SURFACE IMAGE GUIDED RADIOTHERAPY: CLINICAL APPLICATIONS AND MOTION MANAGEMENT

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CONFLICT OF INTEREST STATEMENT

- I receive royalties and licensing fees for computer-aided diagnosis technology through The University of Chicago
- I am co-Chair of TG-302: Surface Image Guided RT
BENEFITS OF SIG RT

- Efficient technology for patient set-up and real-time monitoring:
  - Accurate 3D images
  - Non-ionizing, non-invasive
  - Patient posture visualization
    - Extremities, chin
  - Respiratory gating
  - Used in conjunction with volumetric imaging

Slide Courtesy of Alonso Gutierrez, Ph.D.
OPTICAL-BASED IMAGING

- Each camera is a projector-camera pair
- Sequence of patterns are projected onto the measured surface
- Camera detects the projected patterns
- Reconstruction compares projected and captured patterns to identify the coordinates of each pixel on the captured image

Slide Courtesy of Alonso Gutierrez, Ph.D.  Courtesy of J. Geng
STRUCTURED LIGHT PATTERNS

Slide Courtesy of Alonso Gutierrez, Ph.D.

Zhang et al. 3DPVT (2002)
AlignRT

- Speckle pattern provides visual uniqueness to each point of the imaged surface
- 3D position of a set of points can be determined through triangulation
  - Camera calibration needed
- AlignRT calculates the displacement needed to align the imaged surface with the reference surface
  - Translations
  - Rotations

Slide Courtesy of Adam Paxton, Ph.D.
LEARNING OBJECTIVES

1. Discuss workflow considerations impacting SI accuracy
2. Review SI applications for general positioning
3. Review SI applications for real-time motion monitoring/management
4. Highlight future potential uses of SI

*References from Summer School Ch 13 are abbreviated as in chapter.
*Additional references will be written out completely.
*Screenshots from AAPM Virtual Library Talks/Handouts are referenced as “AAPM VL.”
1. WORKFLOW CONSIDERATIONS IMPACTING SI ACCURACY
WORKFLOW CONSIDERATIONS IMPACTING SI ACCURACY

- Registration Algorithm
- Reference Type
- Threshold
- ROI
- Hardware

SI Accuracy
WORKFLOW CONSIDERATIONS IMPACTING SI ACCURACY

- Reference Type
- ROI
- Hardware
- Registration Algorithm
- Threshold

SI Accuracy
SELECTION OF REFERENCE SURFACE

- Reference surface from CT sim represents the “gold standard”: 1) captured by SI camera**  
  2) created from patient’s external contour (i.e., DICOM)

**Many clinics do not have SI cameras in simulator so internal imaging (e.g., MV ports, CBCT) is used to verify patient’s position before camera is used to capture a reference surface
ADVANTAGES OF USING DICOM SURFACE

- Quantifies both systematic & random errors, enabling improvements in positioning workflow and/or immobilization (Batin et al 2016, Padilla et al 2014)

- Highlights change in anatomy (e.g., breast swelling) from sim
DISADVANTAGES OF USING DICOM SURFACE

- Degraded by breathing motion (quiet respiration)
- Contaminated by artifacts from objects present at sim only
- FOV limited to that of CT scan
- Requires assumption of HU value to tissue density
- Less sensitive to small intra-fraction errors (> 1mm)
DISADVANTAGES OF USING DICOM SURFACE

• Without calibration, inherent bias could be introduced by HU (Li et al 2011, Moser et al 2013)


DIBH for breast cancer (n=1305)
ADVANTAGES OF USING CAMERA SURFACE

- Large FOV (e.g., includes arms/chin for breast patient)
- Monitors intra-fraction motion with high sensitivity (<1mm)
DISADVANTAGES OF USING CAMERA SURFACE

- If not captured at simulation, can introduce systematic error because patient’s posture cannot be perfectly reproduced

Bert et al 2006
Selection of ROI

Requirements
- Accurate surrogate for target/task
- Possess topographically salient features to provide unique registration

Potential Pitfalls
- Too large:
  - Low frame rate for monitoring
  - Insensitive to localized changes (e.g., breast swelling)
- Too small:
  - Cannot characterize posture adequately
  - Susceptible to registration errors due to lack of topography
SELECTION OF ROI

