Non Ionizing Radiation Methods for Real Time Motion Management

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Disclosures

• Accuray
• Siemens
• Varian
• ViewRay advisory board

Methods to Review

• No X-rays or gamma rays!
• Optical
• Radiofrequency
• Ultrasound
• MRI
Optical

- AlignRT - VisionRT

From Fassi et al, JACMP 16 (2015)

VisionRT

- Projects infrared dot pattern
- IR camera offset from projector
- Camera sees distorted pattern – correlated with distance

Evaluation

- Peng et al (Med Phys 37, 5421, 2010) characterized system
- Stereotactic head
- Compared against Cone-Beam CT and Varian SonArray optical tracking system
- Origins within 1.3mm/0.7°
- 0° couch within 0.9mm/0.4°
- Displacements >10mm and 3° within 3.0mm (CBCT) and 0.4mm (SonArray)
- Couch angles to 90° (SonArray only), 1.2mm/0.7°
Gating with Optical

- CT and RT gating
  - Respiratory tracking (gating trigger)
  - Breath hold

Dynamic Breath Hold

- Rong et al (PLOS one, 9, e97933, 2014)
- Left sided breast and CW patients
- DIBH CT sim (RPM)
- MV Cine images to check intrafraction positioning
- Chest wall distances quantified accuracy
- Found RPM insufficient alone for optimal positioning

Rong et al
Rong et al

RPM Versus CW Extension

AlignRT versus CW Extension
Catalyst (C-RAD)

- Freislederer et al, Radiation Oncology, 2015
- Tested on Elekta Synergy
- Developed phantom for dose and film measurements

Latency Measurement

<table>
<thead>
<tr>
<th>Gating level</th>
<th>Relative dose (10 x 10 cm² field)</th>
<th>Relative dose (20 x 20 cm² field)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>99.41 ± 0.07%</td>
<td>99.59 ± 0.05%</td>
</tr>
<tr>
<td>40%</td>
<td>99.43 ± 0.04%</td>
<td>99.53 ± 0.04%</td>
</tr>
<tr>
<td>30%</td>
<td>99.45 ± 0.02%</td>
<td>99.46 ± 0.04%</td>
</tr>
<tr>
<td>20%</td>
<td>98.81 ± 0.05%</td>
<td>99.09 ± 0.05%</td>
</tr>
<tr>
<td>10%</td>
<td>97.85 ± 0.04%</td>
<td>98.28 ± 0.05%</td>
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</tbody>
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Beam off delay = 215 ± 69 ms
Beam on delay = 851 ± 100 ms
Calypso (rf)

Implanted RF beacon
Antenna array aligned with linac coordinate system

Calypso

Measurements at 10 Hz
Sub-mm resolution
Real-time tracking
Potential for fast correction

Real Time Motion Data – Patient 1
Real Time Motion Data – Patient 2

Dynamic Calypso Motion

Murphy et al. Red J 72, 259-299 (2008)

Results
Lung Calypso


Ultrasound

• Kubota et al Med Phys 41 092901 (2014)
• Developed home made system
Kubota et al

- Looked at normal organs
- Correlated breathing waveform to analyzed ultrasound image (2D of 3D image)
- Center deviation approx 1.6mm

Tracking

MRI

- Advantages
  - Arbitrary (optimized) image orientation
  - No contact hardware (except for coils)
  - No implants (unless markers)
  - Commercially available
  - Potential for 3D
- Disadvantages
  - Only 3 in the world
  - Cost > Linac + other systems
Stereotactic Ablative Liver Metastasis Radiation

50Gy in 5 Fx

- Patient driven repeated breath-hold technique with a high duty cycle
- Radiation beam is only on when tumor is in proper position
- Contrast used to highlight the tumor and allow daily tracking
- Unique to be able to see and track actual tumor (not a surrogate) in realtime

MRI Tracking During Treatment

Superior Pole Kidney SBRT

- Tumor tracking required to spare uninvolved kidney
- Tracking algorithm works very well with nice contrast difference
- Track the entire kidney with 98% within PTV for beam on
Conclusions

• Many options for non-ionizing radiation real-time motion management
• Some commercial solutions
• Challenging to integrate potential solutions into clinical workflow
• Have potential for improving treatment planning conformality and delivery accuracy