

Extensive T2* Heterogeneity in White Matter Studied by High Resolution MRI at 7T

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Introduction: T₂*-weighted MRI contrast based on a gradient recalled echo (GRE) pulse sequence is of great interest for microscopic high resolution anatomical imaging at 7 T. In this study, an eight element receiving coil array designed for brain imaging was used to acquire high resolution T₂*-weighted MRI in the brains of normal volunteers at 7 T. The acquisition parameters were adjusted to produce contrast between grey and white matter. The high SNR achieved with the multi-channel array enabled T₂* weighted imaging of the brain with unprecedented spatial resolution of 0.2×0.2×0.5 mm³. Furthermore, extensive T₂* contrast heterogeneity was observed in white matter throughout the brain.

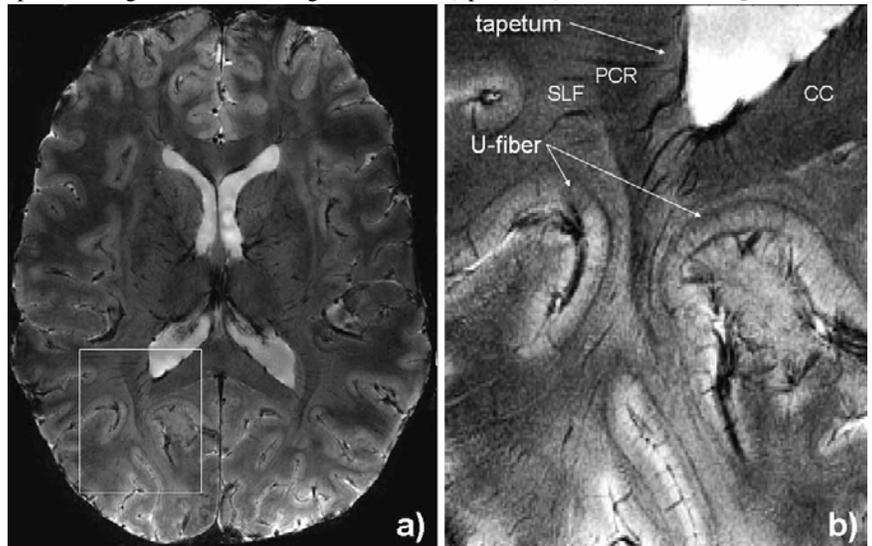
Materials and Methods: The study was conducted using a GE (General Electric) Signa 7T whole-body MRI scanner. The system is equipped with a Twin-Speed gradient system and a dynamically detunable birdcage transmit coil. A whole-brain "Duyn" type parallel imaging receiver array (NOVA Medical Inc, MA) with 8 receivers was used for receiving. A total of 12 healthy volunteers (aged between 23-48 years, female/male=3/9) participated in the study after they gave informed consent. The MRI protocol lasted about 90 min and included the following scans: 1) a fast 3-plane localizer; 2) a whole-brain high-order shimming based on GRE spiral acquisitions at two different echo times; 3) multiple T₂*-weighted scan sessions using a multiple-echo GRE pulse sequence. The multi-echo GRE pulse sequence was adapted from GE's clinical 2D FAST GRE pulse sequence to accommodate image matrix sizes up to 1024×1024 and slice thickness down to 0.4 mm. Quantitative T₂* maps were made by acquiring T₂*-weighted GRE images at 6 different echo times (8.6, 20, 30, 40, 52.9, and 64.2 ms). Typical acquisition parameters included: FOV=220×165 mm², matrix size=1024×768, 11-18 axial slices with slice thickness=0.5-1mm (depending on TR and NEX), receiver bandwidth=15.6 kHz, TR=500-800 ms, flip angle=20-30°.

Results: T₂*-weighted high resolution GRE images of the brain acquired at 7 T were of high quality and with excellent tissue contrast when appropriate acquisition parameters are used. Fig. 1a shows a representative axial slice acquired with the nominal spatial resolution of 0.2×0.2×1mm³. There was excellent detail of the microvasculature, particularly in the white matter due to the loss of signal in veins. This is consistent with previous results obtained at 8 T [1]. The image shown in Fig 1 also demonstrate clearly delineated boundaries between grey matter, white matter and CSF indicating that excellent contrast could be achieved. In addition to these well described features, different white matter fiber bundles had significantly different levels of contrasts. The extensive heterogeneity in white matter contrast in T₂*-weighted MRI at 7 T could be detected throughout white matter in the brain. The different contrast in adjacent white matter fiber bundles are quite striking as shown in Fig. 1b, which shows a zoomed region from the boxed area in Fig 1a. Readily identifiable fiber bundles include the tapetum, posterior region of coronal radiata (PCR), superior longitudinal fasciculus (SLF), and splenium of corpus callosum (CC). The border between gray and white matter in many regions tends to have narrow dark contrast. This is may be due to local u-fibers or blood vessels follow the u-fibers in these areas [1, 2]. Table 1 shows the T₂* values measured from a number of white matter bundles depicted in Fig. 1b. There are large differences (up to 30%) in the measured T₂* values.

Table 1: Apparent transverse relaxation times T₂* for the different fiber bundles depicted in Fig. 1b.

Fiber	tapetum	PCR	SLF	CC
T ₂ * (ms)	21.6	32.3	26.4	32.2

Fig. 1. A typical T₂*-weighted axial GRE image across the lateral ventricles (a) acquired using the empirically optimized T₂*-weighted MRI protocol for human brain at 7T. The acquisition parameters are the following: TR/TE=800/30 ms, flip angle=30°, receiver band width=16.3 kHz, matrix size 1024×768, FOV=220×165 mm², and slice thickness=1 mm, NEX=1. A magnified display of the zoomed region (b) is also shown to illustrate the contrast difference between the different fiber bundles.



Discussion: It is not clear what causes the observed T₂* heterogeneity in white matter. It could be due to T₂ relaxation differences caused by differences in myelin content or residual dipole effects due to orientation of fibers. It could be due to differences in iron content in different regions of white matter. Another possibility is that the observed contrast is due to different amounts or different orientation of venous vascular elements that are below the current MRI resolution. It is well known that white matter vasculature has a preferential orientation with respect to fiber direction and the different contrast could come from different orientation of the vasculature with respect to the magnetic field. It is possible that a few of these different mechanisms are operating to give the contrast detected in different regions. In addition to determining the mechanism underlying the observed T₂* heterogeneity in white matter, it will be very interesting to study if the T₂* contrast at 7 T could be utilized to increase sensitivity to detect pathological changes in white matter disorders such as Multiple Sclerosis.

Reference: 1) Burgess, R.E. et al., *J Comput Assist Tomogr* **23**:, 850 (1999). 2) Wiegell, M. R. et al., *Radiology* **217**:897 (2000).