Feasibility of transcranial displacement imaging: Ex vivo parametric study

Background, Motivation and Objective. Focused ultrasound (FUS) enables a non-invasive, deep, and targeted modulation of neural activity. Displacement imaging allows an estimation of FUS-induced displacement which can guide and monitor FUS. Transcranial displacement imaging has by comparison been challenging. The objectives of this study were to 1) prove the feasibility of transcranial displacement imaging ex vivo in mice and 2) quantify displacement with different frequencies and pressures with and without the skull effects.

Statement of Contribution/Methods. We employed a 128-element linear imaging transducer (L22-14vXLF; Vermon) and an ultrasound research system (Vantage 256 HF; Verasonics). Two single-element FUS transducers (H-204 1.68 MHz, and H-215 4 MHz; SonicConcepts) were used with a 1 ms pulse duration and a peak positive pressure ranged from 0.84 to 4.52 MPa. Fig. B depicts the skull placed on the elasticity phantom (049; 18 kPa, CIRS). RF data (plane waves; 12 angles between ± 3°) was delay-and-sum (DAS) beamformed, and interframe displacement was estimated based on 1D cross-correlation. Cumulative displacement was obtained by accumulating interframe displacement over the course of time. Fig. C depicts mean displacement within FWHM at 5th frame.

Results/Discussion. Fig. A depicts interframe displacement maps when the phantom tissue is displaced upward (blue) following FUS displaced the tissue downward (red). We found a focal displacement map changes with a focal size of 1.68 and 4 MHz FUS (yellow contour) and its offset with the presence of the skull. We found more distorted focal displacement at 4 MHz due to worse aberration and incidence angle of H-215. The interframe and cumulative displacement increase with pressure and are attenuated by the skull (Fig. C). In Fig. D, at 1.68 MHz and 4.52 MPa, peak negative interframe displacement was found to be -7.93 ± 0.06 and -5.39 ± 0.12 with no skull and skull, respectively (Mean ± STD, n=3), showing ~ 32% attenuation (Multiple unpaired t-test, p = 6e-5). At 4 MHz and 3.36 MPa, it was found to be -3.84 ± 0.12 and -2.23 ± 0.21 (~ 42 % attenuation, p = 3e-4). Preliminarily, transcranial displacement imaging in vivo was demonstrated (Fig. E). In conclusion, we demonstrated transcranial displacement imaging ex vivo with a preliminary in vivo result. We quantified microscopic displacement at different frequencies and pressures, and assessed skull attenuation.