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On-the-fly dose reconstruction from in-beam PET activation

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Background and aims: In-beam PET offers rapid treatment feedback, yet faces challenges with high event rates. Clinical implementation requires on-the-fly integration of a fast dose reconstruction algorithm. In this work, we present on-the-fly dose reconstruction from clinical in-beam PET data, using a novel In-beam Dose Estimation tool (IDE-PET), capable of obtaining on-line dose and of detecting range deviations.

Methods: The specific PET setup consisted of 6 phoswich detector blocks with 338 pixels each, with 1.55 x 1.55 x LYSO (7mm)+GSO (8mm) detectors. The system was coupled to a fast data acquisition system able to sustain rates up to 10 Msingles/sec.
Several cylindrical (50-mm diameter and 50-mm height) homogeneous PMMA phantoms were irradiated with a monoenergetic proton beam of 70 MeV oriented along the longitudinal axis of the scanner. Additionally, 5 PMMA range shifter foils of varying thickness (from 1 to 5 mm) were also placed at the proximal surface to investigate range shift prediction accuracy.
For real-time dose estimation, we have developed the IDE-PET tool, which combines a GPU-based 3D reconstruction algorithm [2] with a dictionary-based software capable of estimating deposited doses from the 3D PET activity images [3].

Results: The dose estimation algorithm requires from 0.25 to 1.0 seconds to calculate and display the deposited dose. For a 2 Gy dose fraction, the method was able to spot range variations as small as 1 mm. The average range estimation has a statistical error of 0.1 mm (1σ). Assessment of system sensitivity to proton number changes showed satisfactory results for doses as low as 0.2 Gy.

Conclusions: We can reconstruct dose maps from PET activation on-line, at clinically relevant dose levels and during the beam-on period, with an accuracy better than one millimeter, in the BP fall-off region. This validates the feasibility of the proposed experimental setup to be used for in-beam on-the-fly reconstruction of the 3D dose in a clinical scenario.

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