SPatio-temporal ENcoded Diffusion-Weighted Breast MRI Studies

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Introduction: MRI quantification of water's self-diffusion in tissues has been proposed for the early detection of breast cancer, and for distinguishing between benign and malignant lesions. Diffusion weighted imaging (DWI) studies show apparent diffusion coefficient (ADC) values that are significantly lower in cancers than in normal tissue or in benign breast lesions, due to cancers' higher cellular density [1,2]. Breast MRI studies; however, are complicated by the relatively high environmental heterogeneities that characterize the breast anatomy. In this study, we propose a new MRI methodology based on the ***SP***atio-temporal ***EN***coding (SPEN), to quantify diffusion in breast. SPEN is highly robust in terms of overcoming B_0-inhomogeneities and heterogeneous chemical shift environments [3,4]. A 2D SPEN single-slice diffusion-weighted sequence was tested on a clinical 3T scanner against the DW echo-planar imaging (EPI) sequence, for a series of breast imaging scans. Our results show a substantial image improvement upon using 2D SPEN, with superior faithfulness, resolution and the ability to yield artifact-free ADC maps.

Methods: MRI scans were conducted on a 3T Siemens TIM TRIO clinical system using a 4-channels breast coil. Scans were performed on a series of healthy female volunteers without any history breast disease. In Figure 1 we have acquired anatomical images: (A) axial T2 weighted multi-scan turbo spin-echo (TSE) scanned with a cubic FOV of 360mm, voxel size of 0.8×0.6×2.5 mm and TE of 122ms (without fat suppression); (B) Axial spin echo twice refocused EPI scanned with a cubic FOV of 360mm, voxel size of 1.9×1.9×2.5 mm and TE of 120ms; and (C) the 2D SPEN single-scan image scanned with a FOV of 300mm×122mm, voxel size of 1.6×1.6×2.5 mm and TE of 120ms (In both EPI and SPEN, fat suppression was used). In figure 2, ADC maps were calculated: (A) for the EPI diffusion measurements using the above parameters but with TE of 94m, (B) the SPEN with FOV of 300mm×132mm, voxel size of 1.7×1.7×2.5 mm and TE of 126ms. The SPEN diffusion measurements were based on $\boldsymbol{\delta}$= 26ms, Δ = 40ms and both EPI and SPEN were weighted according to Stejskal-Tanner b-values: 0 150 300 450 600 (s/mm^2). SPEN ADC maps were obtained, after suitably correcting the aforementioned b's to account for all the non-PGSE imaging gradients. All SPEN data were post-processed with in-house Matlab image-reconstruction algorithms based on super-resolution (SR) principles [5].

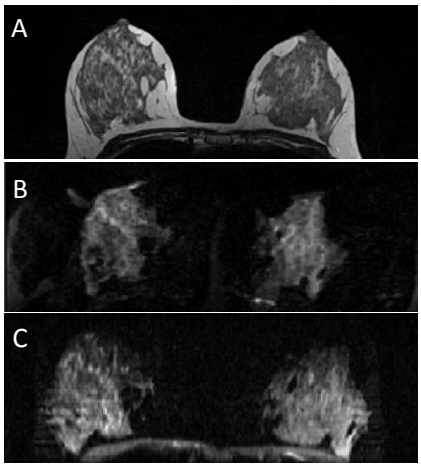

Fig.1: Axial anatomical images of multi-scan TSE (A), single-scan EPI (B) and 2D SPEN (C).

Results and Discussion: The original SPEN-based method [3] was modified to a DWI pulse sequence with a bipolar diffusion gradient on both sides of the π slice-selection pulse. It was then tested against the built-in diffusion EPI pulse sequence of SIEMENS assayed at the 3T with a series of breast imaging scans on female volunteers. Figure 1 shows a comparison between magnitude anatomical images scanned by a turbo spin-echo (A), which serves as a reference contrast between condensed fibro glandular tissue and the surrounding fat tissue, EPI (B), and SPEN (C). The advantage of SPEN is evident both in terms of image quality and of an artifacts' reduction that is mostly noticeable along the right→left (phase-encode) axis. Figure 2 expands this advantage by presenting a summary of ADC analyses that arise upon incorporating diffusion-weighting gradients into these scans, with panels A and B showing the ADC maps that EPI and SPEN single-shot approaches yielded for the breast regions respectively. Although good ADC agreement can be observed between the two 2D images, SPEN yields clearly superior resolution and sensitivity. By contrast to the EPI data, the SPEN maps are free from axial artifacts and of the severe ghosting problems otherwise surrounding and overlapping the breast's region of interest. Additionally, the noise background scattering ratio was 3.5 times higher for the EPI-derived maps, as compared to the SPEN ones. An additional unique advantage of SPEN – particularly in clinical studies – results from its ability to deliver "zoomed" single breast images (data not shown) without paying penalties in either signal-to-noise or fold-over artifacts.

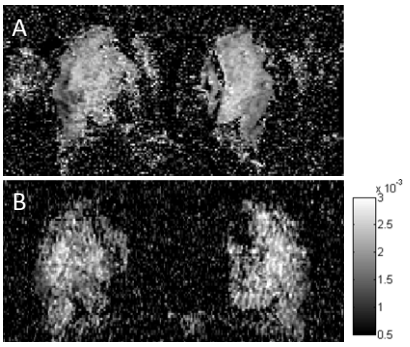

Fig. 2: ADC maps of EPI (A) and 2D SPEN (B).

Conclusions: In this study we present the use of SPEN–based strategy as potential diagnostic tool for clinical diffusion studies in breast imaging. In the results shown above, a significant advantage of resolving better anatomical and diffusional features of the breast were found in using the 2D SPEN over EPI.

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