Validation of a Focused Ultrasound Simulation Platform for Investigating Ocular Thermal Therapies

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Background

- Retinoblastoma (RB) is the most common eye cancer in children [1].
- Arraynge, a k-Wave [2] based simulation platform (Figure 1) developed to investigate ocular therapies using FUS [3].
- Arraynge simulations suggest focused ultrasound (FUS) may enable improved, vision-preserving treatments [3][4].

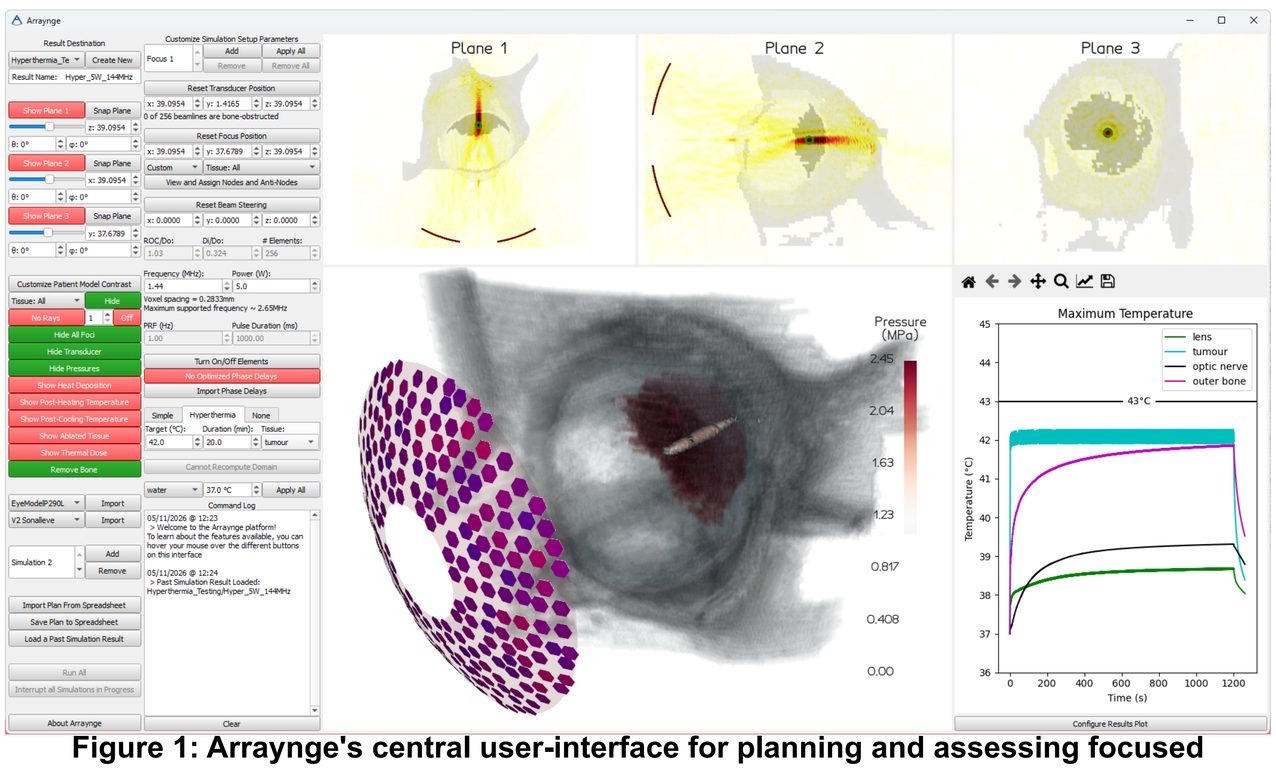

Figure 1: Arraynge's central user-interface for planning and assessing focused ultrasound simulation outcomes.

Objective

To demonstrate the capabilities of simulations to predict the thermal effects of focused ultrasound in the eye using tissue-mimicking phantoms.

Methods

Phantoms

- 25% (v/v) polyacrylamide.
- 12% (w/v) bovine serum albumin.
- 3D printed human orbit or ex *vivo* rabbit orbits used (Figure 2).

