DW-MP-SWIFT for High Spatial Resolution Diffusion Weighted Breast MRI

Curtis A. Corum[1], Djaudat Idiyatullin[1], Diane Hutter[1], Lenore I. Everson[1], Lynn E. Eberly[2], Michael T. Nelson[3], and Michael Garwood[1]
[1]*CMRR, Radiology, Medical School, University of Minnesota, Minneapolis, Minnesota, United States,* [2]*Biostatistics, School of Public Health, University of Minnesota, Minneapolis, Minnesota, United States,* [3]*Breast Center, Radiology, Medical School, University of Minnesota, Minneapolis, Minnesota, United States*

TARGET AUDIENCE Breast radiologists, MRI technologists, and researchers interested in breast imaging.

PURPOSE Develop and test a robust (motion and eddy current resistant) high spatial resolution diffusion-weighted MRI sequence for breast imaging, DW-MP-SWIFT.

INTRODUCTION Diffusion-weighted breast MRI has emerged from a research topic to a promising clinical method, especially due to the potential for increased specificity for pathology without exogenous contrast injection[1]. However, diffusion-weighted breast MRI has many technical issues including limited spatial resolution and geometric distortion, making small lesion identification and co-registration a challenge[1].

METHODS Fig.1 shows the diffusion-weighted magnetization prepared SWIFT[2-3] sequence (DW-MP-SWIFT). A 62.5 kHz SWIFT acquisition, HS2 pulse, rf fraction 0.25, TR 4.4 ms was performed for both 16k and 64k views (total acquisition time 2.5 min and 10 min, respectively) for each *b*-value. The shorter acquisitions were reconstructed to 1.5 mm resolution isotropic 3d images and the longer to 0.75 mm resolution isotropic images. Diffusion preparation was interleaved every 64 views and fat suppression[4] every 16 views in order to correspond to *in vivo* experiments. The gradient duration δ was chosen to be 20 ms and the spacing Δ, 40 ms, giving a maximum *b*-value of ~3000 at 5 gauss/cm for the oblique (all three gradients on) magic angle direction. Gradients are actually cosine shaped. All acquisitions used gap cycling[5] and the sequence, macros, and reconstruction correspond to CMRRpack v 0.45b [http://www.cmrr.umn.edu/swift/] on our Agilent/Siemens 85 cm bore 4 T scanner.

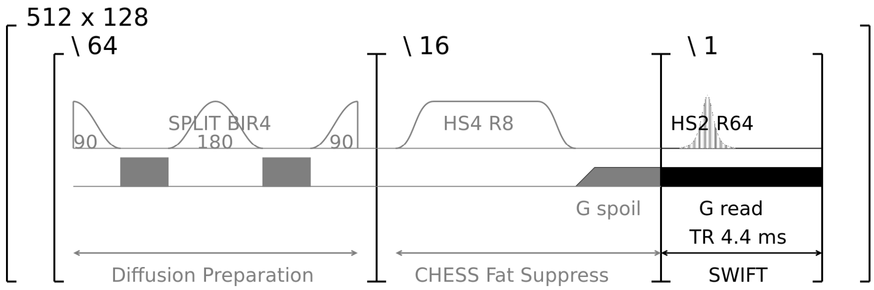

Figure 1 DW-MP-SWIFT sequence with adiabatic split BIR4 diffusion preparation, adiabatic CHESS fat suppression and SWIFT excitation/readout.

