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The potential of semi-analytical dose calculation algorithms for low energy brachytherapy

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Recently dose calculation algorithms accounting for inhomogeneities are actively explored in brachytherapy. While Monte Carlo simulation has been proposed as a time efficient alternative for accurate doseimetry in low energy brachytherapy, semi-analytical models that are simple and do not exhibit statistical uncertainty could be equally accurate for specidic applications.

This work reports on the accuracy of a Sievert type semi-analytical dose calculation model for single 125I source dosimetry. Monte Carlo simulation was used to score the scatter dose distribution of a point source in various tissue materials to arrive at a function of scatter to primary dose ratio versus distance. Simulations were also performed around a commercially available source to characterize the anisotropy of the scatter dose distribution and obtain data for benchmarking purposes. The dose rate per unit air kerma strength distribution around the commercially available source was calculated as the superposition of the contribution by a number of point sources uniformly distributed within the source, using the above data with a simple ray tracing algorithm and narrow beam attenuation coefficients weighted by the initially emitted 125I energy spectrum. Resuts were found in good agreement with corresponding Monte Carlo results. The semi-analytical model can be easily customized to different source models and materials and could prove useful in dosimetry for low energy prostate brachytherapy provided that material segmentation form patient imaging is achievable with limited uncertainty in the future, and that uncertainty due to its inherent 1D pathlength character is abated by the increased number of seed sources implanted.

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On the preparation of virtual brachytherapy sources from monte carlo generated phase space data

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Monte Carlo (MC) simulation is considered the reference computational method for dosimetry in radiation therapy applications. While it has been proposed for the treatment planning of brachytherapy using low energy sources, calculation times remain impractical for 192Ir brachytherapy. This work reports on the preparation of virtual brachytherapy sources for use in MC simulations to reduce memory requirements and improve calculation efficiency.

MC simulation was performed using MCNP6 to record the phase-space file (a source-specific file containing the energy, position, and direction of photons emerging from a source) for a generic 192Ir brachytherapy source proposed recently for the evaluation of commercially available dose calculation algorithms. 6 × 107 initially emitted photons were sampled resulting to a phase-space file size on the order of GBs. The accuracy of the phase-space file was verified through benchmarking of single source dosimetry results. The photon energy distribution was found to have no association with position along the source longitudinal axis, z, polar angle, φ, and, of course, azimuthal angle, θ. The z-distribution of emitted photons was transformed to a probability density distribution and fit to a sum of two p-sigmoid distributions. The probability density function for φ is decribed by a family of normal distributions over z described by their mean and standard deviation as a function of z. Hence a brachytherapy source can be described by a file of size on the order of kB to sample: photon energy from a discrete distribution, position z from a a sum of two p-sigmoid distributions, φ from a normal distribution depending on z, and θ uniformly.

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