ABSTRACT

Purpose: Extensive Monte Carlo modeling was performed using MCNP5 to characterize the Xoft Axxent™ X-ray Source for electronic brachytherapy. This study assessed the dose distribution, dosimetry parameters using the AAPM TG-43/U1 protocol, and the sensitivity of results to source geometric parameters and choice of computational parameters.

Methods and Materials: Monte Carlo simulations of radiation generation and transport utilized the MCNP5 code (versions 5.2.2 and 5.2.3) with the EGSnrc-based multi-architecture transverse code. Geometric parameters were modeled using a modified TG-43/U1 3.0 geometry format. X-ray source parameters for electronic brachytherapy dose rate functions were not appropriate due to significant pair annihilation. Source output was measured in a water phantom using a PTW 33143 Ion Chamber.

Results: Calculated point-source model radial dose functions at d0(r) were 0.10, 0.24, and 0.29 for the 40, 45, and 50 kV voltage settings, respectively. Measured point-source model radial dose functions were 1.0 for all settings. Measured peak-to-valley values for all operating voltages were typically 1.1 along the central axis at 0°, and ranged from 0.08 to 0.14 for 40 kV and 0.10 to 0.19 for 45 kV. Measured peak-to-valley values for photon production transverse to the source for 40, 45, and 50 kV were 0.20, 0.29, and 0.29 for the 40, 45, and 50 kV voltage settings, respectively. Measured point-source model radial dose functions were 0.9 for all settings. Measured peak-to-valley values for all operating voltages were typically 1.1 along the central axis at 0°, and ranged from 0.08 to 0.14 for 40 kV and 0.10 to 0.19 for 45 kV. Measured peak-to-valley values for photon production transverse to the source for 40, 45, and 50 kV were 0.20, 0.29, and 0.29 for the 40, 45, and 50 kV voltage settings, respectively.

Conclusion: A miniature X-ray source for electronic brachytherapy has been characterized using MCNP5. The Xoft Axxent™ X-ray Source agrees with measured results for radial dose function and anisotropy function to within ±10%.

INTRODUCTION

Extensive Monte Carlo modeling was performed using the Monte Carlo N-Particle radiation transport code MCNP5 to characterize the Xoft Axxent™ X-ray Source (Source) for electronic brachytherapy. 'Good Practice' recommendations of the AAPM AAPT-43/U1 report were utilized. Unlike radial dose functions where there are recommended photon energy spectra for 125I and 103Pd, the Source photon energy spectrum was initially unknown. This study assessed the dose distribution, dosimetry parameters using the AAPM TG-43/U1 protocol, and the sensitivity of results to source geometric parameters and choices of computational parameters.

METHODS

All Source components including the water cooling shroud were modeled using proprietary internal dimensions and cations. X-ray emissions and spatial distributions were calculated using 40, 45, and 50 kV mono-energetic electron beams striking the anode surface to generate X-rays that were then transmitted through the anode and subsequently filtered. Due to the inclusion of a water cooling shroud, the calculated energy substep values for photon generation in the anode and shroud were found to be inadequate. Doubling the default energy substep values affected the number of X-rays and brehmsstrahlung photons generated by >1%. Utilizing geometry splitting/rouletting and brehmsstrahlung biasing for variance reduction improved the accuracy of the calculated dose rate by >20%.

RESULTS

Dose rate to water. Table 1 presents the measured and calculated dose rates to water per µA of beam current at the reference position at all three operating voltages. The maximum values for dose rates to water at a reference position were typically 40% less than the Monte Carlo results. This implied that the average field size dependence of the calculated dose rate to water was approximately 60% of that calculated by the MCNP5 model.

Figure 2. Comparison between measured and calculated radial dose functions.

CONCLUSIONS

A miniature X-ray source for electronic brachytherapy has been characterized using MCNP5. The Monte Carlo results agreed with measured results for radial dose function and anisotropy function to within ±10%.

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DEVICE DESCRIPTION

The Xoft Axxent™ Electronic Brachytherapy System, consisting of the X-ray Source, the Balloon Applicator and the Controller. The X-ray Source comprises an X-ray tube in a multi-lumen catheter that allows cooling fluid to circulate over the tube. The balloon applicator, a sterile, disposable, single use device, is designed for use with the water-cooled X-ray source and functions as the applicator.

The controller provides power to the Source, allows translation of the Source, and provides a user interface with a control panel.

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The Xoft Axxent™ Electronic Brachytherapy System is for investigational use only. FDA clearance pending.