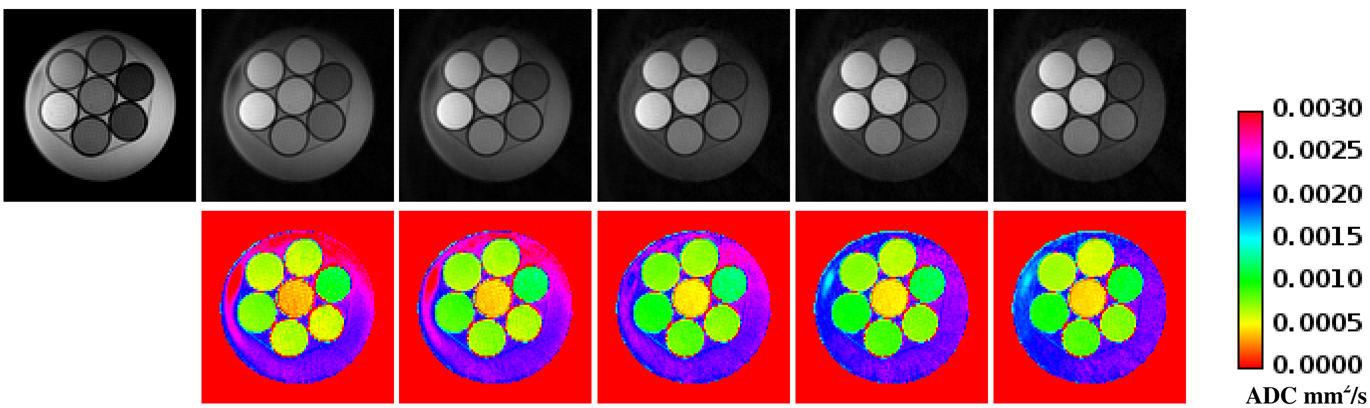

Figure 2 Calibration of *b*-values with agar phantoms and DI water at room temperature; *b*-values are 40, 360, 520, 750, 850, 900.

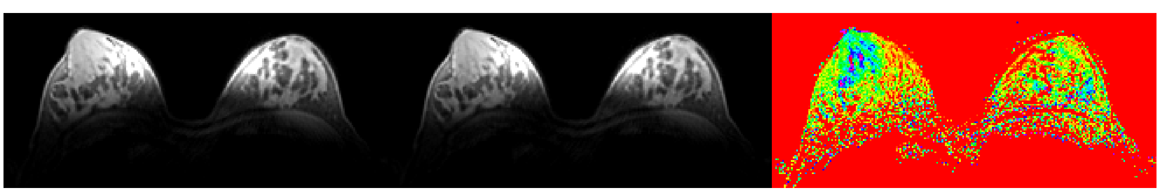

Figure 3 Source images and ADC map from subject number 3; *b*-values are 40, 520. ADC scale is same as Figure 2.

Phantoms consisted of 50 mL centrifuge tubes of known concentrations of agar and Gd-DTPA surrounded by DI water. T_1, T_2 and ADC were measured at room temperature individually for each tube via non-localized spectroscopy and verified periodically with LASER localized spectroscopy. Phantoms were placed in an in-house designed SWIFT-compatible transceiver 4-channel 4 T dual breast coil[4]. 6 *b*-values were chosen, ranging from 40 to 900. 3 normal volunteers were scanned (one twice) in 4 sessions under an IRB-approved protocol at *b*-values 30, 540 and 750.

RESULTS Phantom results are shown in Fig. 2. Some of the raw image intensity difference (especially the tube at 8-o'clock position) is due to T_1. Raw images are scaled to highest intensity; otherwise, higher b-value images would not be visible. Images and ADC maps from subject 3 are shown in Fig. 3.

DISCUSSION The SWIFT sequence combines excitation (frequency-swept RF pulse), spatial encoding (readout gradient), and acquisition into one multiplexed time interval[2-3]. SWIFT excites signal at high bandwidth and receives after a very short dead time (4 µs) and so is highly robust against off-resonance effects and eddy currents. Elimination of eddy current correction produced no degradation in image quality or artifacts. Because of the rapid multiplexing in SWIFT, there is no time within a given TR to insert additional pulses or gradients, and therefore additional weighting must be done by preparing the longitudinal magnetization. Because of the rapid switching times, we primarily utilize local transmit and receive coils with SWIFT, so that most SWIFT imaging occurs with substantial B_1 inhomogeneity. Previously we have demonstrated the use of adiabatic pulses for CHESS fat suppression[4] in our 4-channel transceive 4 T breast coil to overcome B1 inhomogeneity. For diffusion preparation we chose to use a spin echo with flip back consisting of a split BIR4 (B_1 insensitive plane rotation) adiabatic pulse[6] with cosine shaped gradients between the pulse segments. Our intent is to maintain insensitivity to B_1 and B_0 in all preparations and combine this with the B_0 insensitivity of SWIFT readout. In post processing, common mode changes in the flip angle due to B_1 variations are removed, leading to B_0 and B1 robust ADC maps.

CONCLUSION High spatial resolution diffusion imaging has been an unmet need in Breast MRI. We have shown initial phantom and normal subject results for B_1 and B_0 robust high spatial resolution diffusion weighted breast imaging with DW-MP-SWIFT.

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