Unexpected lateral asymmetry in TSE image contrast explained: tissues with short T2 show extreme sensitivity to B1 inhomogeneity

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Introduction: Using heavily T_2 weighted MP-FLAIR at 7T [1], a lateral asymmetry in contrast was observed for the pulvinar (Fig. 1). The pulvinar is a nucleus of the thalamus in the brain. Due to the small distance between the bilateral pulvinar areas, it seems unlikely that this contrast asymmetry is caused by B_1 inhomogeneity. As the normal human brain displays subtle lateral asymmetry in both anatomy and function, (like the specialization of the left hemisphere for language), the asymmetry in contrast could reflect anatomical asymmetry [2]. The purpose of this work is to explain the observed lateral asymmetry by simulations and experiments. We show that TSE trains exhibit a highly T_2-dependent sensitivity to B_1 inhomogeneity, which leads to asymmetry in image *contrast* (rather than in signal intensities alone).

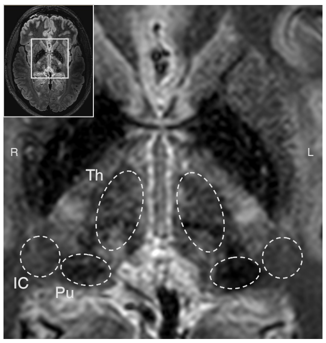

Fig. 1. Example of asymmetric pulvinar contrast. Right/Left signal intensity ratios obtained for the 12 subjects of ref [1] show much larger asymmetry for the pulvinar than for surrounding tissue: Pulvinar (Pu) 1.52±0.20 vs. thalamus (Th) 1.10±0.07 or internal capsule (IC) 1.16±0.11 (mean±SD), P<0.001.

Methods: *Simulations:* The B_1 sensitivity of TSE trains was simulated with the extended phase graph algorithm [3,4], for a range of T_1 (400-2500 ms) and T_2 (1-100 ms). The parameters of the simulated TSE train were taken from the TSE train used for the3D MP-FLAIR images in which the asymmetry was observed [1]: echospacing 4.7 ms, 125 echoes, and a constant refocusing angle of 70° after 3 initial refocusing pulses with angles of 144°, 96°, and 75°, respectively. Simulated TSE signal maps were obtained for two different B_1 values (90% and 80% of desired B_1), based on observed B_1 values in the pulvinar in volunteers. The ratio of the signal maps for the two different B_1 values was used to assess the sensitivity of the TSE train to B_1 inhomogeneity. (For a plain SE, this ratio is independent of T_1 and T_2.) *Experiments:* 4 normal volunteers were scanned on a 7T MRI system (Philips Healthcare) with a 16 channel receive coil and volume transmit coil (Nova Medical). 3D MP-FLAIR images were obtained as described before [1]. Briefly, the parameters were TR/TI/TE: 8000/2250/303ms, refocusing angles 70°, 0.8 mm isotropic acquired resolution. B_1 maps were obtained (Actual Flip angle Imaging) in three of these subjects. All subjects were scanned twice, once feet-first, and once head-first, leaving the volume transmit coil unchanged, in order to flip the asymmetry in the applied B_1 field, relative to the brain anatomy.

Results and Discussion: *Simulations:* Fig. 2a,b shows that the simulated TSE signal decreases for higher relative B_1, reflecting a stronger apparent T_2-weighting with higher refocusing angles. This is true for T_2 values that are low with respect to the equivalent echo time (the TE needed in a plain spin echo sequence that would yield the same contrast for a given T_1 and T_2; for the given train the effective TE is 153 ms for T_1/T_2 is 1600/45ms). As a result, the B_1-sensitivity of the TSE train is strongly T_2-dependent, particularly for low T_2 values (Fig. 2c). For high T_2 values, the TSE signal dependency on B_1 becomes limited, and largely independent of T_1 and T_2, which is very similar to the behavior of a plain SE sequence with a single refocusing pulse.

