

Magnetic Resonance Imaging of Deep Brain Nuclei at 7 Tesla

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Purpose

For movement disorders, deep brain stimulation (DBS) is a surgical treatment involving the implantation of a brain pacemaker into a specific nucleus in the brain [1]. While DBS has proven helpful for some patients, there is a potential for lack of efficacy, unwanted side effects, and occasional serious complications if the electrodes are not correctly placed. The subthalamic nucleus (STN) is the primary target for DBS addressing movement disorders such as Parkinson's disease while other deep brain structures such as the thalamus and globus pallidus are targeted for non-Parkinsonian essential tremor. These deep brain nuclei are typically difficult to visualize on magnetic resonance images at clinical field strengths (1.5T and 3T). A typical localization technique is to use a stereo-tactical procedure with an instrument fixed to the patient's skull that is co-registered to the patient's images and a brain atlas, but inadequate images present a complication.

The objective of this study is to use brain images of healthy volunteers obtained using 3T and 7T MRI scanners with the goal of obtaining high quality images of the deep brain nuclei to create a reliable brain atlas. This high-resolution atlas will be used as a reference for image-guided DBS surgery. In order to develop an atlas of these deep brain structures, 3T images will be used to correct for distortions that are problematic at 7T. These 3T images will also be used to develop and validate the necessary transformations to register clinical images taken at 3T to the established high-resolution brain atlas created from the 7T images. Our hypothesis is that increased sensitivity, resolution, and especially contrast conspicuity of the deep brain structures at the ultra-high field strength of 7T will offer advantages over 3 Tesla allowing reliable delineation using a non-invasive method.

Methods

Using a protocol approved by the Vanderbilt University Medical Center IRB, each subject underwent evaluation at both 3T and 7T using field-strength adjusted, non-contrast enhanced scans including T₁, T₂, and T₂* weighted images. Images were acquired using a Philips Achieva 3T (Philips Healthcare, Best, Netherlands) using an 8-channel head coil (InVivo, Gainesville, FL). A volumetric image set was acquired using a 3D, T1-weighted turbo field echo sequence with a resolution of 1 mm³. 7 Tesla imaging was performed on Philips Achieva 7T scanner (Philips Healthcare, Cleveland, OH) using a 16-channel head coil (Nova Medical, Wilmington, MA). A 3D volumetric data set was acquired using the same T1-weighted turbo field echo method with an isotropic resolution of 0.7 mm³. In addition, a 2D fast field echo was acquired of deep brain structures. The parameters of acquisition for this T2*-weighted sequence were chosen based on T2* calculations of previous data sets to maximize the contrast of deep brain structures at 7 Tesla based on the contrast to noise equation from Bonny, et al. [2].

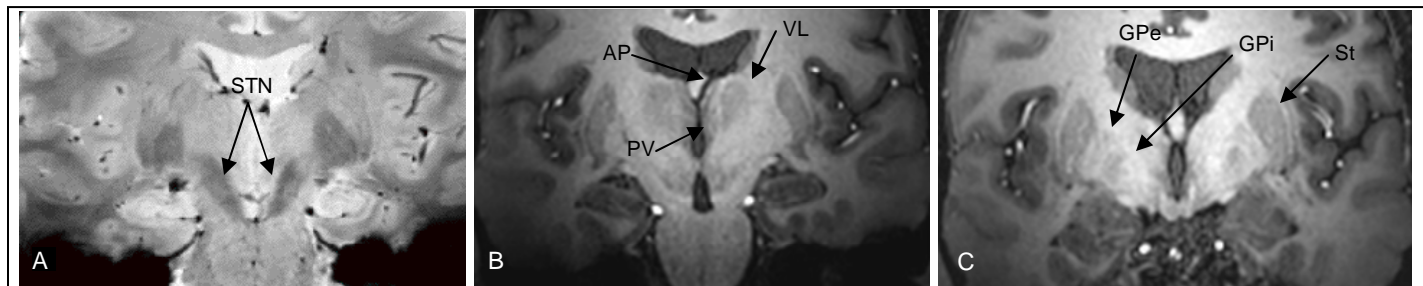


Figure 1 – High-resolution images of deep brain structures acquired at 7T. A) T2* weighted image showing the subthalamic nucleus (STN) clearly delineated, B) T1-weighted image showing the thalamic nuclei (AP – anteroprecuneus, VL – ventrolateral, PV – paraventricular) and C) T1-weighted image with clear separation among the internal globus pallidus (GPi), external (GPe) globus pallidus, and striatum (St).

Results and Conclusions

Figure 1 shows examples of images acquired at 7T, demonstrating excellent contrast of the deep brain structures typically targeted for DBS. The ultra-high field of 7T provides increased resolution with a comparable imaging time to clinical 3T. Increased sensitivity to magnetic field susceptibilities as well as increased signal help to increase the contrast to noise ratio at 7T. The limitations of field and RF inhomogeneity are addressed by registering 7T images to 3T images. We present MR images acquired at 7T allowing visualization of individual deep brain nuclei with sufficient signal and contrast to create an atlas for use in deep brain stimulation.

1. Annals of Neurology, 2001. **49**(2): p. 142-143.

2. Journal of Neuroscience Methods, 2001. **107**(1-2): p. 25-30.