Abstract

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Implementation of a Machine Learning Algorithm for Dose Verification in Proton Beam Therapy: A Head Phantom Study for Brain Tumour Applications

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ABSTRACT

Introduction: Proton beam therapy utilises the Bragg peak to deliver precise dose deposition, offering a distinct advantage over conventional radiotherapy. Inaccurate dose delivery risks underdosing tumours or exposing healthy tissue, with significant consequences for patients. However, real-time dose range verification remains a major clinical limitation. Prompt gamma (PG) radiation, have emerged as a promising candidate for in vivo dose verification due to their spatial correlation with the proton dose distribution. This study investigates the potential of machine learning (ML) to disentangle PG emission data and predict dose distributions in silico.

Methodology: Geant4-based Monte Carlo simulations were performed using a proton-phantom model at three beam energies (120 MeV, 150 MeV, 180 MeV), generating PG datasets containing particle detection time and spatial coordinates. A feedforward neural network with two hidden layers (32 neurons each) was trained on each monoenergetic dataset independently, then on a mixed-energy dataset and tested against each to assess generalisation.

Results: The model accurately predicted Bragg peak positions across all monoenergetic data, with relative errors within the clinically acceptable 4% threshold: 0.94% (120 MeV), 0.63% (150 MeV), and 2.78% (180 MeV). The mixed-energy trained model generalised effectively to monoenergetic data, achieving relative errors of 0.00% (120 MeV), 0.63% (150 MeV), and 2.78% (180 MeV).

Conclusion: This study demonstrates the feasibility of using ML for dose distribution prediction from PG emission data, achieving Bragg peak localisation errors within acceptable tolerances. Future work should focus on advanced neural network architectures and multi-particle emission data to improve treatment precision and patient outcomes.