Improving Homogeneity in Breast Radiotherapy Plans

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Breast Plans
Why homogeneity Matters?

- Whole breast irradiation often leads to both acute and long term toxicities such as moist desquamation, pain, breast discomfort and breast hardness.
- Many studies shown that toxicities were associated with dose inhomogeneity (hot spots).
Randomized trials

- Pignol et al
- 358 patients were randomized in a multicenter double-blind clinical trial to either 2-dimentional treatment planning or IMRT planning with improved dose homogeneity.
- The incidence of moist desquamation in the IMRT group was 31.2% vs 47.8%, p=0.002

Randomized Trials

- Donovan et al

306 patients were randomized to 2D or 3D IMRT. After 5 years 240 patients data was available for analysis. The 2D arm patients were 1.7 times more likely to have changes in breast appearance than IMRT group.

Advantage of Dose Homogeneity

- Breast $V_{105\%}$ and $V_{110\%}$ were significantly associated with increase in acute skin toxicity
  - $V_{110\%} < 200\text{cc}$: 31% grade $>2$ skin toxicity
  - $V_{110\%} > 200\text{cc}$: 61% grade $>2$ skin toxicity

“The use of IMRT in the treatment of the whole breast results in a significant decrease in acute dermatitis, edema, and hyperpigmentation and a reduction in the development of chronic breast edema compared with conventional wedge-based RT.”

Harsolia et.al. *Int. J. Radiat Oncol Biol Phys* 68: 1375-1380; 2007
What kind of IMRT?

Many beams: do we want many beams or two is enough?

- Many beams with different angles may help with dose conformality, but will lead to higher doses in lung, heart and contralateral breast.
- Tangential beams provide best lung, heart and contralateral breast sparing.
Breast IMRT Planning

How to achieve optimal dose distribution?

- Through complex fluence map optimization
Fluence Optimization: Two Types of IMRT

- Inverse plan IMRT
  - Fluence optimization is performed by planning software
  - Commercial algorithms are not available for breast
    - Tangential beams only
    - Including flash

- Forward plan IMRT
  - Fluence optimization is performed by using field-in-field approach (iterative process of manual fluence optimization)
  - More transparent, easier to understand
  - More appropriate for breast planning with 2-beam approach
Forward vs Inverse IMRT

**Inverse plan:**
- Better conformality (+)
- High dose gradient (+)
- Larger volume of small dose due to multiple beam angles (-)
- Complex planning (-)

**Forward plan:**
- Conformality improvements are limited (-)
- Volume of small dose is not expanded (+)
- Dose homogeneity is improved (+)
- Transparent planning (+)
IMRT approaches for breast

- Hybrid techniques
- Forward planned IMRT
Hybrid Techniques

- Mayo et al. (UMAss)
  Two tangents and two IP-IMRT beams

- Descovich et al. (UCSF)
  Two tangents and two direct aperture optimized (DAO) IMRT beams

Faster planning, less dependent on planner’s ability, but need to contour the breast tissue
Forward Planned Breast IMRT:

- Memorial Sloan-Kettering Cancer Center
- Fox Chase Hospital
- William Beaumont Hospital
- Other…
Memorial Sloan-Kettering Cancer Center Technique

Simplified IMRT technique:

- Two tangential fields
- Midpoint of the segment intersecting the treatment volume for each pencil beam is determined
- The dose from the open field to this point is calculated
- The intensity of the pencil beam is determined as proportional to the inverse of the open field dose

Fox Chase Technique

Beamlets optimized based on the dose at the midplane

Monte Carlo method used for dose calculation
MLC segments constructed based on BEV projections

MLCs conformed to isodose surfaces in 5% increments (from 120% to 100%)

Additional MLC segments conforming to lung tissue were added to reduce transmission

“script” program was created within the planning system to automatically optimize the weights of the individual sMLC segments.
IMRT for breast treatment

- Forward planning

- Two tangential open fields and multiple subfields to achieve desired homogeneity
Planning Strategy

- An open beam configuration is first calculated and evaluated.

- 4+ subfields per gantry angle are used to produce an optimal breast plan.

- No wedges.
Subfields

- Generally have 1 lung block and 3 additional subfields per gantry angle

- Lung block is formed by fitting the MLC’s to the shape of the lung. Aids in lateral hot spots.

