Purpose: To compare the clinical adaptability of prompt gamma (PG) imaging and positron emission tomography (PET) as in-vivo treatment verification tools in proton radiation therapy.

Methods: In order to study the proton induced photon emission process in a patient during proton therapy, Monte Carlo simulations were performed using the GEANT4 toolkit. A thorough investigation of several different tumor sites such as head and neck, prostate, spine and abdomen, irradiated by passive scattered and pencil fields was performed. The calculated dose, PG rays and PET isotopes with decay times between 2 and 20 minutes were scored on the CT grid. The acquisition time delay and biological washout were implemented in the PET distribution post simulation. The correlation between dose and PG/PET was analyzed along lines parallel to the beam direction spaced about 2 mm apart from each other.

Results: For all subjects, the PG method showed approximately 10 times higher gamma production rate than the PET method before, and 60 to 80 times higher production after including the washout and time corrections. This rate was directly proportional to the tissue density. For passive fields, the correlation between dose and PG/PET was strongly dependent on the location of the line profile within the field. This dependence can be related to the tissue heterogeneity and the position of the distal falloff within the patient. For pencil beams, the distances between both PG/PET and dose falloffs were consistent and therefore well correlated. This was mainly due to the smaller beam size and better-defined distal falloffs.

Conclusions: PG imaging was found more appropriate than PET for pencil beam scanning due to in-situ capabilities and reduced limitations and uncertainties. However, current detector technology does not allow full utilization of this method, while PET range verification has already been studied clinically.