High-resolution Diffusion-Weighted Imaging of the Breast with Multiband 2D RF Pulses and a Generalized Parallel Imaging Reconstruction

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Target audience: Clinicians and researchers with an interest in breast diffusion-weighted imaging.

Purpose: High-resolution diffusion-weighted imaging (DWI) of targeted breast lesions using 2D RF pulses has been previously demonstrated [1]. Despite the excellent image quality achievable with this technique, its clinical utility is limited to cases where the location of disease is both finite-extent and known *a priori* (e.g. treatment monitoring [2]). For breast DWI to gain clinical acceptance as a tool to increase diagnostic accuracy of current breast MRI protocols when used in conjunction with contrast-enhanced techniques, bilateral coverage and high resolution are needed. In this work we propose a method for high resolution DWI of the breast that combines reduced-FOV (r-FOV) imaging, 2D selective multi-band excitation and a generalized parallel imaging reconstruction to extend the high-resolution and high anatomical fidelity achievable with r-FOV imaging over the much larger FOVs required for diagnostic bilateral breast exams. Clinical evaluation of the technique, with respect to conventional bilateral DWI and targeted (r-FOV) DWI, was performed in 14 breast cancer patients at 3T, where the increased sensitivity to off-resonance and B1 inhomogeneity cause increased anatomical distortion and shading.

Methods: *Pulse sequence:* 2D, single-shot, spin-echo echo-planar imaging (EPI) with 2D-selective excitation [3]. By phase modulating the individual sub-lobes of the 2D RF pulses, multiple co-planar bands of magnetization can be simultaneously excited (Fig. 1a). Restricting the encoded FOV to a single band (Fig. 1b) shortens the echo train length, and reduces both distortion and T2*-induced blurring. By sweeping the multiband (MB) excitation pattern along the phase-encode direction, bilateral coverage can be achieved (Fig. 1b).

Reconstruction: A generalized parallel imaging (PI) reconstruction, whereby physical receiver coils and excitation profiles are equivalently treated as complementary "virtual" coils (cfr. Fig. 1b), can be used to resolve aliasing resulting from phase-encoding a single band, while efficiently combining bands resulting from different excitations, with minimal artifact at the boundary between adjacent bands. For this purpose, an extended Autocalibrated Reconstruction for Cartesian imaging (ARC) [4] was used in conjunction with MB calibration data sweeping the final reconstructed FOV and acquired during the non diffusion-weighted (b=0) portion of the acquisition.

Imaging protocol: 14 patients with known breast lesions were scanned at 3T (GE MR750, GE Healthcare, Waukesha, WI) using a 16-channel breast coil (Sentinelle Medical, Inc, Toronto, ON, Canada). Imaging parameters were set to test the hypothesis that the proposed MB technique can achieve the same image quality and high resolution of clinically available r-FOV methods with whole bilateral coverage. A $0.78 \times 0.78 \times 4 mm^3$ resolution was obtained with both MB DWI (4 MB passes to cover a 40cm FOV, MB factor=3 [4cm wide bands, 13cm apart], 512x512 matrix size, 8x FOV reduction factor [=in-plane PI acceleration], TE/TR=55/3000ms) and r-FOV DWI ($10 \times 5 cm^2$ FOV, 128x64 matrix size, TE/TR=51/3000ms). For conventional DWI (34cm FOV, 256x256 matrix size, 4x PI acceleration, TE/TR=92/3000ms), resolution was $1.3 \times 1.3 \times 4 mm^3$. b=0 (8 NEX) and b = $600 s/mm^2$ (16 NEX), half Fourier with homodyne reconstruction and targeted shimming (bilateral for MB and conventional DWI, matching prescribed FOV for r-FOV) were used.

Qualitative analysis: An experienced radiologist reviewed all images in randomized order on different sessions. Images were scored for a) level of distortion; b) residual aliasing; c) quality of fat suppression; d) perceived SNR and e) anatomical detail on a 5 point scale (1=worst, 5=best). Statistical significance (set at $p<0.05$) was tested using the Wilcoxon signed-rank test.

Results and discussion: Figures 2 and 3 show bilateral images obtained with MB and conventional DWI as well as r-FOV. There was no difference between MB and r-FOV DWI in terms of distortion (p=0.4), quality of fat suppression (p=0.7), perceived SNR (p=0.1) and anatomical detail (p=0.7) (Fig. 4). Minor residual aliasing was noted in MB but not in r-FOV (MB PI factor = 8 vs. no PI for r-FOV). With respect to conventional DWI, MB images were less distorted (p=0.03) and were found to be superior both in terms of anatomical detail (p=0.02) and fat suppression (p=0.03). Perceived SNR and level of residual aliasing were not significantly different.

