

Dynamic slice-dependent shim and center frequency update in 3 T breast DWI

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Target Audience: Researchers/clinicians interested in breast DWI image quality improvement.

Introduction: Susceptibility-induced B_0 inhomogeneity causes significant pixel shift artifacts in 3 T breast diffusion-weighted imaging (DWI). In the past we showed that strategic placement of shim regions of interest (ROIs)[1] and use of a local shim coil [2] can improve B_0 homogeneity in volumetric breast imaging. For 2D imaging, slice-dependent shim update has been previously demonstrated for head and body [3]. The left-right asymmetry of the nearby organs and the half-spherical shape of the breasts [4] suggest that B_0 variation in breast can have significant components of type XZ^n and YZ^n , which can be compensated by slice-dependent shimming in axial imaging. Here we demonstrate implementation of slice-dependent linear shim and center frequency update in gradient-echo (GRE) and echo-planar imaging (EPI) in axial breast scans. Reduction of B_0 inhomogeneity and EPI pixel shift were observed in scans on four volunteers.

Methods:

Sequence modification. A standard DWI-EPI sequence was modified to add a dedicated multi-slice B_0 mapping pre-scan component. The B_0 mapping was based on dual-echo GRE with ΔTE chosen for water/fat rephasing. The added component increased the DWI scan time by less than 2 minutes depending on the number of slices and in-plane resolution. Slice-dependent center frequency (CF) and linear shim values were calculated on the fly based on the saved B_0 maps and slice locations. These values were dynamically applied to the subsequent DWI-EPI scan in a slice-by-slice manner (Fig. 1). Slice-dependent shim update was also implemented in a dual-echo B_0 mapping sequence to verify the accuracy of the shim values.

Volunteer scan. Four normal subjects were scanned without breath-hold in a GE MR750 3T scanner with an 8-channel breast array. An acceleration factor of 2 was used for DWI. Each subject was first scanned with a standard, multi-slice breast DWI protocol with shim values determined in a dual ROI placed on both breasts [1]. Subsequently, using the same CF and shim parameters, the B_0 maps on the same slices were obtained. These two scans provided “baseline” images for DWI and B_0 maps achievable with conventional shimming. The volunteer was then scanned with the modified, dynamically-shimmed DWI and B_0 map sequences with the same

scan prescriptions. For DWI, TR/TE/FOV/resolution/slice thickness = 6 s/87 ms/36 cm/256x256/4 mm. For B_0 mapping, TR/TE1/resolution = 250 ms/4.6 ms/128x128. A high-resolution 3D gradient echo image was also taken to provide reference for DWI pixel shift.

Results:

Figure 2 shows measured improvements in the average off-resonance frequency and B_0 homogeneity in all slices from one of the volunteers (volunteer 3). Typically reduction of B_0 inhomogeneity from dynamic shimming was most pronounced near the superior/inferior end slices. Figure 3 shows an example of B_0 map comparison on one of such slices. Reduction in left-right B_0 asymmetry was consistently observed in many slices with dynamic shimming. Table 1 shows the summary of B_0 variation for all four volunteers. Each data figure in the table represents an average over all slices imaged in a given volunteer. Volunteers with larger breasts tended to show greater improvements from the proposed method. Figure 4 shows anatomy-referenced ADC maps in three axial slices in volunteer 3 obtained with conventional and slice-dependent shim/CF update, demonstrating significant reduction in pixel shift in dynamically-shimmed DWI.

Conclusion: We demonstrated improvement in B_0 homogeneity and DWI image registration in bilateral breast imaging by implementing slice-dependent dynamic shim and CF update. With only linear gradient coils, the method effectively compensates susceptibility-induced in-plane B_0 gradients that vary from slice to slice. The proposed method is expected to potentially enhance diagnostic confidence in DWI-based cancer detection. More quantitative assessment of clinical benefit remains as a future study.

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References: [1] Hancu I. et al., MRM doi: 10.1002/mrm.24307 (2012) [2] Lee S-K.

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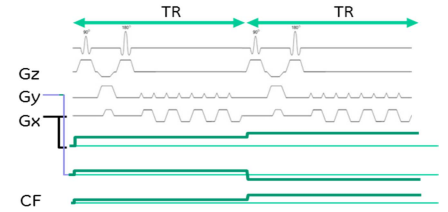


Figure 1. Schematic of a DWI-EPI sequence with slice-dependent linear shim update.

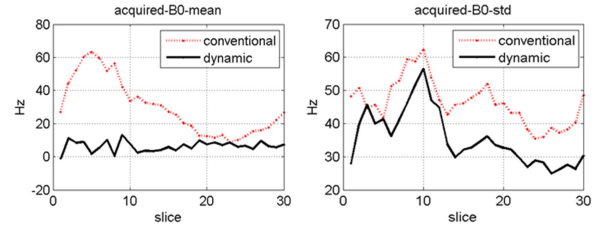


Figure 2. Slice-dependent average off-resonance frequency (left) and B_0 standard deviation (right) for volunteer 3.

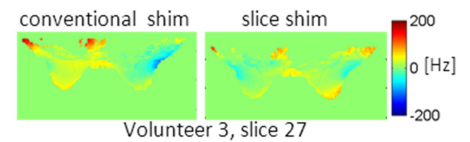


Figure 3. Example of B_0 maps obtained with conventional and dynamic shimming.

volunteer	conventional		dynamic	
	mean(Hz)	s.d. (Hz)	mean(Hz)	s.d. (Hz)
1	7.4	28.2	3.3	19.7
2	51.2	36.9	3.8	33.7
3	29.8	46.4	6.4	35.5
4	8.4	35.1	3.5	28.5

Table 1. Mean and standard deviation of B_0 in all subjects.

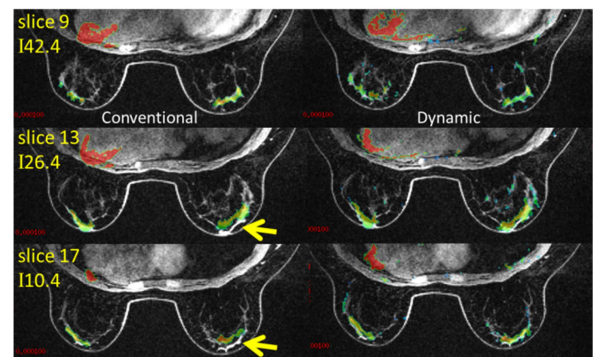


Figure 4. Breast ADC maps (color) overlaid with anatomical images (grey scale). Arrows show misalignment in the conventionally shimmed DWI.