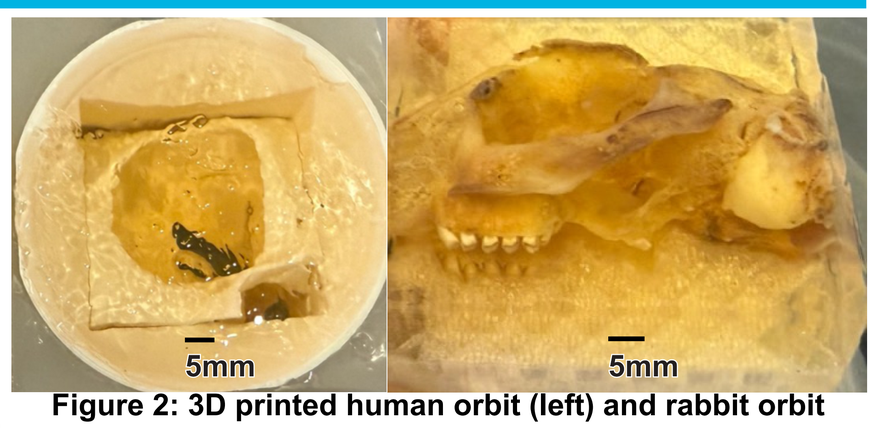

Figure 2: 3D printed human orbit (left) and rabbit orbit (right) phantom models.

Characterization

- Hydrophone measurement of speed of sound, attenuation (Figure 3).
- Thermal properties obtained from literature [5][6][7][8].

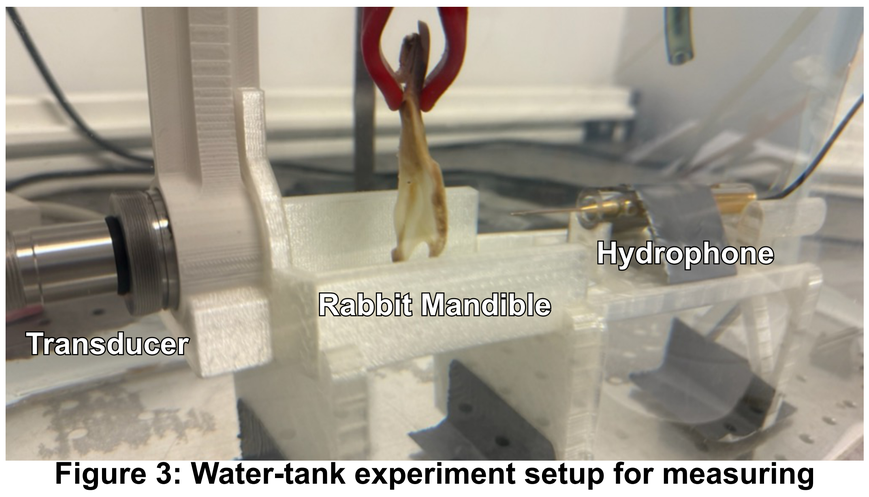

Figure 3: Water-tank experiment setup for measuring phantom acoustic properties.

Validation Sonications

- 1.2MHz, 16s, continuous wave sonications.
- V2 Sonalleve transducer at 15W and 20W (n=8 human, n=5 rabbit).
- Heating measured using magnetic resonance (MR) thermometry.
- Spatiotemporal temperature rise compared between Arraynge simulations and experimental outcomes.

Results

Temporal

- Agreement between simulated and experimental temperature rises over the duration of heating (Figure 4).

