

Spectrally selective Arterial Spin Labeling Imaging For Breast Cancer Perfusion Study

K.-L. Li¹, Y. Du², E. Proctor¹, X. Zhu¹, M. Medved³, G. Karczmar³, and N. Hylton¹

¹Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, California, United States, ²Brain Imaging Center, University of Colorado Denver School of Medicine, Aurora, Colorado, United States, ³Radiology, University of Chicago, Chicago, IL, United States

INTRODUCTION

Arterial spin labeled (ASL) MRI [1] is a non-invasive imaging method for measuring perfusion. With intrinsic tracers, the arterial spin-labeled blood, ASL-MRI can be repeatedly applied in seconds, offering great potential in breast cancer studies, especially in monitoring patients during treatment. There are only very limited studies of breast ASL-MRI [2]. One of the major limiting factors is the abundance of fat tissues in breast. Chemical shift artifacts remain after conventional fat suppression techniques, using rf selective pulses, even after subtraction, which obscure perfusion contrast between tissues when conventional ASL methods are used for breast perfusion MRI. We propose a new approach to incorporate ASL with a breast EPSI (BEPsi) [3] to evaluate perfusion in the spectrally segmented fat and other tissues. This is a feasibility study that aimed 1) to investigate whether we can improve perfusion contrast between lesions and normal tissue; 2) to better characterize tumors using spectral separated fat and water images; 3) to explore the relationship between spectra and perfusion in breast tumors.

MATERIALS AND METHODS

Three healthy female volunteers (age range 27-60 years) and three female patients (age range 31-50 years) were enrolled in this study. The MR images were acquired with a 1.5 T GE clinical system. Signal was detected by using an 8 elements phase-array breast coil (Sentinelle Vanguard System). The ASL-BEPsi consisted of two major elements: 1) ASL: A selective Shinnear Le Roux RF pulse was used that incorporated gradient cycling for arterial spin labeling of the internal mammary artery (IMA) and lateral thoracic artery (LTA). The IMA is the major supply to the breast, providing 20-95% of the total blood supply. The lateral aspect of the breast is variably supplied by the LTA. A third pre-saturation band on the ascending aorta was added for more completed labeling. 2) A 2D EPSI was followed for readout of the control or labeling MR signals with 160 phase encoding steps with a TR = 73 ms. Each echo train consisted of 52 gradient with 0.68 ms echo spacing. 316 samples were sampled for each gradient echoes. The proton FID were sampled using an 35.3 ms echo train, giving spectral resolution of 28 Hz. With 8 averages, total time for acquiring the ASL-BEPsi is 96 seconds. The EPSI readout has high spatial resolution, which is necessary for detecting small lesions in breast, such as ductal carcinoma *in situ* (DCIS). For comparison, a Gd-compounds contrast enhanced (CE)-MRI was obtained following the ASL-BEPsi as the gold standard. The CE-MRI uses gadolinium compounds (Omniscan) at a dose of 0.1 mmol per kilogram of body weight. BEPsi images before, M_0 (control), and after ASL, M (labeled) were processed separately. 3D Fourier transform with respect to two k -space axes and the evolution of FID provide a SI data set. Water and fat images were calculated from their resonance lines respectively. Relative tissue blood flow (rTBF) were obtained based on the ratio of $\Delta M/M_0$ [4]. Paired t -test was used to examine the mean differences in rTBF between tumor tissue and normal tissue for the two methods, the ASL-BEPsi and conventional ASL.

RESULTS

Figure 1 shows representative spectra from selected pixels in a 31 year-old woman with breast cancer immediately after a biopsy. The spectra before (solid line) or after (dashed line) arterial spin labeling were from a region of interest comprising mixed tissues of breast lobules and fat. Reference (control) and labeled (tagged) image at the right corner show sagittal section across the breast carcinoma.

