TARGETING THALAMIC CIRCUITS DURING DEEP BRAIN STIMULATION FOR TRAUMATIC BRAIN INJURY

500.01

A. Janson[1], N. Schiff[2], J. Baker[2], K. Purpura[2], J. Henderson[3], C.R. Butson[1],
[1]Bioeng. Univ. of Utah, Scientific Computing and Imaging (SCI) Inst.; [2]Weill Cornell Med. College; [3]Stanford Univ.

INTRODUCTION

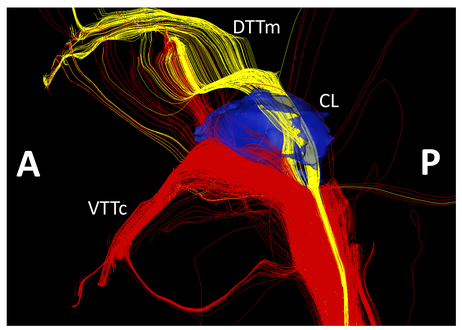
Traumatic brain injury (TBI) is a broad term describing an array of complex symptoms and disabilities that can lead to coma or decreased levels of consciousness. Central thalamic deep brain stimulation (CT-DBS) has been demonstrated to modulate arousal in subjects with TBI[1], and the medial dorsal tegmental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

OBJECTIVES

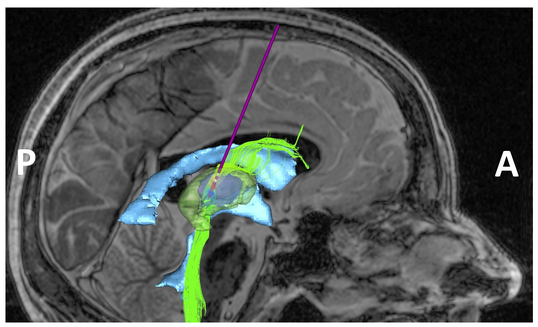
1. Develop a processing pipeline to build patient-specific models combining tractography and MRI segmentations.
2. Simulation of DBS stimulation in near real-time to determine best lead location and orientation.

METHODS

Patient Specific Model: The model used in the simulation was developed by combining both tractography of white matter pathways in the brain and nuclei segmentations from T1 and white-matter-nulled MRI acquisitions. The DTTm was identified using tractography performed from diffusion-weighted imaging (DWI) seeded in the pedunculopontine nucleus (PPN) and filtered by fiber tracts that pass through the central lateral nucleus (CL) of the thalamus. The T1 MRI was first processed by FreeSurfer which provided segmentations of the brain surface, ventricles, and thalamus.



Identification of the DTTm (yellow) from tractography by the branch point with VTTc and projection through CL.

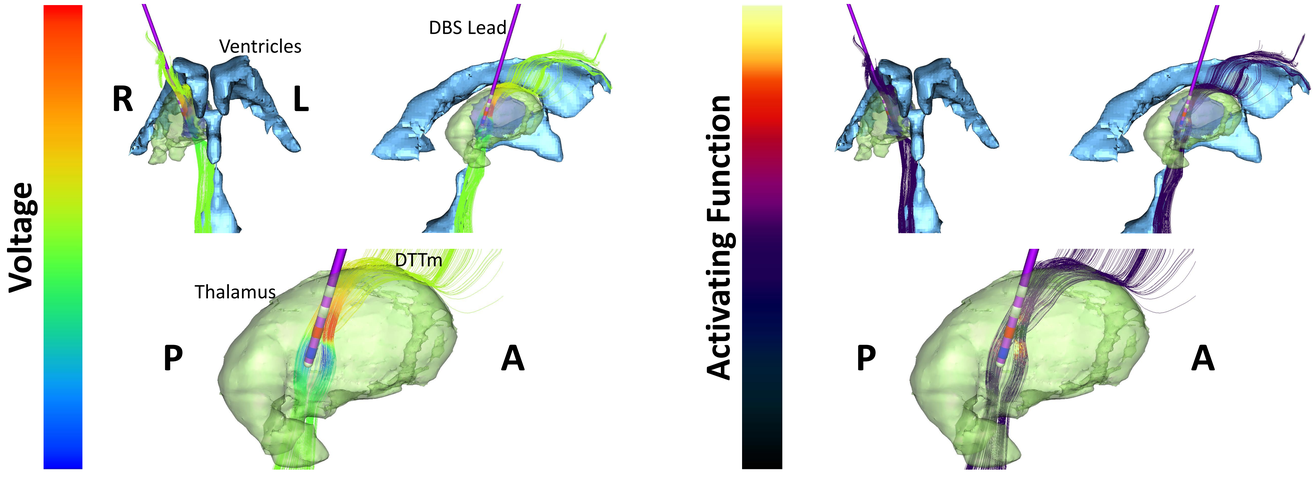


Sagittal view of DBS lead placement (pink) and orientation with respect to the ventricles (light blue), thalamus (green), CL (blue), and DTTm (light green).

