Advanced Technologies for Breast RT - Delivery

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Learning Objectives:

- Understanding rationale, indications and promise for using advanced RT technologies for breast cancer
- Review of recent advances in planning techniques of breast RT
- Review of recent advances in delivery technologies for breast RT, and discussion of clinical implementation and experience for using these advanced technologies
The conformal treatment strategies (e.g., 3DCRT, IMRT, field in field, VMAT) for PBI or WBI+boost require high accuracy and reproducibility in patient positioning and target localization during treatment delivery.

**Need to address:**

- Intra-fractional motion, e.g., respiration
- Inter-fractional variations, e.g., set-up uncertainty, anatomic changes
Effect of respiratory motion for breast irradiation

Max centroid movement

Position changes (cm)

Tumor Lung Heart Chest wall IMC nodes Axillary nodes Br Plexus nodes

Patient 1
Patient 2
Patient 3
Patient 4
Patient 5
Patient 6
Patient 7
Patient 8
Intra-fractional movements: nodes

IMC max dose

IMC
PTV coverage at the prescription dose for phases 0%, 20% and 50%.

![Graph showing PTV coverage for different phases and patient numbers.]
Fig. 6. Variation of heart mean doses among three phases from non-gated irradiation for the 20 study subjects. The symbols from left to right represent mean heart doses at 0, 20 and 50% phase.
Fig. 7. Comparison of dose–volume histograms for a sample case demonstrating potential gains from a gated treatment. The breathing adapted radiation gated plans based on phases of 0%, 50%, and a conventional non-gated plan based on phase 20% images are represented by solid, dotted, and dashed lines, respectively.
Use of respiration gating for breast RT

- For selective patients with large respiration motion (e.g., > 8mm)
- Improving target coverage (e.g., IMC, lumpectomy cavity)
- Reducing heart dose if left-sided breast RT
Technologies to address inter-fraction variations for breast RT:

Image guided patient positioning
- 2D MV/kV imaging with/without fiducial markers
- CT, CBCT, MVCT
- 3D surface imaging (optical)
- Ultrasound

Other approaches:
A variety of Immobilization device

More than 100 articles published.
Commonly-used patient positioning with 2D imaging based on external contour/markers or chest wall may not always lead to correct alignment of CTV/PTV.
In-Room Imaging to account for inter-fractional changes
IGRT breast at MCW

- using CT-on-Rails
- Daily IGRT for PBI and boost
- Patients setup in both supine and prone
- Registration based surgical clips and/or seroma
- Started Dec. 2007
- > 200 patients treated so far.
Breast IGRT
MCW experience
90 patients
Prone vs. Supine setup

Larger daily variations for prone, indicative for IGRT
## Margin estimation

<table>
<thead>
<tr>
<th></th>
<th>$\Sigma$ (mm)</th>
<th>$\Sigma$ (mm)</th>
<th>Margin (mm)</th>
<th>p95-p95 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin marks</td>
<td>6.5</td>
<td>6.4</td>
<td>13.4</td>
<td>14.9</td>
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<tr>
<td>Manual soft tissue</td>
<td>3.2</td>
<td>5.9</td>
<td>10.2</td>
<td>8.4</td>
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<tr>
<td>Center of mass</td>
<td>1.9</td>
<td>4.1</td>
<td>4.5</td>
<td>4.0</td>
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<tr>
<td>Zero mean vector</td>
<td>1.5</td>
<td>3.5</td>
<td>2.5</td>
<td>2.6</td>
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<tr>
<td>2D patient exterior</td>
<td>4.1</td>
<td>4.5</td>
<td>8.2</td>
<td>8.7</td>
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<tr>
<td>2D chest wall</td>
<td>4.9</td>
<td>5.8</td>
<td>11.5</td>
<td>11.1</td>
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<tr>
<td>2D surgical clips</td>
<td>4.3</td>
<td>4.0</td>
<td>6.6</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Abbreviations:** 2D = two-dimensional; DNS = distances along surface normals.

- $\sigma$: Standard deviation of the DSN (random variation).
- $\Sigma$: Average deviation of the DSN (systematic variation).
- Margin = $2 \sigma + 0.7 \Sigma$.
- p95-p95: The amount of expansion that would cover the 95% of points for 95% of days.
Interfractional lumpectomy cavity volume and shape changes
Lumpectomy cavity volume and shape change after IGRT repositioning

Prone

Supine
Interfraction variations (setup errors, anatomy changes) include both random and systematic variations and can be significant during breast RT.