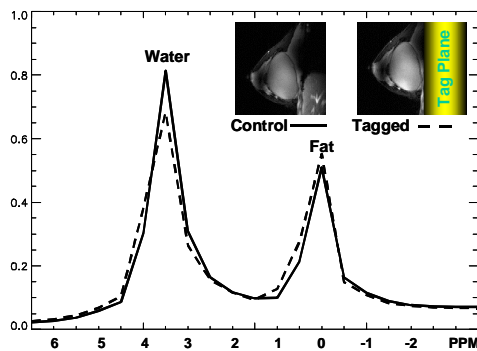


Figure 1. Representative spectra before (solid line) and after (dashed line) labeling from ASL-BEPsi series.

administration of Gd-DTPA (2d). Bottom row shows perfusion-weighted images from conventional ASL (2e) or ASL-BEPsi (2f and 2g), and Gd-DTPA enhanced image (2h). The conventional ASL image (2e) shows mainly edges of the tumor and air-breast interface (arrow head) resulting from chemical shift artifacts. In contrary, the perfusion maps generated from water spectral image, ΔM_{water} , by ASL-BEPsi technique, shows considerable enhancement in area around

Table 1. Comparison of contrast between tumors and normal

	Tumor	Normal Tissue	p values
ASL-BEPsi	5.97 ± 1.36	1.60 ± 0.92	0.08
ASL	3.87 ± 3.65	2.70 ± 2.26	0.37

in CE-MRI. Table 1 lists mean rTBF of tumors and normal tissue for the new and conventional ASL. On ASL-BEPsi the tumor was more discernible as a trend. ($P = 0.08$).

DISCUSSION AND CONCLUSION

The feasibility study shows substantial improvement in restoring perfusion contrast between cancer and normal tissues. Not only the spectrally segmented water images showed increasing blood flow in cancer focus, but also fat images showed spread of neovasculature, indicating fat infiltration of the tumor vessels. The strength of spectrally selective ASL lies in that it does not only completely separate water and fat, but also isolates specific components of the water resonance that have the largest ASL effect – representing water protons associated with blood flow. In conclusion, The EPSI approach is probably the way to do breast ASL imaging, which provides new means to assess perfusion of breast cancers, yielding potentially more accurate diagnosis and more effective monitoring of tumor vascular responses to therapy.

REFERENCES: 1. Detre JA et al, Magn Reson Med, 1992; 23:37-45. 2. Zhu DC et al, Magn Reson Med, 2003; 50:966-75. 3. Fan X et al, J Magn Reson Imaging 2006; 24:1311-15. 4. Silva AC et al, Magn Reson Med, 2000; 44:169-73. **FUNDING SOURCES:** R01 CA 059487 and R01 CA116182.

peaks of water and fat were separated despite apparent line broadening due to local B_0

inhomogeneity. The water peak shows more signal difference ($\Delta M = 12\%$) between labeled and control spectra than fat peaks in this region as expected. The primary change occurs at the center of the water resonance, with much less change in the wings of the resonance.

Figure 2 shows sagittal images across a breast carcinoma from the same woman. The left column shows conventional ASL images (the first echo images in ASL-BEPsi). The two middle columns show water (2b and 2f) and fat (2c and 2g) images from the ASL-BEPsi. The right column shows images at corresponding level from a CE-MRI. The top row shows images without labeling (2a-2c) or before administration of Gd-DTPA (2d). Bottom row shows perfusion-weighted images from conventional ASL (2e) or ASL-BEPsi (2f and 2g), and Gd-DTPA enhanced image (2h). The conventional ASL image (2e) shows mainly edges of the tumor and air-breast interface (arrow head) resulting from chemical shift artifacts. In contrary, the perfusion maps generated from water spectral image, ΔM_{water} , by ASL-BEPsi technique, shows considerable enhancement in area around

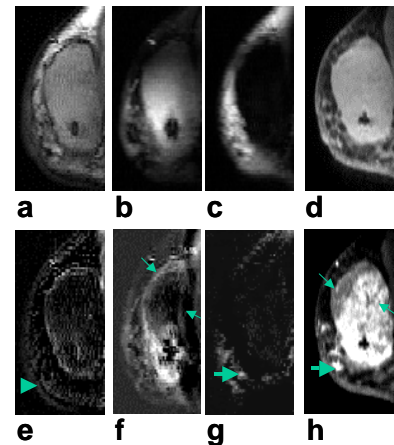


Figure 2. ASL, ASL-BEPsi images without labeling (2a-2c) and CE-MRI images or before administration of Gd compounds (2d) and perfusion-weighted (2e-2g) or Gd-DTPA enhancement after subtraction (2h).

the biopsy site. Most interestingly, tumor infiltration was revealed on the fat spectral image, ΔM_{fat} , agreed with findings from CE-MRI (arrows). The slice thickness was 10 mm in ASL-BEPsi, 2 mm