High Spatial Resolution DTI Sequence for Characterizing Breast Tumor Early Treatment Response: Comparison to Standard DTI Sequence

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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, to date there have been few of studies of treatment effects on DTI parameters in breast cancer. 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. This work utilizes a high-resolution single-shot EPI reduced-field of view DTI acquisition (HR-DTI) 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], resulting in high in-plane resolution images acquired with fewer k-space lines and also reduced off resonance effects. HR-DWI has been shown to improve breast 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 breast tumor fractional anisotropy (FA) and apparent diffusion coefficient (ADC) in patients undergoing neoadjuvant chemotherapy.

Methods: Seven patients with invasive breast cancer were scanned with both HR-DTI and STD-DTI prior to treatment ad after one cycle of taxane based therapy 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 on the pre- and early treatment images. 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 were compared for DTI acquisitions. ADC and FA values calculated from the two sequences were compared using a two tailed t-test and tumor volume change correlations between DTI parameters were assessed with a Pearson's correlation, $p < 0.05$ significant.

Results: Mean tumor ADC and FA values for both techniques are shown in Table 1. No significant difference in mean tumor ADC was found. HR-DTI measured tumor FA was significantly higher than STD-DTI for both time points, and this difference increased at

Table 1	Tumor ADC (x 10^{-3} mm^2/s)			Tumor FA		
Mean (n=7)	HR-DTI	STD-DTI	p-value	HR-DTI	STD-DTI	p-value
Pre-Treatment	1.1	1.2	0.144	0.30	0.17	0.013
Early-Treatment	1.3	1.4	0.127	0.31	0.2	0.001

the early treatment time point. Of the DTI parameters, mean tumor HR-FA had the strongest correlation with tumor volume change at the end of treatment (Figure 1).
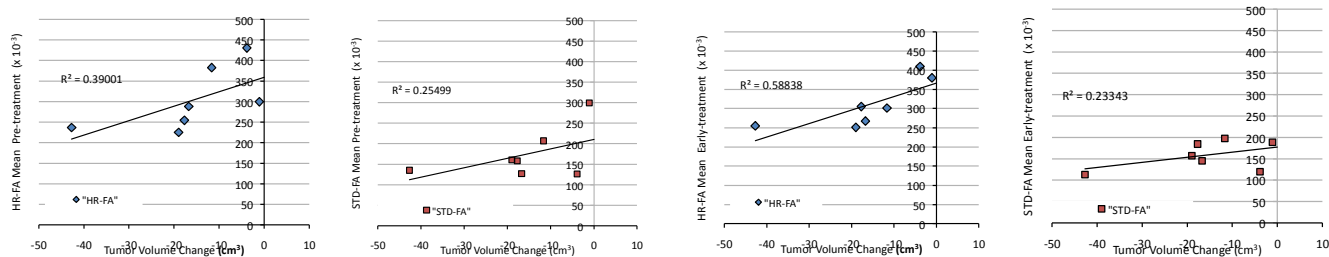

Figure 1. Correlations of pre- and early treatment FA with final tumor volume change a. HR-DTI FA pre Tx b. STD-DTI pre Tx c. HR-DTI FA early Tx, 1d. STD-DTI FA early-Tx

Conclusion: Mean tumor ADC measured by both HR-DTI and STD-DTI were not significantly different, consistent with previous studies. Tumor FA measured by HR-DTI was higher than that measured with STD-DTI with the difference being greater at the early treatment time point. Of the DTI parameters evaluated, HR-DTI FA correlated most strongly with final tumor volume change. The results of this preliminary work suggest that HR-DTI FA may be more sensitive than STD-DTI FA to early treatment related changes in tumors in response to therapy. This study is ongoing and 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)