Visualization of Thalamic and Pallidal Complex Nuclei using High-Resolution, Multi-Averaged T1 Maps

S. C. Deoni[1], B. K. Rutt[1], T. M. Peters[1]

[1]Advanced Imaging Labs, Robarts Research Intitute, London, Ontario, Canada

Introduction:

Previous studies detailing the development of high-resolution, multi-averaged T1-weighted images of the deep-brain[1,2] at 1.5T and 4T have revealed subtle contrast differences within the thalamus and basal ganglia that varies depending on field strength. We attribute these differences to slight variations in T1 within these regions that change with field strength due to the non-linear scaling of T1. We hypothesize that differences in T1 and T2 between the constituent thalamic and pallidal complex nuclei may be used to help delineate these structures and increase deep-brain contrast within images used for surgical guidance. To test our hypothesis, ultra-high resolution (700μm isotropic resolution), multi-averaged T1 maps of the deep-brain of the same individual were acquired. T1 differences were indeed found between the constituent nuclei and the intra-laminar space allowing us to manually segment the major nuclei of the thalamus and globus pallidus. Our segmentation results compare favourably with classic anatomical diagrams. These results represent the first relaxometry studies performed of the entire deep-brain at this resolution and provide the first evidence that T1 variations exist between the thalamic and pallidal complex nuclei, allowing image-based delineation of these structures.

Methods:

To construct our deep-brain 'super' T1 map, 45 individual T1 maps of the deep-brain of the same 26 year old individual were acquired using the DESPOT1 relaxometry method[3] over a period of one week. In DESPOT1, the T1 information is derived from a series of SPGR images acquired with constant TR and varied flip angle (α). Axially-oriented images were acquired over a 18cm x 18cm x 9cm field of view with a 256 x 256 x 128 matrix. Sequence-specific parameters were:TR/TE=13.4/2.9ms, α= 3° and 12°, bandwidth=7.81kHz and imaging time = 14:44. The individual volumetric T1 maps were linearly co-registered[4] and averaged to improve SNR in the resulting 'super' T1 map.

Following generation of the parameter maps, the map was visually inspected for contrast variations. Identified variations were used as a guide for manual segmentation, which was performed in the coronal orientation on a slice-by-slice basis. A mesh grid was generated over the outlined regions to obtain the segmentation results.

Results:

Figure 1 shows a slice-wise comparison of the T1 (inverted colour-map) map with corresponding slices from a high-resolution, 27x averaged T1-weighted image of the same individual[1]. Despite the higher SNR of the weighted images, the map images show distinct structures not seen in the weighted images. Subtle T1 differences are apparent throughout the thalamus, particularly between individual nuclei and the internal medullary lamina. Average T1 values of identified thalamic nuclei were: pulvinar nucleus (1184ms), dorsal medial nucleus (987ms), ventral nuclei (1172ms), nucleus reticularis (925ms) and the internal medullary lamina (856ms). Within the pallidal complex, the globus pallidus externus and internus are separated by the internal medullary lamina, average T1 values of the internus, externus and internal medullary lamina were calculated as 781ms, 798ms and 698ms, respectively.

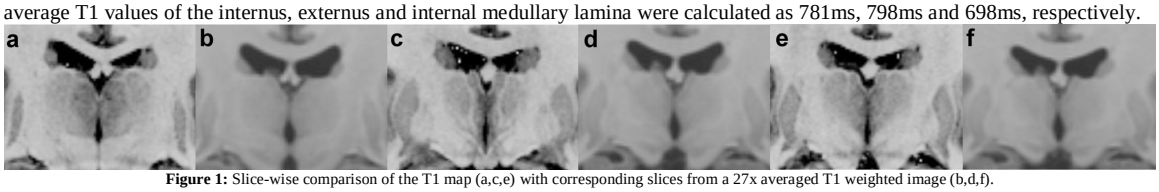

Figure 1: Slice-wise comparison of the T1 map (a,c,e) with corresponding slices from a 27x averaged T1 weighted image (b,d,f).

Using the contrast differences seen in the T1 map, individual regions were manually segmented, Fig. 2. Structures corresponding to the pulvinar, dorsal medial and ventral nuclei as the nucleus reticularis were easily delineated. Additional sub-regions within these nuclei were also distinguishable and with further averaging (i.e. increased SNR) we hope to be able to reliably segment those regions as well.

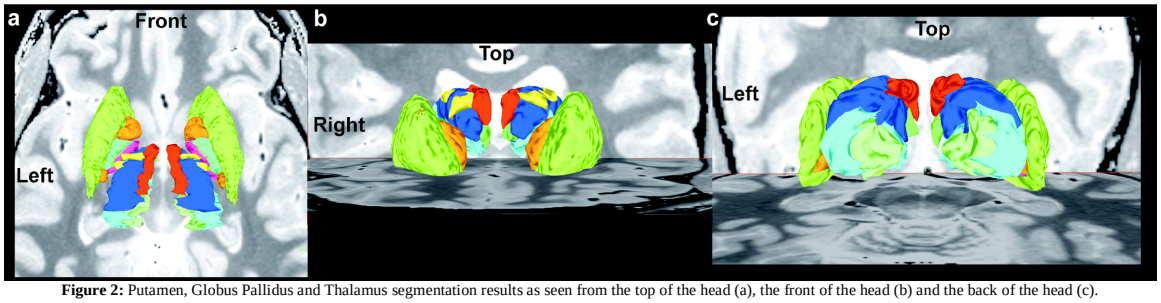

Figure 2: Putamen, Globus Pallidus and Thalamus segmentation results as seen from the top of the head (a), the front of the head (b) and the back of the head (c).

Discussion/Conclusions:

Although T1 and T2 differences in the thalamus have been suspected, high-resolution relaxometry of the deep-brain has not previously been performed. Here we have shown the first deep-brain T1 maps with 700μm isotropic resolution and have provided evidence that relaxation parameters differ between the thalamic nuclei. Further, we have used these differences to delineate the major nuclei, showing the first image-based segmentation of the thalamus. Results shown herein have been derived solely from T1 information. In addition to T1, we have also acquired a similar resolution matched T2 map of the deep brain. Parametric differences within the T2 map are less striking than in T1, however, we hope with future work, greater delineation may be possible by combining both T1 and T2 information using multi-spectral analysis, such as principle component analysis.

References:

[1] Holmes CJ et al. J Comput Assist Tomogr 1998;22(2):324-333. [2] Lee JH et al. Magn Reson Med 1995;34:308-312. [3] Deoni SCL et al. Magn. Reson. Med. 2003;49(3):515-526. [4] Collins DL et al. J. Comput. Assist. Tomogr. 1994;18:192-205.