Improving Initial Setup Accuracy and Treatment Efficiency
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Disclosures
• I am a member of TG-302: Surface image guided RT

Role of Imaging in RT
• Volumetric, x-ray based imaging crucial for interfraction positioning due to highly conformal deliveries
• Limitations:
  – Added dose
  – Temporal snapshot
  – Patient posture visualization
  – No real-time monitoring
  – Motion management
Surface Imaging

- Efficient technology for patient set-up and real-time monitoring:
  - Accurate 3D images
  - Non-ionizing, non-invasive
  - Patient posture visualization
  - Surface as surrogate for respiratory gating
  - Complement x-ray based volumetric imaging

- Why?: Improve the overall (temporal) accuracy of radiation delivery
  - Patient positioning
    - Improve inter-fractional setup accuracy (posture correction)
    - Visualize patient surface changes
    - Reduce setup time (minimize repeating x-ray imaging)
  - Patient monitoring
    - Monitor patient intra-fractionally (assess post x-ray imaging shifts)
    - Quantity inadvertent movements
    - Minimize imaging needs
  - Gated delivery
    - Efficient gating tool for motion management
    - Simultaneous monitoring of patient position and respiratory signal

Video-based Imaging System

Reference: Fraction #

Image: Real-time subtracted

Table 1: Accuracy of conventional and video-assisted setup techniques used on 9 patients

<table>
<thead>
<tr>
<th>Conventional setup</th>
<th>Video-assisted setup</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 2</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Patient 3</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Patient 4</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Patient 5</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Patient 6</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Patient 7</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>1.7</td>
<td></td>
</tr>
</tbody>
</table>

Milliken BD, et al. IJROBP. 1997
Optical Commercial Systems

- VisionRT AlignRT
- C-RAD CatalystHD
- humediQ IDENTIFY

Common SI System Overview

Identification
  - Ability to verify patient identity
  - Identify immobilization devices

Positioning
  - Use of SI to position patients in 6D
  - Posture correction

Monitoring
  - Use of SI to monitor patient motion relative to reference position

Gating
  - Use of SI to provide breathing trace for gated deliveries

Typical Patient Positioning Workflow

1. Ready for tx
2. Call up patient in R&V
3. Patient to vault & perform time out
4. Set-up patient and move to iso
5. Correct posture
6. Position and re-acquire reference if needed
7. Final corrections w/ SI
8. Position to <5mm
9. Image? (Yes/No)
10. Start SI monitoring
11. Deliver Tx
Typical Patient Positioning Workflow

1. Ready for tx
2. Call up patient in R&V
3. Patient to vault & perform time out
4. Set-up patient and move to iso
5. Correct posture
6. Position and re-acquire reference (if needed)
7. Image?
   - Yes: Final corrections w/ SI
   - No: Position to <X mm
8. Start SI monitoring
9. Deliver Tx

Improving Setups: PBI

- SI using a DICOM reference provides significantly better reproducibility compared to lasers or kV orthogonal imaging in 23 patients with surgical clips as reference.

Table 2: Residual range error

<table>
<thead>
<tr>
<th>Technique</th>
<th>Anterior (mm)</th>
<th>Superior (mm)</th>
<th>Right/Left (mm)</th>
<th>Vector (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video surface mapping</td>
<td>1.9 ± 2.0</td>
<td>1.0 ± 1.0</td>
<td>1.6 ± 3.1</td>
<td>4.3 ± 2.5</td>
</tr>
<tr>
<td>Orthogonal imaging</td>
<td>1.2 ± 2.0</td>
<td>1.2 ± 2.0</td>
<td>1.3 ± 3.1</td>
<td>3.1 ± 1.5</td>
</tr>
<tr>
<td>Laser</td>
<td>3.9 ± 3.7</td>
<td>4.6 ± 3.9</td>
<td>4.3 ± 4.5</td>
<td>3.8 ± 4.2</td>
</tr>
</tbody>
</table>

Improvement of >50%

6000 fractions (Stanley et al 2017)
Improving Setups: Extremity

Detect rotations

Table 3: Improvements seen when using a reference surface (image at the first fraction) (Vert/Rel), in reductions of setup variability (comparison to, systematic error (SI)) and rotations (vert). The table includes the mean deviation, SD, and range of values.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Vert (mm)</th>
<th>Rel (mm)</th>
<th>SI (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRT</td>
<td>2.3</td>
<td>3.2</td>
<td>4.0</td>
</tr>
<tr>
<td>LRT</td>
<td>0.6</td>
<td>3.2</td>
<td>4.2</td>
</tr>
<tr>
<td>LAT</td>
<td>1.4</td>
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SI Efficiency Proton PBS Treatments

Treatment fraction completed in 21 minutes

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<td>2.6</td>
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</table>

SI: Systematic error; VRT: Vertically rotated; LAT: Laterally rotated; VRT: Vertically rotated.
## Improving Setup: Pelvis

- Surface may not be a reliable surrogate, especially in prone position due to challenges in reproducing pelvic tilt, back shape and differences in organ filling. (Zhao et al 2016)

<table>
<thead>
<tr>
<th>Use</th>
<th>Patient</th>
<th>Surface</th>
<th>System</th>
<th>Soft tissue</th>
<th>Imaging</th>
<th>Group</th>
<th>Position</th>
<th>Metric reported</th>
<th>AP (mm)</th>
<th>CC (mm)</th>
<th>RL (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvis</td>
<td>DICOM</td>
<td>AlignRT</td>
<td>AlignRT Camera</td>
<td>Pelvic</td>
<td>CT</td>
<td>Weekly</td>
<td>Prone</td>
<td>Mean Residual Shift</td>
<td>3.3</td>
<td>5.1</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Prospective comparison of paired data**

- **Supine:** Alphacradle
  - Mean Residual Shift: 3.3, 5.1, 2.8

- **Prone:** bellyboard
  - Mean Residual Shift: 5.1, 6.3, 6.0

• Surface may not be a reliable surrogate, especially in prone position due to challenges in reproducing pelvic tilt, back shape and differences in organ filling. (Zhao et al 2016)

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## SI Initial Setup Efficiency

### Can surface imaging improve the patient setup for proton postmastectomy chest wall irradiation?

- **Slide Courtesy of H Al-Hallaq**

### SI Initial Setup Efficiency

- Reduce filming frequency
- Increase throughput

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### The University of Chicago Medicine WBRT

<table>
<thead>
<tr>
<th>n=50</th>
<th>Before AlignRT</th>
<th>After AlignRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Patients with shifts &lt; 1cm</td>
<td>64%</td>
<td>92%</td>
</tr>
<tr>
<td>% of Patients with shifts &lt; 1cm; total time &lt; 30mins</td>
<td>44%</td>
<td>72%</td>
</tr>
</tbody>
</table>

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**Slide Courtesy of H Al-Hallaq**
Practical SI Considerations

- Reference image issues
  - Resolution & breathing motion
  - CT FoV
  - HU threshold
  - Reference image fidelity
- ROI selection
  - Large: posture correction
  - Small: tracking
- Learning curve
  - Therapist education
  - Comfort level

Conclusions

- Use of SI technology has increased in recent years
- SI technology has shown to improve accuracy in initial setup for a number of disease sites
- Improvements in overall treatment time have been shown with SI
- Practical issues with SI need to be considered to ensure accurate positioning of patients

Thanks for your attention