Diffusion imaging in vivo with whole-body gradient amplitude of 65 mT/m

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Introduction

In diffusion-weighted imaging (DWI), larger b-values require longer diffusion-gradient pulse widths, which lengthens echo times (TE) and reduces image SNR. For a given b-value, diffusion-gradient pulses can be shortened if larger gradient amplitudes were available. Commercial whole-body systems with patient bore diameters of 60-70 cm can provide maximum gradient amplitudes of 40-50 mT/m. Higher gradient amplitude will reduce TE in all diffusion techniques, especially those that require very high b-values (~10000 sec/mm^2) such as diffusion spectrum imaging (DSI) [1].

Methods

A higher performance gradient driver prototype was developed, capable of delivering gradient amplitudes of G = 65 mT/m on a conventional gradient coil on a commercial whole-body 3T MRI system (GE, MR750). Two normal subjects were recruited in accordance with our IRB for DWI and DSI studies at G = 50 mT/m and at G = 65 mT/m. The slew rate was kept constant at 200 T/m/sec. Subjects were informed on the risk of peripheral nerve stimulation (PNS) due to higher gradient amplitudes [2]. For axial DWI, images were acquired at b-values from 1000-10000 sec/mm^2. White matter (WM) SNR was measured in 30 manually-selected regions per subject (~14 pixels per region), where SNR was determined by the ratio of mean to standard deviation of image intensity of the T2 image. Relative SNR was defined as $\Delta SNR = (SNR_{65} - SNR_{50})/SNR_{50}$. Sagittal DSI was performed with 11^3 q-space sampling at a maximum b-value of 10000 sec/mm^2 (8-channel phased-array brain coil, FOV = 24 cm, slice thickness = 4 mm, TR = 3000 msec, matrix = 128 x 96, slices = 9). In DSI, the number of fibers per voxel was determined by counting the number of peaks in the orientation distribution function [1].

Table 1. TE and SNR at various b-values. Theoretical SNR calculation assumes T2 of white matter of 70 msec.

b-value (sec / mm^2)	TE at 50 mT/m (msec)	TE at 65 mT/m (msec)	Theoretical ΔSNR	Measured ΔSNR	
				Mean	S.D.
1000	82.3	77.5	7.1%	10.5%	43.9%
2000	94.1	87.4	11%	11.6%	29.5%
6400	118.4	107.8	16%	18.1%	23.2%
10000	129.2	116.7	20%	23.2%	29.5%

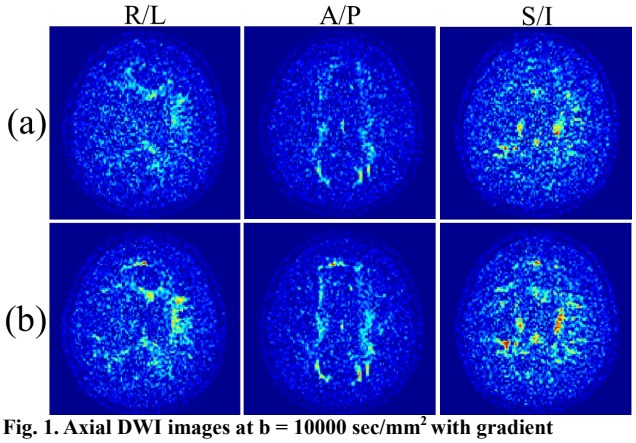

Fig. 1. Axial DWI images at b = 10000 sec/mm^2 with gradient amplitudes of (a) 50 mT/m and (b) 65 mT/m.

Results

Table 1 shows the effect of higher gradient amplitudes on both TE reduction and SNR improvement was more pronounced at higher b-values. The theoretical ΔSNR corresponds to the measured ΔSNR. The high standard deviation of measured ΔSNR is largely due to the SNR measurement method. Fig. 1 compares images acquired at b = 10000 sec/mm^2, showing increased signal at G = 65 mT/m. Fig. 2 shows distributions of fiber count in DSI due to changes in gradient amplitude. Imaging at G = 65 mT/m resulted in a significant increase in the fraction of single-count fibers by 6.3% ($P < 0.05$).

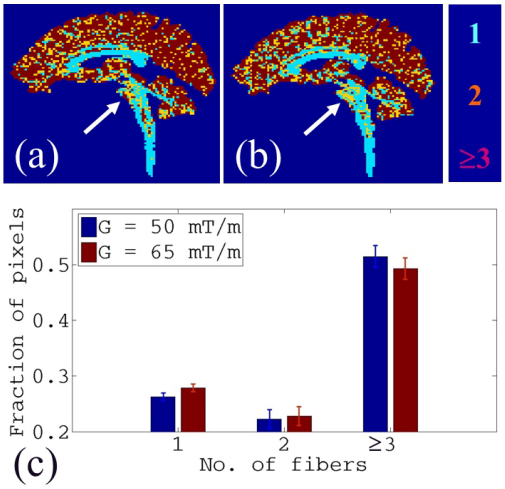

Fig. 2. Maps of fiber count from sagittal DSI at (a) G = 50 mT/m and at (b) G = 65 mT/m, and (c) the corresponding histogram with error bars reflecting standard deviation of difference in the fraction of pixels. The arrows in (a-b) point to observation of reduced fiber count in the brain stem in (b) as compared to (a).

Conclusion and Discussion

A higher performance gradient driver enabled imaging at a higher gradient strength of 65 mT/m, providing higher SNR in diffusion imaging at high b-values. The increase in single-count fibers in DSI suggests that the improved SNR may influence fiber-tracking results. The shorter pulse widths may improve diffusion results due to shorter 'mixing times' but these effects were not studied in detail here. The shorter diffusion pulses may provide an incremental (5-7%) improvement in multi-slice efficiency, but this improvement requires further analysis to ensure that thermal limits due to gradient heating are not exceeded. There was no visible increase in image distortion observed at G = 65 mT/m. PNS was not reported by the subjects.

References

[1] Wedeen VJ et al. Magn Reson Med 54:1377-1386. 2005. [2] Chronik BA and Rutt BK. Magn Reson Med 46:386-394. 2001.