Quantitative Sodium Imaging of Breast Tumors at 7 Tesla: preliminary results

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Target Audience: Scientists specializing in breast MRI

Introduction/Purpose:

Tissue sodium concentration (TSC) is a biomarker for disease specific changes in tumor tissue such as angiogenesis and cellular proliferation. Proliferating cells have higher TSC then healthy, which is elevated as a result of altered Na^+/H^+ transport kinetics and pH[1]. Therefore, TSC could be considered as a sensitive biomarker that provides non-invasive information on the changes in cellular integrity/viability through changes in intracellular sodium concentration and/or extracellular volume. Up-to-date, MRI enabled successful evaluations of morphological and micro-structural alterations in breast lesions using contrast enhanced (CE) and diffusion weighted (DW)-MRI[2]. The biochemical changes that precede these changes can be imaged using sodium imaging (^{23}Na-MRI). This makes TSC quantification an interesting biomarker for cancer assessment and treatment monitoring. The aim of this study was to investigate the clinical feasibility of quantitative high-resolution ^{23}Na-MRI in breast tumor patients at 7.0 T.

Subjects and Methods:

Phantom and *in vivo* measurements were performed on a 7.0 T MRI scanner (Siemens, Erlangen, Germany) with a bilateral dual tuned ^{1}H/^{23}Na phased array breast coil (14 ^{23}Na receive channels). Three healthy volunteers and 18 female patients (age 55±7 years, mean±SD) with 20 histologically verified breast lesions (15 malignant and 5 benign) were recruited. Institutional Review Board (IRB) approval and written informed consent were obtained prior the measurements. The mean size for malignant lesions was 32±6 mm and for benign 13±7 mm. An ultrashort echo-time sequence, acquisition weighted stack of spirals (AWSOS) was applied for data acquisition[3]. Optimization of sequence parameters and estimation of image homogeneity was performed in phantom measurements. A sinc pulse of 0.8 ms duration was used to excite a transversal 64 mm thick slab (16 slices, with 4 mm slice thickness) with repetition/echo time (TR/TE) = 90/0.5 ms and flip angle 85º. *In vivo* data were obtained with a FoV of 320×320 mm with a 208×208 matrix and 45 spiral interleaves. In order to minimize possible inaccuracies, B_0 and B_1^+ field homogeneity were measured. Repeatability tests were performed on healthy subjects. Absolute quantification was performed using 2% acrylic phantoms (matching T2* and T1 relaxation times with healthy breast glandular tissue) with seven different sodium concentrations (15.4; 30.8; 46.2; 61.6; 77.0; 92.4; 154.0 mM) and were used for calibration. Regions of interest (ROIs) were drawn in all lesions and in the contralateral healthy glandular tissue to investigate differences in TSC. ^{23}Na concentrations were measured via linear calibration based on pixel signal intensity[4]. Sodium concentrations of different breast tissue were statistically analyzed (Paired – Samples T test; SPSS16; Chicago, IL, USA).

Results:

^{23}Na images obtained with the AWSOS sequence showed excellent distinction between benign and malignant breast tissue and morpohogical correlation with T1w images (Fig. 1). No data had to be excluded from the study. Repeatability measurements performed on healthy subjects showed no significant differences in SNR between successive measurements and between left/right coil elements (CI=95%, p=0.025). Field mapping showed B_0 inhomogeneity under 45 Hz and B_1^+ field on each side (±10%) as well between right/left coil elements (±10%). At nominal resolution 1.5 mm, mean calculated sodium concentration for fibroglandular tissue was (28.8±7.8) mmol/l and adipose tissue (15.5±9.2) mmol/l. For breast lesions mean TSC was statistically different for malignant (55.2±7.2) mmol/l then for benign lesions (37.4±8.1) mmol/l (CI=95%, p<0.005). Measured TSC value in malignant lesion was for 40% higher then in benign lesions.
Fig. 2. shows TSC distribution for four different tissue types and for all patients.

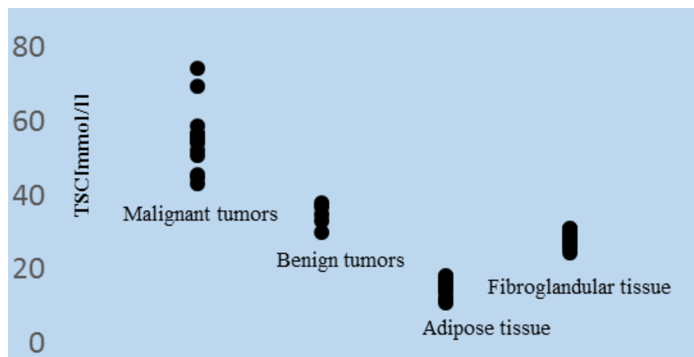

Fig.2: Graphical presentation of our results shows good differentiation of tissue types (malignant, benign, adipose and fibroglandular) based on measured TSC.

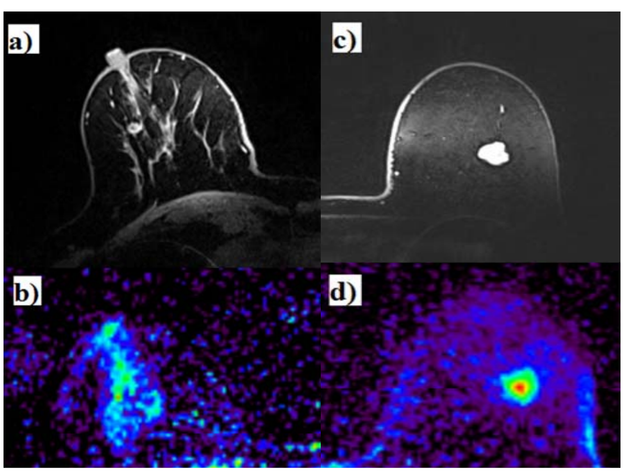

Fig. 1: T1w and sodium image obtained in patient with fibroadenoma (a, b) and breast carcinoma (c, d) showed good correlation between tissue structures and high signal intensity in malignant tumors.

Discussion/Conclusion:

Our work presents first clinical experience of quantitative sodium imaging in patients with breast lesions on a 7.0 T. High image quality and reproducibility were achieved. The generated B0 and $B1^+$ maps showed good field homogeneity and were excluded as a potential sources of errors. Obtained results showed excellent differentiation between malignant and benign tumors based on TSC, and showed good correlation with literature data[5].
At 7.0 T, sodium imaging of the breast with 1.5 mm in plane resolution and clinically feasible imaging time provided good image quality leading to excellent differentiation of benign and malignant breast lesions. In combination with other ^{1}H MRI techniques, ^{23}Na may become an attractive tool for the investigations of breast tumors.

References:

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