In-vivo, Human Diffusion Tensor Imaging at 7T: First Results

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Diffusion Tensor Imaging [1-5] has generated a great deal of research interest in recent years. Most commonly it has been applied to the human brain, where it has been used to probe the connectivity of the brain via fiber tracking techniques. All applications are limited by the relatively low SNR of the diffusion scans. This limits the achievable resolution of in-vivo DTI scans. In turn this does not simply limit the anatomical structures that can be examined, it also creates difficulties when the sample is more complex. A prime example is the problem of 'crossing fibers', i.e. where separate populations of nerve fibers with different orientation intersect. Higher image resolution can aid the separation of these populations.

Ultra High field MRI holds the prospect of increased SNR and thus improved DTI. However to the best knowledge of the authors, no studies have been presented of in-vivo, human DTI on a MRI scanner operating at 7 Tesla. This may be in part due to the higher demands for basic EPI image quality (e.g. shimming, ghost level) and of eddy current control for gradient operation in large magnets. We have found that tune-up procedures that were optimized for low field, clinical systems had to be adapted to work well at higher field. In addition, the RF inhomogeneity at 7T tends to severely reduce the image signal intensity in some (particularly lateral) regions of the brain, presumably due to both excitation and refocusing pulses being well below specified values in these areas. The use of a double echo diffusion preparation compounds this problem. In our experience, the system calibration tends to be correct in central regions of the brain. On this basis the transmit calibration power for DTI scanning was set at approximately 25% higher than the system software determined, resulting in flip angles slightly larger than specified in the middle of the brain, but improved signal from more lateral areas.

Data were acquired on a 7T system based on Siemens Avanto hardware. A detunable birdcage transmit coil was used in combination with an 8 channel receive coil [6,7]. A high performance head gradient set provided up to 100mT/m with slew rate of 800mT/m/ms. DTI data were acquired with the following parameters: FOV 192x192mm, slice thickness 2mm, 40 slices, matrix 96x96 with 7/8 partial Fourier, TR 7.5s, TE 90ms, bandwidth 3064Hz/pixel. Two b=0 images were acquired followed by diffusion weighted images with b=700 in 30 directions.

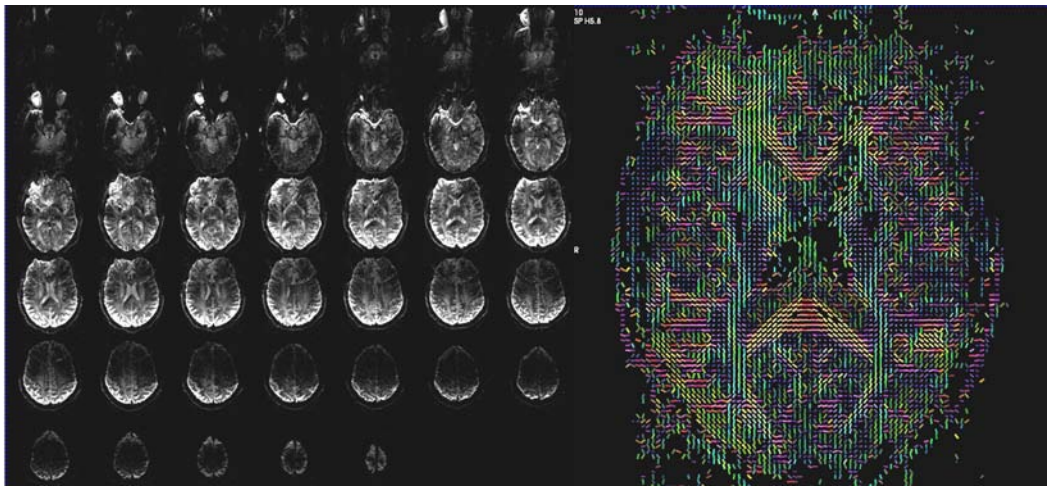

Figure 1: Images from a 7T DTI dataset. The image on the left shows an image with b=700. The loss of signal in superior and inferior regions arises from the limited coverage in the axial direction of the 8 channel receive array. The image on the right is a calculated DTI map from this dataset.

Conclusion: We have presented in-vivo, human DTI images acquired at 7 Tesla. While the non-uniformity of RF excitation caused some signal loss, this could be partially compensated for by appropriate setting of the transmitter calibration. Improvements in high field RF homogeneity via various methods (e.g. transmitter arrays [8]) are expected to reduce this drawback of high-field DTI.

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References:

[1] Mori S, Crain BJ, Chacko VP, van Zijl PC. *Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging.* Ann Neurol 1999; 45: 265-269.

[2] Basser PJ, Pajevic S, Pierpaoli C, Duda J, Aldroubi A. *In vivo fiber tractography using DT-MRI data.* Magn Reson Med 2000;44:625-632.

[3] B. Stieltjes, W.E. Kaufmann, P.C. van Zijl, K. Fredericksen, G.D. Pearlson, M. Solaiyappan and S.Mori. *Diffusion tensor imaging and axonal tracking in the human brainstem.* Neuroimage 14 (2001), pp.723-735.

[4] Mori S, Van Zijl PC. *Fiber tracking: principles and strategies - a technical review.* NMR Biomed. 2002 Nov-Dec;15(7-8):468-80.

[5] Jones DK, Horsfield MA, Simmons A. *Optimal strategies for measuring diffusion in anisotropic systems by magnetic resonance imaging.* Magn Reson Med. 1999 42(3):515-25.

[6] Wiggins GC, Potthast A, Triantafyllou C, Wiggins CJ, Wald LL. *Eight-channel phased array coil and detunable TEM volume coil for 7 T brain imag*ing. Magn Reson Med. 2005 54(1):235-40

[7] Wiggins GC, Wiggins CJ, Potthast A, Alagappan V, Kraff O, Reykowski A, Wald LL. *A 32 Channel Receive-only Head Coil And Detunable Transmit Birdcage Coil For 7 Tesla Brain Imaging*. Proceedings: 14th Annual Meeting of the International Society for Magnetic Resonance in Medicine (ISMRM), 2006 Seattle, USA

[8] Setsompop K, Wald LL, Alagappan V, Gagoski B, Hebrank F, Fontius U, Schmitt F, Adalsteinsson E. *Parallel RF Transmission With Eight Channels at 3 Tesla.* Magn Reson Med 2006 56:1163–1171