

**MRI-guided Focused
Ultrasound robotic
system for brain tumors.**



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ENTERPRISES/0223/SUB-CALL1/0057

NEWSLETTER

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**Development of head phantom with tumor mimics
Assessment of thermal heating capabilities**



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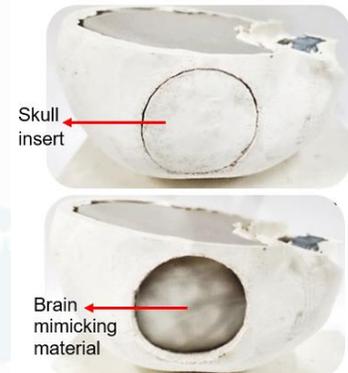
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RECOVERY AND RESILIENCE PLAN



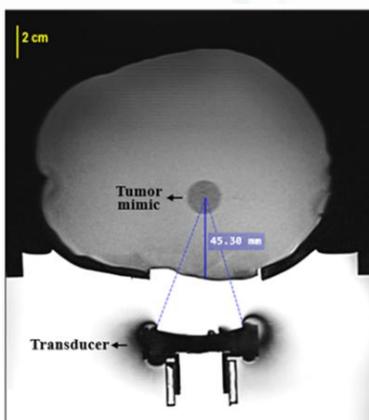
DEVELOPMENT OF HEAD PHANTOM WITH TUMOR MIMICS

An advanced tumor-bearing head phantom was developed following a comprehensive characterization of various inclusion concentrations. This phantom consists of a skull mimic filled with a tissue-mimicking material composed of 6% w/v agar, embedding a tumor mimic with the same agar concentration and supplemented with 4% w/v silica.

The skull bone model was derived by segmenting computed tomography (CT) head scan images from an anonymized female volunteer. A circular segment of the temporal-parietal skull area was isolated (referred to as circular skull insert), resulting in a two-compartment skull model. The designed skull model was 3D-printed with 100% infill and filled with a tissue mimicking material to form the head phantom.



Tumor-bearing brain tissue-skull phantom with removable insert.



T2-Weighted Turbo Spin Echo (T2-W TSE) image of the phantom, with skull opening aligned over the transducer.

The attenuation coefficient of the brain mimicking material (6% agar) at 1 MHz was measured to be 0.743 ± 0.027 dB/cm, aligning sufficiently with reported literature values for brain tissue, which typically range around 0.8 dB/cm.¹ In addition, the silica-doped (4%) phantom exhibited significantly greater heat accumulation and temperature increase compared to the pure 6% agar gel, mimicking the higher density of tumors in real tissue. The specific inclusion compositions also provided excellent contrast between the tumor and its surroundings in MRI scans.

This phantom model served as a critical component in evaluating the BRAINSONIC robotic system and relevant therapeutic protocol, which relies on Magnetic Resonance Imaging-guided Focused Ultrasound (MRgFUS) delivery through a thin skull implant to enable efficient ultrasonic transmission while minimizing off-target heating effects.

¹Guo J et al. Mathematical Model of Ultrasound Attenuation With Skull Thickness for Transcranial-Focused Ultrasound. *Front Neurosci*, 15:778616, 2022.



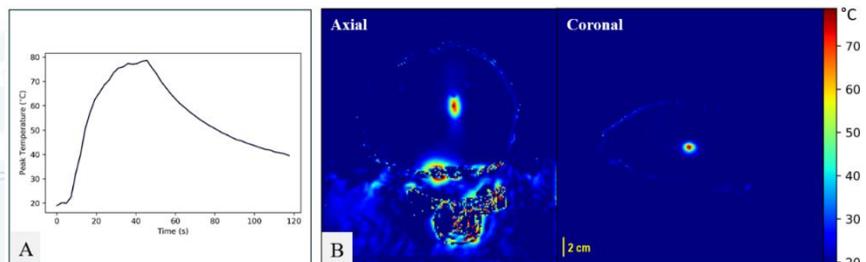
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ASSESSMENT OF THERMAL HEATING CAPABILITIES

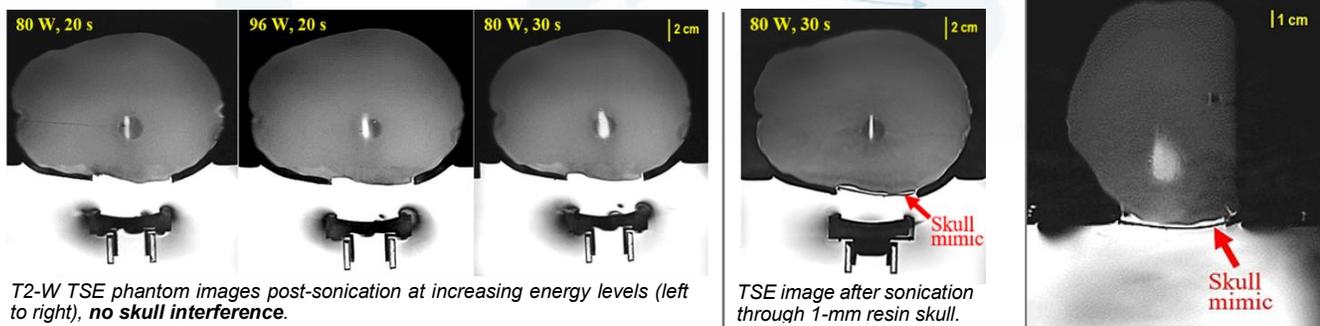
A rigorous investigation of various MRgFUS protocols for both partial and robotic-assisted complete ablation of the tumor simulators was conducted. Typical FUS parameters were applied, with acoustic power ranging from 60–120 W for up to 60 s. Increasing either the power or duration resulted in lesions of larger dimensions. The system demonstrated the capability to generate thin, cigar-shaped lesions within the tumor, regardless of its location, without significant shifting effects, provided that an appropriate transducer was selected.

Typical thermometry outcomes from high-power exposure targeting the tumor mimic without skull obstruction :



(A) Focal temperature profile during and after a 40-s sonication at 120 W (6397 W/cm^2) at 7 cm depth. (B) Corresponding thermal maps showing temperature distribution in tumor.

Tumor ablation results with and without skull mimic interference :



T2-W TSE phantom images post-sonication at increasing energy levels (left to right), *no skull interference*.

TSE image after sonication through 1-mm resin skull.

T2-W TSE sagittal image showing lesion formed by 3x3 sonication at 80 W for 60 s, with 60-s cooling, at a 3.5 cm focal depth through 1-mm Resin skull.

Indicatively, for a typical exposure of 80 W (1838 W/cm^2) over 30 s of unobstructed sonication at 4.5 cm focal depth, the focal temperature increased by $54.6 \text{ }^\circ\text{C}$. The corresponding rise with the 1-mm resin skull was $41.7 \text{ }^\circ\text{C}$, resulting in a thin, cigar-shaped thermal lesion, compared to a larger, oval-shaped lesion for unobstructed sonication.

Importantly, overlapping lesions were successfully created covering the entire tumor using robotic-assisted grid sonication both in free field and with the 1-mm Resin obstructing the beam. **Precise thermal ablation of tumor mimics through the 1-mm resin skull model demonstrated proof of concept for the proposed strategy of treating inoperable brain tumors via FUS delivered through specialized skull implants.**