Diffusion Imaging of Breast in vivo at 3.0 T Using a Single-Shot EPI Sequence with Partially Parallel Imaging Technique

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Introduction Diffusion-weighted MRI (DW-MRI) has been used to characterize breast tumor cellularity based on the apparent diffusion coefficient (ADC) of water molecules in tumor tissue[1]. In brain, high *b* value diffusion imaging and biexponential analysis of the ADC data show potential for differentiation of various tissues[2] and may allow for detecting early response to treatments. However, most breast DW-MRI studies have been restricted to *b* values less than 1000 s/mm^2 due to signal-to-noise ratio (SNR) limitations. Recent advances in high magnetic field whole-body MRI systems provide improved SNR. High performance gradients on these systems, coupled with the partially parallel imaging acquisition techniques, aid in significantly reducing the echo-spacing and echo-train in single-shot EPI methods, thereby enhancing image quality for the same combination of *b* value and resolution. In the present study, one of our goals was to use this added sensitivity to facilitate acquisition of high *b* value diffusion-weighted images of human breast in vivo at 3.0 T using a single-shot EPI sequence with partially parallel imaging.

Diffusion tensor imaging (DTI) is a promising noninvasive method to study tissue micro-structure, based on the varying signal attenuation arising from the restricted diffusion of water. Diffusion tensor imaging of a rat mammary fat pad tumor model has demonstrated that maps of diffusion parameters show structures that agree with those seen in high resolution MR images of the tumor[3]. Therefore, the feasibility of acquiring breast DTI using a single-shot EPI sequence with a partially parallel imaging technique at 3.0 T was also investigated in this study.

Methods Diffusion imaging studies of normal breast were performed on a GE 3.0 T Excite scanner, using an 8-channel phase-array torso coil (GE, Milwaukee, WI) with the subject in the prone position. A diffusion-weighted single-shot EPI pulse sequence using ASSET (Array Spatial Sensitivity Encoding Technique) was employed to acquire axial breast DW images with the following parameters: TR = 6000 ms, TE ranging from 52.8 to 84.9 ms, FOV = 24 cm, matrix size = 128x128, slice thickness/slice gap = 5/1 mm, number of slices = 20, number of signal averages = 1, ASSET reduction factor = 2, and *b* values selected from the range of 0-2000 s/mm^2. The scan time for each *b* value was 24 seconds. At each slice location, the diffusion-weighting gradient was applied along the slice, readout, and phase-encoding directions. To quantitatively calculate ADC values, ROI measurements from glandular tissue were fitted to a biexponential function using IDL (Research Systems, Boulder, CO). Quantitative ADC maps of glandular tissue were also computed pixel-by-pixel using a custom-written single-exponential fitting routine in FuncTool (GE, Milwaukee, WI).

The diffusion tensor images of breast were obtained using the same imaging methodology as DW-MRI. The imaging parameters included: TR = 6000 ms, TE = 63.2 ms, FOV = 24 cm, matrix size = 128x128, slice thickness/slice gap = 5/1 mm, number of slices = 20, number of signal averages = 1, ASSET reduction factor = 2, *b* value = 500 s/mm^2, and number of diffusion directions = 6, 15, or 25. Breast DTI data were post-processed using commercial FuncTool diffusion tensor algorithms.

Fig 2.

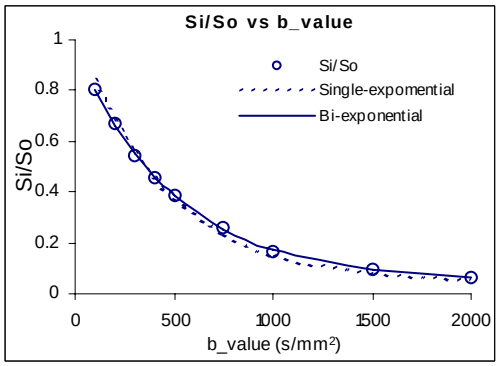
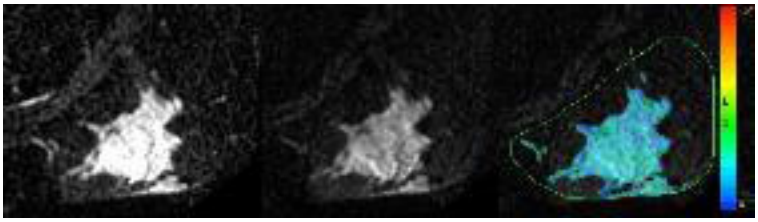
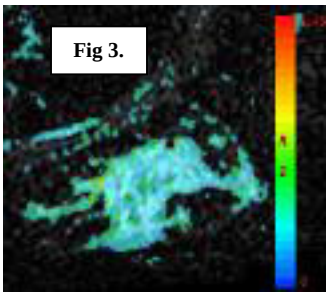


Fig 1. T2-weighted DWI (b=300) ADC map



Results Single-shot EPI images obtained with a partially parallel imaging technique at 3.0 T provide good contrast between breast glandular tissue and fat tissue in T2-weighted and diffusion-weighted images. In addition, quantitative ADC maps demonstrate homogeneous ADC values in normal glandular tissue (Fig 1). High *b* value diffusion-weighted images further allow the biexponential analysis, which better characterizes the diffusion related signal decay compared to a single exponential fit (Fig 2). In Fig 2, the normal glandular tissue biexponential fit yielded a fast ADC component of 2.22x10^{-3} mm^2/s and a slow ADC component of 0.48x10^{-3} mm^2/s, with respective volume fractions of 0.84 and 0.13. The single exponential fit yielded an ADC value of 2.20x10^{-3} mm^2/s. Pixel-by-pixel fractional anisotropy maps showed no directional preference of diffusion in normal glandular tissue (Fig 3).



Discussions/Conclusions A single-shot SENSE-EPI technique has been shown to increase speed of acquisition and reduce artifacts and distortion in breast diffusion-weighted images at 1.5 T[4]. Our results demonstrate the feasibility of acquiring high SNR diffusion-weighted and diffusion tensor images of human breast in vivo at 3.0 T. The use of a single-shot EPI sequence with partially parallel imaging techniques shortens the echo train length and the effective TE, which allows high *b* value diffusion imaging in breast. The phased-array torso coil used in our study is capable of providing good quality of breast diffusion images. However, motion artifact from breathing could be present due to lack of support of the chest wall. The availability of standard bilateral breast coils at 3.0 T will minimize such artifact. It has been reported that tumor cellularity has a significant influence on the ADC values in both benign and malignant breast tumors[1]. Biexponential analysis of the ADC data may better assess tumor cellularity by measuring its intra- and extra-cellular ADC components and the cell volume fraction, which potentially can improve tumor diagnosis and detect early response of tumor to treatments. Diffusion tensor imaging may also provide a more comprehensive characterization of the diffusion in breast tumor based on the diffusion isotropy observed in normal glandular tissue.

References **1.** Guo Y, et al., J Magn Reson Imaging, 2002;16:172-178. **2.** Maier SE, et al., Radiology, 2001;219:842-849. **3.** Friesen Waldner LJ, et al., Proc Intl Soc Mag Reson Med, 2004;p250. **4.** Weatherall P, et al., Proc Intl Soc Mag Reson Med, 2004;p2604.