University of Utah
UNDERGRADUATE RESEARCH JOURNAL

COMPARISON OF TRANSCRANIAL MR-GUIDED FOCUSED ULTRASOUND PHASE CORRECTION SIMULATIONS TO CLINICALLY MEASURED MRTI

Emma Slominski[1] (Dennis Parker, PhD[1,2], Doug Christensen[1,3], PhD, Henrik Odéen[2], PhD, Viola Rieke[2], PhD)
[1]Department of Biomedical Engineering, [2]Department of Radiology and Imaging Sciences, [3]Department of Electrical Engineering

OBJECTIVES

We aimed to compare different methods of phase aberration correction in transcranial magnetic resonance-guided focused ultrasound (tcMRgFUS) thermal simulation modeling. We compared simulated temperature rise to Magnetic Resonance Thermal Imaging (MRTI) obtained during clinical treatments for validation.

METHODS

Three different methods of phase aberration correction were simulated and compared to the MRTI from clinical treatments. The simulation was performed by taking the Computed Tomography (CT) scan of a patient's head from clinical treatments and transforming it into MR treatment space. The CT was then segmented into cortical and cancellous bone, skin, fat, brain, and cerebral spinal fluid. The acoustic properties (speed of sound and attenuation) were estimated based on published values [1] for the different segmented tissues. The power deposition at the focus of the tcMRgFUS system was estimated by simulating the transport of ultrasound through the skull and tissue using the Hybrid Angular Spectrum (HAS) [2] algorithm to generate Q-patterns (W/m^3) using no phase correction, ray-tracing (the phase correction used in the clinical treatment), and the phase correction prediction from time reversal using the estimated acoustic properties. For each phase correction method, the estimated temperature rise images are simulated using the Pennes bioheat equation [3] and downsampled to the same resolution as the MRTI.

RESULTS

Generally, time reversal phase correction produced the highest temperature rise and no phase correction produced the least. Clinical phase correction and MRTI had similar temperature rises between time reversal and no correction. Figure 1 depicts a representative case of the focal spot for the three simulated phase correction methods where time reversal is the hottest and no correction results in a blurred and unfocused focal spot with lower temperature rise. Figure 2 shows the temperature rise for the three methods of phase correction compared to MRTI.

DISCUSSION

The acoustic values used to replicate clinical phase correction were able to match MRTI at higher powers. The simulation was also successful at producing thermal images based on tcMRgFUS treatment data.

ACKNOWLEDGMENTS
This research was supported by the Focused Ultrasound Foundation and NIHR01EB028316.

REFERENCES

[1] Hasgall PA, et al., “IT’IS Database for thermal and electromagnetic parameters of biological tissues,” Version 4.0, May 15, 2018.
[2] U. Vyas et al., *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 59, pp. 1093-1100, Jun. 2012.
[3] H. H. Pennes, *J. Appl. Physiol.*, vol. 1, pp. 93-122, Aug. 1948.

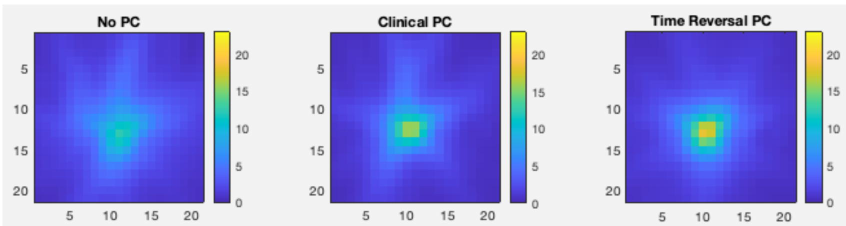

FIGURE 1: Axial plane of 20 x 20 voxels with voxel spacing 0.5 mm x 0.5 mm. Temperature rise is in terms of degrees Celsius. No correction shown heating the least with a blurred focal spot while time reversal had a tighter focus and produced the highest temperature rise.

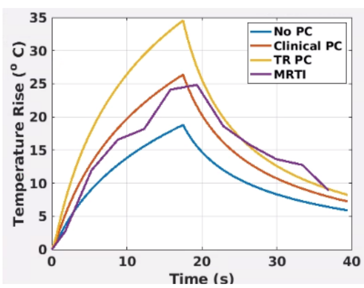

FIGURE 2: Hottest voxel temperature rise over time for the previous temperature images in Figure 1 compared to MRTI. Time reversal shown producing the hottest temperatures and no correction the least. MRTI and clinical phase correction have a similar temperature rise which is expected as they use the same phases.