

# Comparison of MR imaging methods for pre-surgical localisation of the subthalamic nucleus and globus pallidus

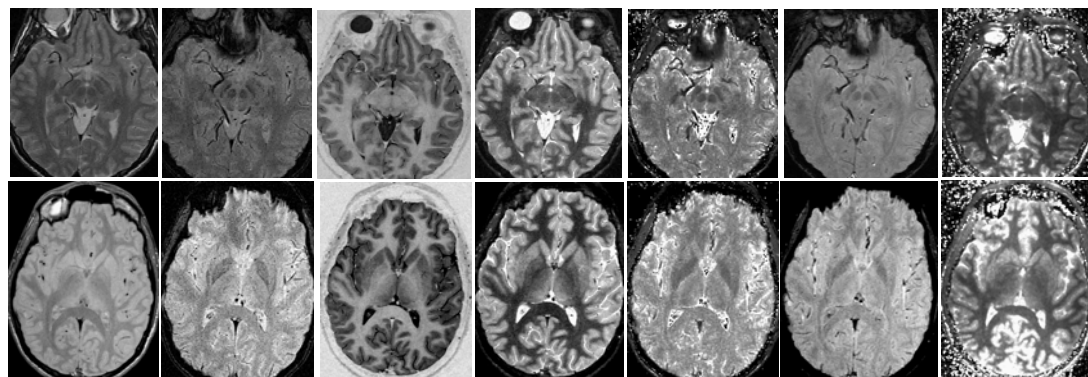
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**Introduction:** Deep brain stimulation (DBS) is a stereotactic neurosurgical technique involving the insertion of electrodes into one of a number of target structures located deep in the brain. DBS has become the surgical treatment of choice for various movement disorders including Parkinson's disease and dystonia, but the success of this technique depends heavily on the accuracy by which the target structures are reached.<sup>1,2</sup> Pre-operative localisation of the target structures can be performed either directly from stereotactic pre-operative MRI or indirectly from atlas coordinates and predefined anatomical landmarks, but given the anatomical variability in position of the target nuclei between patients,<sup>3,4</sup> the direct targeting method is arguably more accurate. However, the limited contrast and low visibility of the target nuclei on standard MRI has limited the widespread adoption of this technique.

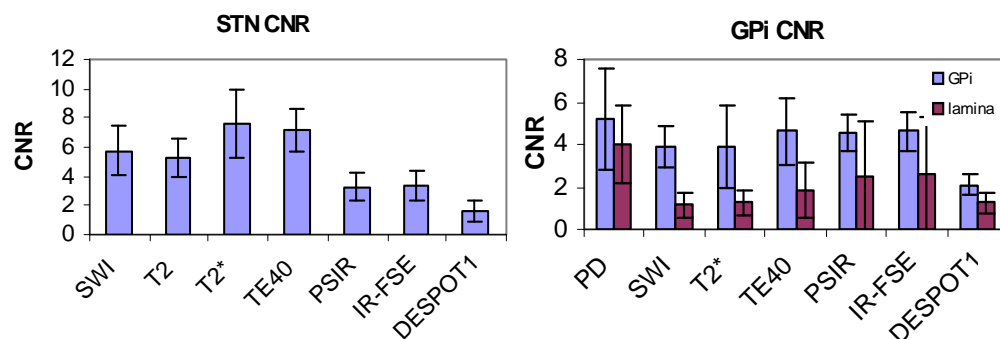
The subthalamic nucleus (STN) and globus pallidus interna (GPi) are two of the target structures used for DBS. Target coordinates for these structures are typically calculated stereotactically from pre-operative T<sub>2</sub> or proton density (PD) weighted FSE images, respectively. However, a number of recent studies have suggested that the visibility of these structures may be improved with alternative MRI methods including phase sensitive inversion recovery (PSIR),<sup>5,6</sup> IR-FSE,<sup>7</sup> quantitative T1 and T2 mapping,<sup>8</sup> T2\* or R2\* mapping,<sup>9,10</sup> or susceptibility-weighted imaging (SWI).<sup>11</sup> The purpose of this study was to quantitatively compare the contrast offered by each of these MR imaging methods and to assess the suitability of each technique for stereotactic targeting, particularly in terms of geometric distortion and other potential artefacts.

