

In Vivo Breast Sodium T1 Measurements Using Inversion Recovery 3D Cones

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INTRODUCTION: Breast cancer is the most common type of cancer affecting women, and 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 MRI has been shown to be more sensitive [2]. Unfortunately, contrast-enhanced proton MRI has limited specificity [3]. Sodium MRI is currently under investigation as a potential complement to contrast-enhanced proton MRI for detection and monitoring of breast cancer. Physiological and biochemical changes associated with proliferating malignant breast tumors cause a significant increase in total tissue sodium concentration in malignant breast tumors as compared to unaffected glandular tissue, adipose tissue, and benign lesions [4]. These concentrations can be assessed using quantitative sodium MRI.

We have previously reported preliminary results for sodium T1 and T2* values in normal glandular tissue [5]. We used a fast-gradient spoiled sequence (SPGR) using the 3D cones k-space trajectory [6]. In our previous work, T1 maps were collected using DESPOT1 [7,8], and relatively large variations were observed in measured T1 values. DESPOT1 uses an SPGR sequence that holds TR constant while changing the flip angles, generating a curve characterized by T1. As such, DESPOT1 is very sensitive to errors in the flip angle, and thus accurate knowledge of the flip angle at each voxel is required for good results. In this work, we have implemented an inversion recovery (IR) T1 measurement technique with the 3D cones sodium sequence, improving the accuracy of sodium T1 measurement. We report an estimate of T1 in the glandular tissue of a healthy volunteer. We were further able to detect both the short- and long-T2 components (T2s and T2l) of the sodium signal with our sequence, and report these values in glandular tissue of the same healthy volunteer.

METHODS: A 3D cones SPGR sequence supporting an inversion-recovery preparation pulse was implemented on a Siemens Trio 3T scanner. The RF coil consisted of a single transmit/receive hydrogen loop and a single transmit/receive sodium loop surrounding the breast parallel to the chest wall. The breast of a healthy woman subject (age 36) was scanned. For T1 determination, scan parameters were: TR/TE 150/0.6 ms, voxel size = 2.5x2.5x8 mm, FOV = 40 cm, TI = 40, 50, 70, 100, and 130 ms. Total scan time per acquisition was 3.5 minutes. A simple least-squares exponential fit was performed on each voxel individually to determine voxel T1. Voxels with sodium signal at least 70% of the maximum signal were assumed to be glandular tissue, and were used to compute average T1 and a standard deviation. For purposes of illustration in Figure 2, the average signal across at each TI is plotted against the average exponential decay computed.

T2s and T2l were determined by performing a least squares bi-exponential fit to signal acquisitions performed at eight different echo times (TE = 0.6, 1.2, 2.4, 4, 6, 8, 12, and 14 ms), also using the 3D cones sodium sequence. A mono-exponential fit was also performed, but the bi-exponential model was more consistent with the data. Other relevant scan parameters were: TR = 40 ms, flip angle = 60 degrees, and total scan time of ~2 minutes per acquisition. Again, voxels with sodium signal less than 70% of the maximum signal were excluded from consideration. A standard GRE hydrogen acquisition was also performed at 3 echo times, and a 3-point Dixon reconstruction used to generate fat and water fraction images for anatomical comparison.

RESULTS: The IR sodium technique yielded a T1 value of 39.0 ± 4.8 ms in healthy glandular tissue. We obtained T2s values of 0.8 ± 0.5 ms (relative fraction of 54%), and T2l values of 21.0 ± 5.9 ms (relative fraction of 46%). Measuring T2 has potential uses in assessing diseased states, as it may change with cell density, which varies with tumors. Future work will include an assessment of how these values change in diseased tissues vs. healthy glandular tissue.

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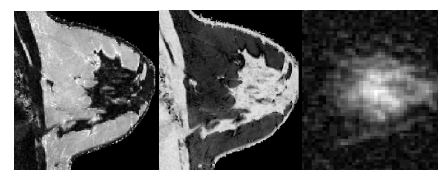


Figure 1: (a) Fat- and (b) water- fraction images obtained using 3-point Dixon on a healthy female volunteer. (c) Corresponding sodium image, showing sodium content in the glandular tissue of the breast.

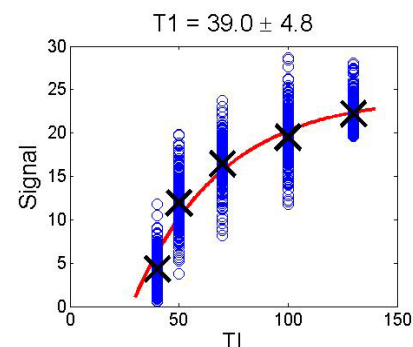


Figure 2: Experimental measurement of sodium T1 in healthy glandular tissue using inversion-recovery 3D cones sodium sequence. Although T1 was estimated on a voxel-by-voxel basis, for illustrative purposes the signals are shown with a blue O, the average signals with a black X, and the average T1 recovery curve shown with a red line.

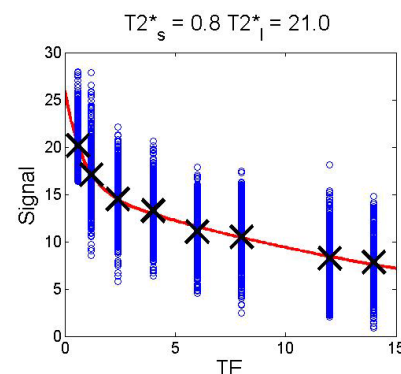


Figure 3: Experimental measurement of T2s and T2l in healthy glandular tissue using 8 echo times and a 3D cones sodium sequence. Again, signal intensities are shown with a blue O, average signal intensities with a black X, and the average bi-exponential decay curve with a red line for illustrative purposes.