What is really causing the contrast in spin-echo imaging at 7T?

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TARGET AUDIENCE: Radiologists, Clinicians, MR scientist, Sequence developers.

PURPOSE: In clinical MRI, spin-echo and turbo-spin-echo images are traditionally described as “T2-weighted”, mainly because they show an inverse contrast between grey and white matter compared with standard T1-weighted images. However, quantitative studies show very little difference in T2 relaxation times of grey and white matter in brain tissue at any field strength[1]. We decided to investigate what contrast mechanisms actually contribute to the signal behavior in a typical spin-echo sequence at 7T.

METHODS: All experiments were performed on a 7 T whole-body MR scanner using a 24-channel phased array head coil. The study was carried out with ethical approval from the local university, and informed consent was obtained. A vendor-provided spin-echo sequence was used for imaging. The images were acquired with five different repetition times (TR = 300 600, 1000, 2500, 5000 ms) and five different echo times (TE = 15, 30, 50, 75, 100 ms), respectively. In order to avoid magnetization transfer effects, only a single axial slice was imaged[2]. For analysis, two ROIs were placed in the image - one containing only cortical grey matter, the second only white matter. In order to avoid bias field effects, the ROIs were chosen adjacent to each other and contained only a small number of voxels (see Fig. 1). The signal intensities in both ROIs were plotted vs TR and TE. Finally, for comparison, a proton density weighted whole-brain data set was acquired using a 3D FLASH sequence (FA = 3°, TR = 1650 ms, TE = 2.45 ms).

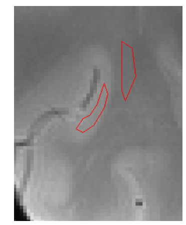

Fig 1. ROIs used.

RESULTS: Figure 2 shows the single axial slice acquired using different combinations of TR and TE. As expected, the overall signal intensity and grey/white contrast depend on the parameters chosen. The signal intensities of grey and white matter vs TR and TE are plotted in Fig. 3. TE clearly has only a minor influence on the signal difference and thus the contrast between grey and white matter. Both curves are running in parallel and for TR = 1 s, they are even almost identical (see Fig. 3B). However, the grey/white contrast is strongly TR dependent (see Fig 3A). With this particular parameter set, the maximum signal difference is achieved using the maximum TR, showing that proton density is the main contributor to the contrast obtained. For comparison, a proton density weighted image, obtained using FLASH is displayed in Fig. 4. Apart from the less severe bias field effects, the grey/white contrast here appears strikingly similar to the spin-echo image acquired with a TR of 5 s (see Fig. 2B).

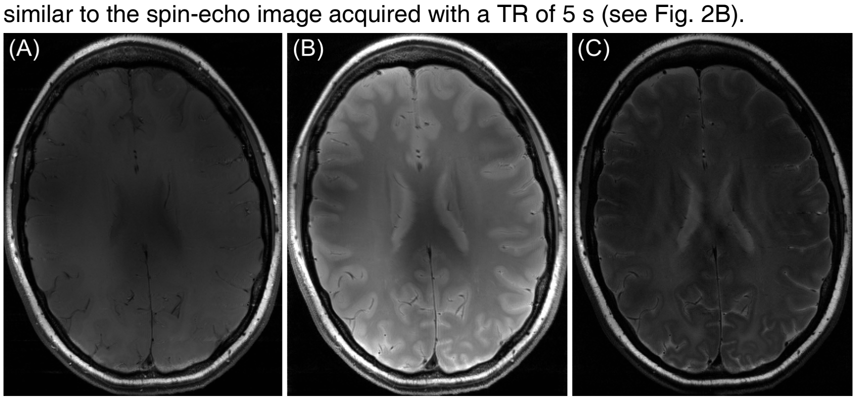

Fig 2. Axial spin-echo image. **A**: TR/TE = 1000/15 ms; **B**: TR/TE = 5000/15ms; **C**: TR/TE = 1000/50ms.

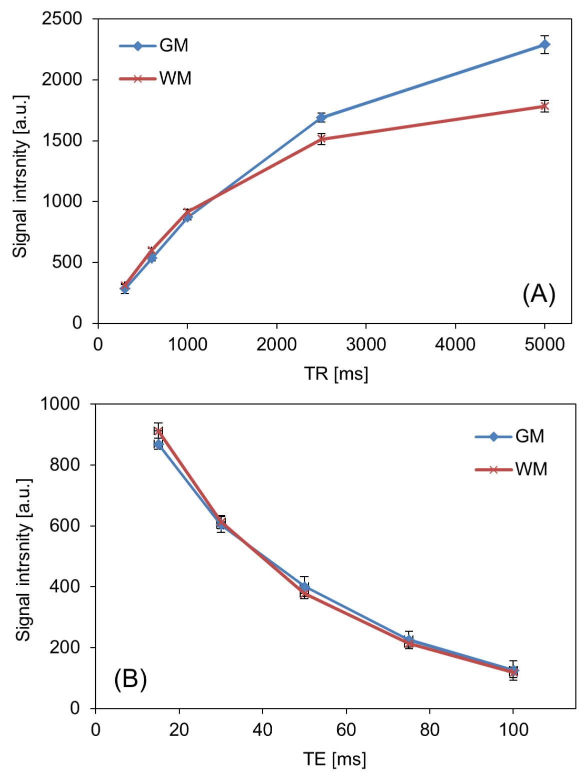

Fig 3. Signal intensity of grey and white matter. **A**: Vs TR (TE = 15 ms); **B**: Vs TE (TR = 1 s). Error bars represent standard deviation.

DISCUSSION: Interest in parcellating the human cortex based on micro-structural features is growing within the MR community[3,4]. While T1 is particularly sensitive to myelin content, and T2* relaxation is sensitive to iron, it remains unclear whether the T2 relaxation time provides any additional information. It is therefore important to recognize that in common spin-echo imaging of brain tissue the contrast is dominated by proton density, T1 relaxation and for multi-slice acquisition, magnetization transfer[2]. However, T2 relaxation time contributes hardly at all to the contrast obtained which must be considered when developing cortical parcellation techniques[4].

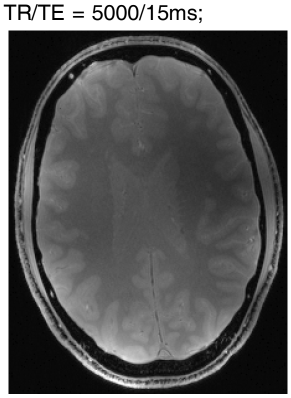

Fig 4. FLASH image.

CONCLUSION: Contrast in spin-echo and turbo-spin-echo brain images at 7T arises mainly from proton density, T1 relaxation, and magnetization transfer.

REFERENCES: [1] Oros-Peusquens et al. Magn Reson Mater Phy 21:131-47 (2008). [2] Thomas et al. Magn Reson Med 51:1254–64 (2004). [3] Geyer et al. Front Hum Neurosci 5:19 (2011). [4] Glasser et al. J Neurosci 31:11597-616 (2011).