

# STEREOTACTIC PERIPHERAL BRACHYTHERAPY AND IMAGE GUIDANCE FOR THE BREAST

Mark J. Rivard, Ph.D.,<sup>1</sup> Raymond J. Bricault Jr., M.Sc.,<sup>2</sup> Christopher S. Melhus, M.Sc.,<sup>1</sup> Piran Sioshansi, Ph.D.,<sup>2</sup>

<sup>1</sup>Tufts-New England Medical Center, Boston, MA, <sup>2</sup>Advanced Radiation Therapy LLC, Billerica, MA

## ABSTRACT

### Purpose

Breast brachytherapy may be applied peripherally without piercing the skin as currently performed with interstitial and MammoSite applications. By virtue of being a protruding and deformable organ, the breast lends itself to peripheral brachytherapy by non-invasive applicators. A novel delivery system was designed by Advanced Radiation Therapy to implement this developmental treatment modality using real-time mammographic image guidance for stereotactic applicator positioning and CTV localization. In this design, therapeutic dose to the lumpectomy cavity is delivered by externally placing opposing plaque-like applicators at multiple orientations to provide conformity while not exceeding skin toxicity threshold. Initial assessment of the system was performed to determine clinical feasibility.

### Materials & Methods

The applicator geometry comprises two curved plates which slightly compress the breast to minimize slab thickness irradiated by the parallel-opposed plaque. Within the applicator are a series of parallel HDR <sup>192</sup>Ir catheters spaced 1 cm apart. For a 6 cm thickness, the breast geometry and applicators were simulated using analytical (Pinnacle<sup>3</sup> treatment planning system) and Monte Carlo (MCNP5) techniques. A breast phantom was used for CT-based treatment planning; however, conventional brachytherapy dosimetry algorithms assume an infinite water phantom. CTV ellipsoids ranged from 2x4x4 cm<sup>3</sup> to 3x6x6 cm<sup>3</sup>. Sources were positioned within the catheters to create a circular loaded region (5-9 cm diam.) to provide uniform CTV coverage. Dose homogeneity index (DHI) for the skin was determined.

### Results & Discussion

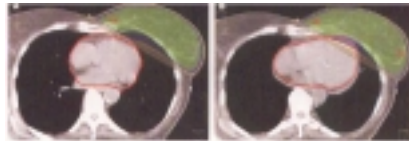
Average ratio of skin-to-tumor dose was < 0.9. Pinnacle and MCNP results gave DHI ~ unity for the CTVs studied. Dose was typically < 2% to lungs, heart, and other critical organs. These simulation results suggest that this technique may be an attractive APBI option.

### Conflict of Interest

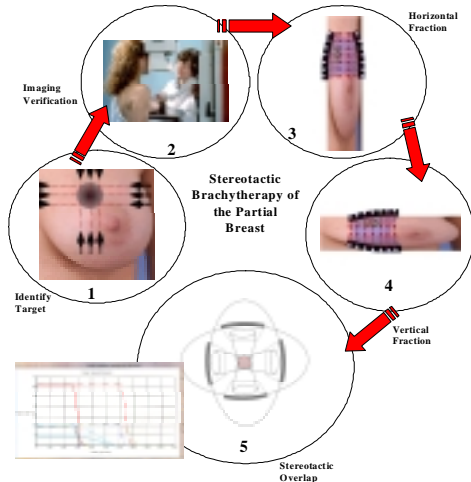
Advanced Radiation Therapy provided the applicator used in this study.

## OVERVIEW

Accelerated partial breast irradiation (APBI) has been performed historically using either brachytherapy sources via interstitial (needles) or intracavitary (balloon catheters) implantation procedures. The RTOG 0413 / NASBP-39 APBI trial opened in March 2005. Eligible patients may receive APBI from interstitial or intracavitary brachytherapy, or from linac-based external beam (XRT). The breast is mobile relative to the XRT source because it is not a rigid structure and subject to motion due to breathing. Thus, treatment margins must be made much larger with XRT than for brachytherapy-based APBI. The "partial" aspect of APBI is not applied well with XRT, which can be comparable to whole breast radiotherapy over a course of 5 days.



A novel system has been developed employing geometric advantage and the penetrative capabilities of HDR <sup>192</sup>Ir through narrow tissues such as a compressed breast. Women with early-stage breast cancer and pathologically-confirmed negative surgical margins following lumpectomy are eligible to receive this therapy. The therapy lends itself for BID treatments with alternating compression orientations around the breast to spare healthy tissue and minimize normal tissue complications such as desquamation. A schema is given below illustrating how the therapy will be applied.



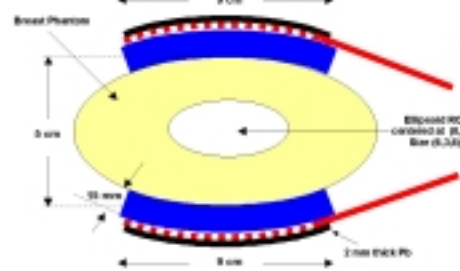
Instead of a mastectomy, most women request breast conserving therapy (BCT) in which the lesion is removed through lumpectomy, with local irradiation to follow. Conventional XRT for women with early-stage breast cancer requires daily hospital visits for 5-7 weeks after lumpectomy. This is a major inconvenience for the elderly and active working women, especially since there are under 2,000 radiotherapy centers distributed across the U.S. Consequently, upto 25% of these women do not complete their radiation therapy and are then subject to a higher risk of recurrence. The advent of APBI helps to address these issues through increased convenience by reducing the treatment time to 5 days BID. However, APBI using interstitial or intracavitary brachytherapy is highly-invasive, at risk for infection, and challenging for untrained physicians.

