The Value of Probabilistic Tractography-Based Targeting for MR-guided Focused Ultrasound for Essential Tremor

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Introduction

Magnetic Resonance-guided Focused UltraSound (MRgFUS) offers an incisionless treatment for essential tremor (ET). Still, this requires identifying the optimal site for lesioning. Here, we seek to understand the predictive value of probabilistic tractography guided thalamic targeting by defining how tractography-defined targets, lesion size and location, and clinical outcomes interrelate.

Methods

MR imaging and clinical outcomes from 12 ET patients undergoing MRgFUS thalamotomy in a pilot study at the University of Virginia were evaluated. FSL was used to evaluate each patient's voxel-wise thalamic connectivity with FreeSurfer generated pre- and post-central gyrus targets, to generate thalamic target maps. The overlap between these thalamic target maps and the MRgFUS lesion was systematically evaluated relative to clinical outcome, using Receiver Operating Characteristic curves. To further define the connectivity characteristics of effective MRgFUS thalamotomy lesions, we evaluated whole brain probabilistic tractography of lesions. The structural connectivity difference was explored between subjects with the best clinical outcome relative to all others.

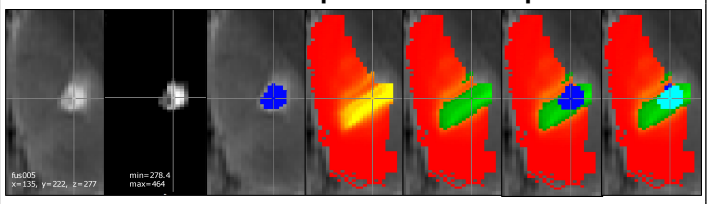
Results

Ten of twelve patients presented high percentage of overlapping between connectivity-based thalamic segmentation maps and lesion area. The improvement of clinical score was predicted (AUC: 0.80) using the volume of intersection between the thalamic target (precentral gyrus) map and MRgFUS induced lesion as feature. The main structural differences between those with superior vs inferior clinical outcomes were observed in connectivity to the precentral gyrus and brainstem/cerebellum.

Conclusions

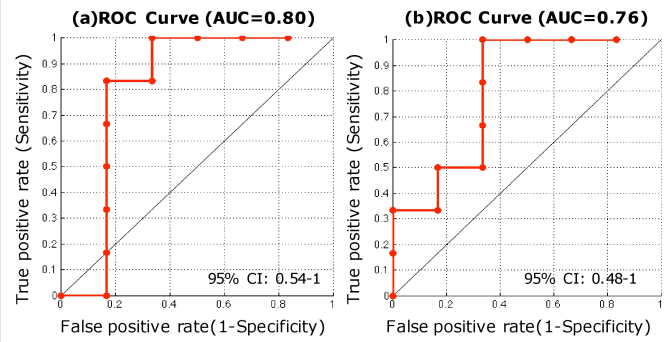
MRgFUS thalamotomy lesions characterized by strong structural connectivity to precentral gyrus demonstrated superior outcomes in a cohort of patients treated with MRgFUS for ET. The intersection between lesion and thalamic-connectivity maps to motor - sensory targets proved to be effective in predicting the response to the therapy. These imaging techniques can be used to increase the efficacy and consistency of outcomes with MRgFUS and potentially shorten treatment times by identifying optimal targets in advance of treatment.

Localization of MRgFUS treatment-induced lesion area and calculation of intersection area between lesion adn thalamic probabilistic maps



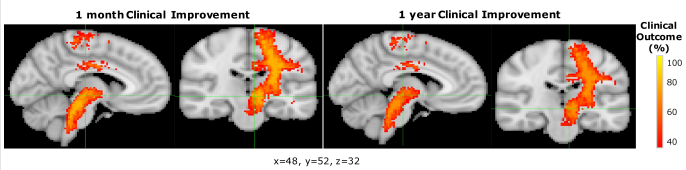
MRgFUS treatment-induced lesion area was localized (T2-weighted image registered to pre T1-weighted image).Connecitivity-based thalamic segmentation maps to pre and post central gyrus targets were found. The intersention between the lesion and the thalamic segmentation maps was calculated.

Prediction of superior clinical outcome



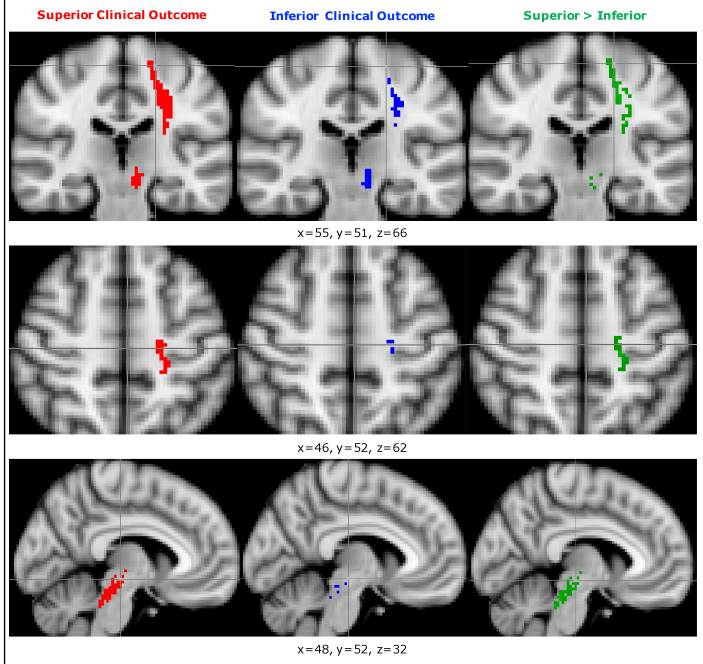
Volume of overlapping between thalamic segmentation map to (a)pre- and (b)post-central gyrus and MRgFUS induced lesion.

Clinical efficacy map using clinical improvement scores 1 month and 1 year after MRgFUS



In both time points patients with higher clinical improvement presented stronger sctructural connectivity to precentral gyrus and brainstem/cerebellum areas.

Whole brain probabilistic tractography of shared fiber tract of MRgFUS induced lesion area



Patients with superior clinical outcome (n=6) present stronger structural connectivity than patients with inferior clinical outcome (n=6) in precentral gyrus and brainstem/cerebellum areas. The differences between the two groups were localized in precentral gyrus and to the caudal projection to the cerebellum.

Learning Objectives

1.Magnetic Resonance imaging-guided Focused Ultrasound could be an alternative noninvasive method to treat essential tremor.

2.The percentage of overlapping between connectivity-based thalamic segmentation maps and the local intracranial lesion area predicted the improvement in clinical outcome.

3.Patients with higher clinical improvement presented stronger structural connectivity to primary precentral gyrus and brainstem/cerebellum.