Characterization of low-energy photon-emitting brachytherapy sources and kilovoltage x-ray beams using spectrometry

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Low-energy photon sources are used in therapeutic radiation oncology for brachytherapy with low dose-rate (LDR) sources and for superficial and orthovoltage therapy with kilovolt-age x-ray beams. Current dosimetry methods for these sources utilize energy-integrating devices, such as thermoluminescent dosimeters and ionization chambers. This thesis work investigates the dosimetry of LDR brachytherapy sources and kilovoltage x-ray beams using spectrometry, which preserves the energy-specific source output.

Several LDR brachytherapy source models were measured with a reverse-electrode germanium (REGe) detector. The measured spectra were corrected for MCNP5-calculated detector response using a deconvolution algorithm (Beach, 2005). The peak areas determined from the corrected spectra were used to calculate the dose-rate constant (Chen and Nath, 2001) and the air-kerma strength. Dose-rate constant results agreed well with the published values (Rivard et al., 2004; Chen and Nath, 2007). Air-kerma strength results were systematically 2%-5% low compared to calibration values and primary air-kerma strength measurements. The spectrometry methods for LDR brachytherapy sources offer a promising alternative to existing experimental techniques, but further work is necessary to improve agreement with the current air-kerma strength standard methodology.

Spectra of 20kVp--250kVp x-ray beams were measured with a low-energy germanium detector (LEGe). The LEGe spectrometry system was modeled in MCNP5 to calculate a detector response function. Backward stripping, which showed less variability than deconvolution, was used for correcting the measured x-ray spectra. The corrected experimental spectra were compared to spectra from: (1) Monte Carlo simulations of the full x-ray tube with EGSnrc, (2) the SpekCalc program (Poludniowski et al., 2009), and (3) the Gesellschaft für Strahlen-und Umweltforschung mbH München (GSF) Report 560. Agreement was best for the UW60-M through UW150-M beams and poorest for the UW20-M and UW-30M beams due to incomplete modeling of tungsten L-shell fluorescence peaks by the EGSnrc code and SpekCalc program. Monte Carlo simulations of thermoluminescent dosimeter and ionization chamber dosimetry demonstrated that variability in response due to the input spectrum was within the limits of accurate geometry simulation. This work has contributed to more accurate x-ray spectra that can be used for future dosimetry investigations with these beams.