Optimized Parameters for Transcranial Ultrasound Monitoring of Intraoperative Brain Shift

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Objective: Novel methods for transmitting ultrasound signals through the skull bone are being investigated to apply towards intraoperative brain shift monitoring. A transcranial method, as compared to the standard method of imaging through a craniotomy, would allow for the placement of a device away from the surgical site. In this way, continuous monitoring can be applied without interfering with the operation.

Methods: A prototype device that uses the shear mode of transcranial ultrasound transmission was designed, constructed, and tested with 10 human subjects. Validation of the device against MRI imagery was performed by comparing the localization and signal-to-noise ratio (SNR) of signals arising from the margins of the insular cortex. Further optimizations of the ultrasound parameters increased the depth-of-view, allowing for the monitoring of deep-set intracranial structures.

Results: Preliminary results demonstrated the ability to accurately (n = 38, R^2 = 0.9962) and with sufficiently high SNR (n = 38, SNR = 25.4±5.2 dB) detect and localize the insular cortex margins. It was shown that the actuation frequency must be lowered in order to counter the attenuating effects of cancellous bone and to increase the depth-of-view for monitoring deep-set anatomical structures. Multiple locations on the skull were tested with optimized ultrasound frequencies, with the finding that a reduction in ultrasound frequency from 1.00 MHz to 0.84 MHz increased the SNR by 22 dB, and extended the effective imaging depth by 62 mm (n = 40).

Discussion: The demonstration that an ultrasound monitor can operate transcranially to provide information with sufficient accuracy and sensitivity is an important step in the development of an intraoperative ultrasound monitor for neurosurgery. The continued refinement and optimization of ultrasound parameters further improves the usability and efficacy of the device.