A Sodium Phased Array Breast Coil with Hydrogen Transceive

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INTRODUCTION: Breast cancer is the most common type of cancer affecting women and is a leading cause of mortality. Hundreds of thousands of new cases are diagnosed each year in the United States alone, and lifetime risk is approximately 1/8 [1]. Early diagnosis, early treatment, and early assessment of treatment can dramatically increase survival rates. While mammography is typically used to detect breast cancer, contrast-enhanced proton (^{1}H) MRI has been shown to be more sensitive [2]. Unfortunately, contrast-enhanced ^{1}H-MRI has limited specificity [3]. Physiological and biochemical changes associated with proliferating malignant breast tumors cause a significant increase in total tissue sodium (^{23}Na) concentration in malignant breast tumors as compared to unaffected glandular tissue, adipose tissue, and benign lesions [4]. Improved specificity could result in fewer unnecessary benign breast biopsies, more accurate evaluation of the extent of disease in newly discovered breast cancer, and expanded use of MRI as a screening examination for breast cancer. ^{23}Na-MRI is currently under investigation as a potential complement to contrast-enhanced ^{1}H-MRI for detection and monitoring of breast cancer.

It is commonly accepted that phased array receive coils will improve SNR for ^{1}H-MRI on typical clinical magnets (1.5T or 3T). This work presents a 5-channel ^{23}Na/single-channel ^{1}H coil configuration for ^{23}Na-MRI of the breast at 3T, and demonstrates significant improvements in ^{23}Na-SNR in the breast with a ^{23}Na phased-array when compared to a single ^{23}Na loop.

METHODS:

^{23}Na Receive Array *(Fig. 1A):* Five circular receive loops were built with 3" diameters from 16 AWG coated copper wire, and were placed on a fiberglass breast former. The loops were positioned and decoupled using standard techniques [5]. No ^{1}H decoupling was implemented.

^{23}Na Transmit Coil *(Fig. 1A):* The ^{23}Na transmit coil consisted of 5 co-axial copper loops equally spaced on a 2.25" tall, 7" diameter acrylic tube. The loops were connected at their capacitors to behave as a single-turn solenoid coil. Decoupling was achieved by placing a PIN-diode in the RF current path so that the coil was tuned when the diode was forward-biased [6], which occurs only during ^{23}Na transmission. Magnetic decoupling between the ^{1}H and ^{23}Na transmit loops was achieved by not forward-biasing the diodes, thereby creating a high resistance at the diodes.

^{1}H Transmit/Receive Coil *(Fig. 1A):* The ^{1}H transceive coil was built similarly to the ^{23}Na transmit coil, but consisted of only 2 copper loops placed co-axially about ½" apart, on the inner surface of the acrylic tube. The coil was broken up with twice as many capacitors to increase capacitor values. It was tuned only during ^{1}H transceive by forward-biasing its PIN-diode.

Single Loop ^{23}Na/^{1}H Transmit/Receive Coil *(Fig. 1B):* For comparison purposes, we repeated all scans with a coil that consisted of a single ^{1}H transceive loop and a single ^{23}Na transceive loop. The ^{1}H and ^{23}Na loops were decoupled using resonant traps. This coil was also placed over a fiberglass breast former so the breast was compressed similarly to the phased array coil.

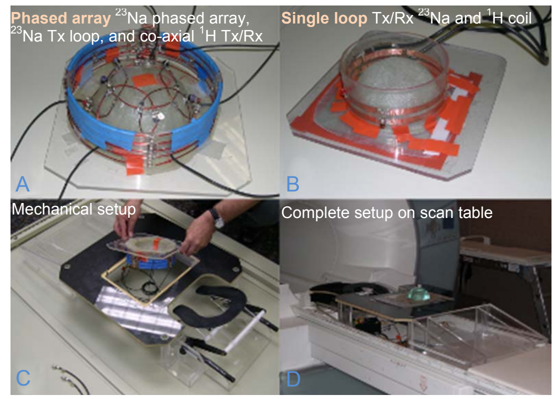

Figure 1: Images of the coils and hardware setup.

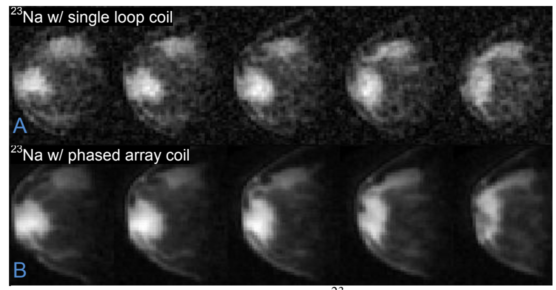

Figure 2: Different sagittal slices of ^{23}Na in the breast of a normal volunteer comparing (A) the single loop coil to (B) the phased array coil.

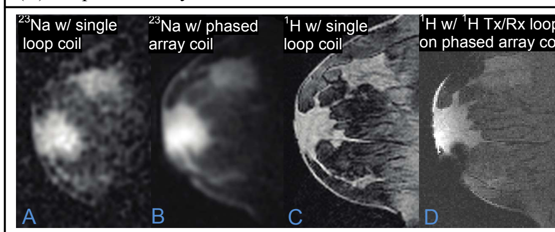

Figure 3: Sagittal slice in the breast of a normal volunteer comparing ^{23}Na with (A) the single loop coil to (B) the phased array coil to a single loop coil, and comparing ^{1}H with the ^{1}H transceive loop on (C) the single loop coil and (D) the phased array coil.

Sequence*:* To image ^{23}Na in a NaCl/$CuSO_4$ phantom and the breast of a normal volunteer, we used a fast-gradient spoiled sequence using the 3D cones k-space trajectory [7] on a Siemens Trio 3T scanner. Scan parameters were: TR/TE = 40/0.5 ms, flip angle = 70º, voxel size = 2x2x4 mm, FOV = 36 cm, averages = 20, with a total scan time of ~20 minutes. A standard GRE hydrogen acquisition was also performed at 3 echo times, and a 3-point Dixon reconstruction was used to generate fat and water fraction images. The subject was moved only when switching coils but not between ^{23}Na and ^{1}H scans.

RESULTS: A significant improvement in ^{23}Na-SNR was shown with the phased array when compared to the dual-tuned coil *(Fig. 2, 3A-B)*, with a 2.5x increase in the area of fibroglandular tissue near the nipple and a 1.5x increase in the superior area of fibroglandular tissue. Phantom images show an average double ^{23}Na-SNR increase. The ^{1}H single loop *(Fig. 3C)* outperforms the ^{1}H loop on the phased array *(Fig. 3D)*. We expect significant improvements to the ^{1}H images when the ^{23}Na phased array loops have proper ^{1}H decoupling.

ACKNOWLEDGEMENTS: Supported by NIH grants 5K08CA112449 and R01DC011497, the Ben B. and Iris M. Margolis Foundation, the Benning Foundation, BYU Fulton College of Engineering, and Siemens Health Care AG.

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