- ROI that is “just right….”
- ROI selection is an “art” not an “algorithm” (Kang et al 2012)
- Consider use of multiple ROIs:
  - Large → postural correction
  - Small → tracking
**SELECTION OF ROI**

- ‘Entire’ ROI detects a roll that is mis-interpreted as a lateral shift when registering ‘Chestwall’ ROI, which lacks sufficient topographic detail.
SELECTION OF ROI

Day 1

Day 24
Action threshold to disable beam/alert therapy team

Similarly to setup margins, thresholds are institution-specific

Selected from a) literature or b) “observing” patients with SI:

- Stanley et al (2017) observed >6000 fractions guided by CBCT in 4 sites (pelvis, abdomen, thorax, chest/breast) and found discrepancies of 5-6mm

- Li et al (2013) observed volunteers’ range of motion in thermoplastic masks and determined <2mm threshold

If positioning errors are reduced over time (i.e., improved immobilization), adjust thresholds
SELECTION OF THRESHOLDS

Larger
- When quantifying systematic & random errors
- Significant deformation is expected (e.g., pendulous breast)

Smaller
- For intra-fraction monitoring following acquisition of reference surface (e.g., frameless SRS)
2. SI FOR GENERAL POSITIONING

• Partial Breast Irradiation (PBI)
• Whole Breast RT (photon, proton)
• Extremity
• Thorax/Pelvis
• SBRT
• Head & Neck
2. SI FOR GENERAL POSITIONING

- Partial Breast Irradiation (PBI)
- Whole Breast RT (photon, proton)
- Extremity
- Thorax/Pelvis
- SBRT
- Head & Neck
## GENERAL POSITIONING: MULTIPLE SITES

<table>
<thead>
<tr>
<th>Author</th>
<th>Anatomical Site</th>
<th>Patient No</th>
<th>Reference Surface</th>
<th>System</th>
<th>IGRT Ground Truth</th>
<th>Comparison Type</th>
<th>Metric reported</th>
<th>AP (mm)</th>
<th>CC (mm)</th>
<th>RL (mm)</th>
<th>3D (mm)</th>
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<tbody>
<tr>
<td>Moser et al 2013</td>
<td>Breast</td>
<td>50</td>
<td>DICOM</td>
<td>Sentinel (single-camera)</td>
<td>MVCT</td>
<td>Retrospective</td>
<td>Median shifts from lasers calculated with SI</td>
<td>-8.7</td>
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<td></td>
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<td>-6.2</td>
<td>0.1</td>
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<tr>
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<td>Head and Neck</td>
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<td>-3.1</td>
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<td>-1.2</td>
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<td>-0.5</td>
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<td>-0.8</td>
<td>-2.7</td>
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<td>Pelvis</td>
<td>SUM = 13</td>
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<td>CBCT</td>
<td>Retrospective</td>
<td>Mean residual shifts</td>
<td>1.8</td>
<td>0.2</td>
<td>1.2</td>
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<td>Thorax</td>
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<td>2.4</td>
<td>0.7</td>
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<td></td>
<td>Head and neck</td>
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<td>0.2</td>
<td>3.7</td>
<td>0.3</td>
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</table>
**Fig. 1.** Cumulative histograms showing the pre-CBCT 3D corrections for a traditional three point localization and surface imaging techniques for the pelvis/lower extremities.

**Fig. 2.** Cumulative histograms showing the pre-CBCT 3D corrections for a traditional three point localization and surface imaging techniques for the abdomen.

**Fig. 3.** Cumulative histograms showing the pre-CBCT 3D corrections for a traditional three point localization and surface imaging techniques for the chest/upper extremities.

**Fig. 4.** Cumulative histograms showing the pre-CBCT 3D corrections for a traditional three point localization and surface imaging techniques for the breast.

6000 fractions (Stanley et al 2017)
GENERAL POSITIONING: WBRT

- WBRT using tangential photon beams opened for “flash” is robust
- Typically, verified weekly with MV ports

Byrne, Hu, Archibald-Heeren 2016
POSITIONING WORKFLOW: REFERENCE IMAGE?

