Abstract

Electronic brachytherapy sources, such as the Xoft Axxent® source must be dosimetrically characterized prior to clinical use. The development of a modified TG43 formalism has been the focus of previous works for the older, water cooled source models. This formalism shifts the standard value from air kerma strength to air kerma rate, and introduces the dose rate conversion coefficient (χ_i). These changes were made to account for bremsstrahlung perturbations from applicators as well as dose rate fluctuations of the x-ray tubes. Thus, the parameters used in this formalism must be determined for each applicator used clinically.

The introduction of a higher density Galden® coolant to these sources, combined with other changes to the anode of the source, will result in a harder energy spectrum when compared to the older sources. It is also critical to determine how this harder spectrum is further filtered when the titanium cervical applicator is used for treatments. These beam hardening effects can have dosimetric and biological implications on these low energy sources.

This work was split into two main sections: dosimetric determination of the modified TG43 parameters for the new, Galden® cooled S7600 Axxent source model and biological characterization of the S7600 bare source and source in applicator for cervical cancer applications. The dosimetric characterization included measuring the air kerma-rate for six S7600 sources using the Attix Free Air Chamber (FAC) and two standard well-chambers at the UWADCL. These sources were compared to the older S7500 sources, and well chamber calibration coefficients were determined for the new S7600 sources. Further, TLD 100 microcubes, an Exradin A26 ionization chamber, and EBT3 film were used to measure the modified dosimetry parameters for the bare S7600 source. These dosimeters were used in previously developed phantoms at the UWMRRC and were evaluated in terms of accuracy and precision.

Additionally, the TOPAS and EGSnrc Monte Carlo user codes were used to simuluate the S7500 and S7600 sources. The differences between the two source spectra with depth in water were simulated using `egs_brachy`. Additionally, TOPAS and the `egs_chamber` codes were used to simulate the radial dose function, polar anisotropy, and air kerma from the bare source and source in titanium applicator. The results from these simulations were

used to determine the values for χ_0 and χ_{Ti} for the bare source and source in applicator respectively. The effects of filtration from the new coolant and the titanium applicator were evaluated. Overall, excellent agreement was seen between the Monte Carlo and experimental results.

The irradiation set up and recipes delivered from the Axxent source for the biological experiments were characterized through dosimetric measurements and simulations for the biological characterization. Clonogenic survival assays were then used to experimentally determine the relative biological effectiveness (RBE) of the bare source and source in applicator. Further, comet assays were used to quantify the number of double strand breaks induced by the radiation sources. These results were also used to calculate the RBE. Finally, a chromosome instability (CIN) assay was performed to quantify the number of mitotic errors caused by the incident radiation. All biological assays were performed with ^{60}Co as the reference radiation quality.

The TOPAS nBio extension was used to evaluate the damage caused to a single cell nucleus from the three radiation qualities. Electron spectra were simulated within the center of the experimental set up, and the average electron energies were calculated. These energies were used as the energy of a monoenergetic electron source used for the nBio simulations. The number of single and double strand breaks were recorded and were sorted into the different causes of damage.

It was found the titanium applicator resulted in a reduced linear energy transfer (LET) and dose rate when compared to the bare source. As a result, the source in applicator was found to have less biological effectiveness. However, for lower doses, it still resulted in more damage when compared to the reference radiation quality.

The results from this work provide valuable dosimetric and biological information for clinical Axxent® source users. With the development of a new standard at NIST for the S7600 source, these sources can fully be implemented for a variety of applications, providing a biological advantage over external beam radiation.