**Methods:** The subject group consisted of 9 healthy adult volunteers, (4 male, 5 female, age range 24-43). Imaging studies were performed with a 1.5T GE HD.x TwinSpeed MRI scanner, (GE Medical Systems, Milwaukee, WI, USA) with a transmit-receive quadrature head coil (compatible with the Leksell stereotactic frame). Images were acquired with T<sub>2</sub>- and PD-weighted FSE (TE/TR=91/3000 ms; 11/4000 ms), SWI (TE/TR=40/2300 ms), PSIR (TE/TR/TI=12/4000/200 ms), T2\* mapping (dual echo GRE, TE1/TE2/TR =9/40/1200 ms, flip angle=75°), and DESPOT<sup>12</sup> T<sub>1</sub> (flip angle=14/4, TE/TR= 2/7.5 ms), and T<sub>2</sub> (flip angle=70/10, TE/TR=1.2/3.7 ms) mapping sequences. All sequences apart from DESPOT were acquired axially with FOV= 250 mm, sl. th.=2 mm, matrix=256<sup>2</sup> (zero-filled to 512<sup>2</sup>). The DESPOT sequences were acquired sagittally with FOV=240 mm, sl. th.=1.2 mm and reformatted axially. Contrast to noise ratios (CNR) for the STN and GPi were measured for all sequences. For the calculated images (SWI, T2\*, DESPOT), due to the spatial nonuniformity of the noise, the noise levels were estimated from the noise in the source images following principles of error propagation. Levels of distortion were assessed (in the absence of the stereotactic frame) with a standard MRI quality assurance test object.<sup>13</sup>



**Figure 1:** Example images at the level of the STN (top) and GPi (bottom) for all sequences. Left to right: T<sub>2</sub> (top)/PD (bottom) FSE, SWI, PSIR, IR-FSE, T2\* map, TE=40 GRE, DESPOT<sub>1</sub>.

**Results/Discussion:** The images acquired for a representative subject at the level of the STN and GPi are shown in figure 1. Due to their high iron content, both the STN and GPi are clearly visible on the SWI and T2\* maps, as well as on the late echo (TE=40ms) from the dual echo gradient echo used for T2\* mapping. The contrast to noise ratios are shown in figure 2. For the STN, the SWI, T2\*, and TE=40 GRE images demonstrate comparable or better CNR relative to the standard T2 FSE. For the GPi, the standard PD FSE demonstrates the highest CNR both between the GPi and surrounding white matter and between the GPi and the internal medullary lamina. Levels of geometric distortion were less than 1% (maximum deviation of 1 mm over 180 mm) for all sequences.



**Figure 2:** Contrast to noise ratios (CNR) measured for the subthalamic nucleus (left) and globus pallidus (right), for all sequences.

**References:** <sup>1</sup>Tisch et al. *JNNP* 78;1314-1319 (2007), <sup>2</sup>Papavassiliou et al. *Neurosurgery* 62 Suppl 2:1120-9 (2008), <sup>3</sup>Ashkan et al. *Br.J Neurosurgery* 21:197-200 (2007), <sup>4</sup>Hirabayashi et al. *Mov Disord* 17 Suppl 3:S130-4 (2002), <sup>5</sup>Ishimori et al. *Mag Res Med Sci* 6:225-229 (2007), <sup>6</sup>Reich et al. *AJNR* 21:928-931, <sup>7</sup>Pinsker et al. *Zentralbl Neurochir.* 69:71-5 (2008), <sup>8</sup>Guo et al. *MICCAI* 9:768-75 (2006), <sup>9</sup>Helms et al. *Proc ISMRM* 2008, abstract 880 <sup>10</sup>Elolf et al. *AJNR* 28:1093-94, <sup>11</sup>Rauscher et al. *Proc ISMRM* 2008, abstract 879, <sup>12</sup>Deoni et al. *MRM* 49:515-526 (2003) <sup>13</sup>McRobbie DW *Med Phys* 24:743-750 (1997)