Documents

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Thermoacoustic range verification during pencil beam delivery of a clinical plan to an abdominal imaging phantom
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[a] University of Wisconsin – Milwaukee, United States
[b] Ion Beam Applications, Belgium
[c] Rutherford Cancer Centres, United Kingdom
[d] HCA Healthcare, United Kingdom
[e] UC Louvain, Belgium
[f] Computerized Imaging Reference Systems, United States
[g] Acoustic Range Estimates, United States

Abstract
Purpose: The purpose of this phantom study is to demonstrate that thermoacoustic range verification could be performed clinically. Thermoacoustic emissions generated in an anatomical multimodality imaging phantom during delivery of a clinical plan are compared to simulated emissions to estimate range shifts compared to the treatment plan. Methods: A single-field 12-layer proton pencil beam scanning (PBS) treatment plan created in Pinnacle prescribing 6 Gy/fraction was delivered by a superconducting synchrocyclotron to a triple modality (CT, MRI, and US) abdominal imaging phantom. Data was acquired by four acoustic receivers rigidly affixed to a linear ultrasound array. Receivers 1–2 were located distal to the treatment volume, whereas 3–4 were lateral. Receivers' room coordinates were computed relative to the ultrasound image plane after co-registration to the planning CT volume. For each prescribed beamlet, a set of thermoacoustic emissions corresponding to varied beam energies were computed. Simulated emissions were compared to measured emissions to estimate shifts of the Bragg peak. Results: Shifts were small for high-dose beamlets that stopped in soft tissue. Signals acquired by channels 1–2 yielded shifts of -0.2±0.7mm relative to Monte Carlo simulations for high dose spots (~40 cGy) in the second layer. Additionally, for beam energy ≥125 MeV, thermoacoustic emissions qualitatively tracked lateral motion of pristine beams in a layered gelatin phantom, and time shifts induced by changing phantom layers were self-consistent within nanoseconds. Conclusions: Acoustic receivers tuned to spectra of thermoacoustic emissions may enable range verification during proton therapy. © 2021 Elsevier B.V.

Author Keywords
Ion therapy; Ionoacoustic; Proton therapy; Range verification; Thermoacoustic

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Correspondence Address
Patch S.K.; Acoustic Range Estimates, United States; email: Sarah.Patch@AcousticRangeEstimates.com

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