Functional Ultrasound (fUS) During Awake Craniotomy Tumor Removal Surgery for Intra-operative Functional Brain and Tumor Mapping

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Background, Motivation, Objective

Oncological neurosurgery relies heavily on making continuous, intra-operative tumor-brain delineations. The widespread introduction of awake craniotomy surgery and electrocortical stimulation mapping (ESM) has greatly improved intra-operative identification of eloquent brain areas and safe tumor removal. However, the inherent limitations of ESM, including lack of depth resolution and risks of epileptic seizure elicitation, greatly warrant the need for new image-guided resection tools. In the current study, we demonstrate the revolutionary potential of functional Ultrasound (fUS) as a new tool for functional brain mapping and tumor vasculature visualization.

Statement of Contribution/Methods

Through high-frame-rate (HFR) ultrasound and subsequent μDoppler processing, small changes in cerebral blood volume (CBV) can be detected, which in turn may reflect changes in metabolic activity of activated neurons due to neurovascular coupling. During conventional awake craniotomy surgery patients were asked to perform 60s functional tasks to elicit cortical responses. Simultaneously, a linear array (ATL L7-4) interfaced with an experimental fUS acquisition unit (Vantage-256, Verasonics, USA), was placed over functional brain areas as defined by ESM. Power Doppler images (PDI), revealing the brain vasculature were obtained using frequency domain beamforming, coherent angle compounding and eigen-based clutter filtering (**Figure 1A**). The functional signal, superimposed on the PDI, was obtained by correlating every PDI pixel with the task signal (**Figure 1B**). In addition, 3D maps of tumor vascularization were reconstructed by stacking the 2D PDIs in a 3D volume.

Results/Discussion

This study shows the ability of fUS to delineate ESM defined functional and non-functional brain tissue. It also provides insight into its potential for visualization of tumor vasculature with high spatial resolution (~ 250 μm) and depth penetration (~ 5.0 cm), opening up possibilities for tumor delineation based on differences in vascular characteristics. While the validation of fUS against gold standard techniques such as ESM and fMRI is in progress, future work also includes development of real-time 3D fUS and incorporation of fUS in intra-operative neuro-navigation software.

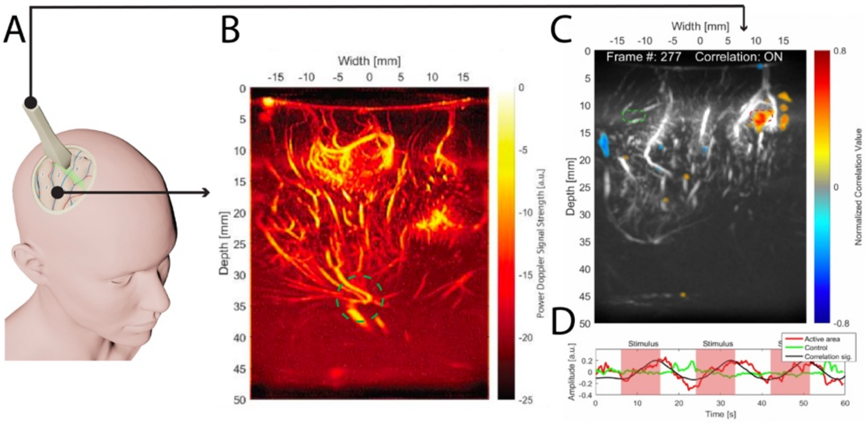

Figure 1 - A,B) Multiple, lineairly acquired 2D PDIs are used to reconstruct 3D tumor vasculature offline. In this particular low grade tumor, an interesting vascular orginization, with a potential vessel of origin facilitating vessel arborization (green), can be seen. **A,C,D)** A conventional language task (*sentence repetition*) in a block design was used to elicit cortical activation. After placing the probe over an area defined by ESM as functional during this task, fUS was able to detect and distinguish functional and non-functional brain areas, with higher depth resolution than ESM.