Dosimetric Effects of the Air Cavity in a New PBI Applicator

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Abstract

Partial breast irradiation (PBI) with brachytherapy is a popular alternative to whole breast irradiation. The first high dose rate brachytherapy device for PBI was the MammoSite® (Cytyc, Marlborough, MA) balloon which has a single central catheter and is typically used with a single dwell position. The SAVI™ device (Cianna Medical, Aliso Viejo, CA) has been developed to enhance this technique. Instead of a single catheter, the SAVI device has 6-10 catheters that surround a central catheter. These surrounding catheters allow geometric optimization of the dwell positions to account for close proximity of skin or pectoralis muscle, or cavity asymmetry. The device was cleared for patient treatments in July 2006.

Introduction

In order to study this problem, we performed Monte Carlo simulations validated by BrachyVision TPS, CC14 ion chamber measurements in a water phantom, and film + TLD measurements. Each of these techniques was used for each device size except for the film + TLD, which was only done for the 10-strut device. The results of each experiment is presented below.

Materials and Methods

The simplest geometry to simulate and measure is the traditional MammoSite balloon with a single dwell position in the central catheter. This is also believed to be the scenario where the air discrepancy will be at its highest due to maximum amount of air being between the source and the calculation point (1 cm away). The results of this study are compared to results using BrachyVision version 8.1. The 10-strut case is shown below.

Monte Carlo Simulation

Monte Carlo (MC) simulations were performed using the EGSnrc suite of programs. We used a 0.7 MeV electron cut-off energy and 10 keV as the photon cut-off energy. The spectra employed included bare Ir-192 and VarixSource Ir-192 with and without nitinol encapsulation. Since the HDR VarixSource is cylindrically symmetric, we employed DOSXYZnrc to calculate absorbed dose from a single source embedded in water and within a quasi-spherical cavity filled with air in order to model the shape created by the SAVI device. The model was verified with treatment planning data for the homogeneous case.

Monte Carlo Results

This graph illustrates the dose fall-off around the edge of the device. The difference between water and air is largest closest to the struts. The table shows the results for the single dwell position MC simulations. The dose difference between filling the device space with air or with water ranges from 3.5 – 7% at the prescription point. The MC uncertainties were less than 0.4% for this study.

TLD and Film Measurements

The 10-strut device was again placed in a condom and fixed to the inside of the water tank and submerged in the water. A single piece of film and the condom filled with water. The ion chamber was then driven away from the edge of the condom while the source was at the central dwell position. After the “air” data was acquired the condom was punctured allowing water to fill the cavity, and the experiment was repeated.

Film and TLD Results

The TLD readings (Kodak, Rochester, NY) were tabulated for each setting and for the air filled balloon and solid water placed 5.7 cm (or the water filled balloon) away from the source. The TLD dose was typically 3% of the prescribed dose. The difference between the air and water filled balloon was about 4%. The TLD air readings were then used to normalize the film and TLD readings and these normalized readings were also normalized to a resulting water calibration value. The prominence of the air cavity effect in PBI is due to the proximity of the air cavity to the applicator surface which is at a higher prescription point.

Discussion

In regular clinical use, source positions and dwells are distributed throughout the peripheral channels of the device, reducing the potential for dose differences shown previously. We performed further Monte Carlo simulations of a more realistic 32 dwell position breast plan using the program DOSXYZnrc both for a water phantom and an air cavity corresponding to a 10-strut catheter. In the simulations, the device space was filled with air or water.

The results for the single dwell position MC simulation. The dose discrepancy is about 4%. Since statistical uncertainty is still high (3% on average), further simulations are necessary.

Summary

This study investigated the effect of air-filled cavities on dose delivered with the 32-channel SAVI© applicator. A single, central HDR source position was used, which was thought to generate the largest possible dose differences between calculated and delivered dose. Monte Carlo simulations were performed, the differences between air and water at the device were calculated at the prescribed point.

For the clinical style loading (using all source lumens), BrachyVision analysis indicated the difference for the 10 strut was approximately 3%. Similar discrepancies were observed for other PBI applicators. The results indicate that the presence of a cavity affects the dosimetry of the procedure and corrections may need to be included.