Diffusion Imaging of Breast Cancer Using Single-Shot SENSE-EPI: Preliminary Results

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Introduction:

Breast cancer remains difficult to accurately diagnosis resulting in unnecessary biopsies of benign tissue and missed malignancy. Initial MR-imaging results indicate a high sensitivity, but low specificity. DWI is a technique that will likely improve MR specificity as benign and malignant breast tissues have significantly different ADC. However, each DWI breast study used different spin echo (SE) and echo planar imaging (EPI) techniques. This resulted in different values for even normal breast tissue (in vivo ADC measurements from 1.63 to 2.37 $x10^{-3}$ mm^2/s) [1,2,3,4] and malignancies (range from 0.96 to1.60)[1,2]. SE is slow and very sensitive to motion. However, there are also a large number of problems that can cause ADC alteration when using diffusion weighted EPI. One problem is the severe geometrical distortion and ghosting artifact caused by magnetic off-resonance and eddy current-induced gradient due to the long echo train length (ETL). In addition, the long ETL in EPI leads to a long TE, which will significantly decrease SNR for breast tissue. SENSE EPI sequences have been found to be effective on these problems for human brain diffusion due to the shortened ETL and TE value[5]. We believe that SENSE EPI will improve the diffusion imaging of human breast.

Methods:

Exams were performed on a Philips 1.5T Intera using a 4-element phased array breast coil (MRI-Devices, Inc.). A diffusion-weighted single-shot spin-echo SENSE EPI sequence provided 14 axial slices to cover the entire breast. Specific parameters included TR/TE/FA = 1.6s/43.3ms/90˚, FOV = 22×22cm, slice /gap = 5/2mm, matrix = 96×96 reconstructed to 128×128, NEX=4, and SENSE reduction factor R = 2. Partial Fourier acquisition (60.8%) and 60mT/m gradients were employed to minimize TE. Prone positioning and oblique transverse phase-encoding direction minimized respiratory and cardiac motion, respectively. Diffusion-gradients were employed along 3 orthogonal directions (P, M, S) with b values of 0, 200, 400 s/mm^2. Total scan duration was 48 seconds. A co-registration of the different diffusion-weighted images was carried out using an unwarping technique based on normalized mutual information to correct eddy current-induced distortion[6] . Regions of interest were determined using b = 0 DWI images in combination with standard images. Image co-registration, ADC map calculation, and further ROI analysis were performed off-line using homemade programs based on IDL (Research Systems Inc). Breast tissue evaluated included known malignancy (n=10), normal parenchyma (n=11), chest wall muscle (n=14), and cysts (n=5).

Results and Discussions:

The statistical results in Table. 1 demonstrate relatively low standard deviation (SD) of ADC values for normal breast parenchyma (n=11) and adjacent muscle (n=14), 0.13 and 0.18, respectively. This suggests an adequate result has been achieved via improved SNR and accurate spatial localization. This compares favorably with the only other report on in vivo DWI assessment of breast disease[2]. The average ADC value of 1.70 (SD= 0.26) obtained for 10 malignancies is nearly identical to previous reports despite the small average lesion sample size of 1.3 cm^2. This has significant clinical value since smaller lesions such as the 1.5cm tumor shown in figure 1, are more difficult to diagnose using standard means. However, our technique is still known to be inaccurate due to the significant perfusion effect that occurs using these low b-values

Table. 1. Statistical Results

	Sample Size	ADC_{av} (10^{-3} mm^2/sec)	Standard Dev. (10^{-3} mm^2/sec)
Malignant	10	1.70	0.26
Normal tissue	11	1.97	0.10
Muscle	14	1.83	0.18
Cyst	5	2.67	0.23

The single-shot SENSE EPI sequence we used for diffusion imaging on human breast is superior to conventional single-shot EPI due to increased speed of acquisition and reduction of artifacts and distortion, while maintaining comparable SNR. SENSE typically causes decreased SNR as phase-encoding profiles are reduced. However, combining SENSE with EPI will decrease echo train length and shorten the minimum possible TE. This is important for breast imaging due to the short T_2 value of the parenchyma (about 50ms). Combining SENSE with 60mT/m gradients and partial Fourier EPI readout allows reduction of TE from 105.1ms to 43.3ms. This leads to improved overall SNR for SENSE compared with that of a conventional diffusion-EPI sequence. Another advantage of SENSE EPI over standard EPI is reduction of geometrical distortion and image blurring due to an increased bandwidth along phase-encoding direction. As a consequence, images are less sensitive to susceptibility variations and eddy current-induced distortion. With SENSE factor = 2, residual ghosting was virtually absent from final images in most of our DWI images, as shown in Fig. 1B.

Despite multiple advantages with SENSE, problems remain. A significant number of artifacts partially obscure areas of interest in our DWI exams prior to (and also after) the use of SENSE technique. Increased aliasing artifacts are directly related to SENSE factors, but were mostly avoided by appropriate increase in field of view or oversampling. In 20% of patients, the ghosting and other artifacts were severe enough to preclude evaluation of the area of interest (not included in study). A low b-value was chosen for this proof of concept experiment. The perfusion effects will be decreased with the use of higher b-values in subsequent studies, likely providing greater differentiation of benign and malignant tissues. Adequate SNR should still be obtained using SENSE technique in combination with a limited number of slices and increased averaging. The SENSE technique also allows us to obtain single slice breath-hold images through known breast lesions avoiding all motion related artifact whilst adding multiple/longer b-value interrogation to improve specificity.

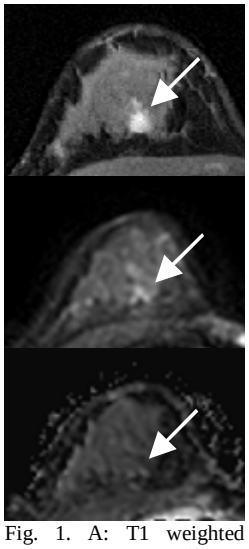

Fig. 1. A: T1 weighted breast image. B: Diffusion weighted SENSE EPI b=0 image. C: ADC map of the same slice.

Conclusions:

1. The SENSE technique for DWI evaluation of Breast disease produces reliable data while decreasing image distortion.
2. SENSE technique provides improved SNR and overall image quality, likely leading to more accurate diagnosis of breast cancer, although a greater number of patients need to be evaluated with increased b-value factors to prove this hypothesis.

References:

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