Shah et al 2013

ROI used for monitoring
**GENERAL POSITIONING: WBRT**

<table>
<thead>
<tr>
<th>Author</th>
<th>Site</th>
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<th>Reference Surface</th>
<th>System</th>
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<th>AP (mm)</th>
<th>CC (mm)</th>
<th>RL (mm)</th>
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<td>Padilla et al 2014</td>
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<td>DICOM</td>
<td>AlignRT</td>
<td>MV port films (once/week)</td>
<td>Retrospective</td>
<td>lasers</td>
<td>Setup margins (MV films) = 2.5<em>Σ +0.7</em>σ</td>
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<td>Shah et al 2013</td>
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<td>50</td>
<td>DICOM (Sim Day)</td>
<td>AlignRT</td>
<td>MV films (60% of fractions)</td>
<td>Prospective</td>
<td>lasers then SI</td>
<td>Setup margins (SI) of laser setup</td>
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<td>4.3</td>
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<tr>
<td>Batin et al 2016</td>
<td>Chestwall</td>
<td>15</td>
<td>DICOM</td>
<td>AlignRT</td>
<td>Radiograph @±3 mm threshold (n=5)</td>
<td>Retrospective/Prospective</td>
<td>tattoos, 3 point, breastboard</td>
<td>Setup margins (X-ray only) = 2.5<em>Σ +0.7</em>σ</td>
<td>9.4</td>
<td>9.9</td>
<td>8.3</td>
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<tr>
<td><strong>PROTON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SI &amp; beamline radiograph (n=10)</td>
<td></td>
<td></td>
<td>Setup margins (+SI) = 2.5<em>Σ +0.7</em>σ</td>
<td>4.2</td>
<td>2.8</td>
<td>4.7</td>
</tr>
</tbody>
</table>

- Mixing and matching of following could explain lack of agreement:
  - Chestwall vs breast
  - DICOM vs camera
  - ROI with vs without breast tissue
GENERAL POSITIONING:
PROTON POST-MASTECTOMY CHEST WALL RT

Batin et al 2016
GENERAL POSITIONING:
PROTON POST-MASTECTOMY CHEST WALL RT

Batin et al 2016
GENERAL POSITIONING: WBRT

- RMS standard deviation of the chest surface ROI (excludes pendulous breast tissue) was 2.4 ± 1.9 mm & correlated significantly with time

Wiant et al 2014
GENERAL POSITIONING: WBRT

- Batin et al: a) immobilization modified to include hand grips, chin straps, b) SI replaced radiographs for daily setup of treatments
- Padilla et al: a) KV-OBI orthogonal films, b) external contour on DRR
- Shah et al: More attention paid by therapist to arm/chin positions
- Wiant et al: Reduce treatment times <15mins to minimize intra-fraction drift
GENERAL POSITIONING: HEAD & NECK

- Ideal for SI due to a) distinct topography & b) rigid anatomy but....
- Surface obscured by thermoplastic mask/immobilization
GENERAL POSITIONING: HEAD & NECK

Li et al 2013
GENERAL POSITIONING: HEAD & NECK

• Deformations due to tumor shrinkage weight loss, shoulder positioning invalidate the correlation between surface and tumor positions:
  
  o Gopan and Wu (2012): discrepancy between surface & bony anatomy via CBCT increased as tumors shrank, which could be mitigated by ROI selection (e.g., forehead, cheek bones, nose)
  
  o Zhao et al (2018): a) custom mold more accurate than shoulder stirrups & b) setup errors per CBCT spiked towards end of treatment due to weight loss
  
  o Cho et al (2013): post-CBCT residual shifts >1mm (CC) but <1mm (AP, RL) attributed to table tilts due to patient weight
3. SI FOR REAL-TIME MONITORING/MANAGEMENT

- Frameless SRS
- Deep-inspiration breath-hold (DIBH) for WBRT
FRAMELESS SRS: INTRA-FRACTION MONITORING

• Workflow
• Selection of frameless mask
• Verification of isocenter coincidence
  o Imaging vs treatment isocenter
  o Effect of couch kicks

Kim, AAPM VL 2013
Typical workflow for SRS

- CT sim with open face mask
- Define a ROI on CT-defined reference surface
- Setup head adjustment attachment on couch (if needed)
- Setup patient on the couch
- Apply shifts given to isocenter
  - Rough positioning
  - Adjust rotations (to limit additional adjustment)
- Place faceless mask and make shifts indicated by AlignRT until approximately zero
  - Fine positioning

