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Designing a detector array for ionoacoustics-based Bragg peak localization and dose reconstruction in a small animal during pulsed proton irradiation

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Introduction

Ionoacoustics (IA) is a promising approach for Bragg peak (BP) localization (BPL) currently being investigated in the development of *a small animal irradiator*. As part of this project, a detector array is to be designed in order to locate the BP inside a mouse. Presented here is a simulation study performed in homogeneous water phantoms where various array designs, based on flat disc sensors, were investigated.

Materials & Methods

3D simulations were run using k-Wave where a detector array recorded IA signals from a 50 MeV proton beam degraded from a 70 MeV clinical beam. The BP was localized by iterative time-reversal-reconstruction (TRR) of the initial dose-induced pressure. The dose was thereafter deduced from the reconstructed pressure by accounting for the medium density and Grüneisen parameter. 2D and 3D arc arrangements constituting of various numbers of sensor elements were considered for a proposed detector array. The arc's eccentricity, its diameter and sensor dimensions were varied in order to minimize BPL error. Prior to the reconstruction, the point-spread-function (PSF) was evaluated to determine the image distortion induced by the array geometry and pulse duration which was then deconvolved from the reconstructed pressure to improve the BPL accuracy.

Results

Deconvolving the PSF reduced BPL error, especially for higher proton pulse widths (viz. BPL error reduced by 75% for 10 μs pulse width). 3D arrangements made up of multiple arcs localized the BP to within 1 mm of the actual BP position.

Summary

The proposed detector array and reconstruction method allow for sub-millimetric BPL error. Although off-line PSF calculation is time-consuming, it negates the need to run multiple iterations of TRR for accurate BPL and hence reduces on-line reconstruction time. Next steps will involve an *in-silico* real mouse study where the medium properties shall be derived from US/CT images.

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