T_1 Mapping of Human Breast Tissue using T_1, T_2 and PD Weighted MRI Images at 3T

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Purpose: Spin lattice relaxation time constant (T_1) is an important intrinsic tissue parameter in MRI data. In addition, this parameter is required during quantitative analysis, particularly during dynamic contrast enhanced (DCE)-MRI data analysis. Quantitative data analysis plays an important role in breast cancer diagnosis as well as monitoring treatment responses. There are number of methods available for T_1 estimation, particularly inversion recovery (1), multiple flip angles (2), and look-locker(3) are widely used. However, these methods require acquisition of additional MRI data. B_1 inhomogeneity at 3T is another source of error in T_1 estimation, particularly for flip angle based method(4). Previously, another fast method based upon only three conventionally acquired T_1, T_2 and PD weighted images was presented for brain MRI data at 1.5T(5). Objective of the current study was to evaluate the feasibility of T_1 mapping using same approach in the breast tissue at 3T MRI.

Materials and Methods: All the MRI experiments were performed at 3T whole body Inginia MRI system (Philips Healthcare, The Netherlands) using a 7 channel biopsy compatible breast coil. Six female subjects, one normal and five with breast cancer, were scanned for MRI data. After a localizer, T_1, T_2 and PD weighted (W) images, with and without fat saturation were acquired using turbo spin echo pulse sequence. Fat saturation was based upon two-point DIXON method. Multiple slices, covering entire breast tissue with slice thickness of 3 mm were acquired for all three data types. For PD-W and T_2-W images echo train length (ETL) of 20 and for T_1-W images ETL of 5 was used. FOV = 338 *338 mm^2 and matrix size = 512 * 512 were used. For PD-W, TR of 2974 ms and TE of 30 ms was used. For T_2-W, TR of 2974 ms and TE of 100 ms was used. For T_1-W, TR of 603 ms and TE of 10 ms was used.

Data Processing: Pre-processing was performed on PD, T_2 and T_1 W images for background noise removal followed by automatic segmentation of breast tissue. Estimation of T_1 was performed using previously described method (5), implemented using in-house written programs and 'lsqnonlin' routine in MATLAB. As described previously (5), three independent TSE images (S1, S2, S3) result in a system of three nonlinear equations in T_1, T_2 and the product K.ρ (ρ is proton density and K is a constant factor): $Sj = K.\rho.exp(-TEj/T_2).(1-exp(-TRj/T_1))$, where j = 1, 2, 3. Elimination of K.ρ and T_2 from the above system of equations reduces it to a single nonlinear equation for T_1, the solution of which results in T_1 estimation. In this study S1, S2 and S3 are PD-W, T_2-W and T_1-W images respectively. Region of interest (ROI) analysis was performed on computed T_1 maps, with and without fat saturation.

Results and Discussion: Conventional T_1, T_2 and PD weighted MR images of human breast, without fat saturation, along with computed T_1 map are shown in **Figure 1**. T_1 values for ROIs in the fibro-glandular and fat tissue (**Fig 1A**) were ***1121±132 and 326±22 ms respectively***. These values are similar to the previously reported T_1 values in the breast tissue measured using IR based method (6). Data corresponding to fat saturation are shown in **Figure 2.** As expected T_1 values increased after fat saturation, particularly in fatty tissues depending upon amount of fat present in tissue. Another comparison of T_1 estimation for data with and without fat saturation is shown in **Figure 3**. For data with fat saturation, T_1 values in fatty tissue showed a large variations (Fig. 3C) depending upon the amount of fat present in the tissue. This may be due to the fact that SNR of breast tissue containing fat was reduced substantially after fat saturation, depending upon amount of fat. For the tissues having dominant fat contribution, low SNR after fat saturation might have introduced some error in T_1 estimation. However, for tissues of interest, particularly cancerous tissue (ROI pointed by white arrow in Fig 3) T_1 values for data without and with fat saturation were similar (***1055 and 1079 ms respectively***). Homogeneity of the T_1 maps for data without fat saturation, particularly in fatty tissues, indicates that T_1 estimation in the current study is less sensitive to B_1 inhomogeneity. Further studies will be performed to systematically evaluate the effect of B_1 inhomogeneity on T_1 estimation and a comparison with other T_1 estimation methods.

