3T MR Imaging of Parkinson's disease for Electrode Targeting for Deep Brain Stimulation

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Introduction

Parkinson's disease (PD) is a neurodegenerative disease typified by motor, cognitive and psychiatric symptoms ascribed to selective anatomical and neurochemical disturbances. Early in the disease course the cardinal symptoms of tremor, rigidity and akinesia are managed by medication. As the disease progresses, symptoms become increasingly difficult to control with medical therapy due to the development of motor fluctuations, dyskinesias and erratic drug effect. Surgery, especially bilateral sub-thalamic nuclei (STN) stimulation, is increasingly used for the management of these problems. Continuous bilateral deep brain stimulation (DBS) of the STN is effective in the treatment of severe forms of PD [1]. DBS improves cardinal motor symptoms at least 50% and reduces antiparkinsonian drug requirements often by more than 50% [2].

The efficacy of STN stimulation is dependent on accurate placement of electrodes. This in turn depends on the reliability of the surgical procedure and on the target criteria. Localization involves three steps; preoperative neuroimaging to visualize the target; intraoperative neurophysiological recordings of the target neuronal activity and intraoperative clinical resolution of cardinal symptoms by electrode stimulation.

The objective here was to improve the accuracy of electrode placement by using neuroimaging at the higher field strength of 3T.

Methods

A Siemens Trio (Siemens Medical Systems, Erlangen, Germany) and an 8-channel head coil (MRI Devices, Orlando, USA) were used. The anterior and posterior commissures were identified in a mid-sagittal planning scan. High-resolution, T2-weighted (TE/TR 103/5500ms, 384x512matrix, 1.5mm slice thickness, iPAT 2) and FLAIR (TE/TI/TR 127/2500/10000, 288x320matrix, 1.5mm slice thickness, iPAT 2) axial images were obtained parallel to the AC-PC plane and coronal images orthogonal to the AC-PC plane pre-operatively. Sequences gave optimum delineation of the STN and related structures.

Seventeen patients were operated on awake and in an "off" state, antiparkinsonian medications having been stopped 12 h previously. A CRW™ stereotactic frame (Radionics, Burlington, USA) was affixed parallel to the orbitomeatal plane and a CT scan undertaken. FLAIR sequences showing the STN were fused with CT scans performed with the frame in situ using compatible software NeuroPlan™ (Radionics, Burlington, USA) and iPLAN® (BrainLAB, Munich, Germany). The coordinates of the target were defined, and a trajectory was planned in the axial plane (with confirmation in the coronal and sagittal planes) avoiding superficial blood vessels, ventricles, aiming for the centre of the dorsal half of the posterior STN. Bilateral STN DBS, electrodes (Medtronic, Minneapolis, USA) were implanted according to well-described surgical procedure under neurophysiological guidance [3] with no significant complications. Intraoperative recording confirmed STN localization bilaterally (both with STN frequency pattern firing and movement evoked changes in firing patterns) before final electrode placement.

Results and Discussion

The STN is a small olive shaped nucleus measuring 3x5x12-mm in size. Errors in targeting in the order millimeters can mean failure of subsequent STN stimulation due to unwanted current spread to surrounding structures such as the pyramidal tract. 3T MRI allows significantly improved visualisation of the anatomic boundaries of the STN as compared with conventional 1.5T imaging and therefore substantially improves stereotactic accuracy. This technique also allows direct targeting of the sensorimotor part of the STN, which occupies the dorsolateral aspect of the nucleus. Consequently it is no longer necessary to rely on the use of brain atlases and standard measurements from intracranial landmarks. Direct visualization allows for anatomical variations in STN anatomy now being appreciated hitherto not recognized. This allows the surgeon to plan a single microelectrode pass through the brain mapping the STN over 4-6 mm on average. Once defined physiologically and clinically the final deep brain electrode is then positioned in the optimal position. It is a widely held belief that the fewer microelectrode tracts through the brain, the less likely a haemorrhagic complication will occur therefore making the procedure safer and more tolerable for the "awake" patient undergoing this procedure.

Conclusions

The 3T MRI-directed technique permits direct target visualization resulting in more efficient placement of electrodes with fewer electrode passes through the brain reducing the risk of complications.

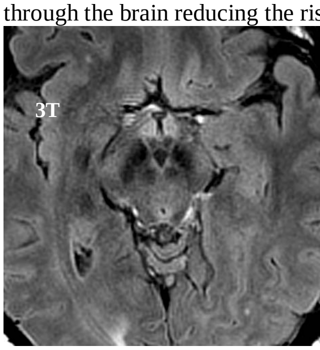

Figure 1: Pre-operative FLAIR imaging of the STN.

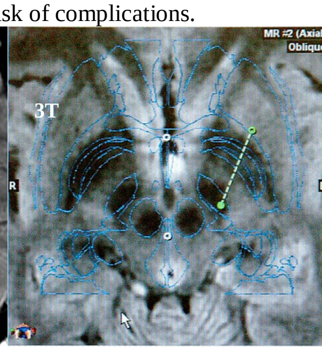

Figure 2: Intraoperative targeting of the STN with atlas overlay.

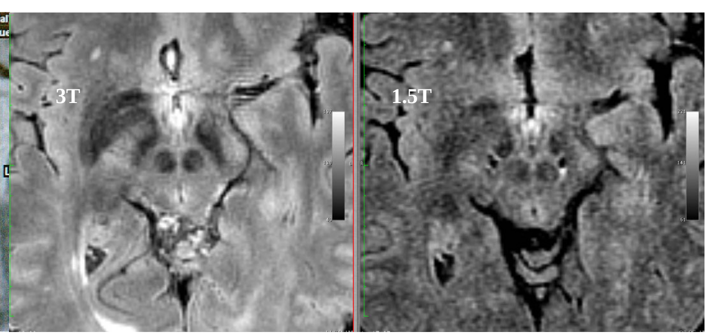

Figure 3: Comparison of pre-operative (3T) and post-operative (1.5T) images showing DBS electrodes within the STN.

References: 1. Limousin, P., et al., N Engl J Med, 1998.**339**(16):p. 1105-1111; **2.** Valldeoriola, F., et al.,. Movement Disorders, 2002. **17**(1): p. 125-132; **3**. Hutchison, W.D., et al., Annals of Neurology, 1998. **44**(2): p. 622-628.