Comparison of T2* Measurements in Human Brain at 1.5, 3 and 7 T

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Introduction:

Accurate knowledge of the T_2^* values in cortical grey matter is important for the optimisation of MR protocols at different field strengths [1]. In addition T_2^* relaxation times are sensitive to the iron content of brain tissue [2-4], leading to differences in relaxation rate between grey matter regions and to changes in this rate in various disease states. Here we describe T_2^* relaxometry experiments, which have been carried out at three different field strengths (1.5, 3 and 7 T) with the aim of characterising the variation of T_2^* across different brain tissues, in normal subjects, as a function of field strength. Accurate measurement of T_2^* in the presence of significant large-scale magnetic field inhomogeneity is difficult due to the resulting enhanced signal decay and consequent underestimation of T_2^*. The approach employed here [5] allowed the signal decay due to large-scale field inhomogeneity to be measured and removed from the data, facilitating accurate measurement of T_2^* even at ultra-high field.

Methods:

Image Acquistion: T_2^*-measurements were made on six subjects of age 37 ± 10.9 (mean ± standard deviation) using an identical protocol at field strengths of 1.5, 3 and 7 T. A multi-slice, multi-echo sequence formed by switching off the blipped, phase-encoding gradients of a conventional echo-planar imaging sequence and adding a phase encoding gradient immediately following slice selection was employed. 64 echoes spanning 44 ms were acquired from 7 axial slices ($\alpha = 30^o$, TR = 311 ms), yielding phase and magnitude image data sets with 128^2 matrix size (270 mm FOV, 8 mm slice thickness) in a 41 s measurement time. Slices were positioned so as to cover the putamen, caudate nucleus and thalamus. In two subjects, further measurements were made using a 3 mm slice thickness with slices positioned so as to sample cortical grey matter. Double inversion recovery TSE images with white matter and CSF nulled were also acquired from the same slices, so as to allow identification of grey matter voxels for subsequent analysis.

Data Analysis: T_2^* maps were calculated from the data using the approach recently proposed by Dahnke and Schaeffter [5] which corrects for signal decay due to through-slice dephasing. This assumes that the dominant effect of field inhomogeneity can be modelled in terms of a linear gradient, G, in the slice direction, which causes a modulation of the exponential signal decay by a sinc function. The signal variation is then characterised by

$$S(TE) = S_0 \exp(-TE / T_2^*)\mathrm{sinc}(\gamma G \Delta z TE/2)$$

where Δz is the slice thickness [6]. The measured signal is fitted to this expression using an initial estimate of $\gamma G \Delta z$ obtained from frequency maps produced using the phase maps measured at each echo-time. T_2^*-maps were also calculated without correction for through-slice dephasing by fitting to an exponential decay. ROI's in the putamen, caudate nucleus and thalamus were sampled to find average T_2^*(corrected) and T_2^*(uncorrected) values. The double inversion recovery TSE images were used to form masks of grey matter regions in the thinner-slice data. The average and standard deviation of the T_2^*-values within these regions were evaluated. T_2^* in regions of the brain falling outside the mask, mainly corresponding to white matter, were also calculated.

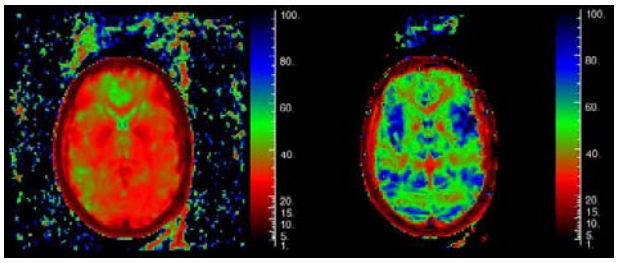

Figure 1: Corrected (right) and uncorrected (left) T_2 maps for a single representative subject at 3 T.*

Field Strength	***1.5 T***	***3.0 T***	***7.0 T***
Left Caudate nucleus	*59.2 (55.0)*	*45.7 (29.1)*	***22.6 (16.0)***
Right Caudate nucleus	*60.7 (54.7)*	*47.2 (27.4)*	***24.2 (16.5)***
Left Putamen	*57.8 (55.5)*	*44.9 (35.3)*	***24.3 (14.1)***
Right Putamen	*56.6 (54.8)*	*44.8 (34.3)*	***22.1 (14.3)***
Grey Matter	*89.3 (84.8)*	*59.7 (47.1)*	***32.7 (27.2)***
White Matter	***71.7 (70.5)***	***54.6 (44.0)***	***28.6 (23.6)***

Table 1: Mean Corrected T_2 values in ms for all regions and field strengths. (Uncorrected values are given in brackets).*

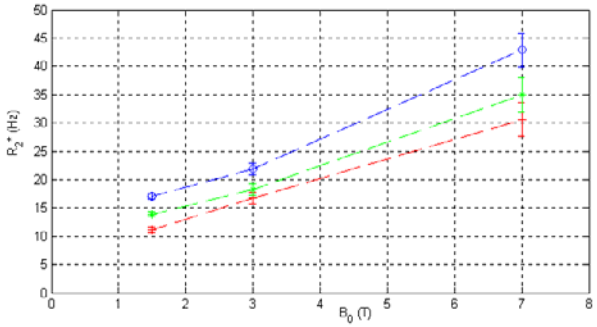

Figure 2: R_2 versus field for grey matter (red) white matter (green) and the deep grey matter nuclei (blue).*

Results and Discussion:

Figure 1 shows the corrected and uncorrected T_2* maps for a single representative subject at 3 T. A general increase in T_2* values is seen in the corrected map as a result of the removal of through-slice dephasing effects. Table 1 shows corrected and uncorrected values of T_2^* at all three field strengths for cortical grey matter, cortical white matter, and the deep grey matter nuclei (caudate nucleus and putamen). There is good agreement between values measured in structures on the right and left sides of the brain. As expected, all values of R_2^* increase with increasing field strength and this increase appears to be linear as shown in Fig. 2. Across all field strengths, cortical grey matter T_2^* is greater that cortical white matter T_2^* as expected. White matter values here may be artificially elevated due to contamination by CSF due to the masking process employed. The T_2^* values of the deep grey matter structures are significantly shorter than cortical grey matter, as found previously [3]. This may result from the higher iron concentration in these structures [4].

References:

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