BILATERAL IN VIVO MAPPING OF SODIUM RELAXATION TIMES IN BREASTS AT 7T

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TARGET AUDIENCE: Radiologists and physicists interested in sodium relaxation times in breast.

PURPOSE: MRI has become a powerful tool for breast cancer detection. High resolution MRI, dynamic contrast-enhanced MRI or diffusion-weighted imaging showed high sensitivity for lesion detection. However, these methods detect mainly morphological changes. Additional information on cellular physiology and metabolism can be provided by sodium MRI. Since sodium concentration is known to increase in malignant lesions when compared to healthy tissue [1], sodium MRI may be able to improve specificity of evaluation of breast lesions. The knowledge of sodium relaxation times in breast is essential for optimizing imaging parameters and for the quantification of the tissue sodium concentration. Only one study reports sodium T1 and T2* values in breast calculated by monoexponential fitting [2]. However, sodium motion in tissue is restricted and exhibits biexponential T2* decay. Therefore the aim of this study was to map sodium T1 and T2* relaxation times as well as fast (T2*f) and slow (T2*s) component of the biexponential T2* relaxation of glandular tissue in breast.

METHODS: This study was approved by local ethics committee. Both breasts of four healthy females (age: 24-37 years) were measured at 7T whole body system (Magnetom, Siemens Healthcare, Erlangen, Germany). All images were acquired with a double-resonant proton/sodium bilateral phased array breast coil having 2 transmit and 14 receive elements for sodium imaging (Quality Electrodynamics, Mayfield Village, OH, USA). For morphological proton imaging, the gradient echo with k-space undersampling and data sharing time-resolved angiography with stochastic trajectories (TWIST) sequence was recorded with following parameters: TR/TE= 5.6/2.79 ms, resolution of $1.7\times1.7\times1.8$ mm^3, FOV= 330 mm, 8° flip angle, 300 Hz/pixel bandwidth and acquisition time of 27 seconds. For mapping sodium T1 relaxation times, inversion recovery (IR) method using density-adapted 3D radial projection reconstruction (DA-3DRP) pulse sequence was employed [3]. Five measurements with different inversion times were acquired with the following parameters: TIs= 3, 15, 30, 60, 120 ms; TR= 250ms, TE= 0.8 ms, 2600 projections, FOV= 300 mm, nominal resolution of $6.6\times6.6\times6.6$ mm^3, bandwidth of 100 Hz/pix and acquisition time of 11 to 16 minutes. To enable the biexponential evaluation of sodium T2* relaxation, five multiecho (ME) DA-3DRP sequences with four TEs each (resulting in 20 TEs) were recorded with following parameters: TEs= 0.4, 0.6, 1, 2, 5, 10, 12,…, 50 ms; TR= 65 ms, 9000 projections, FOV= 300 mm, nominal resolution of $5.77\times5.77\times5.77$ mm^3, bandwidth of 115 Hz/pix and acquisition time of 9:45 minutes.

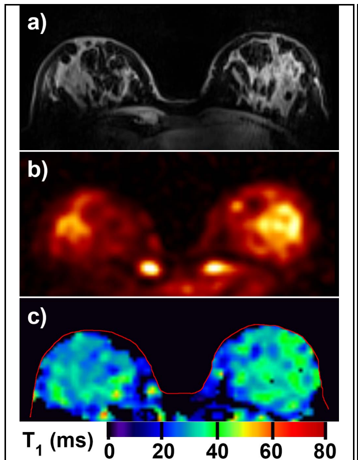

Fig.1: a) Morphological TWIST image, b) color-coded sodium image (TI= 120ms), and c) sodium T1 map.

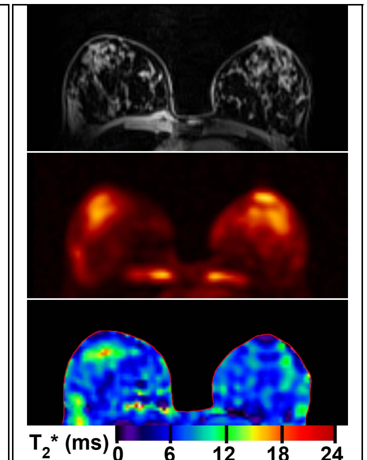

Fig.2: a) Morphological TWIST image, b) color-coded sodium image (TE= 0.4ms), and c) T2* map.

