Diffusion Weighted Imaging at 7T with STEAM-EPI and GRAPPA

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Introduction:
Diffusion Imaging at 7 Tesla has been quite a challenge. Standard diffusion sequences require long time to play diffusion gradients, especially for high b-values. This compromises higher intrinsic SNR [1]at 7T with shorter T2 relaxation. At 7T twice refocused spin echo [2] used for standard diffusion weighted imaging also suffers from high SAR. Magnetic field inhomogeneities that come together with higher field also contribute towards distortions in for echo-planar imaging [3]. We use STEAM sequence for slice localization and EPI [4] with parallel imaging to acquire diffusion weighted images. While STEAM-EPI loses half the signal, it still benefits from a long T1 of the tissue to achieve high b-values: parallel imaging shortens EPI echo train leading to reduced distortions. STEAM-EPI is thus, the method of choice for 7 Tesla (Figure 1).

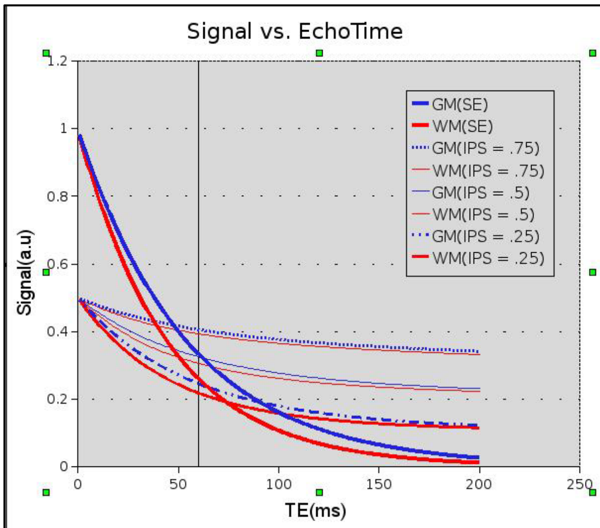

Figure1: Signal Decay in Spin Echo and STEAM for Gray Matter and White matter at 7 Tesla. IPS is ratio of time between two latter 90 degree pulses and the echo time. This is the T1 weighted time in the sequence where signal loss is minimum. T2 values taken as 55and 45 ms and T1 values taken as 1900 and 1600ms for GM and WM respectively.

Methods:
We obtained diffusion weighted images at a 7T whole body scanner (Siemens, Erlangen, Germany) with gradients 40 mT/m, 24 element phase array coil (Nova Medical Systems). The parameters used were TR/TE = 7500/100 ms, inter 90 degree pulse spacing = 48.74 ms (IPS = 0.49)(Figure 1), BW = 1562 Hz/Pixel, squared FOV of 192 mm with base resolution of 128 , 6/8 partial-Fourier and GRAPPA factor 3 resulting in a isotropic voxel size of 1.5mm. B values of [50,1000] s/mm^2 were used with 60 gradient directions for each b value with b value of 1000 s/mm^2 averaged 3 times resulting in 240 total images. With 60 slices interleaved acquisition, whole head routine diffusion weighted scan was performed in 30 minutes. The data was then used to calculate diffusion tensor using Siemens standard software.

Results:
STEAM acquisition suffers from initial halving of the signal (Figure 1). However, at 7 Tesla where the T2 relaxation of grey and white matter is quite short, STEAM acquisition uses T1 weighted time for diffusion weighing. The images acquired with STEAM-EPI look impressive with contrast preserved at b value of 1000 s/mm^2 (Figure 2b). Few eddy current related artifacts can be seen in our system which highlights great gradient coil shielding.

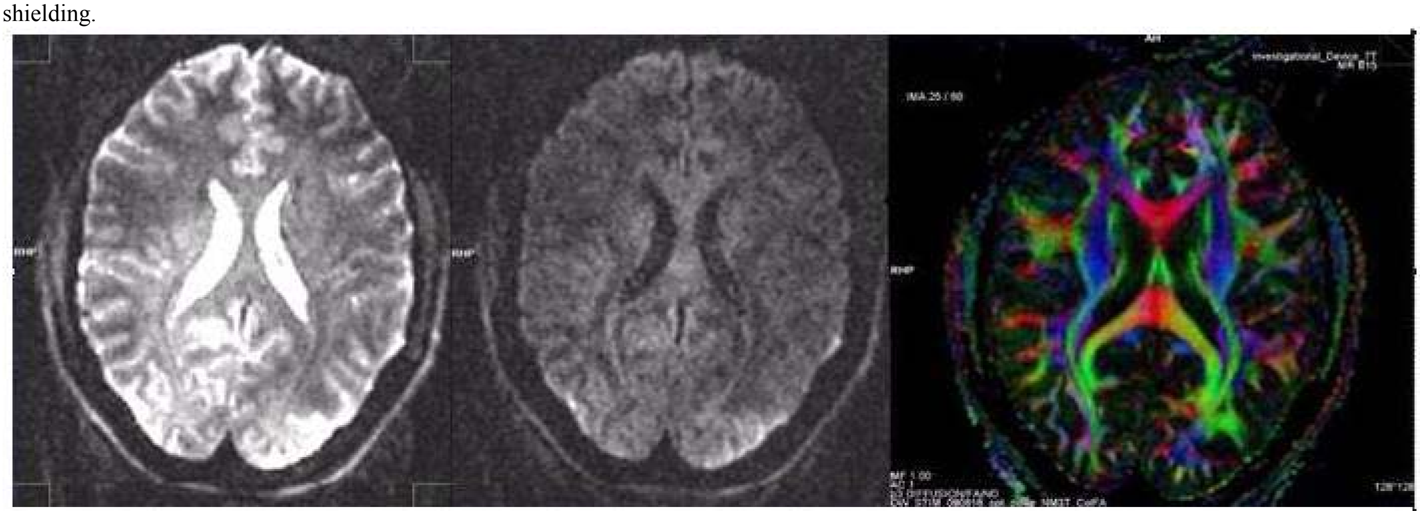

Figure2: Diffusion Weighted Images: b= 50 s/mm^2 (left), b=1000 s/mm^2 (middle), Colored FA map (right)

Conclusion and Discussion:
STEAM-EPI addresses the known problems at high field and can be used for routine DTI. Furthermore, STEAM-EPI also allows diffusion imaging with higher b-values without compromising SNR. This allows us to explore Diffusion Spectrum Imaging (DSI) at 7 Tesla. A further benefit of STEAM possibility of inner volume excitation[4] to get small image field of view. Inner volume excitation would shorten EPI echo train, which allows one to decrease echo time or increase b-values. STEAM-EPI thus allows to more options to explore diffusion imaging while performing well for routine DTI application..

References: [1] Vaughan et al. *Magn Reson Med*, 2001. **46**(1): p. 24. [2] Reese et al. *Magn Reson Med*, 2003. **49**(1): p. 177.
[3] Mansfield. *Journal of Physics C-Solid State Physics*, 1977. **10**(3): p. L55. [4] Turner et al. *Magn Reson Med*, 1990. **14**(2): p. 401.