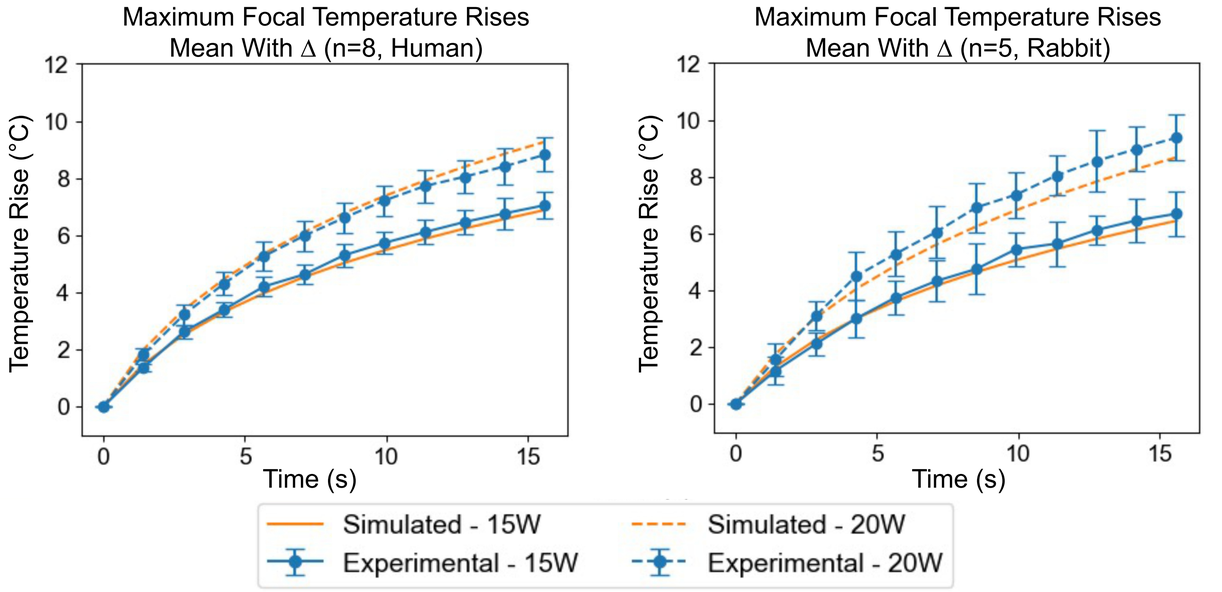

Figure 4: Comparison of simulated and experimental temperature rises during sonications in human (left) and rabbit orbit (right) phantoms.

Spatial

- 85-99% agreement between focal temperature rise predictions.
- Maximum error of 1.5-2.3°C within human orbits.
- Maximum error of 1.9-3.4°C within rabbit orbits.

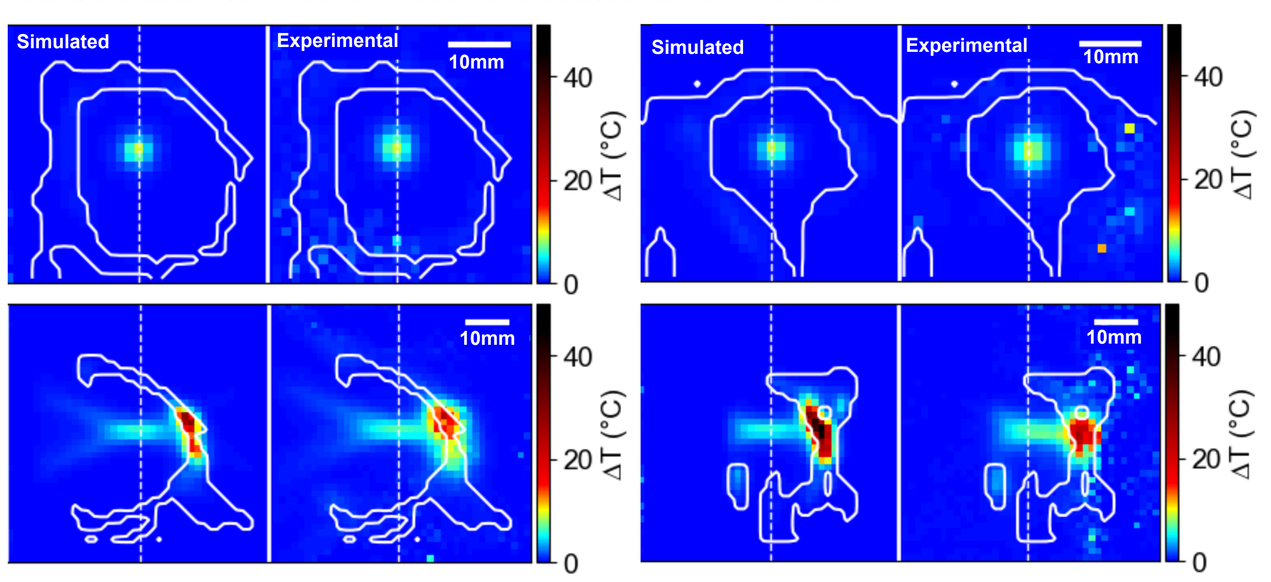

Figure 5: Comparison of simulated and experimental temperature rises following 20W FUS sonications in human (left) and rabbit orbit (right) phantoms. Coronal (top) and transverse (bottom) temperature rise distributions shown.

Conclusions

- Strong agreement between simulated, experimental outcomes.
- Errors in the vicinity of bone due to weak MR thermometry signal.
- FUS simulations can reasonably predict intraocular outcomes.
- These findings support the use of FUS for improved ocular therapies.

Acknowledgements

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