BOLD MRI of the Kidneys under water loading at 7 Tesla using parallel Transmission and RF Shimming of individual slices

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Introduction

Renal oxygenation is an important parameter of the total renal function. Recently, BOLD MRI of the kidneys has been proposed to determine renal oxygenation through the measurement of the changes of R_2^* during water loading [1]. So far, renal BOLD MRI has only been applied at clinical field strengths up to 3T [2]; however, it is expected that the BOLD effect becomes more sensitive at higher field strengths thus facilitating R_2^* measurements in the kidney. Compared to 3T, abdominal imaging at 7T is challenging due to SAR constraints, RF inhomogeneity and, the lack of a body resonator for RF transmission. In this work we report first preliminary results of renal BOLD MRI at 7T using a dedicated parallel transmission coil setup.

Materials and Methods

For renal BOLD MRI at 7T a dedicated 8Tx/32Rx RF coil (QED, Mayfield Village, OH) was used [3]. The coil consists of an anterior and a posterior part, each being equipped with 4 parallel Tx strip lines in head-foot-direction and 16 Rx loop coils arranged in a 4x4 array. The coil was connected to a 7T MR system (Siemens Healthcare, Erlangen, Germany) equipped with an 8-channel pTx console (Step 2). For the BOLD measurements the coil halves were placed at the level of the kidneys on 4 healthy volunteers. The B_1^+ profile of each individual slice was shimmed using magnitude least square algorithm [4] to increase the B_1^+ homogeneity at kidney region. For R_2^* mapping 3 coronal slices of a multi-echo 2D FLASH sequence were placed through the kidneys using the following imaging parameters: TR=96-ms, 10 echoes at TE = 2, 6.6, … 29.1 ms, matrix = 256×256 mm³, slice thickness = 6 mm, FOV = 256 mm. Images were acquired in a breathhold (TA = 24 s).

For one volunteer we additionally measured R_2^* in transverse slice orientation to identify which orientation provides a better result. For comparison and to validate the sequence, one volunteer was measured at 3 Tesla using an 8Rx abdominal coil and similar scan parameters: TR = 118 ms, TE = 4.9, 7.5, … 33 ms, TA = 21.9 s. All volunteers were instructed not to drink or eat at least one hour before the measurement and in the MR system they had to drink normal tap water (up to 750 ml) rapidly after baseline measurements. R_2^* measurements were acquired before and immediately after drinking, and were repeated up to 50 min after the water loading.

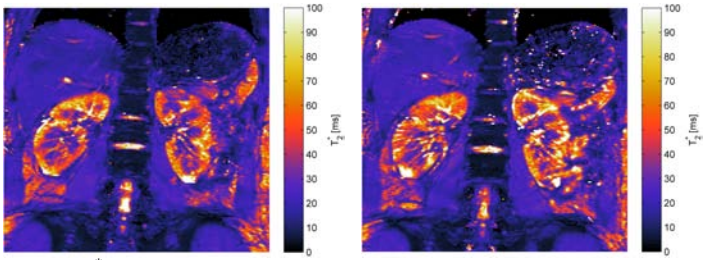

Fig.1: T_2^* maps acquired at 3T before (left) and 3½ min after drinking water (right). Volunteer: 52kg, drank 700 ml of water within 3min.

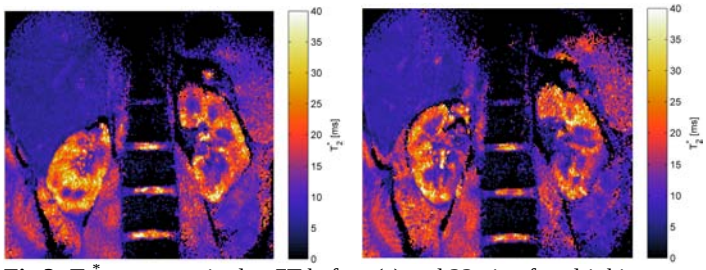

Fig.2: T_2^* maps acquired at 7T before (a) and 22min after drinking water (b). Volunteer: 72kg, drank 700 ml of water within 3min.

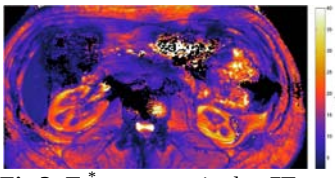

Fig.3: T_2^* maps acquired at 7T before drinking in transversal orientation.

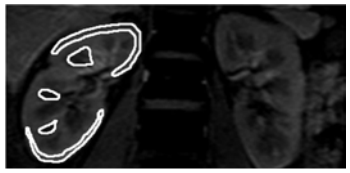

Fig.4: Typical cortical and medullar ROIs for calculating R_2^* values.

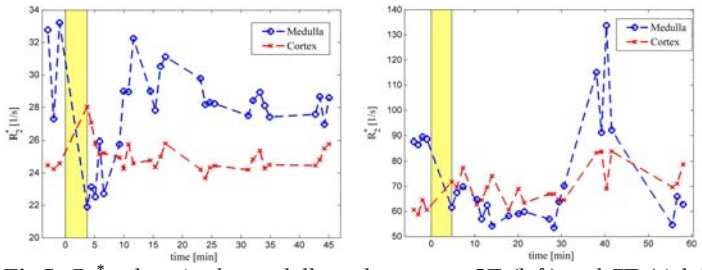

Fig.5: R_2^* values in the medulla and cortex at 3T (left) and 7T (right) during water challenge dependent on time. The yellow region represents the time of water loading.

Results and Discussion

B_1^+ shimming increased the homogeneity at kidney region by more than 30%. Figures 1 and 2 show coronal T_2^* maps at 3T and 7T before and after drinking of tap water. The liver, stomach, and both kidneys are well visualized, and the T_2^* change in the renal calyx system is visible at both field strengths. To calculate R_2^* time courses, ROIs were placed in the renal medulla and cortex (Fig. 4). For every experiment we computed the mean over the three kidney slices and plated the resulting R_2^* data versus time (Fig. 5). After the water challenge a reduction of R_2^* by about $\Delta R_2^* = 7s^{-1}$ is seen at 3T for about 5min, after which it returns to the baseline value of $29s^{-1}$. In the cortex, almost no R_2^* changes are observed (baseline $R_2^* = 25s^{-1}$). At 7T, R_2^* values in the medulla are reduced from a baseline of $90s^{-1}$ to $60s^{-1}$ during activation of about 25 min and a nearly constant cortical R_2^* of about $69s^{-1}$ was found. In Fig. 3 one transversal slice of the kidney region is shown as T_2^* map measured at 7T before drinking water. In this orientation, it was difficult to extract the medulla regions in the images after drinking.

In this work we present that it is possible to measure R_2^* of the kidneys under water loading at 7T. The measurements at 7T show that a stronger R_2^* change is seen both at baseline and during water loading which facilitates the detection of the R_2^* changes. Furthermore, a maximum T_2^* of 25 ms was observed at 7T which allows choosing a shorter echo train and, thus, reduces the total acquisition time. The breath hold times of 25 s were acceptable for all volunteers, but might need to be shortened for some patients. Motion correction of the kidneys between acquisitions would further improve the quality of the results, as currently only small regions in the medulla and the cortex can be used for evaluation.

References: [1] Magn Reson Imaging Clin N Am. 2008;16(4):613-viii. [2] Kidney Int. 2006;70(1): 139-143. [3] Darji et al. ISMRM 2013 #4403. [4] Setsompop, K. Magn. Reson. Med. 2008, 59, 908-915.

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