Improvement of DTI measurement using the Composite Gradient Systems on a Clinical 3T MRI System

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INTRODUCTION: Diffusion Tensor Imaging (DTI) techniques have improved due to increased magnetic field strength and improved RF and gradient coil performance. Further improvement in gradient performance could be used to shorten the echo space duration (ESP) or increase the number of echoes in the same readout duration and thereby be of substantial benefit for high resolution DTI acquisition. Although, insert gradient coils can improve gradient performance for the benefit of EPI, diffusion and short TE imaging[1,2], their use typically requires that the insert gradients replace the body gradients, which is a logistically difficult process. The ideal MRI system may allow insert gradients to be used in concert with the whole-body gradients so that the best qualities of each gradient system can be dynamically selected for each acquisition. We have implemented hardware on our research 3T MRI scanner to allow simultaneous operation of two gradient systems. To test the potential utility of this system for DTI measurement, we have acquired DTI images of the excised goat heart using a combination of local insert and standard whole body gradients and whole body gradients only.

METHODS: The head neck insert coil was constructed based on a design obtained using the Boundary Element (BE) method[3]. All MRI scans were performed on a Siemens 3Tesla TIM Trio scanner, where the standard system was augmented with three additional gradient amplifiers and master/slave configured computers capable of controlling extra gradient channels. The control hardware and software were developed and provided by Siemens. Pulse sequences were implemented to control both gradient coils synchronously. The master computer was used to 1) maintain all computer controlled shims, including the first order gradient shims obtained using the standard body gradients, 2) control RF excitation and reception, 3) control standard whole body imaging gradients, and 4) synchronously trigger the slave computer. The slave computer executed a pulse sequence controlling the insert gradients. DTI of the excised heart were acquired using 2D ss-IMIV-DWEPI[4] and composite gradients (with insert and body at the same strength) with the following parameters: matrix=184x60, slice thickness=2 mm, TR=3s, 12 diffusion directions of b=1000 s/mm^2. The resultant in-plane resolution of DTI was 0.7x0.7 mm^2. The same DTI acquisition was performed on the body gradients with adjustments of imaging parameters such as FOV, slice thickness and TE to obtain the same in-plane (0.7x0.7 mm^2) resolution and b (1000 s/mm^2) value used in the composite gradients.

RESULTS:

Table 1 DTI imaging parameters

DTI (b=1000 s/mm^2)	TE (ms)	ESP(ms)
Composite Gradients (Fig 1(a))	72	0.95
Body Gradients (Fig 1(b))	102	1.44

Table 1 summarized TE/ESP (ms) used in composite and body gradients for DTI measurements. Fig. 1(b) displays Fractional Anisotropy (FA) maps and color presentation of the direction of principal eigenvector obtained from the 3 slices using composite gradients (b). The vector map of the principal eigenvector of slice 3 in (b) is projected onto the short axis plane in (d). The corresponding fiber tracts are shown in (c). Detailed structure of the myocardial muscle is well presented in both the vector and fiber maps. Because of longer readout duration and echo time DTI results using body gradients (a) showed more distortion artifacts than DTI by using composite gradient (see red arrows).

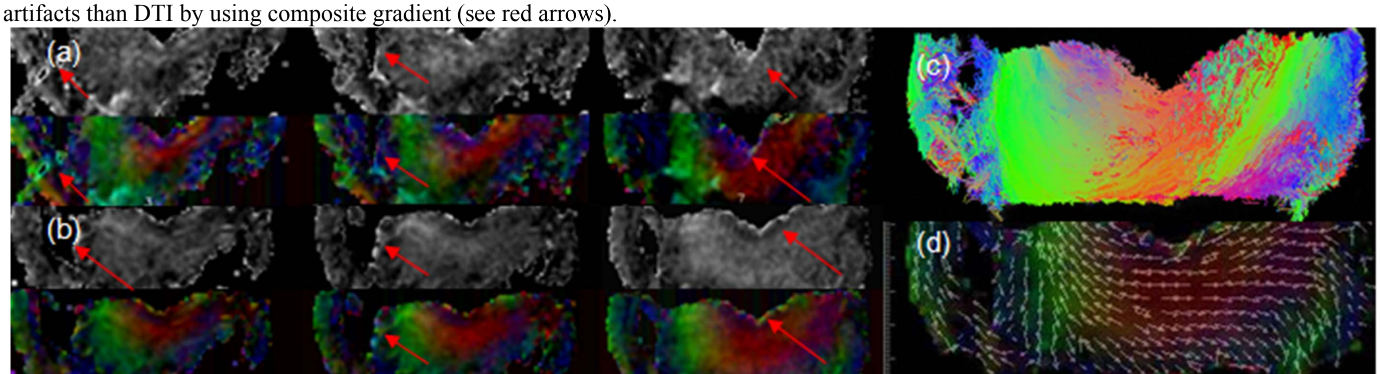

Fig 1 FA and the color maps of principal eigenvector map obtained using body (a) and composite gradients (b). The colors represent the directions: vertical (Red), horizontal (Green), in-out (Blue). Projected vector map of tensor principal component (d) and fiber tracts (c) obtained using DTI from composite gradients for slice 3.

DISCUSSION: The results presented here are very important because this composite gradient system that we are investigating is designed to function in studies of the human brain in vivo. This composite system has the distinct advantage that both gradient systems can be operated simultaneously and/or independently. With simultaneous acquisition, the gradient strength available from either system alone can be increased. Although there are many challenges associated with simultaneous operation, we have successfully demonstrated that this is possible, and that this can have a substantial effect on improving image quality in EPI sequences, such as DTI. In conventional systems, spatial resolution and SNR in DWI techniques have been improved with multiple shots and averages. However, multi-shot DWI in human applications usually suffers from artifact induced by phase error between each shot. Further, the long scan time can result in additional motion problems. As we have demonstrated in this study, the composite gradient system can acquire better DTI with showing less distorted artifacts in human studies than can be obtained with body gradient coils alone. This system can also provide high resolution fMRI datasets with better imaging quality compared to data obtained using the standard gradient system.

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REFERENCES: 1. Alsop DC, Connick TJ. *Mag. Reson. Med*. 35:875-866(1996). 2. Mayer D, et al.*Neuroimage* 35(5):1077-1085(2007) 3.Handler WB, et al. *Proc. Intl. Soc. Mag. Reson. Med*. 19:1834(2011). 4. Jeong EK, et al. *MRM* 54:1575-1582(2005).