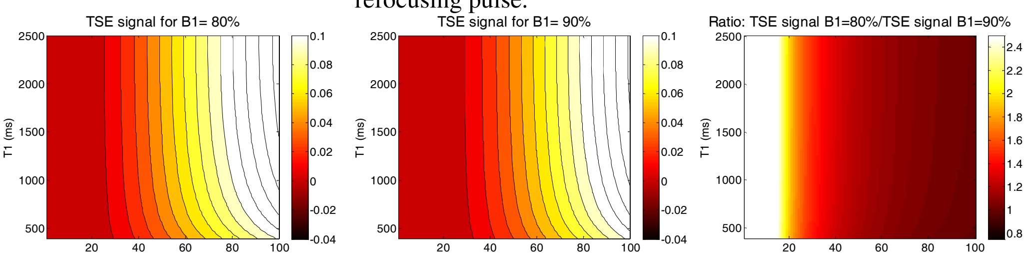

Fig. 2. ***a)*** *Simulated TSE signal (a.u.) at k=0 (half way the TSE train, at the 63th echo) for a relative B_1 of 80%.* ***b)*** *Idem, for a relative B_1 of 90%.* ***c)*** *The ratio of the TSE signal at B_1 = 80% over that obtained at B_1 = 90%. Note the strong sensitivity to B_1 for low T_2 values.*

Experiments: In all 4 subjects, the asymmetry in the pulvinar contrast reversed when the B_1 asymmetry was reversed by scanning in feet-first orientation instead of head-first orientation (Fig. 3). The ratio of (antomically defined) right/left signal of the pulvinar changed from 1.44±0.07 (head-first) to 0.75±0.15 (feet-first, P<0.005, n=4, paired t-test). The measured B_1 right/left ratio (asymmetry) in the pulvinar was 0.90±0.03 when scanned head-first, and 1.2±0.1 when scanned feet-first (P = 0.07, n=3, paired t-test). The results show that subtle but distinct asymmetry in *contrast* (rather than intensity) can be obtained for heavily T_2 weighted TSE trains, as a result of high sensitivity to B_1 inhomogeneity of tissue with low T_2 values. This holds for a wide range of T_1 values, and is, thus, not a field strength specific phenomenon. Lower signal-to-noise could mask the effect, as it will be lost in the background of the (Rician) noise. This finding urges for careful interpretation of TSE images, also at clinical field strengths, and highlights the need for precise B_1 shimming.

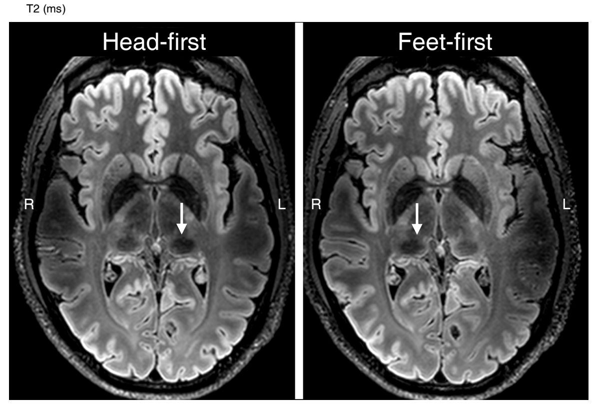

Fig. 3. Example of the contrast-asymmetry of the pulvinar, which reverses when the B_1 inhomogeneity pattern is reversed by scanning feet-first instead of head first.

Conclusion: TSE trains show a T_2-dependent B_1 sensitivity, which can become extremely strong for low T_2 values relative to the equivalent TE of the TSE train, and can lead to biased image contrast in heavily T_2-weighted images.

References: [1] Visser F, MRM 2010;64:194-202. [2] Toga AW, Nat Rev Neurosci 2003;4:37-48. [3] Hennig J, J Magn Reson 1988;78:397–407. [4] Scheffler K, Concept Magnetic Res 1999;11:291-304.