Comparison of a high spatial resolution DTI sequence to standard DTI for evaluating fractional anisotropy of breast tumors

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Background: Diffusion-weighted imaging (DWI) utilizes motion-sensitizing gradients to characterize the magnitude of water motion within a tissue, and provides information about tissue microstructure. In studies of breast cancer, DWI increased diagnostic accuracy and showed promise as a biomarker of early treatment response [1]. Diffusion tensor imaging (DTI) employs additional diffusion weighting gradients to obtain measurements of directionality of water movement, such as fractional anisotropy (FA). A recent study of DTI in breast cancer found that the FA was significantly lower in breast tumors than in normal breast fibroglandular tissue, and that FA provided increased diagnostic accuracy over ADC alone [2]. However, one limitation of standard commercially available echo planar imaging (EPI)-based DTI sequences (STD-DTI) is that the spatial resolution is generally not as high as with sequences such as T1-w acquisitions used for dynamic contrast enhanced (DCE) MRI. The larger voxel size of STD-DTI results in increased volume averaging and may limit the ability of DTI to discriminate between normal and tumor tissues. In this work a high-resolution single-shot EPI reduced-field of view DTI acquisition (HR-DTI) was optimized for breast imaging. The sequence utilizes a 2D spatially-selective echo-planar RF excitation pulse and a 180-degree refocusing pulse to reduce the FOV in the phase-encode (PE) direction [3]. The shortened readout allows high in-plane resolution images to be acquired with fewer k-space lines and also reduces off resonance effects. In previous work, HR-DWI had improved image quality and a different distribution of tumor ADC values compared to standard DWI [4]. The goal of the current study is to compare the HR-DTI and STD-DTI sequences for characterizing fractional anisotropy (FA) and apparent diffusion coefficient (ADC) in breast tumors and normal appearing fibroglandular tissue.

Methods: Ten patients with invasive breast cancer were scanned with both HR-DTI and STD-DTI prior to receiving treatment as part of an ongoing IRB approved study at our institution. All patients gave informed consent. Imaging was performed on a 1.5T GE Signa scanner LX (GE Healthcare) using an 8-channel bilateral phased array breast coil (Sentinelle Medical, Toronto, Canada).
HR-DTI: TR/TE:4000ms/64.8ms, FOV:140x70 mm, matrix:128x64, slth:4mm, NEX:10, b=0,600 s/mm^2, 6 dir, voxel size:4.8mm^3, AT:4.73 min
STD-DTI: TR/TE:6000ms/69.6ms, FOV:400x400 mm, matrix:128x128, slth:3mm, NEX:6, b=0,600 s/mm^2, 6 dir, voxel size:29.3mm^3, AT:4.30 min
ADC and FA maps were calculated for both acquisitions using in-house software. One tumor region of interest (ROI) was defined on the HR-DTI slice estimated to contain the largest tumor area and one ROI was defined in normal appearing breast tissue on the ipsilateral breast. These ROIs were then mapped to the corresponding slice on the STD-DTI and HR-DTI ADC and FA maps. Mean tumor ADC and FA of tumor tissue and normal appearing ipsilateral breast tissue were compared for DTI acquisitions. ADC and FA values calculated from the two sequences were compared using a Wilcoxon-signed rank test, p<0.05 considered significant.

Results: Representative ADC and FA maps from STD-DTI and HR-DTI acquisitions are shown in Figure 1. Mean tumor and normal tissue ADC and FA values for both techniques are shown in Table 1. Mean tumor ADC was significantly lower than normal tissue ADC 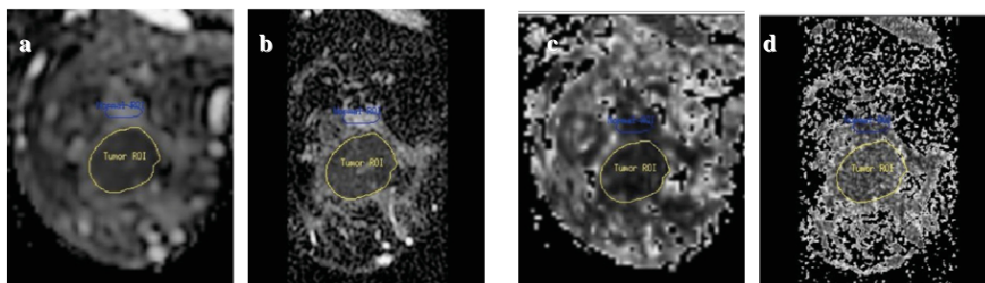for both the HR-DTI and STD-DTI. Tumor FA was significantly lower than normal tissue FA using HR-DTI, but not STD-DTI. No significant difference was found between mean tumor ADC values measured by the two methods, but there was a significant difference between mean tumor FAs .

Figure 1a . STD-DTI ADC map, 1b. HR-DTI ADC map, 1c. STD-DTI FA map, 1d. HR-DTI FA map

Table 1	High-resolution DTI			Standard DTI		
Mean (n=10)	Tumor	Normal	p -value	Tumor	Normal	p -value
ADC (× 10^{-3} mm^2/s)	1.15 ± 0.18	1.89 ± 0.17	0.002	1.18 ± 0.18	2.04 ± 0.15	0.002
FA	0.31 ± 0.08	0.36 ± 0.05	0.014	0.17 ± 0.05	0.20 ± 0.09	0.275

Conclusion: Tumor ADC measured by both HR-DTI and STD-DTI was significantly lower than normal tissue ADC consistent with other studies. Tumor FA measured by HR-DTI was significantly lower than normal tissue FA, consistent with a recent study using standard DTI in a larger population [2]. No significant difference between tumor and normal tissue FA was found for STD-DTI. The results of this preliminary investigation suggest that the HR-DTI technique may be more sensitive to detecting differences between FA in tumor and normal breast tissue. Future work will evaluate HR-DTI in a larger number of breast cancer patients.

References: [1] Pickles MD, Magn Reson Imaging, 2006 [2] Partridge SC, J Magn Reson Imag, 2010 [3] Saritas EU, Magn Reson Med, 2008 [4] Singer L, Academ Radiol (2011)