Oh no, where did my contrast go? - Righting the Shameful Wrong about SE T1 contrast at High Field.

R. Bammer[1], A. M. Saywer[1], J. J. Hsu[1], G. H. Glover[1], and R. D. Newbould[1]
[1]Radiology, Stanford University, Stanford, CA, United States

Introduction: Over the last few years concerns have been raised throughout the neuroimaging community about the lack of contrast in SE T1-weighted sequences. Particularly, neuroradiologists have criticized 3T's ability to provide adequate GM/WM contrast in the brain and spine. That said, it has been known for a long time that the T1 relaxation times of semi-solid tissue will increase with field strength (~ $B_0^{0.3}$), whereas T1 of CSF or T2 relaxation times remain almost unchanged across B_0. In fact, Rooney *et al* [1] not only confirmed the predicted increase of T1 with B_0 but also showed an increase in T1 dispersion with increasing polarization field strength both of which would actually benefit T1w imaging at high field. The objective of this study was to determine the optimal T1 contrast at 1.5T, 3T, and 7T and to find out whether or not there is truly a loss in tissue contrast with increasing B_0.

Materials and Methods: Within 3 days one male (34yrs) subject was scanned at 1.5T, 3.0T, and 7.0T on whole body units running the same software platform (GE Signa 12.0M5). At 1.5T and 3.0T excitation was performed with the body coil, whilst signal reception was done with an 8ch head array coil (MR Devices). At 7T transmit and receive was done with a 16ch head array coil (Nova Medical). Underlying T1 mapping was performed using the method of Hsu, Lowe and Glover [2, 3] using single-shot spiral readouts. The sample time was {0, 800, 1400, 2000} ms and NEX=8. Conventional T1w Spin-Echo was performed in single- or multi-slice fashion. At 1.5T the TR times ranged from 200 to 800ms, at 3.0T they ranged from 200 to 1000ms, and at 7.0T they ranged from 600 to 1400ms, all in increments of 100ms. The other scan parameters were as follows: TE=minful (10-12ms), FOV=22cm, thickness/gap=5mm/5mm, acquisition matrix=256^2, number of slices=6. The 1.5T and 3T images were reconstructed using the sum-of-squares (SoS) method, whilst the 7T was reconstructed using a phase-sensitive reconstruction to minimize the quadratic intensity modulation effect from the coil sensitivities otherwise seen in the SoS method. The change in SNR between B_0s was compensated by signal averaging.

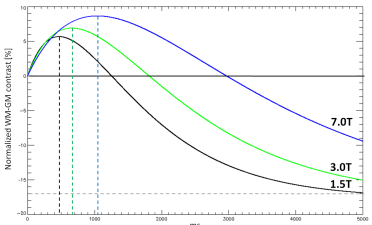

***Fig. 1** – Normalized WM-GM contrast as a function of TR at 1.5T, 3T, and 7T. The graph also shows the PD contrast at longer TRs. The TR for optimal GM/WM T1 contrast is shown by the dashed lines.*

Results: The optimal GM/WM contrast can be found by theoretical calculations using the underlying T1 times of each tissue, a proton density of WM that is 82% of that of GM, and the underlying signal equations. Specifically, the measured T1s of cortical gray matter were: 1036±44ms, 1400±92ms, and 2132±94ms for 1.5T, 3.0T, and 7.0T. Similarly, T1s of white matter were: 656±31ms, 850±24ms, and 1220±36ms. This yielded TR values for optimal T1 contrast of 470ms, 655ms, and 1040ms for 1.5, 3T, and 7T (Fig 1), which were also reflected by maximum GM/WM contrast to noise ratios. From Fig. 1 it is also apparent that the contrast differences increase with field strength regardless of SNR. For 1.5T and 3T the evolution of the contrast can be seen very well in Fig 2, whilst this is more challenging to see at 7T because of receive B1 inhomogeneity issues. A new phase-sensitive reconstruction significantly reduced the modulation from the coil sensitivities otherwise known for SoS reconstruction without any other homogeneity correction applied (Fig. 3). A comparison of multi-slice and single-slice acquisitions was also performed at 1.5T and 3T to assess whether or not potential MT effects from adjacent slice excitation and refocusing pulses could affect T1 contrast. However, for the optimal TR there was no significant change in GM/WM contrast observable between single-slice and multi-slice acquisition (Fig. 4). Most importantly, the GM/WM contrast remained almost unchanged between 1.5T and 3T when using the optimal TR for each field strength. Even at 7T, an adequate T1 contrast could be achieved (Fig.3) although profound coil sensitivity variations render the optimal contrast difficult to display and may require further homogeneity correction. Some loss in cortical GM/WM contrast was seen on the right frontal and the left occipital area which is due mostly to fixable B_1^+ issues (Fig. 4), but is unrelated from relaxation issues.