Stereotactic peripheral brachytherapy (SPB) delivers the prescribed therapeutic dose to the tumor bed from a non-invasive applicator placed on the periphery of the breast. SPB uses real-time mammography image guidance for targeting dose in every fraction. The SPB design utilizes a pair of parallel plate applicators that slightly compresses the breast and positions any conventional HDR source within the applicators facing the opposing sides of the breast to uniformly treat the tumor bed. Applicator plate orientation is altered between fractions such that a therapeutic dose is accumulated in the tumor bed without exceeding the skin exposure threshold for a given fraction. To further limit normal tissue dose and control the direction of the exposure field, the SPB applicators rely on built-in apertures that shape the field produced at each source dwell position. This feature allows unimpeded irradiation of the target volume while minimizing the superficial (skin) exposure. Furthermore, aperture orientation near the chest wall minimizes exposure to the heart and lungs.

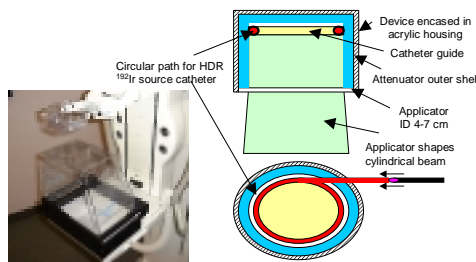
## MATERIALS & METHODS

Two types of applicators were examined using Monte Carlo methods to simulate radiation transport. For both studies, the MCNP5 radiation transport code was used with the F6 energy deposition tally / estimator. The voxel size was 1x1x1 mm<sup>3</sup> for a breast compressed to between 5 and 7 cm thick. The resulting coronal breast cross-section was ellipsoidal with a maximum lateral dimension of 14 cm. CTV ellipsoids ranged from 2x4x4 cm<sup>3</sup> to 3x6x6 cm<sup>3</sup>. The coordinate origin was located 7 cm from the chest wall. The <sup>192</sup>Ir source spectrum was simulated using 44 discrete lines, and positioned where the actual source would be for therapy. Mass densities used were Pb = 11.3; ICRU 44 Breast / Lesion = 1.02; and acrylic = 1.19 g/cm<sup>3</sup>. Applicator periphery and internal region were modeled with air = 1.2 mg/cm<sup>3</sup>.

The first applicator geometry comprised two parallel-opposed curved plates around a slightly compressed breast. Within the applicator are a series of parallel catheters spaced 1 cm apart in a single plane. For a 6 cm thickness, the breast geometry and applicators were simulated using analytical (Pinnacle<sup>3</sup> treatment planning system) and Monte Carlo (MCNP5) techniques. Sources were positioned within the catheters to create a circular edge-weighted region (5-9 cm diameter) providing uniform CTV coverage. The dose homogeneity index (DHI) for the skin was determined.

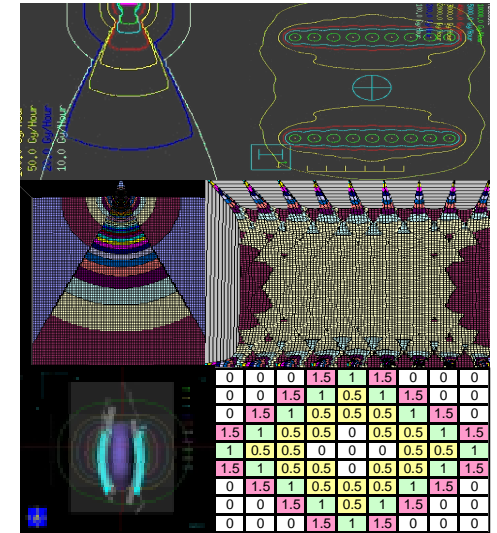


For the second type of applicator, a cylindrically symmetric design similar to a mammographic spot paddle was developed. Here the source design was much simpler, and used only a single catheter curved into a circle within a collimating aperture. Based on the applicator diameter and distance from the skin to the circular catheter ring, a variety of lesions may be treated since the approach accounts for varying breast sizes, lesion size, and lesion location. Additionally, non-uniform weighting across the treatment field may be obtained through non-uniform weighting of dwell times or use of attenuating compensators.

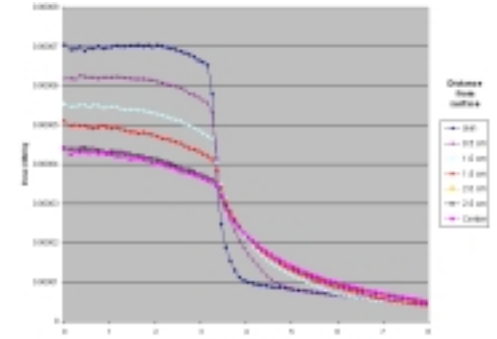


## RESULTS

The first type of SPB applicator employed parallel plates. Simulated dose rate distributions (individual sources with collimation at left, and uncollimated arrays at right) compare results from Pinnacle<sup>3</sup> (top) and finite element analysis (bottom), and show both good agreement and favorable dose distributions using the normalized 9 x 9 loading pattern and relative dwell positions given in the table



The second applicator type used opposing cylinders each with a single peripheral collimator, and consequently produced more uniform yet conformal dose distributions and was more readily simulated. Operation of a preliminary SPB compression system is shown, with relative dose rate distributions for a 6.5 cm diameter cylinder with Pb collimator and catheter guide are shown below.



## SUMMARY

A novel means of applying breast brachytherapy has been developed. The applicator described has recently received 510k clearance by the FDA. Preliminary analyses of calculated dose rate distributions may have a significant DHI, lesion conformity, and skin dose advantage over all other APBI modalities. Additional research is underway to validate these results with measurements and develop a protocol for clinical implementation.