- Additional subfields are generated by manually fitting MLC’s to “hot” areas. Ex. 115%, 110%, etc…
Subfields

Open

Sub 1

Sub 2 115%

Sub 3 110%

Sub 4 105%
Weighting of Subfields

- Generally, the open beam portion receives ~80% of the dose while the subfields contribute ~20%.

- This makes FP IMRT similar to conventional treatment.

- Minimizes effects of patient movement on target coverage.
Normalization

- Conventional breast plans are generally normalized to 97%

- Normalization for IMRT plans are based on coverage
Alternative Strategy
Create initial subfield; weight until just before 100% compromised.

Temporarily increase weight to produce 5 additional MUs.

Create opposing subfield. Conform MLCs to remaining 100% dose cloud.

Restore weighting of previous field by removing 5 MUs. Weight new field until just before 100% compromised.
How Many Subfields

Patient Characteristics That Predict the Need for Intensity Modulated Radiation Therapy (IMRT) of Breast

C. Harrington, Y. Lyatskaya, M. Czerminska, J. Harris, R. Cormack
Dana-Farber /Brigham and Women’s Cancer Center
The plans of 100 patients were analyzed.

Variable values were (median [min- max]):
- Separation: (20.9 [14.7-31.9] cm)
- Size: (8 [4.0-15.3] cm)
- Volume: (1660 [676-4151] cc)
- Maximum open field dose: (116 [110.3-126.3] %)
- Number of subfields: (6 [4-10])
One third of patients required seven or more subfields to achieve the planning method’s dose homogeneity goal.

A maximum open field dose over 120% predicts necessity for 8 or more subfields with high (0.9) specificity and selectivity.
Can we always achieve a perfect homogeneity?

Two Tangents with 4 subfields from each side
Too hot!

Unacceptable hot spots
Patients with Large Separations

31.7 cm

29.6 cm
Oblique Fields Technique

Tangential field border

Oblique field order
Oblique field Technique
Improved homogeneity

Global
Dmax=110.5%
Sagittal
Lung and Heart DVH
More reasons to improve homogeneity

Hypo-fractionation

• Canadian 266 cGy x 16
• Danish 267 cGy x 15
• British (RMH) 300 cGy x 13
Fractionation

Canadian Randomized Trial

Randomized Trial of Breast Irradiation Schedules After Lumpectomy for Women With Lymph Node-Negative Breast Cancer


Journal of the National Cancer Institute, Vol. 94, No. 15, August 7, 2002
Canadian Study

Randomized trial with 1234 patients.
Women with invasive breast cancer who were treated by lumpectomy and had pathologically clear resection margins and negative axillary lymph nodes were randomly assigned to receive whole breast irradiation of:

- 42.5 Gy in 16 fractions over 22 days (short arm)
- 50 Gy in 25 fractions over 35 days (long arm)

Whelan et. Al. Journal of the National Cancer Institute, Vol. 94, No. 15, August 7, 2002
Results

- No difference in cosmetic outcome after 3 and 5 years
- No difference in late radiation toxicities
- No difference in disease free survival and overall survival

<table>
<thead>
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<th>Site</th>
<th>Grade</th>
<th>Short arm (n = 515)</th>
<th>Long arm (n = 492)</th>
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<td></td>
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<td>% of Patients with no Toxicity</td>
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Whelan et. Al. Journal of the National Cancer Institute, Vol. 94, No. 15, August 7, 2002
Canadian Study

Conclusion:

• “Our results support the use of a shorter fractionation schedule for irradiation of women with lymph node-negative breast cancer treated by lumpectomy.

• The results are not applicable to women with very large breasts (i.e., with widths >25 cm)”

Whelan et. Al. Journal of the National Cancer Institute, Vol. 94, No. 15, August 7, 2002
Canadian Fractionation at our Institution

- 266 cGy x 16 fractions
- Patients over 60 with clear margins
- Non-high grade disease
- No chemo
- Negative nodes
- Small separation
- Hot spots < 107%
Example 1

- Right sided
- Separation 21.3 cm
- Energy 10 MV
- Tangents with subfields
Coronal
Subfields

[Images of medical scans showing different subfields labeled as 'Medial' and 'Lateral']
Example 2

- Right sided
- Separation 26.6 cm
- Energy 10 MV
- Tangents with subfields and oblique fields
Oblique fields
Dose Distribution

Global Hot Spot 107.2%
### DFCI/BWH Breast Cases with Canadian Fractionation in 2012

<table>
<thead>
<tr>
<th>Patient</th>
<th>Separation [cm]</th>
<th>Technique</th>
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