Breast Perfusion Imaging Using Arterial Spin Labeling

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Introduction: Malignant tumors induce high level angiogenesis [1], resulting in increased vascularity and perfusion. For breast MRI, dynamic contrast-enhanced (DCE) MRI has shown great potential to detect and characterize tumors by quantifying signal intensity changes as the contrast agent passes through tissue [2]. Arterial spin labeling (ASL) can also delineate tumors by measuring tissue perfusion through labeling arterial blood, without contrast agent administration [3]. However, due to low baseline flow and complicated breast vasculature, ASL application to breast has been hindered. In this work, we present our experience in breast ASL imaging using flow-sensitive alternating inversion recovery (FAIR) [4] with multiple inversion recovery preparation (for background suppression) [5] and 2D single-shot fast spin-echo (SSFSE) acquisition.

Methods: Arterial spin labeling was conducted by locating an inversion slab in the coronal orientation to tag mammary arterial branches, where blood largely flows in the posterior to anterior direction. For each label and control sequence, slice-selective (4 cm) and non-selective inversions, respectively, were conducted using a frequency offset corrected inversion (FOCI) pulse [6]. To reduce noise on difference images by motion or other system instabilities, static tissue was suppressed using four quadratic phase slab saturation pulses and four nonselective adiabatic inversion pulses [5]. Timing of the inversion pulses was determined to suppress both glandular tissue and fat. Acquisition was started at a certain delay time after the end of the FOCI inversion pulses using a 2D SSFSE sequence with 10 mm slice thickness, 128 × 128 imaging matrix, 9/16 partial k_y and 32 × 32 cm^2 imaging FOV. TR/TE were 6 s/50 ms for 1.5T, and 8 s/50 ms for 3T, to allow for full recovery of blood. Multiple pairs of control and label images were acquired. Perfusion data per coil was acquired after subtraction of label-control pairs and averaging the subtractions in complex *k*-space. Homodyne reconstruction was performed for each coil, and multiple coil images were combined (using estimated coil sensitivity maps from a separate reference scan) to generate the final perfusion image.

Volunteer scans were conducted at both 1.5T Excite scanner and 3T MR750 scanners (GE Healthcare, Waukesha, WI) using the eight channel phased array coil (GE Healthcare). For volunteers, different delay times between labeling and acquisition were tested to investigate blood inflow. Two patient exams were conducted at 3T by incorporating QUIPSS II [7] to provide a tag bolus of 800 ms.

Results: When comparing volunteer ASL images at 1.5T and 3T, 3T provides better SNR due to increased T1 of blood and static field magnetic strength but increased field inhomogeneity also generates artifacts, degrading sensitivity of perfusion in some regions. Figure 1 shows perfusion images from one volunteer for three different delay times of 1 s, 1.5 s and 2 s. Sixteen pairs of label-control acquisitions were averaged. Arteries, which are normally located close to the skin, were depicted well, but normal glandular tissue perfusion was hardly observed. With increasing delay times, blood signal tends to decrease due to T1 recovery, but some arteries (arrow in Fig. 1d) starts to show up late, maybe due to a long transit time. A patient ASL study from eleven pairs of acquisitions is illustrated in Fig. 2, compared with a maximum intensity projection (MIP) of the corresponding slice thickness from post-contrast images. The tumor, diagnosed as high grade invasive ductal carcinoma, was enhanced in the post-contrast image, and ASL also provides higher perfusion signal in that region than normal glandular tissue. Inflow is shown in vessels again.

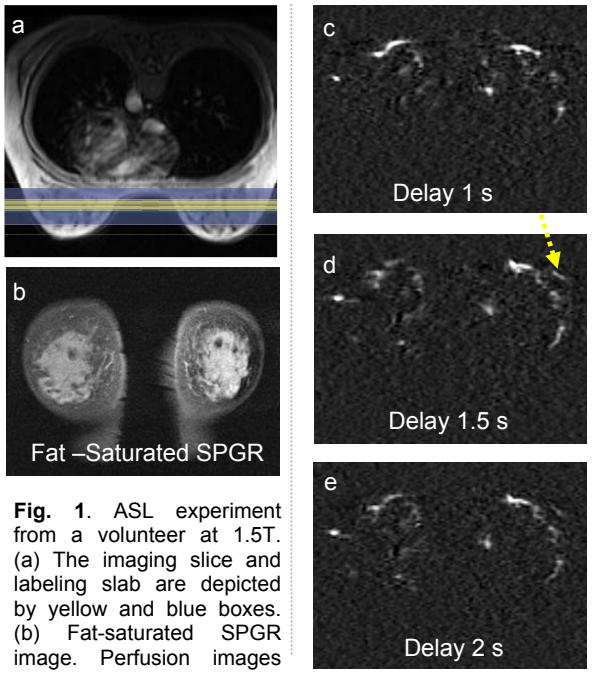

Fig. 1. ASL experiment from a volunteer at 1.5T. (a) The imaging slice and labeling slab are depicted by yellow and blue boxes. (b) Fat-saturated SPGR image. Perfusion images are shown in (c-e) for delay times of 1 s, 1.5 s and 2 s. Arteries located close to the skin are depicted well; however, perfusion in glandular tissue is hardly visible. The yellow arrow shows an artery which does not appear with 1 s delay time.

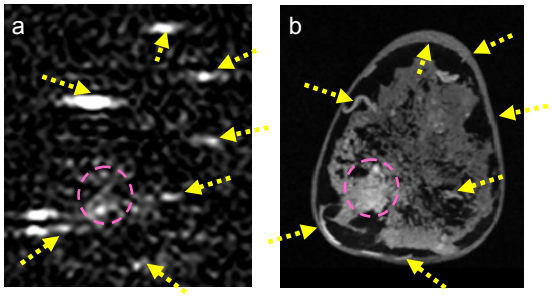

Fig. 2. Patient experiment at 3T. (a) Perfusion image from ASL sequence. (b) MIP from post-contrast T1 weighted image of water image. By ASL, high perfusion signal is measured in tumor, shown by a pink circle, that is enhanced by contrast injection. Vessels are denoted by arrows in both images.

Discussion: Applying ASL to breast MRI is challenging because of low SNR arising from low baseline flow. Furthermore, motion and large field inhomogeneity across breasts can degrade ASL images easily. However, robust background suppression methods combined with spin echo acquisition reduces degradation effects substantially and perfusion in tumors can be measured. With our preliminary results, we believe that ASL would be useful to quantify true perfusion in breast tumors, which is difficult with DCE techniques as both perfusion and vessel permeability affect signal intensity change. Our ASL result is SNR limited but improvements can be made by careful optimization of acquisition parameters.

References

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