Slide Courtesy of Adam Paxton, Ph.D.
Typical workflow for SRS

- kV/kV match to check for rotations (e.g., pitch)
- CBCT-indicated shifts are used to put patient in their final Tx position
- New reference image is captured with AlignRT (zero offsets)
- Monitor patient’s position during treatment
- Discontinue treatment and reposition if offsets exceed a limit
  - 1 mm
- Couch angle changed in AlignRT for beams utilizing couch rotations

Slide Courtesy of Adam Paxton, Ph.D.
Active mask should be used as custom head mold alone cannot control involuntary motion (e.g., coughing, falling asleep)
FRAMELESS SRS: QA OF ISOCENTER COINCIDENCE

- End-to-end testing including imaging coincidence should be performed with characterization of effects of table rotations

Wen et al 2015

Fig. 2. The OSMS QA phantom (a) sitting on top of an acrylic base plate. The localization (b) of phantom surface using the OSMS system. The difference (delta) between the current position of the OSMS phantom and its reference position is shown in 6DoF. The six degree automatic fusion (c) between planning CT and CBCT after adjusting the contrast of the acquired image and reference image to achieve optimal visualization of the BBs. An orthogonal MV (d)/KV (e) image set is taken and 2D–3D image fusion is performed to quantify the residual error. Four representative (f) MLC defined portal images of the Winston-Lutz test.
End-to-end testing including imaging coincidence should be performed with characterization of effects of table rotations.

Wen et al 2015
FRAMELESS SRS: INTRA-FRACTION MONITORING

Paxton et al 2017
Results: AlignRT-captured ref surface

- Displacement magnitude increases with couch rotations for long and lateral miscalibrations
  - Faster increase for larger miscalibrations
- Average displacement at 0° was 0.2 mm
- Average displacement at ±90° was 4.3 and 1.6 mm for 3.0 mm and 1.0 mm miscalibrations
- For vertical miscalibrations, the largest indicated displacement was 0.6 mm

Slide Courtesy of Adam Paxton, Ph.D.
Results: after isocentre calibration

- With an AlignRT-captured ref surface
- Displacements ranged from 0.1 to 0.5mm for all couch rotations
- These values are within the expected range of walkout observed for this couch from ongoing QA tests

Slide Courtesy of Adam Paxton, Ph.D.
WBRT DIBH: INTRA-FRACTION MONITORING

- Accuracy of voluntary breath-hold
- Verification of heart position
- Identifying changes in breath-hold pattern
- Field matching
Risk of Ischemic Heart Disease in Women after Radiotherapy for Breast Cancer

- Population-based study in Sweden & Denmark
- Breast RT from 1958-2001:
  - 963 major coronary events
  - 1205 controls
- Heart dose estimated:
  - “CT scan of a woman with typical anatomy”
NSABP B-51 SETS DE FAC TO STANDARD

Ipsilateral lung:
- Arm 1/Group 1A:
  - $\leq 15\%$ of the ipsilateral lung should receive $\geq 20$ Gy
  - $\leq 35\%$ of the ipsilateral lung should receive $\geq 10$ Gy
  - $\leq 50\%$ of the ipsilateral lung should receive $\geq 5$ Gy
- Arm 2/Groups 2A and 2B:
  - $\leq 30\%$ of the ipsilateral lung should receive $\geq 20$ Gy
  - $\leq 50\%$ of the ipsilateral lung should receive $\geq 10$ Gy
  - $\leq 65\%$ of the ipsilateral lung should receive $\geq 5$ Gy

Contralateral lung:
- $\leq 10\%$ of the contralateral lung should receive $\geq 5$ Gy

Heart:
- Arm 1/Group 1A
  - $\leq 5\%$ of the whole heart should receive $\geq 20$ Gy for left-sided breast cancers, and $0\%$ of the heart should receive $\geq 20$ Gy for right-sided breast cancers
  - $\leq 30\%$ of the whole heart should receive $\geq 10$ Gy for left-sided breast cancers, and $\leq 10\%$ of the heart should receive $\geq 10$ Gy for right-sided breast cancers
  - Mean heart dose should be $\leq 400$ cGy
- Arm 2/Groups 2A and 2B
  - $\leq 5\%$ of the whole heart should receive $\geq 25$ Gy for left-sided breast cancers, and $0\%$ of the heart should receive $\geq 25$ Gy for right-sided breast cancers
  - $\leq 30\%$ of the whole heart should receive $\geq 15$ Gy for left-sided breast cancers, and $\leq 10\%$ of the heart should receive $\geq 15$ Gy for right-sided breast cancers
  - Mean heart dose should be $\leq 400$ cGy
ADVANTAGES OF DIBH