**IGRT**
- reposition the patient without modifying plan
- addresses setup error and organ translational variation but not organ deformation and volume changes

Solution: *Adaptive RT*
Evaluation of adaptive RT for breast

Create adaptive plan based on daily CT

Use a fast replanning algorithm (aperture morphing and weight optimization)

Both online and offline ART are applicable
ART for PBI

- Improve target conformity
- Reduce skin dose
Repositioning vs Adaptive Plan: Supine

- Clip-based Repositioning
- Contour-based Repositioning
- Adaptive
- Re-optimized

Ipsilateral Breast Reference Volume

Ipsilateral Lung

95% Dose
## Two sample cases: supine PBI

<table>
<thead>
<tr>
<th>Case</th>
<th>Struture</th>
<th>Quantity</th>
<th>Repositioning</th>
<th>Adaptive</th>
<th>Re-opt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>clip</td>
<td>LC contour</td>
<td></td>
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<tr>
<td>Large change</td>
<td>PTV_eval</td>
<td>(V_{95}) (100)</td>
<td>86.1</td>
<td>88.5</td>
<td>95.4</td>
</tr>
<tr>
<td></td>
<td>Breast (lpsi)</td>
<td>(V_{50})</td>
<td>46.1</td>
<td>46.1</td>
<td>42.5</td>
</tr>
<tr>
<td></td>
<td>Breast (lpsi) – PTV-EVAL</td>
<td>(V_{100})</td>
<td>10.5</td>
<td>5.6</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Breast (lpsi) – PTV-EVAL</td>
<td>(V_{50})</td>
<td>56.5</td>
<td>50.7</td>
<td>45.5</td>
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<tr>
<td>Small change</td>
<td>PTV_eval</td>
<td>(V_{95}) (100)</td>
<td>91.8</td>
<td>96.2</td>
<td>95.9</td>
</tr>
<tr>
<td></td>
<td>Breast (lpsi)</td>
<td>(V_{50})</td>
<td>48.1</td>
<td>47.4</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td>Breast (lpsi) – PTV-EVAL</td>
<td>(V_{100})</td>
<td>2.1</td>
<td>1.9</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Breast (lpsi) – PTV-EVAL</td>
<td>(V_{50})</td>
<td>44.0</td>
<td>40.9</td>
<td>35.9</td>
</tr>
</tbody>
</table>
ART for PBI

• Standard CTV/PTV margins (1.5+1.0 cm) can account for these variations for most cases (70%).

• Adaptive replanning (either online or offline) is helpful for cases with large changes in lumpectomy cavity.
Breast WBI + boost
Changes in lump cavity between daily CT at boost and plan CT.
Adaptive plan at boost

Lump cavity increase

Lump cavity decrease
# Breast WBI + ART for boost

<table>
<thead>
<tr>
<th>Structure</th>
<th>Quantity</th>
<th>IGRT</th>
<th>ART</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV_eval</td>
<td>$V_{95%}$</td>
<td>93.7%</td>
<td>96.0%</td>
</tr>
<tr>
<td>Breast_eval</td>
<td>$V_{50%}$</td>
<td>42.3%</td>
<td>39.3%</td>
</tr>
<tr>
<td>Breast_eval</td>
<td>$V_{100%}$</td>
<td>18.6%</td>
<td>17.0%</td>
</tr>
<tr>
<td>PTV_eval</td>
<td>CI</td>
<td>2.0</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Offline ART for IMRT SIB

• ART replanning based on new CT at 10\textsuperscript{th} fr (28 fr total)
• Eligibility:
  ➢ lump cavity > 30 cc
• Findings
  ➢ 9\% of patient eligible
  ➢ significant reduction of high dose volume

Hurkmans et al, Radiother Oncol. 2012;103:183-7
A study in design at MCW

Whole breast irradiation + ART boost

• ART plan based on CT one day before boost; boost treated with ART plan

• Eligibility:
  ➢ lump cavity > 30 cc
  ➢ V54Gy > 40%

• End points:
  ➢ Primary: reduction of fibrosis
  ➢ Secondary: reduction of local recurrence
Concluding Remarks

- Management of intra- and inter-fractional variations is important to deliver conformal RT for breast cancer

- IGRT online repositioning addresses setup error and translational variation but not organ (lump cavity) deformation and volume changes

- Adaptive replanning can account for the deformation and volume change, resulting in improved target coverage and/or reduced high-dose volume in PBI or boost.
Use of advanced RT planning and delivery technologies for breast cancer is fully justified!