An In Vivo Investigation into the Potential Benefit of High-field MR for Diffusion Imaging

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Target Audience: MR scientists interested in diffusion imaging at high field

Purpose: In this study we investigate the actual difference in SNR at 7T vs. 3T for the purpose of diffusion-weighted imaging (DWI). High-field strength provides an intrinsic increase in magnetization, however T2 relaxation is shortened. DWI requires a preparation period and thus, long echo times (TE) must be used. Theoretical calculations predict that at TEs needed for typical diffusion weighting (b-value=1000 s/mm^2) and maximum gradient strengths (~45 mT/m) there should be greater SNR at 7T. However, in vivo verification has been inconclusive as the scan parameters and receiver coils used to acquire 7T and 3T data were significantly different [1, 2]. In this study, identical scan parameters and comparable receiver coils were used to map out the difference in SNR between 7T and 3T over a range of relevant echo times for DWI.

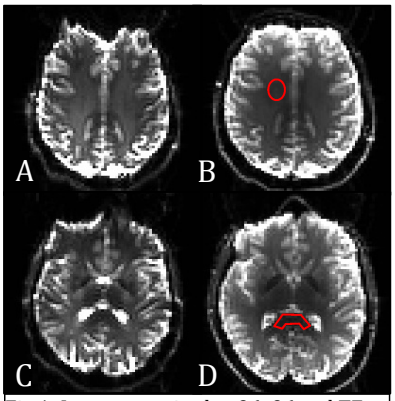

Fig 1: Images acquired at 96x96 and TE= 64ms through the CSV and SCC at 7T (A, C) and 3T (B, D), respectively. ROIs in red.

Methods: 3 healthy volunteers were scanned under an approved IRB protocol on both a 7T and 3T system using 32-channel phased-array coils. Data was acquired with a spin-echo single-shot EPI (SSEPI) sequence with three matrices and the following scan parameters: TR=5000ms, FOV=24cm, slice thickness=2.5mm, gap=2.5mm, 20 slices, 64x64 with TE=41-200ms and esp=0.5ms, 96x96 with TE=64-200ms and esp=0.6ms, 128x128 with TE=95-180ms and esp=0.71ms. The signal was measured in the splenium of the corpus callosum (SCC) and in the centrum semiovale (CSV) with manually drawn ROIs (see Fig 1). The noise was measured in an ROI at the edge of the FOV in a superior slice. The SNR at each TE was calculated as the mean signal of the ROI divided by the mean standard deviation of the noise from all TEs. The SNR measured for all volunteers was averaged at each TE for SCC and CSV.

Results: As seen in Fig 2, the signal decay of the CSV at 7T fits well to a mono-exponential with a time constant of 55.5ms, for all resolutions. This is similar to values reported for the average T2 of white matter (WM) at 7T [3]. The SCC shows a signal decay that doesn't fit well to a mono-exponential, and thus a single decay constant cannot be reported. Also seen in Fig 2, the signal decay of the SCC and CSV at 3T does fit well to a mono-exponential with time constants of 76.9, 83.3, 100 ms for 64, 96, 128 matrix and 71.4, 76.9, 83.3 ms for 64, 96, 128 matrix, respectively. These values are similar to those reported for the average T2 of WM at 3T [3]. The SNR in both WM ROIs is greater at 7T than 3T for all TEs investigated. As illustrated in Fig 3, the SNR improvement at 7T is ~100% at TEs typical of DWI (80ms). In addition, the divergence from mono-exponential decay for the SCC at 7T results in a larger %SNR improvement at longer TEs. The time at which the diverence occurs differs between acquisition matrices.

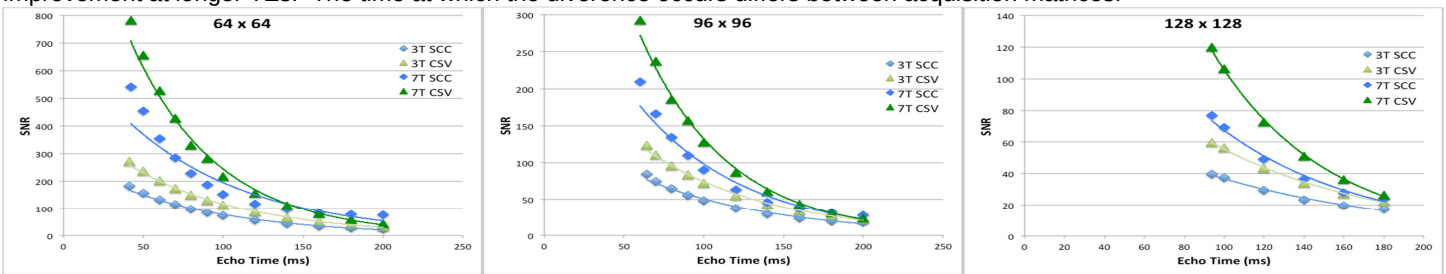

Fig 2: Plots of SNR for varying TE for the SCC and CSV at 7T and 3T. The lines are the resulting mono-exponential decay fits.

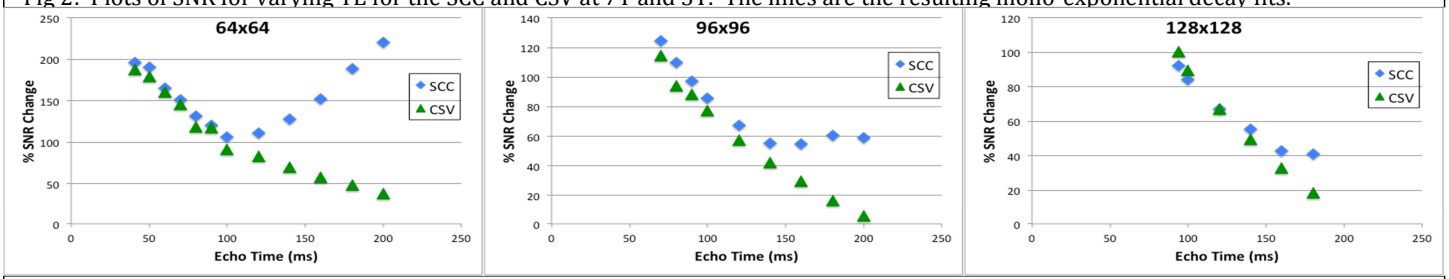

Fig 3: Plots of % SNR change between 7T and 3T for the SCC and CSV. Note, 7T is a higher SNR for all acquisition matrices.

Discussion/Conclusions: We have presented strong evidence that in selected WM regions SNR is greater at 7T than 3T for TEs relevant to DWI, even when acquired with SSEPI. The improvement in SNR varies between WM regions. Faster WM signal decay at 7T does not annul the SNR advantage of higher field, and thus, from an SNR perspective, DWI studies should benefit from 7T. We hypothesize that the divergence from mono-exponential decay seen in the SCC at 7T may be related to the orientation of the WM bundle with respect to B0. However, further investigation is needed to confirm this observation.

References: [1] Polders, *et. al.,* JMRI, 33:1456-1463, 2011. [2] Speck and Zhong, 17th ISMRM, 1462, 2009. [3] Reischauer, et. al., MRM, 67:679-690, 2012.