APBI using Proton Therapy

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SAM Joint Imaging Therapy Educational Course: Advances in Breast Cancer Diagnosis and Treatment: Mammography, Breast Biopsy, SBRT, APBI
Outline

1) Background
2) CT Simulation
3) Planning Technique
4) Discussion
• RTOG 0413 trail: accelerated partial breast irradiation (APBI) compared to whole breast irradiation (WBI) for early-stage breast cancer.
  ➢ similar 10 year recurrence rate: 4.6% vs 3.9%‡
• WBI late effects: fibrosis, shrinkage, edema and skin thickening
• APBI has the potential of improved cosmesis
• APBI delivers radiation directly to the tumor resected cavity that is at highest risk for recurrence and limits the dose to the surrounding healthy breast tissue
• APBI is more convenient for the patient due to the shorter treatment course of 5 to 8 days

Background

• Forms of APBI:
  • Brachytherapy
  • 3D conformal radiotherapy (3DCRT) (non-invasive and higher dose homogenity)
  • Proton (e.g. passive scattering)
  
  More challenging planning technique over PBS
Comparing Proton APBI vs Photon 3DCRT

Pros
- less normal breast tissue irradiated
- less lung and heart dose

Cons
- More acute skin toxicity
- More rib pain and fractures

Improving planning technique
• Primary Objective:
  - assessing the cosmesis and toxicity of partial breast irradiation using proton beam irradiation

• Eligibility:
  - stage 0, I, II with < 3cm
  - negative surgical margins
  - lumpectomy cavity must be clearly delineated
  - cavity volume <30% of whole breast

• Prescription:
  34 Gy in 10 fraction BID, > 6 hours apart
Simulation: Arm position

- Patient in supine position
- Vaclok on acrylic board with variable slant (0, 5, 10, or 15 deg)

<table>
<thead>
<tr>
<th>Arm Up</th>
<th>Arm Down</th>
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<tbody>
<tr>
<td>![Arm Up Image]</td>
<td>![Arm Down Image]</td>
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Simulation: Arm position

Arm Down

- Arm pushes breast into a mound
- More beam angles to the surface normal
- Breast tissue not very stable
- Relies on good IGRT (e.g. X-ray; fids and surg. clips)
- Not working for lateral tumors

Arm Up

- Breast tissue stretched out across chest wall
- More tangential beam
- May reduce distance between tumor and chestwall
- Stable and reproducible setup
Simulation: Arm position

Arm Down

Arm is not inside FOV of CT:
- imaging artifact
- clearance difficult to estimate
Simulation: Arm position

Arm Up

Arm and vacloc are not in CT scan

Clearance issue between snout and arm

Patient-Geometry-Check software by Dr. Y. Hojo, MDACC
Simulation: Marking

- Midline (red)
- Marked Isocenter (blue)
- Surgical scar (wire)
- BBs on skin pigments (Beekley non-metallic)
- BBs on nipple (Beekley non-metallic)
- Surgical clips (if present, e.g. Biozorb)
Clinical Target Volume (CTV)
- 1.5 cm expansion from GTV
- Excludes pectoralis muscle and chest wall
- Exclude 5mm skin rind

Planning Target Volume for Evaluation
- 0.5 cm expansion of CTV
- Excludes pectoralis muscle and chest wall
- Exclude 0.5 cm skin rind
• Normal Breast (Ipsilateral Breast)
• Uninvolved Breast (Normal Breast – CTV)
• Heart
• Ipsilateral Lung
• Contralateral Lung
• Contralateral Breast
• Skin 2mm
• Skin 5mm
Passive Scattering Devices

Range Modulator Wheel
(function of energy, field size)

Aperture collimator:
- brass,
- 3 sizes (e.g. 18x18 cm)
- Thickness: 2cm
- Number, typical 2 pieces

Compensator
- Acrylic plastic
- Smooth surface
- Thickness variable 2-15 cm

Courtesy: A. Smith, UTMDACC
Planning: Beam Angle Selection

- Contradicting goals: skin sparing vs robust plan
- Maximize hinge angle -> tangential beams
- Robust plan has en-face beam (but there is only 1 angle)
- Compromise between skin sparing and robustness.
Planning: Beam Angle Selection

• Use 3 fields!
• First, create en-face beam (in 3D) (couch kick required)

• add 3 more beams surrounding the en-face-beam and “maximize” hinge angle while maintaining the following limits:
Planning: Beam Angle Selection - Limits

1. Grazing angle
   >~30 deg

Visualize in Eclipse:
Planning: Beam Angle Selection - Limits

2. Avoid flash to arm or contralateral side
Planning: Beam Angle Selection - Limits

3) Snout position in TPS < 20 cm  Airgap < 15 cm (ensures lateral target coverage)

4) Patient-Geometry-Check-software, clearance: 6-10 cm

- Adjust gantry angle if needed.
Planning: Beam Line Parameter

- No proximal margin (to limit skin dose)
- Distal margin\(^\ddagger\): \(DM = \text{Range} \times 3.5\% + 0.1\, \text{cm}\)
- Compensator smear (to account for setup uncertainties):
  - 1.0 cm for arms down (higher variability) and 0.7 cm for arms up
- Aperture margin are between 0.7 and 1.0 cm depending on how much coverage to the PTV is wanted

\(^\ddagger\text{Moyer et al. IJROBP 49(5) 2001}\)
• Orthogonal X-ray
• BBs & wires placed on skin, but removed for treatment
• A 10 patient study ‡ average deviation over 100 Tx: 0.3-0.5 cm (1σ=0.2 cm)

‡Strom et al. Practical Radiation Oncology (2015) 5
Patient Outcome

Clinical outcome of the first 100 patients‡

- No acute or late grade 3 skin toxicity
- Acute dermatitis (week 6): 58% grade 1, 11% grade 2
- Hyperpigmentation (week 6): 45% grade 1 (<10% area), 2% (>10% area)
- Physicians and patient cosmesis 83% and 93%
- Late skin effect (>18 month); spider veins ~35%
  - dosimetric threshold 3525 cGy to 1 cm³ of “2-mm” skin ≡ 2.5 cm²
  - at least 3 fields
- No patient experienced fat necrosis, fibrosis, infection or breast shrinkage

‡ Pasalic et al. IJROBP 109(2) 2021
Patient Outcome

Cosmesis outcome selected patients after 1 year‡

- Hyperpigmentation in the irradiated field

‡ Strom et al. Practical Radiation Oncology (2015) 5, e283-e290
Photon vs Proton

- Skin dose is lower for photon plan
- Uninvolved breast dose is much lower for proton plan
Passive (3 fld) vs Scanning (1 fld)

- Skin dose is lower for scanning beam plan
- Uninvolved breast dose is lower for passive plan
Costs of Proton Partial breast

- There has been many publication regarding cost effectiveness advocating the use for proton treatment, e.g. Ovalle‡
- It was found that the costs of proton treatment is competitive with brachytherapy and standard FiF treatment
- The most expensive method was WBI IMRT

‡ Ovalle et al. IJROBP 95 (1), (2016)
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