# HOW RELIABLE IS TRACTOGRAPHY-BASED TARGETING DURING CENTRAL THALAMIC DEEP BRAIN STIMULATION FOR THE TREATMENT OF TRAUMATIC BRAIN INJURY? A. Janson<sup>1</sup>, J. Henderson<sup>2</sup>, N. Schiff<sup>3</sup>, J. Baker<sup>3</sup>, J. Su<sup>2</sup>, B. Rutt<sup>2</sup>, C.R. Butson<sup>1</sup>, <sup>1</sup>Bioeng. Univ. of Utah, Scientific Computing and Imaging (SCI) Inst.; <sup>2</sup>Stanford Univ., <sup>3</sup>Weill Cornell Med. College

### INTRODUCTION

Traumatic brain injury (TBI) is a broad term describing an array of complex symptoms and disabilities that can lead to coma or decreased levels of consciousness. Central thalamic deep brain stimulation (CT-DBS) has been demonstrated to modulate arousal in subjects with TBI<sup>1</sup>, and the medial dorsal tegmental tract (DTTm) is a specific pathway that has recently been implicated in this response<sup>2</sup>. Surgical placement of DBS leads is often guided by anatomical atlases that identify nuclei rather than detailed pathways. Moving towards tractography-based targeting requires additional information and techniques to guide presurgical planning resulting in DBS lead placement that best modulates these circuits.

### OBJECTIVES

- Identify conditions under which target pathways can be reproduced across different diffusion acquisitions and reconstruction techniques.
- Determine how variability in diffusion-weighted tractography reconstructions can influence decisions in DBS lead placement and choice of stimulation parameters.

### METHODS

**Diffusion Weighted Imaging (DWI):** Volumes were acquired on a TBI patient with an Extended Glasgow Outcome Scale of 6, at two b-values (1000 and 2500 s/mm<sup>2</sup>) and three gradients directions (30, 60, and 120). Each image volume was processed through the FMRIB Software Library (FSL) with and without FSL Topup.



Patient-specific thalamic segmentations, with the central lateral (CL) nucleus used as a spatial filter with Generalized Q-sampling diffusion imaging (GQI) reconstruction to perform tractography in DSI Studio.

**Tractography Reconstruction:** Automated patient-specific thalamic segmentation<sup>3</sup> was performed to obtain detailed representations of the central lateral (CL) nucleus for use as a spatial filter to identify the DTTm projecting from the brainstem to the frontal cortex. DSI Studio was used to perform Generalized Q-sampling image reconstruction on the diffusion volumes and then perform the subsequent tractography.

**Simulations and Analysis:** For each tractography reconstruction a DBS lead was placed to maximally cover the fiber bundle in the target region. Activation predictions were performed using finite element bioelectric field modeling and multi-compartment neuron simulation with a fixed lead location for each tractography reconstruction. The fraction of total fiber bundle activation was then computed in response to varying voltage amplitudes.









DBS lead location adjusted to provide coverage of the reconstructed pathway in each of the four tractography results compared with the lead location of the first minimally conscious (MCS) patient<sup>1</sup>.

## CONCLUSIONS

Variability in diffusion based tractography reconstruction across different image acquisitions parameters can influence both the positioning of electrodes for DBS targeting and predictions about the activation of the target pathway. This variability is due to deviations in the projections of reconstructed fibers through the target region based upon the quality of the image acquisition.

### REFERENCES

- human primates. Submitted.

### ACKNOWLEDGEMENTS Support Contributed by NIH, NINDS Grant # UH3NS095554

### **Acquisition Distortion and Gradient Directions Effect on Tractography**

2500 s/mm<sup>2</sup>, 60 Directions

Comparison of target pathway activation predictions for the MCS patient's lead location for each of the four tractography results with monopolar stimulation through contact 1 of the DBS lead across three voltage amplitudes at 150Hz and 60µs pulse width.

1. Schiff, N. D., et al. Behavioral improvements with thalamic stimulation after severe traumatic brain injury. Nature 2007. 2. Baker, J. Robust modulation of arousal regulation, performance and frontostriatal activity through central thalamic deep brain stimulation in healthy non-

3. Tourdias, T., & Rutt, B. K. (2012). Visualization of intra-thalamic nuclei with optimized white- matter-nulled MPRAGE at 7T. Neuroimage, 29, 997–1003.



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### 2500 s/mm<sup>2</sup>, 120 Directions

DWI varying and diffusion directions. Reconstruction of the target pathway was not possible with 30 gradient directions. The bottom row effect distortion correction has on the quality and location of the target pathway for both gradient