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A Monte Carlo based dose calculation and evaluation method for TARGIT brachytherapy applications using the INTRABEAM system

Autor: Sven Clausen
Institut / Klinik: Klinik für Strahlentherapie und Radioonkologie
Doktorvater: Prof. Dr. F. Wenz

Purpose: To generate and validate a source model of a miniature X-ray generator (INTRABEAM, Carl Zeiss Surgical, Oberkochen, Germany) for TARGIT brachytherapy and IORT a Geant4-based Monte Carlo tool was developed. For the first time the model was used to calculate accurate dose distributions for the source with a variety of applicators available for actual or up coming treatments.

Methods and Materials: Geometries with given materials of the x-ray source and applicator were implemented in a Geant4-based dose calculation framework. Phase space files for circular electron beam foci were precalculated for a set of different beam radii to speed up calculation time. This had to be done because the electron beam geometry of the electron beam is not known in advance. To estimate the electron beam radius distribution of the system, a mean squared error term between an EBT film measured dose distribution and a simulation was minimized. Further evaluation was done with cadaver measurements and depth dose comparisons.

Results: Resulting dose distributions were compared with Gafchromic EBT film measurements to validate the tool. In a region of interest around the source, the 2%/2mm gamma criterion matched with 98.23% for the cylindrical applicator. Profiles showed very good agreement between measurement and simulation. The calculation time to simulate an entire treatment was twelve minutes. The new applicators were simulated and proved the correctness of the MC simulation.

Conclusions: The electron beam radius distribution was reconstructed. This results in having a full Monte Carlo simulation tool of the miniature x-ray source. The dose calculation method yields dose distributions for TARGIT brachytherapy and IORT matching measured dose distributions within clinically accepted limits.