The Impact of the Orbital Bone in the Far Field on Ablation Volume During Focused Ultrasound Sonication of Intraocular Tissue

Barry L. Bytensky[1,2], Joshua Craig[3], Matthew Jenkins[1,2], James Drake[1,2], Ashwin Mallipatna[3,4], George M. Ibrahim[1,3,5], Adam C. Waspe[1,6,7]

[1]Posluns Centre for Image Guided Innovation and Therapeutic Intervention, The Hospital for Sick Children, Toronto, ON, Canada, [2]Institute of Biomedical Engineering, University of Toronto, Toronto, ON, Canada, [3]Department of Ophthalmology and Vision Sciences, The Hospital for Sick Children, Toronto, ON, Canada, [4]Department of Ophthalmology and Vision Sciences, University of Toronto, Toronto, ON, Canada, [5]Division of Neurosurgery, The Hospital for Sick Children, Toronto, ON, Canada, [6]Department of Medical Imaging, University of Toronto, Toronto, ON, Canada, [7]Department of Material Science and Engineering, University of Toronto, Toronto, ON,

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Background

Retinoblastoma (RB)

- RB is the most common eye cancer in children [1].
- Standard treatments such as chemotherapy are potentially damaging and may fail to prevent tumour recurrence [2].

Focused Ultrasound (FUS)

- FUS is a precise non-invasive therapeutic tool suitable for drug delivery and thermal ablation.
- May enable improved vision preserving treatments.

Focused Ultrasound for Retinoblastoma

- Prospective therapies have been investigated *in silico* and *ex vivo*.
- Previous studies have not directly evaluated far field heating of the optic nerve, in the vicinity of the orbital bone [3][4][5].
- FUS simulations suggest that the inclusion of orbital bone leads to increased heating that does not compromise the optic nerve [6].

Objective

Using tissue mimicking phantoms, the objective of this work is to validate experimentally that the inclusion of the orbital bone leads to increased focal thermal dose, while achieving similar maximum focal temperatures.

Methods

Phantoms

- 25% (v/v) polyacrylamide (PAA) was used to model soft tissue.
- 12% (w/v) bovine serum albumin (BSA) was added to PAA.
- An orbital bone model was 3D printed.
- Bone-in and bone-out phantoms were sonicated using Profound Medical's V2 Sonalleve transducer.
- A 16-second, continuous-wave (CW), ultrasound exposure at a 25mm sonication depth and 1.2MHz sonication frequency was used.

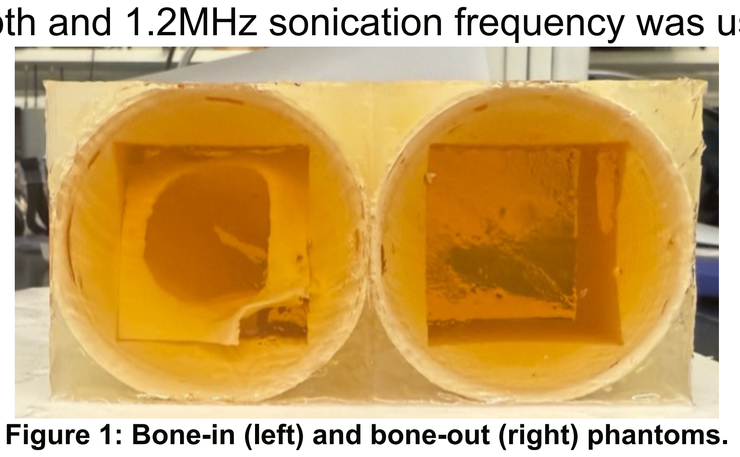

Figure 1: Bone-in (left) and bone-out (right) phantoms.

Temperature Rise Validation

- Phantoms were exposed to 15W and 20W CW ultrasound. Low powers were used to avoid denaturing BSA.
- Temperature rises were measured using magnetic resonance (MR) thermometry.

Thermal Dose Validation

- A 150W CW sonication was conducted to denature BSA.
- Volumes of denatured BSA were measured through segmentation of T2-weighted, post-sonication, MR scans.

