosing optimal pitch based on breathing rate

<table>
<thead>
<tr>
<th>Breath Rate (breaths per minute)</th>
<th>Rotation Time (sec)</th>
<th>Breath Rate x Rotation Time</th>
<th>Pitch No Higher Than</th>
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<td>20</td>
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<td>2.4</td>
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<tr>
<td>10</td>
<td>0.06</td>
<td>0.60</td>
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</tbody>
</table>

Breathing rate slows during scan acquisition.

Mid-Scan Breathing Rate Slows

Image review and artifacts

Wrong Pitch

Image review and artifacts

Big Pause
Mid-Scan Amplitude Change

Image review and artifacts

Heart
Intensity-Projection-over-phases

MIP

MiniP

Avg

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

Breathing Rate Difference (Coaching Effects)

9 bpm

14 bpm

Breathing Rate Difference (Coaching Effects)

9 bpm

MIP

14 bpm

9 mm difference
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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