Abstract einer Präsentation auf der Joint Conference of the ÖGMP, DGMP and SGSMP, 19.-22. September 2021, *Dreiländertagung 2021, Abstractband.* Deutsche Gesellschaft für Medizinische Physik, Stuttgart, Deutschland ISBN 978-3-948023-16-4

Feasibility study of correlated Bragg peak localization via ultrasound and ionoacoustics in an abdominal imaging phantom

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Introduction: The deposited energy of a pulsed proton beam in a medium converts to heat and provokes thermoacoustic waves [1]. Detecting the so-called ionoacoustic (IA) waves on the patient surface and correlating its signal with an ultrasound (US) image of the traversed medium allows deriving the BP location in such US image. As both modalities rely on acoustic waves propagating through the same tissue [2,3], a relative BP localization on the underlying anatomy should demonstrated for clinically relevant dose levels.

Materials & Methods: This feasibility study is based on an abdominal imaging phantom (CIRS057A) comprised of nine hydrogel materials. CT and MR images were acquired and contouring/image fusion was done using 3DSlicer. Dose calculation is based on an analytical pencil beam algorithm and is currently being replaced by Monte Carlo simulations to reproduce the clinical beam foreseen for future experimental studies (appendix1). IA wave propagation was simulated in-silico and recorded by a hydrophone (Catecean305X). To emulate the clinical experiment upfront, the Catecean305X hydrophone was tested using a pulsed 30 Watt laser pointed onto the phantom to create optoacoustic (OA) waves. The laser intensity was tuned to mimic acoustic emissions produced by clinical proton beams. Co-registration between US and hydrophone was achieved by an in-house developed holder with known spatial offsets.

Results: Based on simulations a relative BP localization is feasible (appendix2). Realistic 30mPa pressure amplitudes were measured with the hydrophone using the OA testbench. Averaging 300 individual measurements was required to identify the OA signal, which translates to a total dose of 2.4Gy at the BP. Post-processing will further reduce the minimum total dose necessary for signal detection.

Summary: Investigations on assessing IA/OA-US correlations in realistic clinical-like anatomies are ongoing and will be presented for in-silico studies and accompanying experiments from the OA testbench. Experiments at a synchrocyclotron facility are planned.

Appendix1

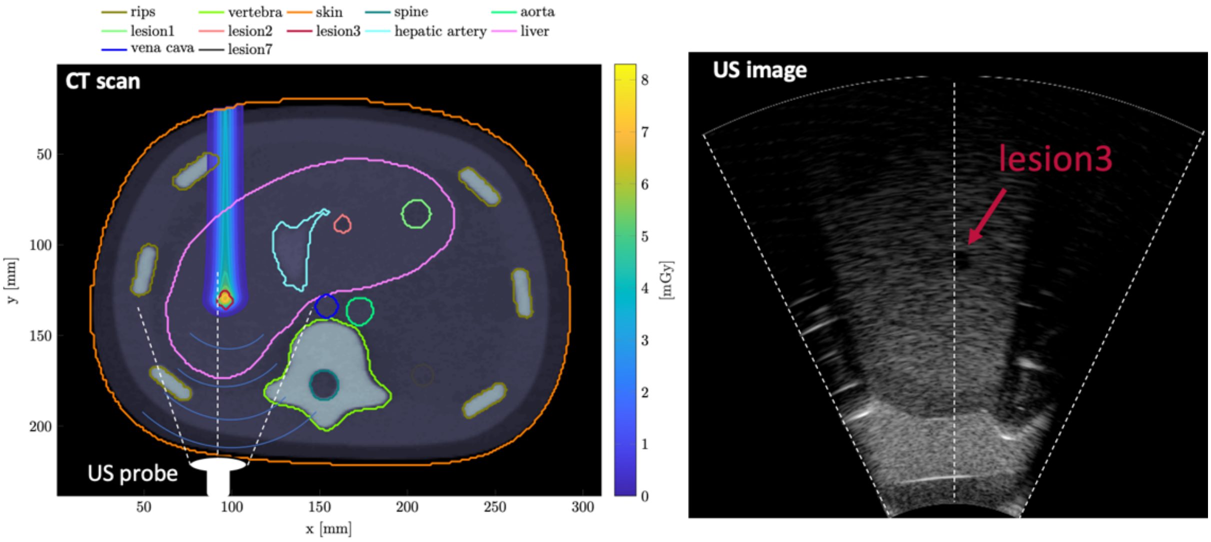

Figure 1: The dose deposition of 122 MeV protons targeting a lesion within the liver is shown on the left panel. A curved US probe (Interson, GP-C01, 3.5MHz) was positioned distal to the beam. The US image is shown on the right panel with the red arrow pointing to the considered lesion.

Appendix2

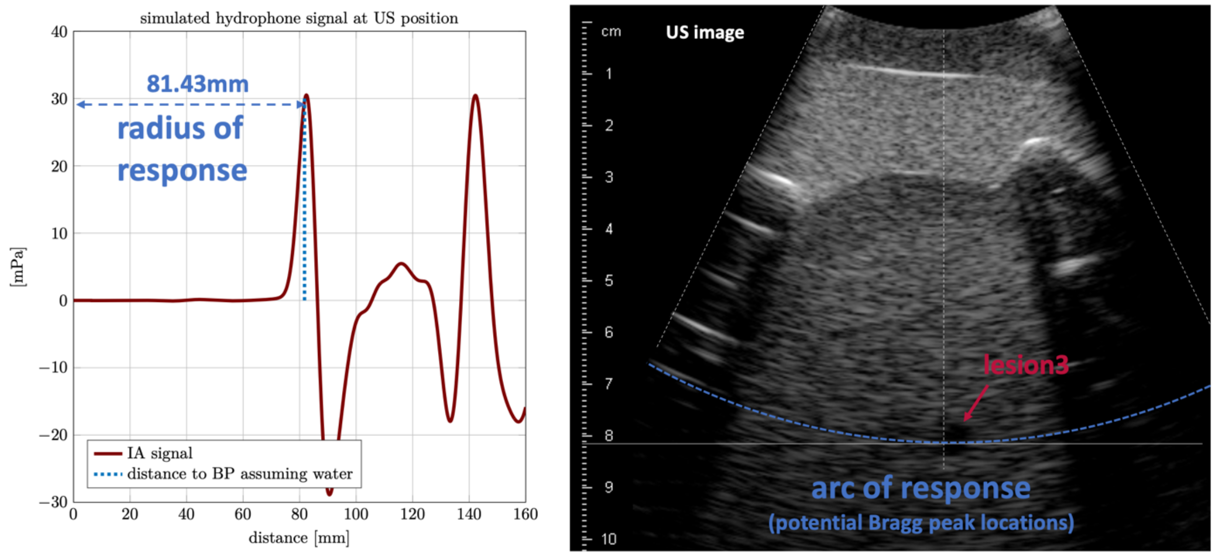

Figure 2: The left panel presents the simulated noiseless pressure amplitude of the IA wave at the position of the US probe. The maximum dose deposition of the Bragg peak is marked by a dashed blue arrow (radius of response) on the left panel. The x-axis is given in millimeter assuming a constant speed of sound identical to the US system. The radius of response corresponds in the 2D US image to an arc of response, which is overlaid in the right panel onto the US image.

Acknowledgement: The authors kindly acknowledge the financial support by the German Research Foundation (DFG), the European Research Council and the European Union Attract initiative.

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