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

Method and Materials: Monte Carlo simulations of radiation generation and transport utilized the MCNP5 code and EPDL97-based mcpplib04 cross-section library. Dosimetry parameters using a modified TG-43U1 2-D dosimetry formalism were determined at 40, 45, and 50 kV operating voltages. While the source was modeled as a point due to small anode size, < 1 mm, the 1-D brachytherapy dosimetry formalism is not appropriate due to significant polar anisotropy. Source output was measured in a water phantom using a PTW 34013 Ion Chamber.

Results: Calculated point-source model radial dose functions at gP(5) were 0.19, 0.24, and 0.29 for the 40, 45, and 50 kV voltage settings, respectively. Measured point-source model radial dose functions were ± 10% of the calculated results for 1.5 cm ≤ r ≤ 7.0 cm. Calculated F(r,θ) values for all operating voltages were typically 1.1 along the distal end (θ = 0°) and ranged from F(0.5, 160°) = 0.2 to F(10, 160°) = 0.5 near the catheter proximal end. Default energy substep values, estep, for photon generation in the anode film and substrate were found to be adequate. Doubling the default values effected the number of x-rays and brehmsstrahlung photons generated by <1%. Utilizing geometry splitting/roulette and brehmsstrahlung biasing for variance reduction improved the computational efficiency by >30x.

Conclusion: 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%.

Conflict of Interest: Research was supported by Xoft, Inc.