T_2 measurements in the human brain at 4.7T using an adiabatic multi-echo sequence - Correlation between T_2 and the tissue iron content

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Introduction

T_2 is an important parameter which reflects microscopic characteristics of the in vivo water molecule, such as its mobility and magnetic environment. Thus, T_2-weighted contrast is routinely used for diagnosing various diseases. In contrast, quantitative measurement of T_2 has been pursued to a imited extent, due in part to obstacles in obtaining accurate T_2 values with slice-selective spin-echo sequences. First, imperfections in the slice profile produced by the refocusing pulse result in a loss of coherence. When multiple echoes are collected, the loss is cumulative at each refocusing step, leading to erroneous T_2 measurements. Second, if a single echo is collected by varying TE values, loss of phase coherence occurs during the longer TE values due to diffusion and exchange. At higher fields these two types of effects become more pronounced due to increased B_1 inhomogeniety and larger microscopic susceptibility gradients. A pair of adiabatic full-passage (AFP) pulses for the refocusing gives very precise slice selection, as was shown in localized spectroscopy [1] and single echo imaging [2]. In the present study we implemented multiple pairs of AFP pulses for refocusing in a spin-echo sequence to obtain an artifact-free T_2 decay in the multi-echo measurement. The sequence was validated with gel phantom measurements and applied to measure water T_2 values in human brain at 4.7 Tesla.

Materials and Methods

Figure 1 shows a fully-adiabatic spin-echo imaging sequence. The 90 degree pulse is a 2ms adiabatic half passage pulse, and the 180 degree pulse is a 7ms AFP pulse. Slice selection was performed only with the first pair of 180 degree pulses, and only a quarter of the slice gradient amplitude was used with the subsequent refocusing pulses to avoid ghosts due to movements. Every even echo was collected to estimate T_2 values. Echo spacing and the minimum echo time (TE) were 13 and 26 ms, respectively. For the validation of the sequence, T_2 measurements were conducted on 12 agarose gel phantoms with T_2 values spread in the range from 34 to 105ms by changing the agarose contents. T_1 values were also adjusted to 1.7s, or 1.0s by adding $CuSO_4$ to mimic grey and white matter tissues, respectively. Human brain measurements were performed on 12 (six male and six female) healthy volunteers. Six echoes were collected with TR/TE of 4000/26, 52, 78, 104, 130, and 156ms. Data matrix of 256 x 128 was collected in the FOV of 25.6 x 25.6cm with a slice thickness of 2.5mm, giving a spatial resolution of 1 x 2 x 2.5mm. Slice plane was set across the basal ganglia region in the transaxial orientation. All the measurements were performed on a 4.7T wholebody MRI system using a TEM head coil.

Results and Discussion

T_2 values of gel phantoms obtained with the new sequence were in good agreement with those measured with a nonselective CPMG sequence with an echo spacing of 2ms, validating the sequence. Figure 2 demonstrates a typical T_2 map obtained by a single exponential fitting of the signal intensities of 6 echoes in a human brain. Average T_2 values (12 subjects) in grey matter (GM) corresponding to globus pallidus, putamen, caudate, thalamus, and frontal cortex were 38±2, 49±3, 54±2, 56±3, 64±2ms, respectively (Fig. 2). The values in white matter (WM) corresponding to genu and splenium in corpus callosum were 53±3, and 64±4ms, respectively. The T_2 value at CSF was 840±150ms. In general, T_2 values in the brain parenchyma at 4.7T were approximately 30~40% decreased compared with those values at 1.5T. Of particular note, the T_2 value in the 5 GM regions (above) exhibited a good correlation ($r^2 = 0.94$) with the tissue content of non-haemin iron [3] (Fig.3). From the correlation, the T_2 value was extrapolated to 66ms at zero iron content, which represents an apparent intrinsic T_2 value of brain parenchyma at 4.7T. It was also reported that the iron content in WM was higher in the frontal than the posterior region [4]. These results suggest that the brain T_2 values measured with this new adiabatic pulse sequence are predominantly affected by the non-haemin iron content in the tissue rather than its tissue types (GM or WM).

Conclusions

We successfully implemented multiple pairs of adiabatic pulses in a multi-echo spin echo sequence to allow artifact-free T_2 measurements at 4.7T. The T_2 values in the different human brain regions seem to be predominantly determined by their iron content.

References

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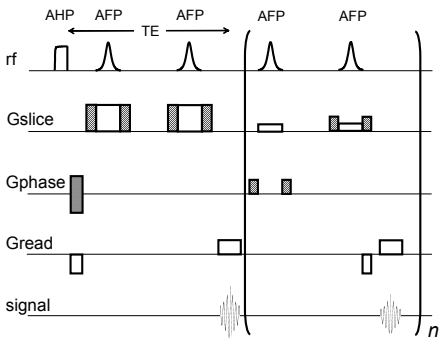

Fig.1. Adiabatic spin echo imaging sequence

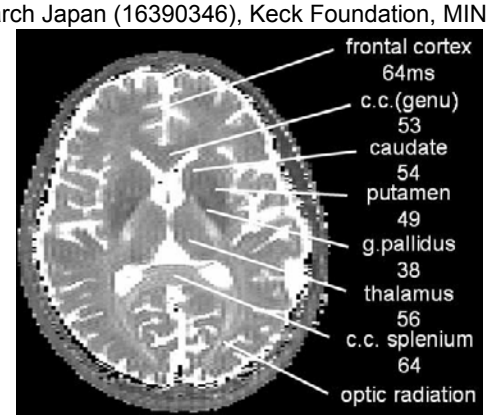

Fig.2. T_2 map of a human brain with average T_2 values (12 subjects).

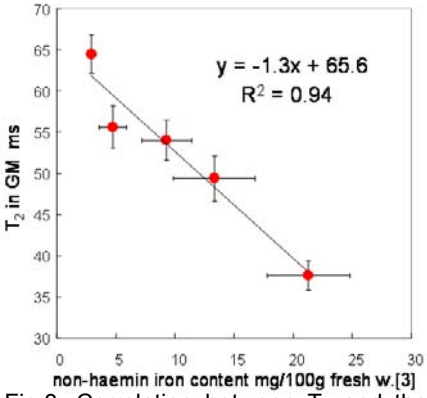

Fig.3. Correlation between T_2 and the iron content in the human brain.