

The gray-white contrast in spin-echo imaging at 7 T

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

PURPOSE: Despite the common notion in clinical MRI, that the gray-white contrast obtained by spin-echo and turbo-spin-echo techniques is “T2-weighted”, transverse relaxation does not cause the different signal intensities of gray and white matter for those sequences [1]. However, for quantification of MR images and the desired understanding of causes for signal intensity, it is essential to pin down the actual source of image contrast for any type of MR imaging technique. Therefore, we investigated whether proton density, T1 relaxation, and/or magnetization transfer effects are the source of gray-white contrast in typical spin-echo imaging at 7 T.

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 at an isotropic resolution of (1mm)³. For T2 mapping, nine different echo times (TE = 10, 21, 31, 42, 52, 63, 73, 84, 94 ms) were used. To avoid T1 and magnetization transfer effects, only a single slice with a TR of 10 s was acquired. In order to investigate the influence of T1 relaxation, TR was varied between 1 s and 10 s. For those experiments TE was 10 ms. To check for magnetization transfer effects, multi-slice acquisitions (55 slices) in descending and ascending order were performed (TR = 10 s, TE = 10 ms) as proposed by Thomas et al [2]. For analysis, T2 maps were calculated by fitting each voxel to the equation $S = S_0 \cdot \exp(-TE/T2)$. Furthermore, the contrast-to-noise ratio (CNR) between gray and white matter was estimated for the different parameter sets by placing ROIs in gray and white matter and determining $CNR = SNR_{GM} - SNR_{WM}$.

RESULTS: Figure 1 shows a T2 map obtained using a single slice acquisition. It can clearly be seen that the difference in T2 relaxation rate between gray and white matter is negligible and can therefore be ruled out as source of gray-white contrast at 7 T. However, using a TR of 10 s and a single slice acquisition still produces strong gray-white contrast (see Fig. 2A) indicating that proton density is the main source of contrast. As expected, decreasing the TR below 5 s changes the gray-white contrast significantly (see Fig. 2) as both tissue types have substantially different longitudinal relaxation times at 7 T (approximately 1.2 s for white matter and 1.9 s for gray matter; see Ref. 3). For a TR of 1 s, the gray-white contrast vanished completely, proving that T1 weighting counter-balances the proton density contrast. Changing the acquisition order in multi-slice imaging has a somewhat smaller effect on the gray-white contrast. The

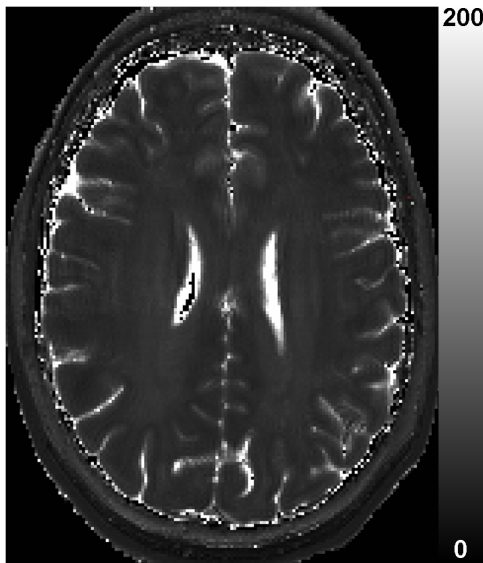


Fig 1. T2 map. Color bar represents T2 in ms.

CNR between gray and white matter changes from 14.7 to 18.5 depending on whether the slice was acquired first (no magnetization transfer) or last during the data acquisition. It has to be mentioned that the SNR of gray matter stays constant (82.4) whereas the SNR of white matter decreases from 67.7 (slice is acquired first) to 63.9 (slice is acquired last) due to its high content of macro-molecules.

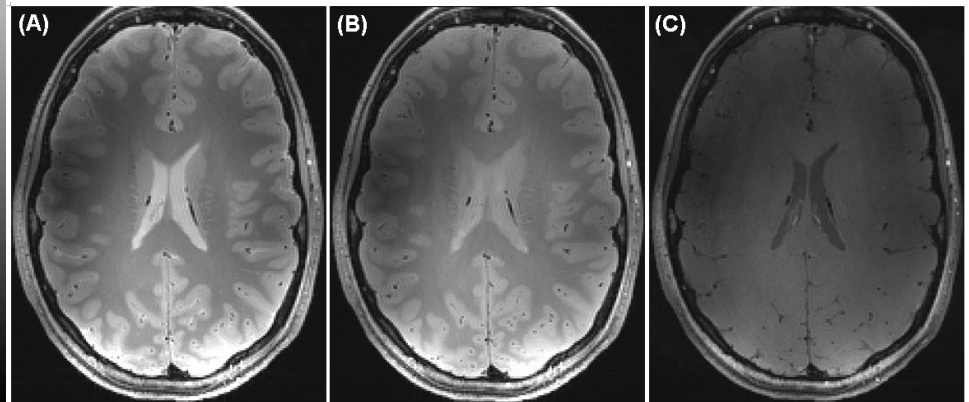


Fig 2. Axial spin-echo image. TE = 10 ms. (A) TR = 10 s; (B) TR = 5 s; (C) TR = 1 s.

DISCUSSION: Our experiments show clearly that T2 relaxation does not contribute to the gray-white contrast obtained in spin-echo imaging at 7 T. In fact, mainly proton density and for small TRs also T1 relaxation drives the contrast between gray and white matter. Depending on the number of slices, magnetization transfer further influences the contrast but not as strongly as proton density and T1 relaxation. It is important to notice that magnetization transfer effects increase the gray-white contrast caused by proton density. However, additional T1 weighting is counter-productive for the gray-white contrast achievable in spin-echo imaging.

CONCLUSION: Gray-white contrast in spin-echo brain images at 7T arises mainly from proton density and T1 relaxation, depending on TR. Magnetization transfer has a somewhat smaller influence, while the influence of T2 variations in tissue is negligible.

REFERENCES: [1] Trampel et al. ISMRM 21:4282 (2013). [2] Thomas et al. Magn Reson Med 51:1254–64 (2004). [3] Marques et al. Neuroimage 49:1271-81 (2010).