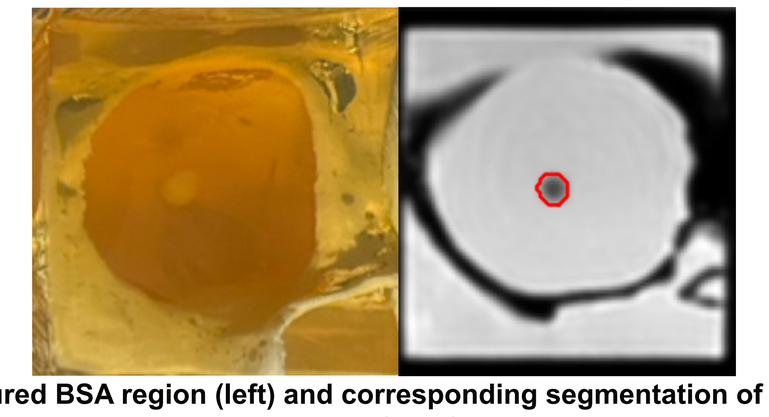

Figure 2: Denatured BSA region (left) and corresponding segmentation of T2-weighted MR scan (right)

Results

Temperature Rise Validation

- Maximum focal temperature rises in bone-in phantoms were within 1°C of those observed in bone-out phantoms at the focus.
- Far field heating was observed in the vicinity of the orbital bone.

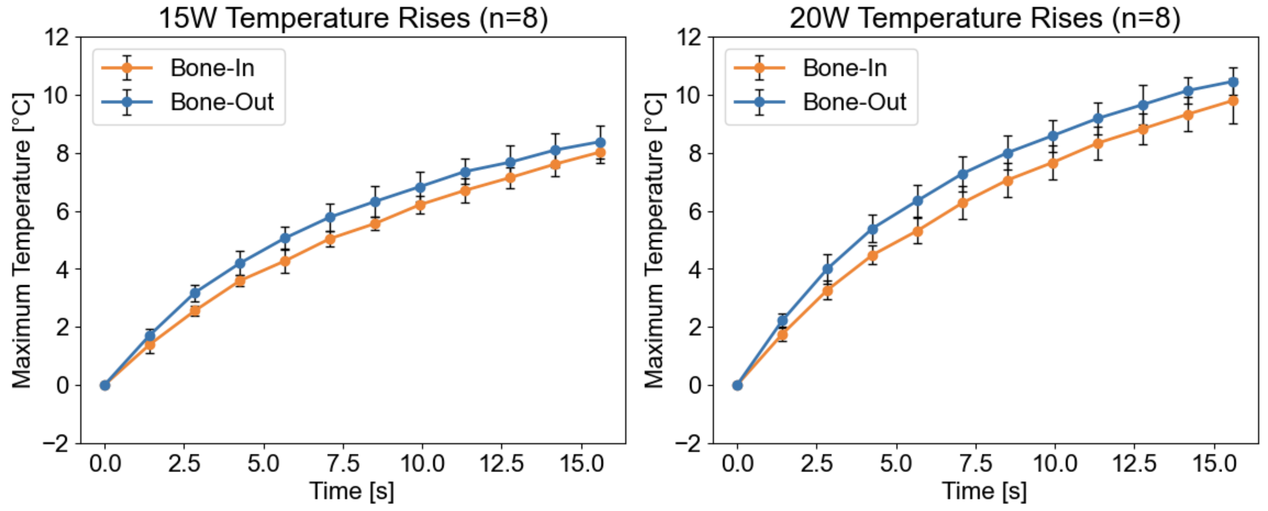

Figure 3: Comparison of focal temperature rises during 15W (left) and 20W (right) sonications.

