Direct Visualization of Surgical DBS Targets Using High-field (7T) MRI

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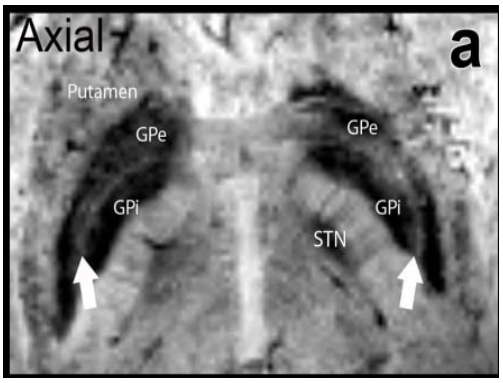
Introduction:

Deep brain stimulation (DBS) surgery is used for treating movement disorders, including Parkinson's disease, essential tremor, and dystonia. Successful DBS surgery is critically dependent on the precise placement of DBS electrodes into the target structures of interest. Current clinical imaging methods do not allow for direct visualization of the target nuclei, as a result, most DBS surgeries today rely on an ***indirect targeting*** method; normalized atlas-derived schematic diagrams are superimposed on a patient's MRI brain scan, followed by microelectrode recordings to refine the ultimate DBS electrode placement. To further complicate things, these microelectrode recordings carry a risk of hemorrhage and require active patient participation during the procedure.

An alternative approach would be ***direct targeting***, i.e., surgery based on direct visualization of the target structure. Currently, however, inadequate image resolution and contrast to identify the target structures preclude the use of this method. Here, by combining high-field (7T) and susceptibility-weighted imaging (SWI)(1,2) and capitalizing on the superior image resolution and enhanced image contrast obtainable, we developed a new approach for the direct visualization of DBS targets.



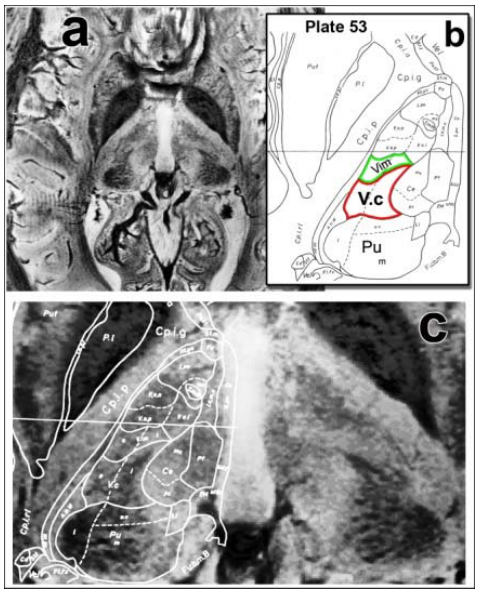
Methods:

Subjects were scanned on a 7T magnet driven by a Siemens console. A 16-channel transmit/receive head coil was used, with the RF power split evenly between the channels(3). Images were acquired in an axial orientation.

SWI acquisitions: A 3D flow-compensated gradient echo sequence was acquired using the following parameters: 72 slices, FOV = 192 x 192 mm^2, matrix size = 512 x 512 (0.375 x 0.375 x 1.0 mm^3), TR/TE = 28/20 msec, flip = 10 degrees, BW = 120 Hz/pixel, 6/8 Partial Fourier with an acceleration factor (GRAPPA) of 4 along the phase-encoding direction. One average was used, for a total acquisition time of approximately 7 minutes. Bilinear interpolation was applied to all images.

Results:

SWI at high-field provides extraordinary contrast that allows for direct visualization of several major structures that are clinically relevant and are FDA-approved targets for DBS surgery. Figure 1 demonstrates the clear division of the two compartments of the globus pallidus (GP); GP -*interna* (GP*i*) from -*externa* (GP*e*), and the visualization of the *Lamina pallidi medialis*, the thin layer (arrows) separating GP*i* from GP*e*. GP*i* is the DBS target for Dystonia treatment. Figure 2 exhibits the wealth of information attained by the superb image contrast within gray matter. An axial SWI slice through thalamus, at the level of the AC-PC plane, is shown. Figure 2b shows the corresponding histologically-defined anatomical landmarks from the Schaltenbrand and Wahren atlas (plate #53). Figure 2c shows a magnified section of the image overlaid with outlines of histologically identified structures (outlines of plate #53). Note the clear visualization of the anterior and medial boundaries of the pulvinar (Pu). Furthermore, the arrowhead shape of Vc (red outline) - the main somatosensory relay nucleus of the thalamus - is easily identified. Situated more anteriorly, the Vim (green outline) can be resolved based on contrast modulation within the thalamus. It should be emphasized that these images were acquired ***in-vivo***, and to our knowledge, these are the first anatomical MRI images that clearly delineate and allow for the identification of internal thalamic nuclei *in vivo*.



Conclusion: Technical developments in MRI at 7T have yielded improved anatomical resolution of deep brain structures, thereby holding the promise of improving direct targeting for DBS surgery. If direct targeting methods could be improved, the accuracy of DBS placement would increase and microelectrode recording and its attendant risks would be eliminated. This would result in enhanced patient safety and comfort, with faster surgical recovery times, and ultimately improved clinical outcome for patients

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References: 1) Yablonskiy & Haacke, MRM 1994; 2) Haacke et al., MRM 2004; 3) Adriany et al., MRM 2008.