Neonatal neurosurgery

Intraventricular Hemorrhage (IVH) is one of the most serious neurovascular complications resulting from premature birth. It can result in clotting of blood within the ventricles, which causes a buildup of cerebrospinal fluid that can lead to posthemorrhagic ventricular dilation and posthemorrhagic hydrocephalus of prematurity. Currently, there are no direct treatments for these blood clots as the standard of care is invasive surgery to insert a shunt. Transcranial magnetic resonance-guided focused ultrasound (MRgHIFU) has been investigated as a non-invasive treatment to lyse blood clots. However, current MRgHIFU systems are not suitable in the context of treating IVH in neonates.

Purpose: We have developed a robotic MRgHIFU neurosurgical platform designed to treat the neonatal brain. This platform facilitates ergonomic patient positioning and directs treatment through their open anterior fontanelle while providing a larger treatment volume. The platform is based on an MR-compatible robot developed by our group. Further development of the platform has warranted investigation of its targeting ability to assess its feasibility in the neonatal brain. This study aimed to quantify the platform's targeting accuracy, precision, and repeatability using a brain phantom and clinical MRI system.

Methods: A thermosensitive brain-mimicking phantom was developed to test the platform's targeting accuracy. Rectangular grid patterns were created with HIFU thermal energy “lesions” in the phantoms by targeting specific coordinate points. The intended target locations were demarcated by inserting carbon fibre rods through a targeting assessment template. Coordinates for the intended and actual targets were derived from T2-weighted MRI scans and the centroid distance between them was measured. Subsequently, the platform's targeting accuracy was quantified according to equations derived from ISO Standard 9283:1998.

Results: HIFU ablation resulted in distinct thermal lesions within the thermosensitive phantoms, which appeared as discrete hypointense regions in T2-weighted MR scans. A total of 127 target points were included in the data analysis, which yielded a targeting accuracy of 0.6mm and targeting precision of 1.2mm.

Conclusions: The robotic MRgHIFU platform was shown to have a high degree of accuracy, precision, and repeatability. The results demonstrate the platform's functionality when targeting through simulated brain matter. These results serve as an initial verification of the platform targeting ability and showed promise towards the final application in a neonatal brain [1].

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Raghuram H, Keunen B, Soucier N, Looi T, Pichardo S, Waspe AC, Drake JM. A robotic magnetic resonance-guided high-intensity focused ultrasound platform for neonatal neurosurgery: Assessment of targeting accuracy and precision in a brain phantom. Med Phys. 2022 Feb 17. doi: 10.1002/mp.15540. Epub ahead of print. PMID: 35174892.