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Impact of the skull model on simulated TFUS beam profiles

Cristina Pasquinelli, Hazael Montanaro, Esra Neufeld, Hyunjoo J. Lee, Axel Thielscher, *Member, IEEE*

Abstract — **Simulations of TFUS (transcranial focused ultrasound stimulation) beam profiles are important for targeting and estimations of the US intensity distribution inside the head. Here, we demonstrate the importance of the skull model for accurate calculations of the distributions, based on systematic comparisons with water-tank measurements.**

I. Introduction

Simulations play a key role in targeting and dose calculations for the design and analysis of TFUS experiments, as well as for treatment assessment and personalization. When modeling the skull as homogeneous, our simulations deviated strongly from experimental data. Here, we report initial results of a systematic study to identify the relevant parameters for the skull model that determine the acoustic exposure by TFUS. In particular, we test whether inhomogeneous material properties estimated from CT intensity data improve the correspondence between measurements and simulations.

II. Methods

A curved single-element transducer (500 KHz) was immersed in a water tank and the pressure field measured using a calibrated hydrophone with/without precisely positioned pig and sheep skull fragments, characterized by computed tomography (CT). The measurements were compared to acoustic simulations of the corresponding setup models. The skull acoustic velocity and attenuation properties were first modeled as homogeneous bone (cortical or average of CT image-based bone property maps). Then, the acoustic properties were derived from CT intensity data as described in [1]. The sensitivity of the simulated beams to the parameters of the (linear and non-linear) mapping functions from CT to acoustic properties was tested.

III. Results & Conclusion

Fig. 1 compares measurements and simulations. Absorption maps have been found to impact intensity but only weakly affect focus shape and pressure distributions. When modeling skull as homogeneous, focus shape strongly deviates from the measured shape. Considering CT-based skull inhomogeneity information results in much improved agreement, and optimization of the bone absorption property results in good prediction of intensity (<10% error in predicting the important transducer distance dependence). However, different absorption relations had to be used for sheep and pig skulls (otherwise, a factor 4 disagreement results). This could be the result of species specific CT-properties relationships, or of strong relationship non-linearity. Additional imaging involving reference materials is currently performed to narrow the related uncertainty. These findings demonstrate the need to better characterize the relationship between CT density and acoustic properties, in line with the important variability found in literature [1,2].

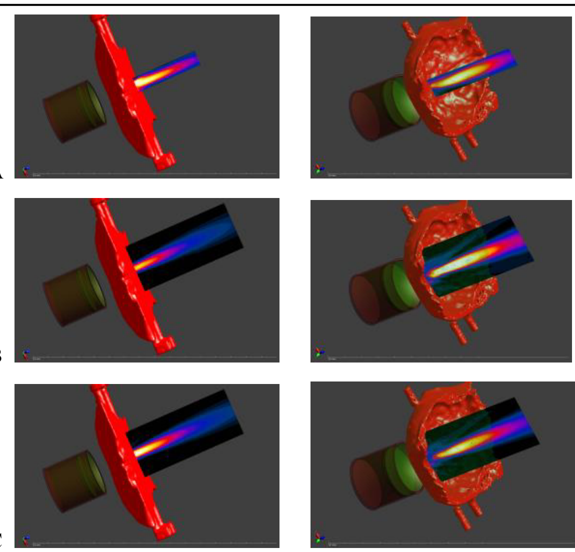
A
B
C

Figure 1. Comparison between intensity measurements (A), and simulations with the skulls modelled as homogeneous (B) or inhomogeneous material (C). Left: Pig skull; Right: Sheep skull. The scales have been normalized to peak intensity in water.

C. P. (cripas@elektro.dtu.dk) is with the Department of Electrical Engineering, Technical University of Denmark (DTU Elektro), Kgs. Lyngby, Denmark and the Danish Research Center for Magnetic Resonance (DRCMR), Copenhagen University Hospital Hvidovre, Denmark.

H. M. (montanaro@itis.ethz.ch) is with Foundation for Research on Information Technologies in Society (IT'IS), Zürich, Switzerland and Department of Information Technology and Electrical Engineering, Swiss Federal Institute of Technology (ETH), Zürich, Switzerland.

E. N. (neufeld@itis.ethz.ch) is with the IT'IS Foundation.

H. J. L. (hyunjoo.lee@kaist.ac.kr) is with the School of Electrical Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea.

A. T. (axthi@dtu.dk) is with the DRCMR and DTU Elektro.
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