Commissioning a CT compatible LDR T&O applicator using 3D dosimetry

Innovation/Impact: While High Dose Rate (HDR) and Pulsed Dose Rate (PDR) brachytherapy techniques are becoming more popular in clinical practice, Low Dose Rate (LDR) brachytherapy is still utilized in many radiation oncology departments for treatment of Gynecological cancers<sup>1-3</sup>. Here we use 3D dosimetry in the commissioning of a newly available CT-compatible LDR T&O applicator; the technique for which is a novel application of 3D dosimetry which may be applied to the commissioning of other brachytherapy applicators.

Purpose: Asymmetric shielding of the ovoid sources for the CT-compatible T&O applicator is achieved using afterloading buckets with gold shielding; separate CT compatible buckets are used during imaging (see Figure 1). Our purpose is to characterize the attenuation characteristics of the high density afterloading buckets of a commercially available LDR tandem and ovoid applicator using a 3D dosimetry system.

Materials & Methods: The 3D dose distribution was measured using a cylindrical polymer based 3D dosimeter. The dosimeter was manufactured just large enough to measure dose out to a radial distance of 4cm (9.5cm diameter, 9.2cm height) with a 6mm channel drilled in the center to nearly midway through. An optical CT pre-irradiation scan of the dosimeter was acquired with the 6mm channel being filled with a refractive fluid and the entire dosimeter being immersed for the scan. The fluid was then removed and a Cesium-137 source was placed within the afterloading bucket and inserted into the dosimeter channel (Figure 2). The bucket was left in the dosimeter for a sufficient amount of time to deliver an unattenuated dose of 7.7Gy at 1cm from the source. Immediately a post irradiation optical CT scan was acquired. The 3D dose distribution was reconstructed with a 0.5mm<sup>3</sup> isotropic voxel size with no median filtering. All optical CT scans were acquired with 720 projections at 0.5° increments, and were flood and dark field corrected with an acquisition time of ~15 minutes.

The dosimetric effect of the bucket attenuation on the prescription point (Point A) and clinical organs at risk was evaluated for a single tandem and ovoid implantation. The patient plan used consisted of a 35Gy implant with three sources in the tandem and one source per ovoid. Dose to Points A, bladder, rectum, bowel, and sigmoid, were calculated with and without accounting for attenuation of the ovoid sources from the afterloading buckets. To account for attenuation through the afterloading buckets, a 3D distribution of the transmission rate through the afterloading bucket was calculated using the 3D dose distribution. This transmission rate consisted of the quotient of the 3D dose distribution to the published source distribution at each point.

Figure 1: Gold (treatment) & CT compatible (imaging) afterloading buckets

Figure 2: 3D dosimeter with afterloading bucket.

Figure 3: Measured vs. calc. dose.
Results: Figure 3 shows the calculated and measured dose profile through the midplane of the source versus radial distance from the Cesium-137 source in water and within the gold bucket (Figure 3). For the plots, the measured and calculated doses are normalized to the expected dose from the source in water at a radial distance of 1.0cm. Figure 4 shows a number of transparent 3D isodose clouds (levels = 0.05, 0.09, 0.19, 0.38, and 0.66 when unattenuated dose is normalized to 1 at r=1cm) surrounding a model of the afterloading bucket (A), along with the sagittal (B) and axial (C) 2D isodose distributions for the measurement (blue) and calculation (red). Figure 6D shows the transmission rate calculated from the measurement. For the patient case, the dose metrics decreased most for rectum and sigmoid, while the dose to Points A decreased 4.1% and 3.9% when tandem and ovoid source strength was not adjusted to account for the attenuation.