Interactive Image Guided Peripheral Brachytherapy for the Boost Dose in Breast Irradiation

PURPOSE
The AccuBoost system (Advanced Radiation Therapy, Billerica, MA) applies breast brachytherapy without invasive catheters, and with mammographic image guidance using stereotactic localization of markers implanted during lumpectomy. This high-resolution imaging permits accurate localization of the region to be treated and assists with radiotherapy beam positioning. A combination of parallel-opposed HDR $^{192}$Ir beams are directed into the breast towards maximizing target dose uniformity and minimizing dose to skin and other healthy breast tissues (Fig. 1). Studies examining dosimetric characterization and system commissioning for clinical use are presented.

MATERIALS & METHODS
The AccuBoost system is FDA-approved, and includes a fully-functional mammography system (model Siregaphos 800T by GE Healthcare, Piscataway, NJ), a computed radiography (CR) image analysis system (model CR 825 by Kodak, New Haven, CT) using a phosphor plate, five applicators with inner diameters ranging from 4-8 cm, and custom mammography paddles for precision applicator positioning on a compressed breast (Fig. 2). The applicators have a single 6F catheter lead which is compatible with Nucletron and Varian HDR $^{192}$Ir remote afterloading systems. Patient treatments entail slight compression (3-8mm) of the breast, paddle positioning, mammographic imaging with CR, image analysis for gratitude repositioning, planning calculations for the appropriately sized applicator, and parallel-opposed irradiation. Towards benchmarking this novel treatment modality, localization accuracy based on image-guidance of the paddle/applicator assembly was assessed with a breast phantom (model 051 by CIRS, Norfolk, VA) containing radio-opaque markers under a variety of clinically-relevant conditions. Measurements (ionization chambers and GaChromatic EBT film) were performed and compared to Monte Carlo (MCNP5) simulations of dose distributions as a function of depth, position, and various breast compression thicknesses.

RESULTS
Film irradiated with the AccuBoost applicators were scanned and converted to absolute dose (Fig. 3). Marker localization within 1 mm was readily achievable (Fig. 4a-d), and imaging with $^{192}$Ir was examined. For all conditions, agreement of MC simulations with ion chamber results were within 2% for dose falloff and within 6% for dose profiles measured using film. For 4 orthogonal beams, calculated skin/target dose ratio varied between 0.5-1.1; more favorable results were observed for thinner compressed breasts.

CONCLUSION
Under image-guidance, the AccuBoost system can apply a conformal and uniform breast boost dose in a stereotactic configuration. MC simulations readily characterized the clinical environment as shown by good agreement with the measured film and ionization chamber results.