Ultrahigh Field T2 in Human Brain: Regional Differences and Changes with Age

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Introduction

With normal aging, a range of morphologic, physiology and biochemical changes occur in human brain, including overall atrophy, enlarged vascular spaces and changes in vasculature/micro-vasculature, myelin changes and axonal dystrophy. Further, there is great variability in brain iron (3-21mg Fe/100g tissue) with an overall increase with age [1] which may be due to disturbances in iron homeostasis and storage mechanisms. The resultant increase of brain iron catalyzes the production of free radicals thus causing further cell damage through oxidative stress. T2-weighted MRI is sensitive to all of these changes: increased water content will increase T2, whereas paramagnetic vascular deoxyhemoglobin or parenchymal iron will decrease T2. Consequently, there has been some controversy regarding interpretation of transverse relaxation changes with aging and in disease. Different authors attribute observed transverse relaxation characteristics either predominantly to cytoarchitecture [2], vascular deoxyhemoglobin [3] or parenchymal iron [4-6]. For example, Zhou et al observed shorter T2 in occipital cortex grey matter compared to adjacent white matter at 1.5T, but Stevanovic et al did not. It is expected that contributions from susceptibility effects are more pronounced at ultrahigh field strength, whereas effects from microstructure and water may dominate at clinical field strength. We present here T2 measurements at 7T and at 8T for healthy subjects of different ages.

Methods

Six healthy subjects age 20-49 were imaged at 8T (Bruker/Magnex) using a GESSE sequence [7], i.e. a spin echo sequence with a single central echo at TE=50ms and two gradient echoes preceding and following the central spin echo with ΔTE=13.4ms (TR=1500ms, FOV=16cm, 512x256, 3mm single coronal slice). T2 maps were calculated pixels-wise from $T2=2\Delta TE/\ln(S_-(TE-\Delta TE)/S_+(TE+\Delta TE))$. In addition, 8-echo CPMG (τ=22ms), and four single echo images (TE=22,50,90,134ms) were acquired. The single echo images could not be used for T2 measurements in all but 2 cases, because of subject motion. The CMPG data were fitted pixel-wise by a single exponential. In a second part of the study, another 6 healthy subjects were scanned at 7T (Philips Achieva, Cleveland) with a dual-echo, multi-slice spin echo sequence (TR= 2000ms, TE=10 & 50ms, FOV=24cm, 256x192, 3mm 14 coronal and 7 axial slices). For comparison, we also acquired dual spin echo images at 1.5T with TE=10 and 100ms and otherwise identical parameters. In all cases, ROIs were manually traced in the sensorimotor cortex, adjacent WM, and in frontal cortex GM and adjacent WM.

Results

In all ultrahigh field T2-weighted studies, GM/WM contrast varied in different brain regions, e.g. in the frontal cortex grey matter has higher signal than adjacent whit matter, and it is inverted in the sensorimotor cortex (Fig 1). These differences change with age, i.e. the GM/WM difference is more pronounced in older subjects. The differences observed in T2-weighted images are also reflected in quantitative T2 measurements at 7T and 8T (Table 1), though overall the GM/WM T2 difference is small. Furthermore there is a significant difference between single and multi-echo T2s, which is indicative of the prominent contribution of water molecule diffusion in the susceptibility field of paramagnetic material. To assess the T2-dependence on age and brain iron content, the subjects' age and published data on iron content for different ages and brain regions [1] were used. Fig 2 shows the 1/T2 relaxation rate from the 8T GESSE studies versus iron content for sensory motor cortex GM and adjacent WM. In both cases, the relaxation rate increases linearly with iron content.

Discussion

The presented results clearly demonstrate that ultrahigh field T2-weighted MRI is sensitive to susceptibility effects and the correlation between T2 and tissue iron may indicate that effects for brain iron are a prominent factor in ultrahigh field T2 contrast. However, further work is needed to distinguish more clearly if effects from vascular deoxyhemoglobin contribute as well and to what degree.

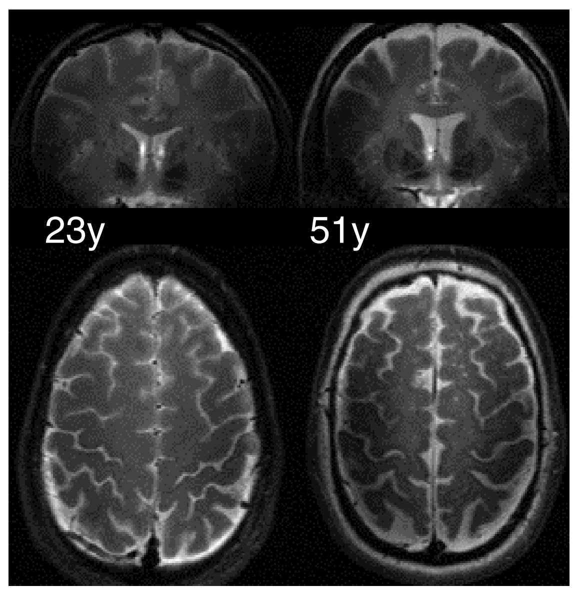

Fig 1: T2-Weighted images at 7T

Table 1: Transverse Relaxation at 7T and 8T

	7T dual	8T GESSE	8T CPMG
Motor GM	28.0± (n=6)	35.6±4.8 (n=5)	74.3±9.2 (n=2)
Motor WM	31.3± (n=6)	39.3±6.5 (n=5)	74.5±3.4 (n=3)
Frontal GM	34.9± (n=6)	44.8 (n=1)	71.4 (n=1)
Frontal WM	29.3± (n=6)	38.4 (n=1)	-

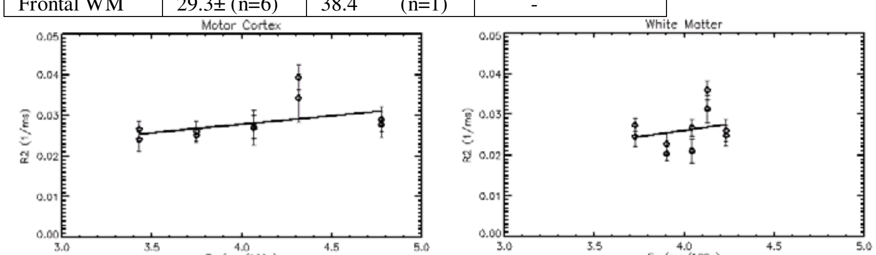

Fig 2: R2 versus Iron Content

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Acknowledgements This research was supported by the Ohio Department of Development (AGMT TECH 03-051) and the Wright Center of Innovation - The Biomedical Structural, Functional and Molecular Imaging Enterprise.