**Introduction**

The Xsoft® Axxent® Electronic Brachytherapy System is an effective treatment for the early-stage endorectal adenocarcinoma, specifically for tumors up to 3 cm in diameter and within 10 cm from the rectal opening. It utilizes a low-energy X-ray source with an average energy of around 24 keV, initially characterized in 2006 [1].

Subsequent modifications by the manufacturer included adding a plastic anode-centering insert, which resulted in work by Hii et al. [2015] [2].

As shown in [3], the deviations in source design can impact dose rates by over 2%, exceeding standard as recommended by TG-156 [3]. Moreover, variations in elemental composition, particularly close to the anode, contribute to spectral differences among sources of the same model. In 2022, the manufacturer provided different thickness values for an Ag layer and distinct epoxy material.

Due to the sources of uncertainty in the manufacturing of the source, accurate modeling and a robust pipeline is crucial to obtain precise X-ray spectra and dose distributions.

Given these factors, our research focuses on creating the pipeline to characterize the Xsoft electron beam brachytherapy source design and beam quality and circumvent the uncertainties due to source-to-source differences. We aim to establish a systematic approach by creating a simulation and measurement pipeline for characterizing the dosimetric and spectrometric properties of the Xsoft source.

**Materials and Methods**

- **Software**
  - Axxent® Monte Carlo-based dose calculation software package, developed using the Geant 4 Monte Carlo toolkit.

First the source was prepared:

1. Geometry and material descriptions for the Xsoft electron beam brachytherapy source were obtained from CAD format by Xsoft.
2. CAD files were converted to GEML format using GIMMesh, a Python-based tool.
3. Material composition and mass densities were assigned to source geometry parts.

Monte Carlo simulation in the E-Brachy consisted of two parts:

1. Simulations start with electrons as primary particles. Generating X-rays upon anode bombardment, electrons are cooled and saved in each phase space file.
2. The phase space file is used to investigate interactions between x-rays and applications/detectors/patients.

In the second part of the simulations:

- The energy spectrum of the generated x-rays 178 cm from the origin of the source was investigated for various material compositions that were provided by the vendor and were compared to the measured spectra at NIST at the similar distance.
- Beam half value layer of the beam generated by the source was investigated by adding layers of Al in the simulation environment 50 cm from the source in air, calculating the resulting air kerma, and observing when the value drops to the 50% of the value without layers of Al.
- To calculate dosimetric properties of the source, the volume around the source was cylindrically parameterized with concentric cylindrical shells sectioned in 2 and 4 directions and simulated times with varying section sizes of dp=r=0.01 cm at r=0-10 cm, dp=r=0.05 cm at r=0-5 cm dp=r=0.10 cm at r=0-10 cm and dp=r=0.2 cm at r=0-20 cm as per suggested by Taylor et al. [2007].

**Results and Discussion**

- **Material Composition Uncertainties:** In the red material distribution, there were uncertainties. These uncertainties encompassed factors such as the level of Ag used in the epoxy surrounding the anode and the thickness of the Ag wall that encased the x-ray source's vacuum. To resolve these uncertainties, different material compositions were compared. Ultimately, the material composition that closely matched NIST measurements (the red line) was selected for generating x-rays in the initial simulations.

- **Beam Half Value Layer (HVL):** The beam half value layer was measured and set at 0.04, with a deviation of ±0.1%. This measurement provides crucial information about the beam quality.

- **Comparison Between Models S7500 and S700:** Despite minimal reported differences between models S7500 and S7500 (the previous model) by the vendor, studies by Hii et al. in 2015 [2] revealed that the geometry and material compositions of sources, even within the same model, had undergone changes. Moreover, due to the small size and manufacturing limitations, certain parts of the source are manually handled. Consequently, a comparison of dosimetric properties between models S7500 and S7500 was conducted. Although both models exhibited similar radial dose functions (figure 3), they displayed discrepancies in their anisotropy properties (figure 4).

- **Table of Summary of S7500 vs S700 Results:** In Table 2, a summary of ratios between model S7500 and S7500 is provided, normalized to the more recent model S75000.

**Conclusion**

- Developed a Monte Carlo dosimetry package for electronic brachytherapy.
- Optimized the package's performance.
- Calculated the source spectrum with various material compositions.
- Selected the composition closest to NIST experimental measurements.
- Found the beam's half-value layer to be 0.344 mm ± 0.1% Aluminum at 50 cm from the source.
- Compared dosimetry of the received model (S7500) with a previously studied one [2].
- Noted that radial dose functions matched, but anisotropy function discrepancies increased at higher angles and shorter distances from the source in the two models.

**References**


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