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Verification of proton range in proton therapy using conversion of PGT spectrum to prompt γ-ray emission profile

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Abstract

One of the on-line range verification techniques in proton therapy is time -of-flight (TOF) measurement for prompt gamma. In this technique, the prompt gamma timing spectra are measured using the time difference between passage of the particle bunch through the target entrance of the beam and the arrival time of the corresponding prompt γ-ray at the detector. In this study, homogeneous PMMA phantom and PMMA phantoms with a slice of bone or air cavity were simulated in GEANT4 simulation. These targets were irradiated with a proton pencil beam with an initial energy of 150 MeV, and the resulting PGT spectra were recorded by scintillation detectors. Then, a code was programmed in MATLAB software to analytically solve the kinematics of proton movement in the phantom, and the PGT spectrum obtained from GEANT4 was given as an input to this software code and the prompt gamma-ray emission profiles were obtained in the phantom. In this study, the effect of the type and position of the heterogeneous slice on the PGT spectrum and the prompt gamma-ray emission profiles resulting from the PGT transformation was investigated. From the comparison of the prompt gamma-ray emission profile resulting from PGT spectra conversion, with the energy deposition spectra resulting from GEANT4 simulation, it was observed that the range shift and the shift of energy deposition location resulting from an inhomogeneity in PMMA have a significant relationship compared to the reference phantom.The presence of an inhomogeneous slice of bone and air cavity with a thickness of 10 mm shifts the range of the proton compared to its range in the reference phantom by 4 mm and 9.6 mm, respectively, and the spectra of energy deposition for these states are respectively 4.8 mm and 9.9 mm shifted relative to the energy deposition spectra of the reference phantom. Therefore, the PGT spectra reflects the proton transit time in the target material and provides the possibility of determining the prompt gamma-ray emission profiles and the possibility of confirming the delivery of the dose to the patient's body.

Keywords: proton therapy, on-line monitoring of the proton range, prompt gamma time of flight, PGT, GEANT4.

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