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Development of a GEANT4 dosimetric system for orthovoltage x-ray minibeam radiation therapy clinical trials

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Aims:
Recently the first first-in-human minibeam radiation therapy (MBRT) treatments with an orthovoltage x-ray unit at Mayo Clinic, Rochester, Minnesota was presented. We present the development of a GEANT4-based radiation transport model to simulate the minibeam radiation field produced using a clinical orthovoltage machine.

Materials and Methods:
The full clinical orthovoltage machine was modelled in GEANT4 monte carlo toolkit (version 11.1.0) based off the Xstrahl 300 orthovoltage unit used in clinical treatments, with a Phase Space File created at the cone exit. A separate GEANT4 simulation was used to model the orthovoltage x-rays downstream from the cone, where the multi-slit collimator and PlasticWaterTM was setup with the same dimensions as those used when obtaining experimental measurements.
The experimental film measurements were compared to the resulting simulation dose results, for both broad beam and MBRT peak and valley percentage depth dose (PDD) curves. The model was validated for a range of cone sizes (3, 4, 5, 8 and 10cm) and beam energies (100, 180, 250kV).

Results:
For BB PDDs an agreement within 4% was observed between the GEANT4 simulation and experimental results for all field sizes and beam energies investigated. For the minibeam peak PDDs there was good agreement with the largest percentage difference of 9%. For the valley dose PDDs however, the GEANT4 simulations consistently underestimated the valley dose with average percentage differences ranging from 7% to 27%, depending on the cone size and beam energy. Furthermore, when simulating the MSC rotated 90 degrees, with respect to the anode-axis, this resulted in large differences in peak-to-valley-dose-ratio at depths from 40mm, which was confirmed experimentally.
Overall, the model had good agreement between the broad beam and minibeam peak PDDs when compared to experimental results, presenting the first step towards MBRT dose calculations for patient specific volumes.

Authors: Mr WHITE, Christopher (Centre for Medical Radiation Physics, University of Wollongong); Mr QUINTERO MATEUS, Chrystian (Department of Radiation Oncology, Mayo Clinic); Dr GARCIA, Darwin (Department of Radiation Oncology, Mayo Clinic); Dr MOSELEY, Douglas (Department of Radiation Oncology, Mayo Clinic); Dr PAINO, Jason (University of Wollongong); Prof. PETASECCA, Marco (University of Wollongong); Dr MASHAYEKHI, Maryam (Department of Radiation Oncology, Mayo Clinic); Dr GRAMS, Michael (Department of Radiation Oncology, Mayo Clinic); LERCH, Michael (University of Wollongong); Mr NIKANDROVS, Mihails (St. Luke's Radiation Oncology Network, Dublin); Dr MUTTER, Robert (Department of Radiation Oncology, Mayo Clinic); Dr LESTER, Scott (Department of Radiation Oncology, Mayo Clinic); Dr PARK, Sean (Department of Radiation Oncology, Mayo Clinic); Prof. GUATELLI, Susanna (University of Wollongong); DE ROVER, Vincent (University of Wollongong)

Presenter: DE ROVER, Vincent (University of Wollongong)

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