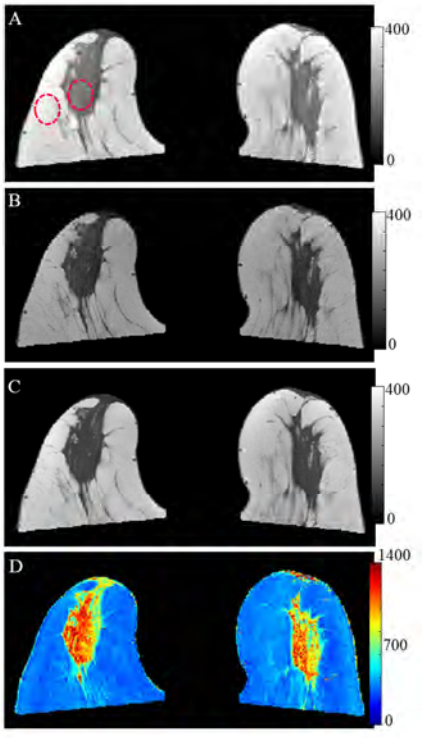

Figure 1: PD (A), T_2 (B) and T_1 (C) weighted MR images, without fat sat, of breast tissue. All images are cropped and segmented. Computed T1 map (ms) is shown in last row (D).

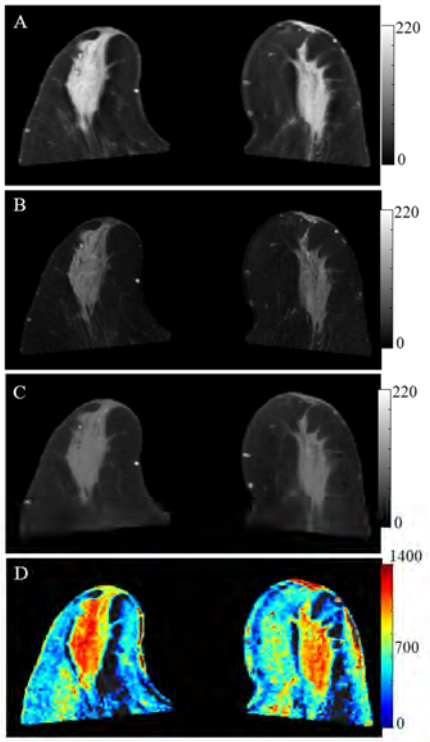

Figure 2: PD (A), T_2 (B) and T1 (C) weighted MR images, with fat sat, of breast tissue. All images are cropped and segmented. Computed T1 map (ms) is shown in last row (D).

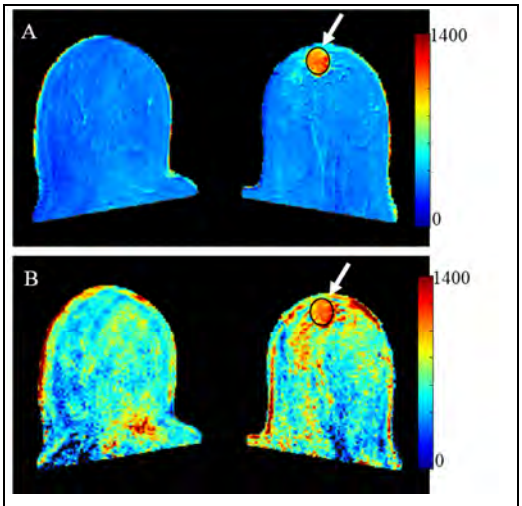

Figure 3: Computed T1 maps (ms) of breast tissue without fat saturation (A) and with fat saturation (B) for a breast cancer patient. Image were cropped and segmented. White arrow points to encircled cancerous tissue.

Conclusion: In conclusion, results of the current study show that absolute T_1 values of human breast tissue can be computed using a simple method based on conventional T_1, T_2 and PD weighted MRI images, which are routinely acquired on clinical MRI scanners.

References: [1] Crawley and Henkelman, MRM 1988; [2] Fram et al., MRI 1987; [3] Kay and Henkelman, MRM 1991; [4] Sung K, et al., JMRI 2014; [5] Singh A, et al. JMRI 2007. [6] Rebecca RP, et al., JMRI 2006.