Visualization of Thalamic Nuclei on High Resolution, Multi-Averaged T1 and T2 Maps Acquired at 1.5T

S. C. Deoni[1], M. J. Josseau[1], B. K. Rutt[1], T. M. Peters[1]
[1]Imaging Research Laboratories, Robarts Research Institute, London, Ontario, Canada

Introduction: The ability to non-invasively differentiate between the primary nuclear divisions of the thalamus has immediate clinical applicability for surgical planning and guidance of functional stereotactic procedures. Prior qualitative MRI studies performed at 1.5 and 4 Tesla field strengths have revealed contrast within the thalamus that varies with field strength, suggesting possible differences in the inherent T1 and T2 relaxation times of the constituent nuclei. In this study we investigate this hypothesis through the acquisition of high resolution, multi-averaged deep brain T1 and T2 maps of a healthy volunteer.

Methods: A set of multi-averaged, high resolution ($0.34mm^3$ isotropic voxels) T1 and T2 maps were acquired of a healthy male using the DESPOT1 and DESPOT2 quantitative imaging methods[2]. Acquisition parameters were: DESPOT1: *TR/TE* = 11.4ms / 2.9ms, $\alpha = 4°$ and 16°, *BW* = ±7.81kHz. DESPOT2: *TR/TE* = 4.2ms / 2.1ms, $\alpha = 15°$ and 55°, *BW* = ±62.5kHz. FOV and matrix size were 18cm x 18cm x 9cm and 256 x 256 x 128, respectively. To generate high SNR maps, 55 individual T1 and 25 T2 maps were acquired from the same subject, linearly co-registered[3] and averaged.

Following map generation, the centre-of-mass coordinates (defined in Talairach space[4]) of the following nuclei were mapped onto the T1 and T2 maps: dorsomedial (MD), centre median (CM), ventral anterior (VA), ventral lateral anterior (VLa), ventral posterolateral and posteromedial (VPL, VPM), ventral lateral posterior (VLP), lateral posterior and dorsal (LP, LD), pulvinar (Pul), medial and lateral geniculate (MG, LG) and sub-thalamic nucleus (STHn). Mean relaxation time values were calculated from 25 voxel regions of interest placed around each of the *COM* points.

Results: Average T1 and T2 values calculated from each nuclei are shown in Fig 1 using a two-dimensional T1 vs. T2 'feature-space' plot where the origin of each ellipse represents the mean T1 and T2 values in each region and the major and minor axes represent the standard deviations. These results reveal measurable differences in T1 and T2 between the nuclear divisions, with a gradual decrease in both T1 and T2 moving from the posterior to anterior and medial to lateral aspects of the thalamus. These results agree well with prior observations by Magnotta et al.[4] and Holmes et al.[5]. In addition to these large scale differences, thin regions of hypointense T1 and T2 are noticeable throughout the thalamus (shown in Fig. 2 (a-e)). To emphasize these regions, they are manually outlined, as shown in Fig. 2 (f-j). Comparing slices through the T1 map with representative atlas images (Fig. 3), these regions appear to outline some of the known nuclear structures, suggesting they may represent thin myelin sheaths separating the bodies of the individual nuclei.

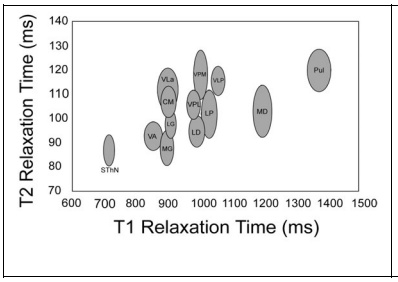

Figure 1: 2D 'feature-space' representation of the average T1 and T2 values calculated for each nucleus.

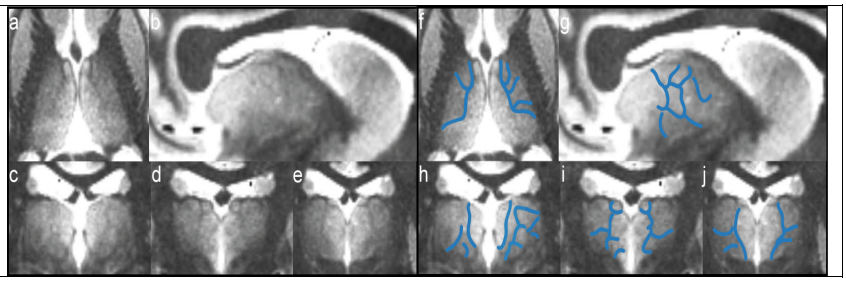

Figure 2: Regions of reduced T1 (and T2) are visible separating the nuclear divisions. To emphasize these borders, we have superimposed manual tracings.

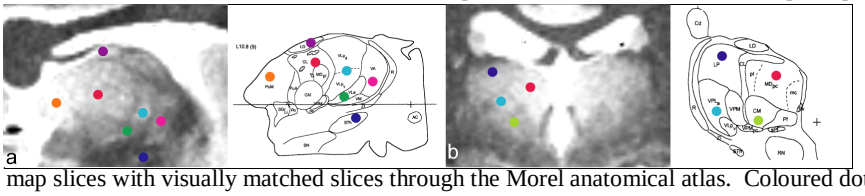

Figure 3: Comparison of T1 map slices with visually matched slices through the Morel anatomical atlas. Coloured dots identify consistent nuclei.

Discussion and Conclusions: We have produced a set of high resolution, matched T1 and T2 maps of the human thalamus and have shown measurable differences in both T1 and T2 throughout the thalamus on a nuclei-specific basis that agree well with prior observations [4,5]. The thin regions of reduced T1 and T2 that appear to surround and separate many of the known nuclear divisions are reminiscent of similar regions observed on histological sections stained for cell bodes[6], suggesting they may be myelinated sheaths, consistent with their reduced T1 and T2. These results demonstrate the potential of high resolution quantitative imaging to identify and delineate the thalamic nuclei and suggest future applications in surgical planning of minimally-invasive surgical procedures of the deep brain.

References: [1] Talairach J et al. Masson & Cie, Paris, 1957 [2] Deoni SCL et al. MRM 49:515-516, 2003 [3] Collins DL et al. J Comp Assist Tomogr 18;192-205, 1994 [4] Magnotta VA et al. NeuroImage 11;341-346, 2000 [5] Holmes CJ et al. J Comp Assist Tomogr 22;324-333, 1998 [6] Jones EG. Plenum Press, New York, 1985