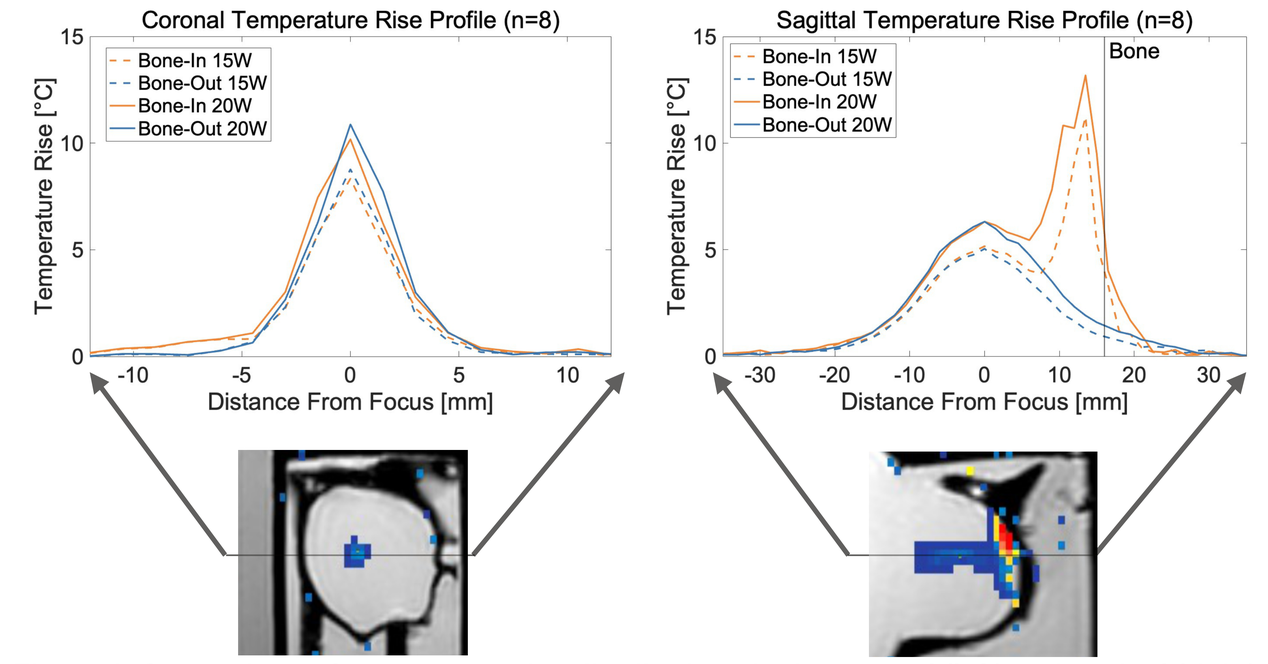

Figure 4: Comparison of temperature rise distributions in the coronal (left) and sagittal (right) planes.

Thermal Dose Validation

- Inclusion of the orbital bone led to larger denatured volumes of BSA (p=0.007).

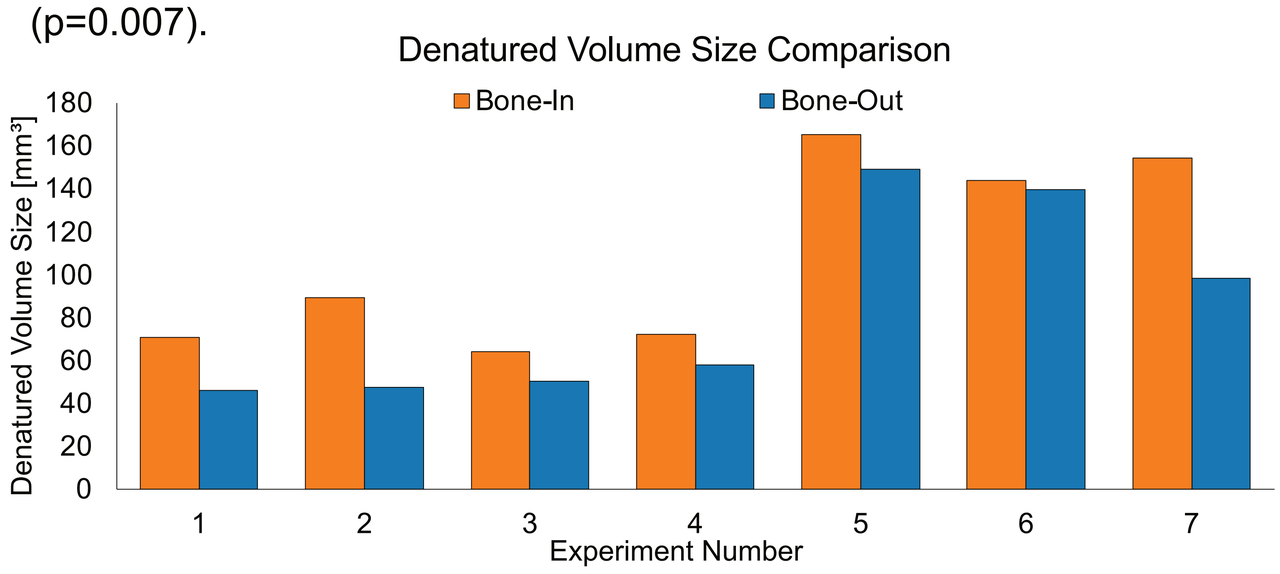

Figure 5: Comparison of bone-in and bone-out denatured BSA volume sizes.

Conclusions

- Bone-in phantoms saw increased focal ablation volume relative to bone-out phantoms while showing similar maximum focal temperatures.
- This validates recent simulation findings and enables further investigation of prospective intraocular applications [6].

References

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