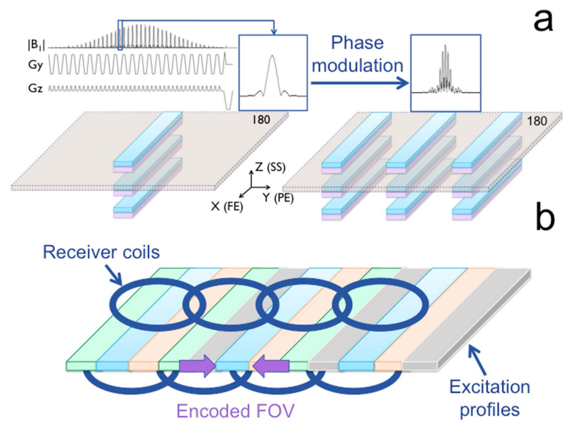

Figure 1: (a) 2D excitation profile before and after phase modulation of the individual sub-lobes of the 2D RF pulse (note misregistration between fat and water in the slice-select (SS) direction and refocusing profile of the 180 pulse which simultaneously suppresses periodic replicas and fat); (b) Bilateral coverage obtained by sweeping the MB excitation pattern in the PE direction.

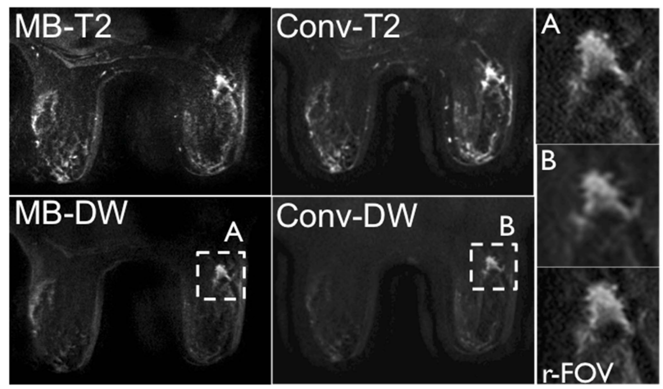

Figure 2: Comparison between MB, conventional (Conv) and r-FOV DWI

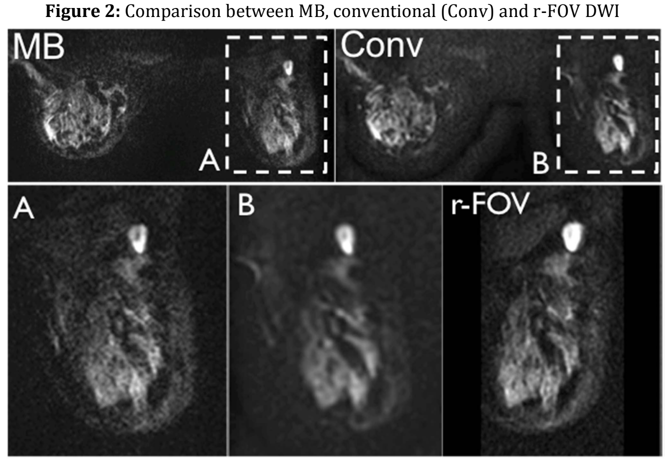

Figure 3: Comparison between MB, conventional (Conv) and r-FOV DWI ($b=600 s/mm^2$)

Conclusion: We developed a novel technique for bilateral high-resolution DWI in the breast that provides coverage equivalent to conventional DWI, together with much higher spatial resolution and image quality, that are not significantly different from recently reported r-FOV methods, at the expense of prolonged scan time (~4min. for MB, ~1min. for conventional and r-FOV DWI).

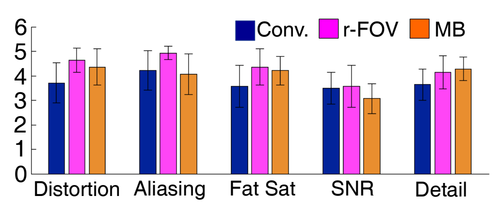

Figure 4: Qualitative assessment of image quality (N=14).

References: [1] Singer L. et al. Acad Radiol 2012; 19(5):526; [2] Wilmes L.J. Acad Radiol 2013; 20(5):581; [3] Saritas E.U. et al. MRM 2008; 60: 468; [4] Brau A.C. et al. MRM 2008; 59:382.