Spectrally selective excitation for improved DWI, APT and MRS of the breast

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Target Audience: Investigators interested in development and application of quantitative MRI/MRS of breast cancer

Purpose: Though diagnostic breast MRI can provide higher sensitivity than mammography [1], considerable research efforts have been devoted to improving MRI's comparatively low specificity. A multi-modality breast exam including diffusion weighted imaging (DWI) [2], amide proton transfer (APT) [3] and magnetic resonance spectroscopy (MRS) [4] is of interest because these methods have established several biomarkers for lesions elsewhere in the body such as the brain. However, techniques that work well in the brain may face additional challenges and require significant modifications to be successfully used in the breast. For example, lipid suppression presents an area where proven approaches in the brain often fail because of more heterogeneous water-fat distribution in the breast. Recently, water only excitation was implemented for dynamic contrast enhanced (DCE)-MRI of the breast [5] showing superior results to conventional lipid suppression. This concept can be applied to all methods in a multi-modality breast MR exam. Here, we present our initial experience combining spectrally selective excitation with DWI, APT and MRS in the breast.

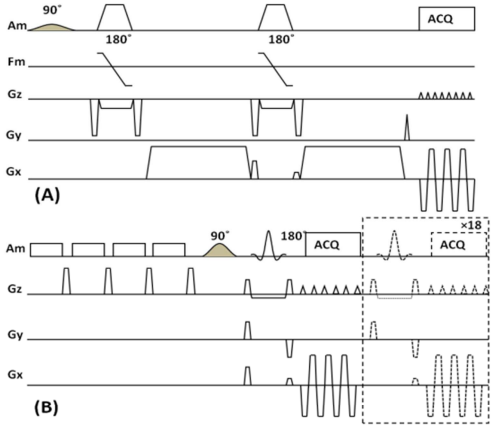

Figure 1. Sequence Diagrams of water only DWI and APT.

Methods: All *in vivo scans* were performed on a 3T whole body scanner with a 16 channel phased array breast coil (Achieva, Philips Healthcare, Best, the Netherlands). Spectrally selective excitation was implemented with three spin echo (SE) based pulse sequences. Unlike the gradient echo sequence [5], where the only RF pulse was modified to be spectrally and spatially selective, SE based sequences allowed us to test the same concept with frequency selective excitation and slice-selective refocusing pulses. Specifically, for DWI, a sinc-gaussian (SG) pulse with a bandwidth (BW) of 200 Hz was combined with two adiabatic full passage (AFP) pulses (5.8 ms duration and 2.5 kHz BW). The arrangement of the diffusion gradients was adapted to one extra 180□ pulse and increased crusher gradients (Fig. 1A). The rest of the parameters were: TE/TR=76ms/1s, slice thickness=3mm, FOV=(192 mm)^2 (FH×AP), resolution=(2 mm)^2, b-factors=0, 50, 600 s/mm^2, NSA=10, scan time=1:41 min. For the APT sequence, the same SG pulse replaced lipid suppression and slice selective excitation in a newly developed CEST 3D sequence [6] with gradient spin echo (GRASE) readout (Fig. 1B). The other parameters were: TE/TR=36 ms/2.5 s, FOV=160×160×40mm^3 (AP×FH×RL); resolution= 2×2×4mm^3; RF saturation=200ms×4 with a B_1 of 2 μT, full z-spectrum at 26 offsets=M_0, 0-6 ppm in 0.5 ppm step size, scan time=4:28 min. For MRS, a standard PRESS sequence was modified so that three slice selective refocusing pulses defined a volume and a frequency selective 90□ pulse specified a desired spectral region to excite (Fig. 4A). (This sequence was denoted 'PRESS with Excitation Restriction', or PRESSER.) The PRESSER sequence was intended to excite a small spectral window around the Choline (Cho) resonance frequency. As a biomarker for breast cancer, Cho is difficult to detect in healthy breast tissues. As we have yet to optimize the PRESSER sequence for Cho detection, it was used as a tool to validate the excitation profile of the SG pulse of the DWI and APT sequences *in vivo*. A sagittal volume was prescribed to match the coverage of DWI or APT sequences TE/TR=61 ms/2 s, NSA=16, scan time=34 sec. For high quality shimming, we relied on a 3D sagittal B_0 mapping method and a shim optimization software, 'shimtool'[7]. Shimming and center frequency (F0) conditions for every scan were confirmed with a preparation procedure to preview a well-shimmed water peak before making an F0 selection.

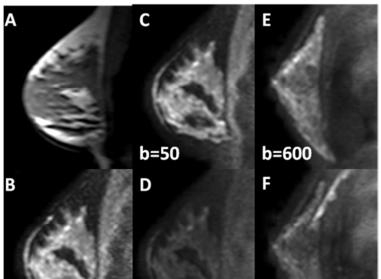

Figure 2. Survey (A) and water only DWI images (B,C,D&E). (F) Standard DWI with fat suppression

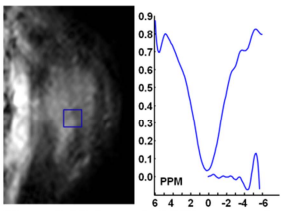

Figure 3. Water only APT image and a z-spectrum from marked ROI.

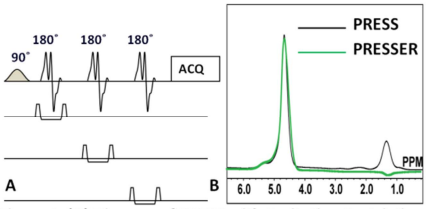

Figure 4. (A) Diagram of PRESS with Excitation Restriction (PRESSER); (B) Spectra acquired with PRESS and PRESSER.

Results: Figure 2 shows a survey image (A) and water only DWI images (B,C&D; b = 0, 50 and 600s/mm^2). Fig. 2E&F compares images of water only DWI and standard DWI with fat suppression. Figure 3 shows an M_0 image of the water only APT sequence and a z-spectrum from the marked location. Figure 4B shows a water only spectrum acquired with PRESSER and a complete spectrum acquired with PRESS.

Discussion: The heterogeneous distribution of water and fat in breast tissues could lead to poor performance of fat suppression for various MRI and MRS methods. This could contaminate quantitative measurements of water signals for MRI. For example, when DWI is used to monitor treatment response of neoadjuvent chemotherapy, the change of water ADC could be skewed by overlapping residual fat signal (Fig.2F). When asymmetry analysis is used for breast APT, unsuppressed fat signal centered around -3.4ppm (=1.3ppm-4.7ppm) in a z-spectrum could overwhelm expected APT response around +3.5ppm. As for breast MRS for Cho detection, poorly suppressed fat (and water) would be stronger than expected Cho signal by orders of magnitude. All these obstacles need to be addressed before a multi-modality breast exam can become reality in clinical practice.

Conclusion: Spectrally selective excitation was incorporated into conventional DWI and APT sequences for water only breast imaging. The selectivity of the excitation was confirmed using a similarly modified MRS sequence. These results demonstrated water only excitation as a feasible alternative to existing methods of fat suppression with a moderate increase in echo time.

References: [1] Kriege et al N. Eng. J. Med. (351): 427-437 (2004) [2] Atuegwu et al MRM 66: 1689-1696 (2011) [3] Zhou et al MRM. 50: 1120-1126 (2003) [4] Bolan et al MRM 50:1134-1143 (2003) [5] Pickles et al ISMRM 1488 (2012) [6] Zhu et al MRM 64:638-644 (2010) [7] Schär et al MRM 63:419-426 (2010) **Acknowledgments:** NCI 1U01CA142565 and NCI P30 CA68485