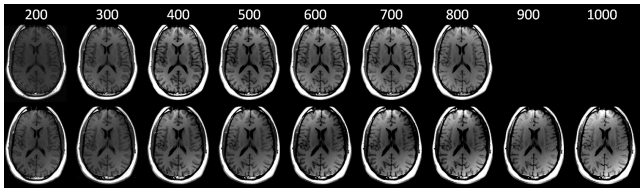

***Fig. 2** – T1w SE images as a function of TR scanned at 1.5T (top) and 3.0T (bottom). A step initial change in overall signal and contrast can be seen as well as the expected optimal contrast for longer TRs at 3.0T.*

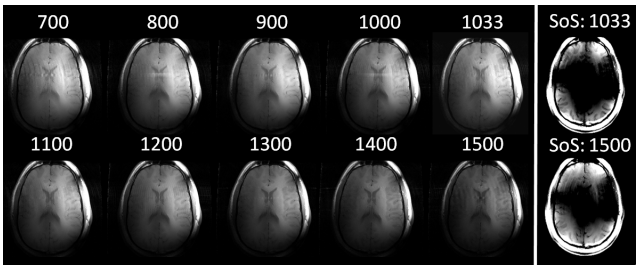

***Fig. 3** – T1w SE images as a function of TR at 7.0T using a phase-sensitive reconstruction. The profound signal modulation from squaring the effect of coil sensitivities in the SoS reconstruction can be well appreciated in the separate column on the right. Like for 1.5T and 3T and as predicted in Fig.1 there is a steep initial change in contrast for the shorter TRs with a relatively flat contrast for longer TRs.*

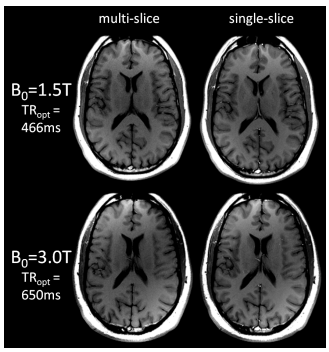

***Fig. 4** – T1w-SE multi-slice vs. single-slice at 1.5 and 3T.*

Conclusion: A comparative evaluation of T1-weighted SE scans was performed at three different field strengths to investigate the effect of field strength on T1 contrast. Despite concerns raised recently, in our study there was no observable loss in T1 contrast between 1.5T and 3T. T1 contrast at 7T could be achieved as well but was modulated by coil sensitivity variations, although the phase-sensitive reconstruction reduced this modulation substantially. This reconstruction technique is of particular advantage if no homogeneous receive coil is available (e.g. body coil) to which coil sensitivities can be normalized and provides also a better starting point for homogeneity correction algorithms. Our findings support the observations of Rooney *et al* and indicate that with appropriate adjustment of TR the T1 contrast can be maintained across B_0 if not increased (Fig. 1). Of note is also that with increasing B_0 the T1contrast *vs.* TR flattens and, for example, at 7T the TR can be varied across a wide range with only little loss in T1 contrast (Fig. 1). Overall, the prolonged T1 requires a longer TR and, hence, at 1.5T 40% and 120% more signal averaging than at 3T and 7T could be done. Assuming a linear increase of SNR with field strength, this would lower the effective SNR benefit of 3T and 7T over 1.5T from x2 and x4.67 to x1.69 and x3.14, respectively. On the other hand, for an interleaved slice acquisition the number of slices that will fit within TR can be increased simultaneously, which can increase scan efficiency and reduce motion-induced misregistration between slices if fewer slabs are needed.

References: [1]Rooney WD, Johnson G, LiX, et al. MRM 57: 308-318, 2007. [2]Hsu JJ, Lowe IJ, J Magn Reson 169: 270-278, 2004; [3]Hsu JJ, Glover GH, J Magn Reson 181: 98-106, 2006. **Acknowledgements:** This work was supported in part by the NIH (2R01EB002711,1R21EB006860, P41RR09784), the Lucas foundation, and the Oak foundation.