Reliability of Diffusion-Tractography-Based Thalamic Segmentation for Identifying Targets for Noninvasive Neuromodulation Using MR-guided Focused Ultrasound

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Introduction

While noninvasive modalities like MR-guided focused ultrasound and radiosurgery may provide opportunities for neuromodulation, the success and risk profile will ultimately depend on optimizing targeting. Diffusion tractography based thalamic segmentation has previously been shown to be a reliable method for identifying final targets in invasive neuromodulation, namely deep brain stimulation. The objective of this study was to investigate the role of tractography -based thalamic segmentation for noninvasive neuromodulation, evaluating final MRgFUS thalamotomy sites with that predicted by the proposed imaging technique. This analysis has potential significant implications for noninvasive neuromodulation.

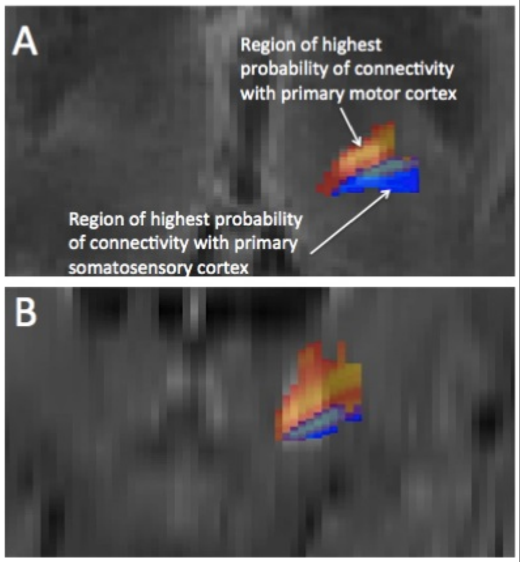
Methods

Fifteen patients with medically refractory essential tremor who underwent MRgFUS generated thalamotomy (ExAblate InSightec) at the University of Virginia Health System were studied. Targeting was performed using indirect targeting methodologies on baseline T1-weighted MR images obtained in all patients. Individual connectivity masks were defined for the thalamus and two cortical target regions: primary motor cortex (M1) and primary somatosensory cortex (PSC). The authors retrospectively performed image analysis for each patient comparing the final thalamotomy location with the predicted optimal site for both motor and sensory outcomes based on connectivity-based thalamic segmentation.

Results

Fifteen unilateral thalamotomies were performed with MRgFUS using indirect targeting. The location of the thalamotomy had a high degree of colocalization to the site predicted by connectivity-based segmentation.

Optimal FUS lesion position relative to thalamic M1 and primary somatosensory connectivity.



Probabilistic connectivity of each thalamic voxel with the anatomically defined primary motor cortex (M1) and primary somatosensory cortex (PSC) were determined using probabilistic tractography. These thalamic maps were fused with post-procedure flair MRI. A. Axial and B. Coronal flair MR images with connectivity maps overlaid on FUS lesion. Optimal motor connectivity (yellow) is consistently anterior to sensory (blue).

Conclusions

This report demonstrates the patient-specific reliability of diffusion tractography based thalamic segmentation to predict final target thalamotomies generated by MRgFUS in the treatment of tremor. This imaging technique can be utilized in other noninvasive modalities such as stereotactic radiosurgery to improve the accuracy and precision of targeting, as well as account for individual differences in subcortical anatomic and functional connectivity.

Learning Objectives

By the conclusion of this session, participants should be able to: 1) Describe the importance of precise and accurate targeting in noninvasive neuromodulation. 2) Describe how advanced neuroimaging techniques such as diffusion tractography can improve targeting in noninvasive stereotactic neurosurgery.

References

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