Interactive DBS Simulation: The segmentation of the brain surface and Medtronic 3387 DBS lead geometry were used to create a finite element model (FEM) used to solve the bioelectric field induced by stimulation from any of the DBS contacts. The interactive, 3-D environment allows the user to move and rotate the DBS lead anywhere in patient space. Active contacts and stimulation strength can also be adjusted, increasing the parameter space that can be explored with this tool. Once the voltage distribution throughout the brain is solved for a specific lead location and orientation, it is mapped onto the DTTm fiber bundle. The activating function, which is proportional to the second spatial derivative of voltage along the fiber, is then calculated. Comparisons are then made between different stimulation settings and lead placements using average DTTm activation.[3]

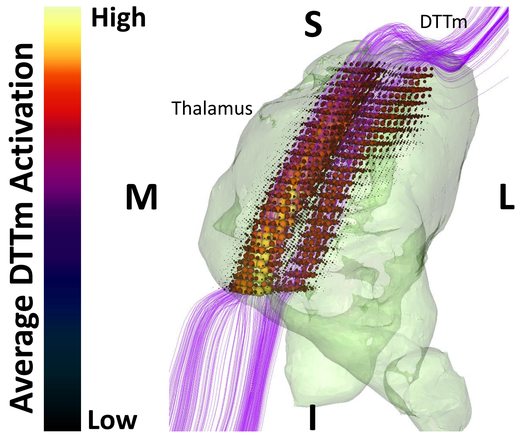
RESULTS

Bioelectric Field and Predicted Activation

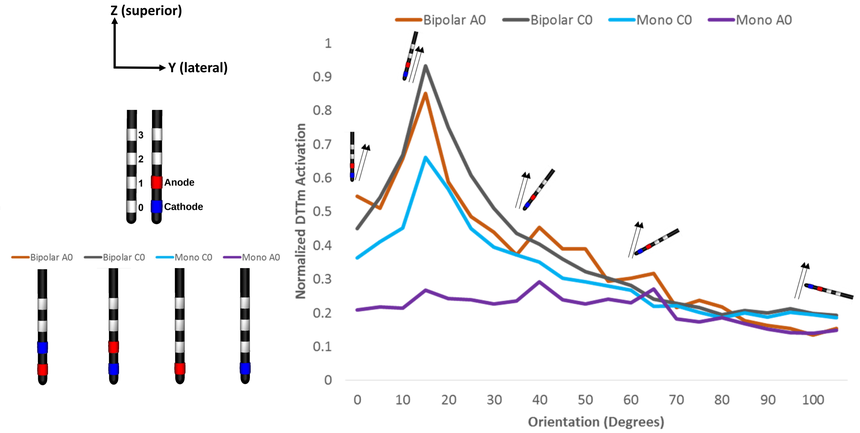


Voltage mapping from the bioelectric field solution onto the DTTm and activating function calculation for a single lead location, orientation, and bipolar stimulation.

Location and Orientation Effect on DTTm Activation



Average DTTm activation for a number of different lead locations. Each sphere represents a single lead location. Highest activation occurs where the DTTm bundle is more compact.



Comparison of bipolar and monopolar stimulation and the effect of lead angle with respect to the z-axis. Maximum activation occurs when the lead is parallel to the DTTm, approximately 15° off z-axis. Bipolar stimulation increases average DTTm activation.

CONCLUSIONS

DBS lead location and orientation with respect to the DTTm projection through the thalamus are important factors for robust modulation. Bipolar stimulation results in more robust activation of the DTTm over monopolar stimulation. Lead orientations parallel to the projection of the DTTm result in more robust activation of the DTTm.

REFERENCES

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-human primates. Submitted.
3. Butson, C. R., et al. Patient-specific analysis of the volume of tissue activated during deep brain stimulation. NeuroImage 2007.

ACKNOWLEDGEMENTS Support Contributed by NIH, NINDS Grant # UH3NS095554