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Monte Carlo Simulations of a Nozzle for the Treatment of Ocular Tumors with High-Energy Proton Beams

Purpose: To develop a Monte Carlo simulation model for ocular proton beam therapy, validate its predictions with measurements, and commission an ocular treatment planning system using simulated proton beam data.

Method and Materials:
We commissioned the EYEPLAN ocular treatment planning system for proton radiotherapy using only dosimetric data from Monte Carlo simulations. The commissioning comprised two main tasks: generating nozzle-specific parameters and dose profiles and entering them into the treatment planning system, and testing the accuracy of the planning system's dose predictions under various beam conditions that are representative of ocular melanoma treatments. The MCNPX Monte Carlo simulation code was used with a detailed, 3-dimensional model of an ocular beamline. Simulations were carried out to generate both input dose distributions for the treatment planning system as well as validation data to test the accuracy of the TPS predictions. The simulation model was benchmarked against measured dose distribution from Harvard Cyclotron Laboratory (Cambridge) and the Northeast Proton Therapy Center (Boston). Measurements were made with ionization chambers, diodes, and radiographic film.

Results:
Benchmark comparisons revealed maximum differences between absorbed dose profiles from simulations and measurements of 6% and 0.6 mm, while typical differences were less than 2% and 0.2 mm. The computation time for the entire virtual commissioning process is less than one day.

Conclusion:
The study revealed that, after a significant development effort, a Monte Carlo model of a proton therapy apparatus is sufficiently accurate and fast for commissioning a treatment planning system. With relatively little additional effort, additional capability can be added to the model, such as the prediction of output factors.