- Freeze organ/tumor motion
- Separate heart from target (breast, IMN)
- Increase total lung volume

VOLUNTARY BREATH HOLD VS. ABC

- 23 patients receiving 40 Gy in 15 fractions:
  - Randomized to v_DIBH or ABC_DIBH for 7 fractions & vice versa
  - Daily portal imaging & CBCT for 6 fractions
- No significant Δ: setup errors, normal tissue doses
- Patients & therapists significantly preferred v_DIBH!

BREAST/CHEST WALL SURFACE VS. ABC

“Spirometer-based control does not guarantee a stable and reproducible position of the external surface in left-breast DIBH”

**BREAST/CHESTWALL SURFACE VS. ABC**

**Table 4** Intra-DIBH stability and intrafraction reproducibility from 31 left-sided patients in this analysis compared to those of spirometry-based results from seven patients as reported on in Fassi et al.

<table>
<thead>
<tr>
<th></th>
<th>Intra-DIBH variability (mm)</th>
<th>Intrafraction reproducibility (mm)</th>
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<tbody>
<tr>
<td></td>
<td>A/P</td>
<td>S/I</td>
</tr>
<tr>
<td>Fassi et al. (n = 7) Surface monitoring + spirometry</td>
<td>1.37</td>
<td>1.78</td>
</tr>
<tr>
<td>This analysis (n = 31) SI + voluntary DIBH</td>
<td>0.66</td>
<td>0.58</td>
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<tr>
<td>% within 2 mm</td>
<td>72.1</td>
<td>76.3</td>
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<td>% within 3 mm</td>
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<td>% within 5 mm</td>
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<td>% within 7 mm</td>
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WBRT DIBH: INTRA-FRACTION MONITORING
VERIFICATION OF HEART POSITION

- **2D imaging:**
  - MV Portal images
  - MV Cine images
- **3D imaging:**
  - CBCT
VERIFICATION OF HEART POSITION: MV PORTAL IMAGES

Mean heart dose reduced from 4.8 Gy (FB) to 1.2 Gy (vDIBH)
VERIFICATION OF HEART POSITION: MV PORTAL IMAGES

- Correlation between distance measured on port films to DRR = 0.81
- Inherent differences in image resolution?
- More dose to the heart than planned?

Tang et al 2014
VERIFICATION OF HEART POSITION:
MV CINE IMAGES

Rong et al 2014
VERIFICATION OF HEART POSITION: CBCT

- NKI group recommends planning organ-at-risk margins:
  - Bony anatomy alignment with CBCT = 1-2mm
  - AlignRT = 1.1mm LR, 6.7mm CC, 2.5mm AP
- SI: “Harder to distinguish whether a setup error ... is caused by anatomic changes or by a change in BH”

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Planned</th>
<th>Offline</th>
<th>Online</th>
<th>Planned vs. Offline</th>
<th>Planned vs. Online</th>
<th>Offline vs. Online</th>
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<tr>
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<td>1.9</td>
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<td>0.04</td>
<td>0.71</td>
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<td>Heart $D_{\text{max}}$</td>
<td>40.2</td>
<td>36.2</td>
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<td>Left coronary artery $D_{\text{mean}}$</td>
<td>6.5</td>
<td>7.5</td>
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<td>0.05</td>
<td>0.53</td>
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<td>Left coronary artery $D_{\text{max}}$</td>
<td>26.6</td>
<td>25.9</td>
<td>25.0</td>
<td>0.37</td>
<td>0.09</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*Abbreviations: $D_{\text{max}} =$ maximum dose; $D_{\text{mean}} =$ mean dose.*

For offline and online protocols, the dose was first accumulated over all breathing phases and then over all fractions. Wilcoxon signed-rank test was calculated to determine statistical significance dose difference between the protocols.

