Combination of Multinuclear and Multiparametric Breast MRI with ISODATA Analysis

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Introduction: Breast lesions are heterogeneous and it is unlikely that a single MR parameter can characterize a specific tissue type. By using The Iterative Self-Organizing Data Analysis Technique (ISODATA) clusters data from a multiparametric dataset of MR images, an object can be segmented based on the basis of pixel intensity values in each of the input images[1]. Clusters of pixels with similar properties are identified by statistics without a-priori knowledge and the ISODATA method iteratively tests for optimal clustering based on the distance between cluster centers (interset-Euclidean distance (IED)) and the spread of the clusters (intraset- Euclidean Distance, IAD). The quality of the resulting tissue segmentation can be gauged by cluster spread (IAD), by vector angle, and by distances between clusters (IED). The purpose of this study was to evaluate the combination of multiparametric MR (T_1, T_2, and dynamic contrast MR) and sodium ^{23}Na MR imaging together may provide a comprehensive data set that could significantly improve specificity. So that by combining these different input images into the multiparametric ISODATA vector model of breast lesion may increase specificity and improve the segmentation of different tissue types. To test this model we used the statistical data from the different tissue types from the segmented images.

Methods: Twelve patients with suspicious breast lesions (BI-RADS 4-5) were scanned with a 23Na-1H-MRI protocol on a 1.5 T MR scanner (General Electric Med. Sys. Wankesku, WI), using a phased array breast coil (MRI Devices, Milwaukee, WI) with a custom made solenoid 23Na coil insert. MRI sequences were: sagittal fat suppressed T2WI spin echo (TR/TE=5700/102) and fast spoiled gradient echo (FSPGR) T1WI (TR/TE =200/4.4) with field of view (FOV) =18x18 cm, matrix=256x192, slice thickness, 4 mm, 1mm gap). In addition, sagittal fat suppressed three dimensional FSPGR T1WI (TR/TE=20/4, matrix=512x160, slice thickness, 2 mm) pre- and post- contrast images were obtained after intravenous administration of GdDTPA contrast agent (Omniscan, Amersham Health, 0.2 mL/kg =0.1 mmol/kg + 10 sec hand injection 20 cc saline flush). 23Na images (TR/TE = 100/0.4 ms) were acquired using adiabatic excitation with twisted projection imaging in 12min for a 0.2 ml voxel size[2-3]. An embedded coil phantom with 150 mM NaCl served as fiducial marker. Total scan time for the entire protocol is less than 45 minutes. Tissue types were defined using ISODATA with and without 23NA sodium MR [2,3]. ISODATA tissue clusters were tested for similarity using the inner product between tissue signature vectors, intraset- Euclidean (IAD) and interset-Euclidean (IED) distances are calculated between pixel vectors and cluster centers. The IED is defined as the distance between cluster centers The IAD is defined as the variance of each tissue cluster. The differences in different MR data set were evaluated using paired t-tests. Statistical significance was set at $p<0.05$.

Results: The tissue segmentation was essentially unaltered in all cases except for small changes in the number of independent tissue types identified by the algorithm by the inclusion of the sodium data for individual cases as shown in Figure 1. No significant changes in the number of tissue types were noted, however, there was better definition of the tissue types. Moreover, areas of increased sodium were noted. The multiparametric vector angle difference between lesion and adipose or between glandular tissue and adipose was not altered. The IED between lesion and adipose and between glandular and adipose was not significantly altered. Figure 2 illustrates that the spread of the clusters, expressed as IAD decreased significantly. The IAD for glandular tissue decreased by 7.5%, $p<0.045$, the IAD for lesions decreased by 10% $p<0.004$ (in paired t-tests N=12)

Conclusion: With ISODATA analysis we have seen evidence that 23Na MRI adds valuable information to the breast MRI exam. The decrease in the IAD, results in "tighter" clusters and provides better delineation between fatty, glandular, and lesion tissue. This better separation of tissue types maybe in part due to the low in sodium concentration in fat than other tissues. However, it may be possible to discern different or malignant phenotypes because of the different concentrations of sodium in glandular and lesion tissue. This report provides a basis for further exploration of this important concept. In addition, incorporating functional MR (sodium) may be used for monitoring the response to treatment. However, future studies are needed to better assess the impact of including sodium into the "diagnostic" MR imaging of the breast[4].

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References: [1] Jacobs MA, et al, Radiology 2003;229(1):225-232. [2]Ouwerkerk R. et al. 2005 JMRI 21(5) p546-55. [3] Boada FE, et al,Magn Reson Med 1997;37(5):706-715. [4]Schnall MD, et al,Radiology 2006;238(1):42-53.

Figure 1. A-H) ISODATA maps of four patients with suspicious lesions comprised of 1H-MRI data alone (A-D) and 1H-plus 23Na MRI data (E-F) The red area in image E is high in sodium.

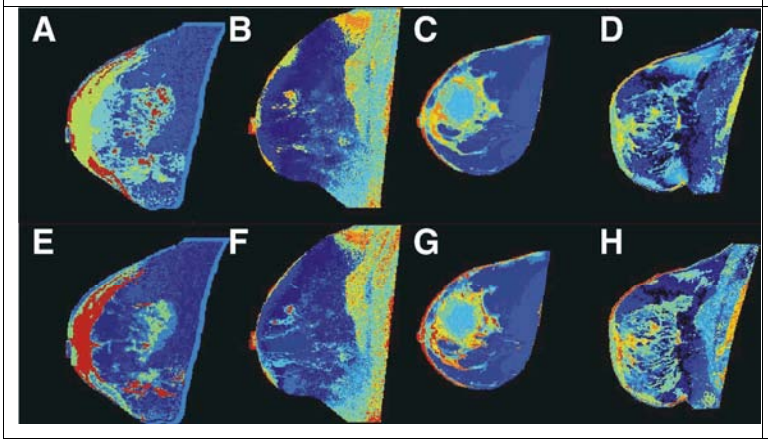

Figure 2. The IAD decrease as a result of adding 23Na data to the ISODATA analysis.