The T1 and T2* maps (Fig.1,2) were calculated by fitting the sodium signal evolution monoexponentially on a pixel-by-pixel basis using a least squares fitting routine with three parameters respectively written in IDL (Research Systems Inc, Boulder, CO, USA) (Fig. 3). One fitted parameter used in fitting of IR data compensated for the variation of flip angle within the coil volume. For calculation of T2*f and T2*s maps, the bi-exponential decay of sodium signal was fitted using the IDL routine with five parameters (Fig. 4). The same ME data were used for monoexponential and for biexponential analyses of sodium T2* relaxation. Measure of goodness-of-fit (R^2) map was calculated for all relaxation maps to enable evaluation of the fitting precision. In each volunteer, five slices of relaxation maps were evaluated using JiveX (VISUS GmbH, Bochum, Germany). All regions-of-interest (ROI) were drawn on glandular tissue in TWIST images and subsequently transferred to corresponding relaxation and R^2 maps. Both breasts of each volunteer were evaluated, totaling to 40 ROIs for all relaxation parameters. All statistical analyses were performed in SPSS (SPSS Institute, Chicago, IL, USA). A paired t-test was used to compare R^2 values between monoexponential and biexponential T2* analysis.

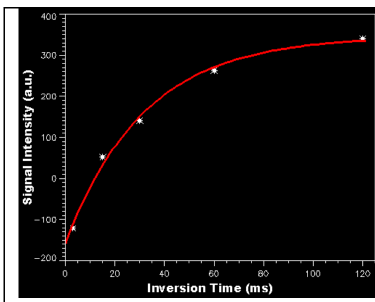

Fig.3: T1 fit of sodium signal from an arbitrary pixel (T1= 31.8ms, R^2= 0.995).

RESULTS: The mean sodium T1 in glandular tissue of volunteers was 32±3 ms. The T1 values were fitted with high mean precision of R^2= 0.994. Monoexponential analysis of ME data resulted in mean T2*= 11±2 ms and mean R^2= 0.969. Biexponential analysis of ME data brought mean T2*f= 0.54±0.15 ms, mean T2*s= 17±4 ms and mean R^2= 0.992. Fast component comprised 53% and slow component 47% of total signal respectively. Biexponential analysis resulted in significantly higher R^2 values compared to monoexponential fitting ($p<0.005$) (Fig. 4).

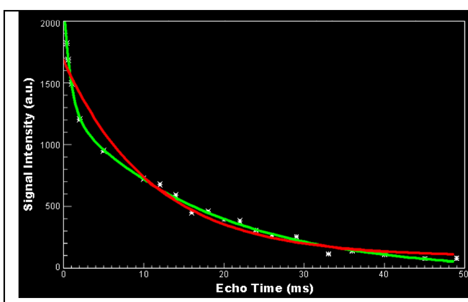

Fig.4: Comparison of monoexponential (red curve, T2*= 11.1ms, R^2= 0.975) and biexponential (green curve, T2*f = 0.8ms (42%) T2*s = 18.0ms (58%), R^2= 0.998) T2* fit of sodium signal from 1 pixel.

DISCUSSION: Our results demonstrate bilateral *in vivo* measurements of sodium relaxation times in breast with good resolution in feasible times at 7T. Our T1 and T2* values are in good agreement with previous findings of Staroswiecki et al., who reported T1 values between 35 and 50 ms and T2* values between 12 and 25 ms in breast of healthy volunteers [2]. However, previous T2* evaluation at 3T was limited by shortest TE of 1 ms that hinder biexponential T2* analysis. Presented T2* results underline advantage of techniques, such as DA-3DRP, that allow to acquire sodium signal with TE< 0.6 ms and thus provide images with higher intrinsic SNR.

CONCLUSION: To our best knowledge, this is the first report on biexponential analysis of sodium T2* times in the glandular tissue of breast *in vivo*. Presented results may provide basis for more accurate quantification of sodium concentration in breast and could help to optimize sequences for sodium MRI of breast. Since sodium seems to be a promising method for the noninvasive evaluation of breast lesions, we are planning to apply presented protocols for the evaluation of sodium relaxation times in patients with breast lesions.

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