Learning objectives

(1) To review current practice of breast SBRT and APBI.
(2) To learn treatment planning and delivery techniques for breast SBRT and APBI using Linac, GammaPod and Proton.
(3) To improve efficiency, accuracy and safety though experience.

Disclosure

• No conflict of interest

Preoperative partial breast radiosurgery (SBRT)

- Edibility criteria: Age ≥ 55yr with cT1N0, noninvasive, tumor ≤ 2cm, biopsy
- Phase I: Dose escalation study (32 patients. Started in 2007)
  - 8 patients at 15Gy, 8 patients at 18Gy, and 16 patients at 21Gy
  - To determine the maximum tolerated dose of single-dose partial breast irradiation based on toxicity
- Phase II: Evaluation of single-fraction treatment (100 patients. Finished in 2022)
  - 21Gy → modified to SIB 15Gy to PTV_CTV and 21Gy to PTV_GTV
  - To determine rate of good/excellent cosmesis
  - Single fraction

Immovilization and CT/MRI simulation

- Planning CT
- MRI
  - breast surface coil
  - T1-weighted/T2-weighted/inversion-recovery/diffusion weighted (DWI), and dynamic contrast enhanced (DCE)
CT and MRI

Challenge! Different immobilization devices make the breast shape different
Solution! All patients have a biopsy marker (clip) at the tumor location.
Image registration: Align CT clip to MR clip, and confirm with soft tissue pattern.

CT
MRI

Dose constraints – updated phase II

- Prescription: SIB. Single fraction. 15Gy to PTV_CTVeval and 21Gy to PTV_GTVeval
- Target coverage
  - CTV: V100% (100% of 15Gy) >= 95%
  - PTV_CTVeval: V95% (95% of 15Gy) >= 90%
  - PTV_GTVeval: V95% (95% of 21Gy) >= 95%
- OAR constraints
  - Ipsilateral breast: V50% <= 30%
  - Contralateral breast: Dmax <= 2.1 Gy
  - Lungs: Dmean <= 3.6 Gy
  - Heart: Dmean <= 1.5 Gy
  - Chest wall: D20cc <= 16.3 Gy
- Skin dose: Dmax <= 21Gy, D1cc <=14Gy, D10cc <= 9Gy

Structures

- Biopsy clip
- GTV (CT and MR combined)
- CTV= GTV + 1.5cm; exclude 5mm from skin surface;
- Skin (3mm layer);
- chestwall; Lt/Rt breast; Rt/Lt lung; heart;

Phase I and Phase II

- PTV= CTV+0.5cm; PTV_eval to exclude chestwall and 5 mm from skin surface

Modified Phase II SIB

- PTV_GTV= GTV+0.5cm; PTV_GTVeval to exclude chestwall and 5mm from skin surface
- PTV_CTV= CTV+0.5cm; PTV_CTVeval to exclude chestwall and 5mm from skin surface

Planning – Limited beam angles

- 4 to 7 beams for IMRT
- Limited beam angles to
  - avoid posterior beams
  - avoid contralateral breast
  - minimize heart exposure

Planning comparison

- 3D non-coplanar IMRT non-coplanar IMRT co-planar VMAT

Yoo et al. – JACMP 2015

15Gy, 18Gy, 21Gy
15Gy
21Gy
15Gy
Planning comparison

1) VMAT
   - Good OAR sparing
   - Poor HI, poor CI

2) IMRT
   - Good target coverage
   - Good skin sparing

3) non-coplanar IMRT
   - Slightly better for skin sparing than coplanar

Planning – Beam setting based on BEV

1) Isocenter at GTV.
2) Non-coplanar beams.
   (4 to 7 beams, mostly 5 beams)

Challenge! Collision
Challenge! Limited range for couch rotation.

Planning – Beam setting based on BEV

1) Isocenter at CT 0
2) Coplanar beams

Solution! Oblique orthogonal KV images

IGRT analysis

Orthogonal KV images to align the biopsy clip
Challenge! Clip often not visible due to long path length (30% cases) or board plate (10% cases)

Solution! Oblique orthogonal KV images

IGRT: Clip display

Orthogonal KV images to align the biopsy clip
Challenge! Clip often not visible due to long path length (30% cases) or board plate (10% cases)

Solution! Oblique orthogonal KV images
IGRT: Post-tx shift

<table>
<thead>
<tr>
<th>Shift (cm)</th>
<th>Lng. (cm)</th>
<th>Lat. (cm)</th>
<th>Vector (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-tx shift</td>
<td>-0.17±0.23</td>
<td>-0.08±0.14</td>
<td>-0.02±0.16</td>
</tr>
</tbody>
</table>

- To evaluate the patient motion during treatment delivery;
- Mostly in Vertical direction due to roll.

**Challenge!** 1.1cm shift vertically found for one patient.

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IGRT: Mid-Tx imaging

**Solution!** Mid-Tx imaging implemented in between treatment beams
- To verify and correct patient motion during treatment delivery.
- Clip should be clearly visible and identify patient motion in vertical direction.
- Minimize unnecessary gantry rotation for efficient treatment.
- 2 lateral or lateral oblique images are included.

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Efficiency – (a) Initial 2D2D

- Average ~ 7 min
- > 17 min due to collision check and re-positioning
- ~ 5 min save with iso from GTV to CT0 and non coplanar beams to coplanar beams.
- Improvement over time.

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Efficiency – (c) Pre-Tx 2D2D

- Average ~ 5 min
- Imaging time + shift + couch rotation + collision check + timeout
- Improvement with iso from GTV to CT0 and non coplanar beams to coplanar beams
- ~3 min saving (saving from no couch rotation and no collision check)
Efficiency – (d) Treatment delivery

- Average ~ 12 min = beam-on time + beam preparation time
  - Improved beam-on time: 600 MU/min ~ 8 min vs FFF 1400 MU/min ~ 3 min
  - Improved beam preparation: non-coplanar plan ~ 10 min vs coplanar plan ~ 4 min
  - Mid-tx imaging added ~ 2 min

Summary

- Preoperative single fraction partial breast radiosurgery using Linac.
- MRI utilized to identify the tumor.
- Static coplanar IMRT.
- Beams set to avoid contralateral breast and to minimize heart exposure.
- Skin sparing achieved through optimization.
- Biopsy clip is used to localize the target during IGRT.
- Improvements made through experience for efficiency, accuracy and safety.

Efficiency – Summary

- Initial 2D 7.4 min
- Pre-tx 3D 14.6 min
- Treatment delivery 11.7 min
- Others: 6.9 min
- Post-tx 2D or 3D 2.5 min

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Treatment process

Improvements made through experience!

1) Efficiency improved.
   - Total treatment time reduced ~ 18 min.
   - Isocenter at GTV → CT0: ~ 4 min saved.
   - Plans with non-coplanar → coplanar
     ~ 3 min saved before treatment delivery
     ~ 6 min saved during treatment delivery.
   - 600MU/min → 1400MU/min with FFF: ~ 5 min saved for beam-on time
2) Accuracy and quality improved.
   - Oblique orthogonal kV images: improve clip visibility
   - Mid-tx kV imaging: correct patient motion during treatment
3) Safety improved.
   - Collision free with iso at CT0 and coplanar beams.

Thank you!