Clinical Application of 7T MRI for Deep Brain Stimulation (DBS) Surgery and Postoperative Programming

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Background: Recent studies have demonstrated that structural MR images of the human brain acquired at 7 Tesla (T) exhibit greater informational content than current clinical MR systems with potential utility that may substantially impact clinical MR applications and patient care [1, 2]. In particular, 7T imaging was demonstrated to improve the resolution of the internal architecture of the basal ganglia and thalamus, which is of significance for deep brain stimulation (DBS) surgical targeting (*i.e.*, subthalamic nucleus (STN), globus pallidus internal (GPi) and Thalamus VIM) [3]. Previous work has shown (relatively) minor geometric distortion in 7T images relative to clinical "gold standard" 1.5T images, especially in the diencephalon where most current DBS targets are located [4]. Here we utilized 7T images to create patient-specific anatomical models to enhance pre-surgical DBS targeting as well as post-surgical visualization of the DBS lead position and orientation, including its four individual contacts. These new visualization capabilities will enhance and improve DBS outcomes.

Methods: Fifteen candidates for DBS surgery (15 electrodes) to treat Parkinson's disease were scanned preoperatively on standard clinical 1.5T and 7T MRI systems. Segmentations and 3D volume rendering of the anatomical target (GPi or STN) and adjacent structures (e.g., red nucleus (RN), substantia nigra (SN) and GPe) were generated based on susceptibility-weighted images (SWI) and T_2-weighted images acquired at 7T. Intra-operatively, stereotactic 1.5T images were merged to stereotactic CT images using the StealthStation® system to localize the DBS target. Next, serial microelectrode recording (MER) techniques were used to map the target region and optimize DBS placement. A postoperative CT was obtained and co-registered to the preoperative 7T MRI. The registered images were then used to assess electrode and intraoperative microelectrode locations relative to the 3D anatomical model and compared with MER mapping and clinical programming data.

Results: Our analysis indicates excellent agreement between the 3D model of DBS targets, the MER mapping and the post-operative electrode programing configuration. Example DBS lead positions are shown in figure 1 for (a) STN and (b) GPi targets. MER path is shown as red bar.

Conclusion: Structural 7T MRI can be used to create accurate, patient-specific models for use in DBS procedures. Specifically, these models may be of use to (1) visualize the intended structures for direct targeting; (2) verify final DBS lead location, including individual stimulation contacts, post-surgery; 3) guide and facilitate initial DBS programming for maximum benefit to the patient; and (4) allow for further understanding of the optimal location of the DBS electrode within the target region.

Figure 1: Anatomical model generated with 7T images for DBS procedure. a) STN-DBS target & b) GPi-DBS target. Structures are color-coded.

References: 1) Abosch, A., et al., Neurosurgery, 2010. **67**(6): p. 1745-56. 2) Cho, Z.H., et al., J Neurosurg, 2010. **113**(3): p. 639-47. 3) Lenglet, C., et al., PLoS One, 2012. **7**(1): p. e29153. 4) Duchin, Y., 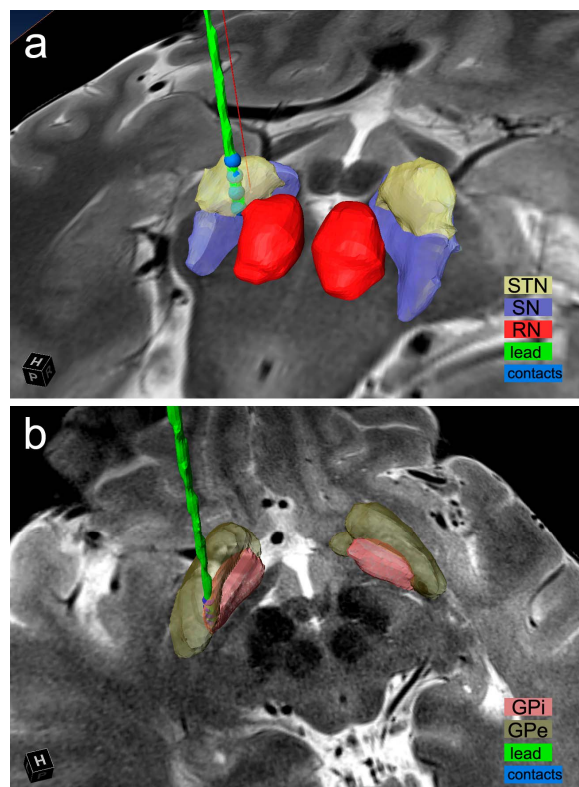et al., PLoS One, 2012. **7**(5): p. e37328.