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Modeling of Acoustic Holograms for Intensity-Modulated Ultrasound in Pediatric Brain Tumors

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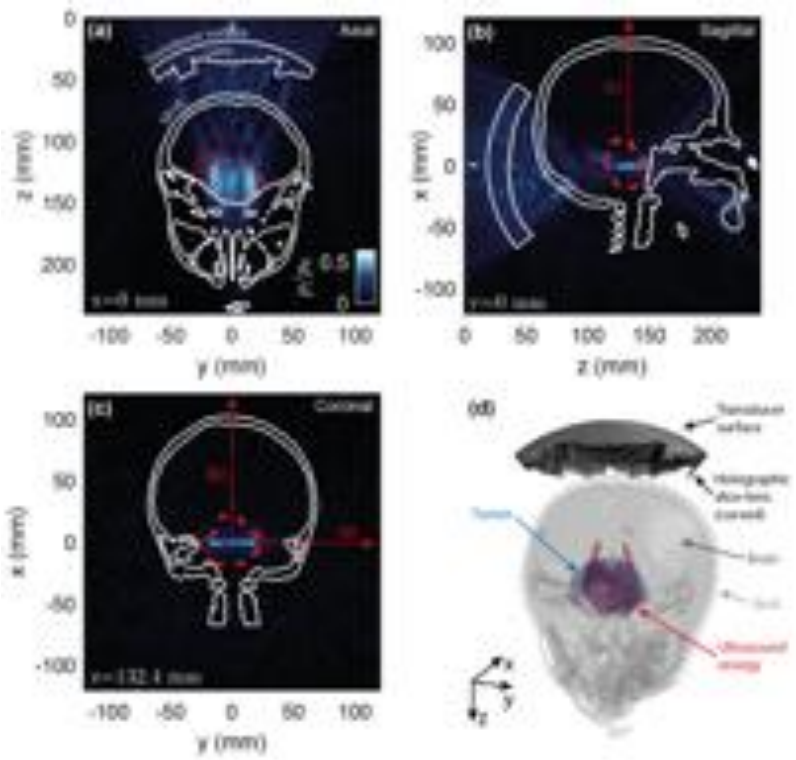
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We design 3D-printed acoustic holograms to open the blood-brain barrier for localized chemotherapy in pediatric brain tumors. These lenses compensate the aberrations of the skull and produce ultrasonic fields matching the large shape of tumors into the deep-brain. Several targeting configurations are numerically studied, with the objective of increasing the overlapped tumor volume but controlling a reduced energy delivery outside the tumor.

We use the pseudospectral method implemented in the k-Wave Matlab toolbox. Simulations are based on a CT-scan of a pediatric patient's skull and an MRI to identify the tumor geometry and location. We employ a 250-kHz single-element FUS-transducer with different size depending on configuration (ROC=110 mm, OD=110 or 132 mm, ID=0 or 44 mm). Time-reversal method is used to obtain the phase of the back-propagation from the target to the design surface. Lens geometry is obtained by converting the phase to height using the Fabry-Perot resonator transmission coefficient, assuming each element of the lens to vibrate longitudinally.

The best configuration provides a 16 % of tumor coverage, maintaining a small 0.06 % of targeted non-desired brain tissue. However, as the focus is not a single spot and it spreads across a single plane of the tumor, the focusing gain or performance decreases 1.6 times.

The duration of the sonication procedure and the number of microbubble injections can be reduced 3.2 times, defining a time- and cost-efficient approach. Therefore, the reported acoustic holographic lenses are a simple, low-cost, and feasible approach to considerably improve pediatric-chemotherapeutical trials.



Normalized pressure field distribution obtained with the curved slice-hologram lens. (a) Axial cut at x=0 mm, showing the transducer surface, lens and skull boundaries (continuous white) and the tumor boundary (dashed red). (b) Sagittal cut at y=0 mm. (c) Coronal cut at z=132.4 mm. (d) 3D view.