Non-Invasive Brachytherapy of the Breast

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Presentation Outline

- Breast radiotherapy facts and data
- Shortcomings in current procedures
- Partial solutions in recent years
- Introduction of peripheral brachytherapy
- Dose engineering studies
- Imaging integration
Breast Radiotherapy

Facts

- Early stage lesions are treated by lumpectomy followed by radiotherapy.
- Patients who undergo lumpectomy and follow the radiotherapy protocols have an excellent chance of survival.
- Those who don’t finish the course of radiation are at increased risk of recurrence.
- Large patient population.
The Problem/Shortcomings

- Conventional radiotherapy of the breast (by XBRT) takes too long, is an exhaustive experience, and is taxing on active working women, those who live away from hospitals, the elderly and frail patients.

- XBRT may cause collateral damage to normal tissue.
The Solution

(only partial)

- Accelerated partial breast irradiation (APBI) is performed in 5 days; however, it is highly invasive.
- The dose homogeneity of APBI is far from ideal.
- It requires strong surgical skills and is not a forgiving procedure in some instances.
The New 3-D Conformal Radiotherapy

- is performed in 5 days;
- may cause additional exposure to healthy tissue;
- may be more sensitive to patient positioning;
- may be more sensitive to the breathing cycle.
The Search for a Patient Friendly and Convenient Method for Breast Irradiation Continues....

This presentation introduces a novel concept/design for addressing radiotherapy of the breast.
Motivation/ Rationale

The breast is a protruding deformable organ, and as such, it allows for positioning the radiation source(s) on its periphery to superposition the radiation fields in the interior of the breast from various exposure angles. This approach builds up a therapeutic dose on the inner tissue without exceeding the skin toxicity limit.
“Peripheral” Brachytherapy

A new phrase has been coined – *peripheral brachytherapy* (as opposed to interstitial, intra-cavitary or intra-luminal) to describe source placement near the surface of the breast with the intention of delivering a therapeutic dose to the margin of a lumpectomy cavity.
Design Concepts

- Many design concepts work.
- We have chosen a pair of applicators positioned on opposite sides to stabilize the breast during imaging and therapy.
- In this design, the plates are mammographic type "paddles" with embedded lumens for receiving the HDR source.
- The applicators irradiate the breast from two orthogonal directions.
Peripheral Brachytherapy Approach

Treatment of lumpectomy cavity margin from multiple directions

Horizontal compression in one session

Vertical compression in a subsequent session

The HDR applicator plates positioned within the mammography applicator “head”
Stereotactic Treatment Process

Horizontal Exposure
Stereotactic Treatment Process

Vertical Exposure
Stereotactic Treatment
Process
Superposition
Curved Applicators

24 cm radius

12 cm radius
The Opportunity to Integrate Image Guidance

- This method is most effective if real-time imaging is used to accurately target the radiation field.
- High resolution is not required; it is sufficient to identify the lumpectomy cavity margins.
- Various imaging modalities may work.
- Implantable markers may prove valuable.
Dose Engineering Effort

- dose simulation using the Pinnacle (v6.2b) treatment planning software;
- dose simulation using the Plato (Nucletron) system;
- dose simulation using finite element analysis (FEA);
- dosimetry by TLD (not yet performed).
Curved Plate Simulation
9x9 Matrix Uniformly Distributed Source Plan
### 9x9 Matrix Optimum Loading

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7x7 Matrix Optimum Loading

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Plato Treatment Planning on a CT Scanned Phantom
FEA Simulation
Parallel Plates
Implementation of Field Shaping Structures

90 degree inclusion angle

50 degree inclusion angle
FEA Analysis Using Field Shaping Structures

Without Field Shaping

With Field Shaping
Designs Requiring Development/Optimization:

- curvature of the applicator;
- inside spacer thickness;
- source loading pattern as a function of lumpectomy size, shape, location and breast size;
- integration of IGRT into the system;
- software routines to add the dose from two orthogonal planes.
Why a Curved Applicator?

- to lessen patient discomfort;
- less likely to push the lumpectomy cavity out of the way;
- increases dose uniformity near the edges.
Comparison of Two Curvatures

24 cm Radius

14 cm Radius
Spacer Thickness

- The spacer prevents localized hot spots on the skin.
- The thicker the spacer, the less field gradient is near the skin.
- The thicker the spacer, the more inefficient the procedure and the longer it takes.
- Practical spacer limits are between 10 to 20 mm.
Comparison of 2 Spacer Thicknesses

15 mm Spacer

20 mm Spacer
Impact of Plate Separation (Breast Compression)

- 6 cm spacing
- 5 cm spacing
- 4 cm spacing
Impact of Plate Separation

SCD Ratio vs. Plate Separation

- Uniform Distribution
- Edge Weighted Distribution
Impact of Matrix Size

Optimized SCD ratio vs plate separation
(single fraction)

- 5x5 matrix
- 7x7 matrix
- 9x9 matrix
Each loading is specific to the patient.

The loading pattern is designed to match the lumpectomy cavity margin.

Requires leaner source utilization near the center.

Edge weighting increases lateral uniformity.
Applicator Loading Pattern

- It is a function of lumpectomy location, size, breast size, etc.
- Source distribution center must coincide with the lumpectomy center in each exposure.
Identify the extreme limits of the (original) lumpectomy cavity:
- transfer the limits to the applicator;
- decide on the distal and proximal source travel in each lumen;
- verify the source location by the HDR cable (dummy source);
- use optimum source dwell pattern.
Integration of Image Guidance into the Treatment Planning Process for Targeting Radiation Dose
There is a need to develop a routine to add up the dose from the two orthogonal planes and keep track of accumulated dose from one session to the next.

Routines to track dose homogeneity and define the “quality” of dose.

Importation and integration of image into treatment planning.
Other Need/Wants Identified:

- optimum dosing schedule;
- dose escalation optimization;
- consideration of ultrasound for IGRT.
Summary

- Peripheral brachytherapy of the breast offers a new option for breast irradiation.
- The design offers acceptable tissue dose without exceeding the (average) skin toxicity threshold.
- The dose homogeneity is superior to other brachytherapy designs.
- Collateral damage to normal tissue and organs is minimal.
- It has built-in image guidance features.
Summary
(continued)

- Lots of help/input is required from the medical physics community to understand, evaluate, and optimize the design features of peripheral brachytherapy.
Acknowledgements

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