

Theme: Physics
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Protoacoustic Range Verification by Direct Comparison with Beam Range Measurements Using a Tissue-Equivalent Polymer Gel

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Background / Aims:

Protoacoustics (PA) offers a promising method for *in vivo* range verification in proton therapy. However, experimentally assessing its accuracy with conventional tissue-mimicking phantoms (TMPs) often relies on Monte Carlo (MC) simulations to estimate the ground truth. Limited knowledge of material properties or insufficient fine-tuning of dose models can introduce range errors in these MC simulations. This study aims to propose a TMP capable of concurrently measuring the dose distribution and the PA signal, thereby circumventing the need for MC simulations and their associated uncertainties.

Methods:

Normoxic N-vinylpyrrolidone-based polymer gel dosimeters (iVIPET) were employed as TMPs. Two gel dosimeters of varying thicknesses (TMP I: 280 mm, TMP II: 140 mm) were irradiated with a 226.5 MeV proton beam from a clinical synchrocyclotron (IBA S2C2, Louvain-la-Neuve, Belgium). Post-irradiation, MRI was used to determine the beam range (R2 range) within the gels. Concurrently, PA ranges were measured using an optical hydrophone (Eta250L Ultra, XARION Laser Acoustics GmbH, Austria) and an acoustic simulation-based approach. The ranges obtained from the gel dosimeters were then compared with those from the PA method.

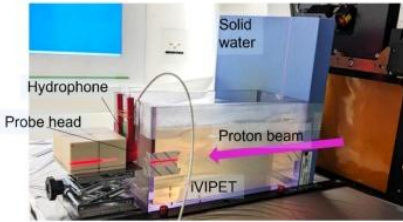


Figure 1. Experimental setup. PA waves were detected downstream of the Bragg peak.

Results:

The range differences between R2 measurements and the PA method were within 1 mm for both TMPs, while the maximum deviation between the PA- and MC simulation-derived ranges was 2.1 mm. This maximum deviation is potentially attributable to inaccuracies in the assumed material properties within the MC simulation.

Table 1. Bragg peak positions in TMPs estimated by the R2, PA, and MC methods. All values are in millimeters (mm).

	R2	PA	MC
TMP I	257.8	258.3	258.3
TMP II	120.5	120.8	118.7

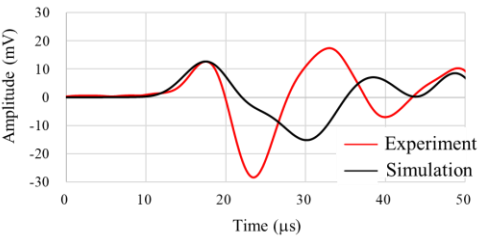


Figure 2. PA waveform emitted from TMP I. The arrival time of the experimental compression peak (red curve) agreed with the simulation (black curve) within 0.3 μ s.

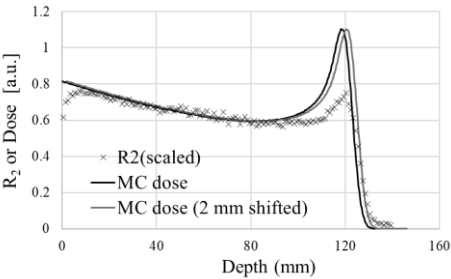


Figure 3. R2 and MC profiles for TMP II. The R2 and MC profiles generally showed good agreement, except for signal reduction in the high LET and entrance regions.