DOSE BETWEEN BREATH-HOLDS

<table>
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<th>DIBH1</th>
<th>DIBH2</th>
<th>FB</th>
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<tbody>
<tr>
<td>Heart Mean Dose (Gy)</td>
<td>1.8</td>
<td>2.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Lung V20 (%)</td>
<td>24%</td>
<td>29%</td>
<td>39%</td>
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</tbody>
</table>
IDENTIFICATION OF CHANGES IN BREATH-HOLD
IDENTIFICATION OF CHANGES IN BREATH-HOLD

Planning CT DIBH

Repeat CT DIBH2
IDENTIFICATION OF CHANGES IN BREATH-HOLD

<table>
<thead>
<tr>
<th></th>
<th>CT1</th>
<th>CT2</th>
<th>FB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Heart Dose</td>
<td>0.5 Gy</td>
<td>1.4 Gy</td>
<td>2.7 Gy</td>
</tr>
<tr>
<td>Lung V20Gy</td>
<td>15%</td>
<td>17.7%</td>
<td>23%</td>
</tr>
</tbody>
</table>
IDENTIFICATION OF CHANGES IN BREATH-HOLD

- Verify with internal imaging
- Adapt the plan as necessary
- Acknowledge that variability exists!
FIELD MATCHING

- SI accuracy better at isocenter (Wiersma et al 2013), which coincides with the matchline for plans in which tangential and supraclavicular fields have a common isocenter.

- Kügele et al (2018) showed that DIBH isocenter reproducibility with SI was better for patients with tangential and supraclavicular fields compared to those with tangential fields only, possibly due to the isocenter placement at the matchline rather than in deformable breast tissue.

- Xiao et al (2018) found significantly smaller setup errors in CC direction for 3-field vs 2-field DIBH treatments.
4. FUTURE APPLICATIONS OF SI

- Collision prediction
- Facial recognition
- Biometrics
4. FUTURE APPLICATIONS OF SI

- Collision prediction
- Facial recognition
- Biometrics
Collision prediction software for radiotherapy treatments

Laura Padilla
Virginia Commonwealth University Medical Center, Richmond, Virginia 23298

Erik A. Pearson
Techna Institute and the Princess Margaret Cancer Center, University Health Network, Toronto, Ontario M5G 2M9, Canada

Charles A. Pelizzari
Department of Radiation and Cellular Oncology, The University of Chicago, Chicago, Illinois 60637

Padilla, Pearson, Pelizzari 2015
The development and verification of a highly accurate collision prediction model for automated noncoplanar plan delivery

Victoria Y. Yu, Angelia Tran, Dan Nguyen, Minsong Cao, Dan Ruan, Daniel A. Low, and Ke Sheng

Department of Radiation Oncology, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, California 90024
Facial recognition system created with Kinect using its facial mapping library; 35 points extracted from 4 poses.

- Sensitivity = 96.5%; Specificity = 96.7%; algorithm affected glasses, scarves, and hair covering the face.
- No facial recognition module in current commercial systems!

Silverstein et al. 2017
IDENTIFICATION

- Biometric identification
  - Palm
  - Facial
- Correct immobilization devices and location on treatment table verification

Slide Courtesy of Alonso Gutierrez, Ph.D.  
Courtesy of C-RAD & Humediq
ADDITIONAL BENEFITS OF SI?

- Safety Checks:
  - Correct immobilization?
  - Correct isocenter treated?
- Treatment Quality:
  - Efficiency?
DIBH BREAST CASE: FIRST DAY SI

Pitch problem caused by changed in breath-hold pattern or positioning?
DIBH BREAST CASE: FIRST DAY FILMS

AP kV

LAT kV

DRR/Med MV port
DIBH BREAST CASE: CT SCAN COMPARISON
DIBH BREAST CASE: CT SCAN COMPARISON
DIBH BREAST CASE: NEXT DAY SI

Pitch resolved!
SI TO IMPROVE EFFICIENCY?

- Reduce filming frequency
- Increase throughput

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>
SUMMARY

• Implementation of SI is clinic-specific & task-specific: reference surface, ROI, thresholds interplay with immobilization/motion management
• SI accuracy generally higher when surface is a good surrogate for target (e.g., higher for brain than pelvis)
• SI has the potential to benefit every patient (e.g., improving immobilization, efficiency, safety)
THANK YOU FOR YOUR ATTENTION!

Acknowledgements:
Co-authors: Alonso Gutierrez, Laura Padilla
Colleagues & Therapists at Univ. of Chicago