Using T2/T2* - contrast to characterize kidney function during a waterload examination: Initial results at 3 Tesla

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Introduction

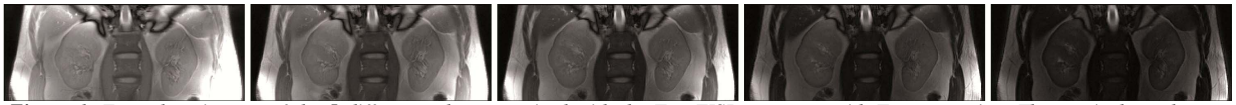

Figure 1. *Exemplary images of the 5 different echoes acquired with the TrueFISP sequence with T_2 preparation. The particular echoes were acquired at TE = 0/20/40/80/160 ms.*

The renal blood oxygenation level dependent (BOLD) examination [1] is an approach to assess the function of the kidneys without the use of an endogenous contrast agent. Considering the oxygen supply, the medulla operates at a likewise poor oxygenation whereas the blood flow in the cortex delivers an excess of oxygen to the cortical tissue. Especially the maintenance of the osmotic gradient requires a large amount of oxygen. Therefore, the assessment of the intra-renal oxygenation is crucial for the pathophysiology in acute [2] and chronic [3] hypoxia cases. Perturbations in the renal blood supply are caused by stenosis, occlusion or small vessel lesions like atherosclerosis and vasculitis and can lead to acute renal failure. Especially renal hypoxia [4] is known to initiate and enforce chronic kidney disease. However, the assessment of renal oxygenation proves difficult since the measurement of the local transversal relaxation time T_2^* is prone to image distortions and most measurement techniques produce results which are too inaccurate to compute changes in the local T_2^* time. Furthermore, recent studies show that the local oxygenation changes measured with T_2^*-weighted sequences do not reflect kidney function [5]. Here, we present an approach to measure the transversal relaxation time T_2 to characterize kidney function during a water charge examination.

Materials and Methods

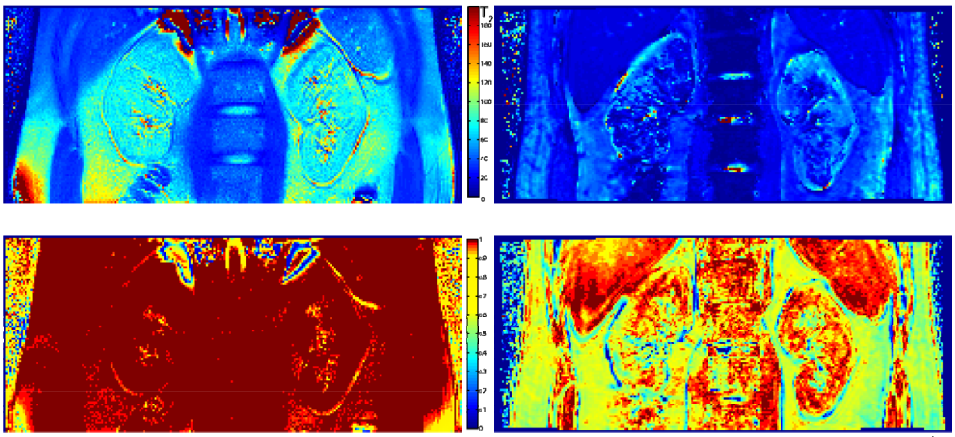

Figure 2. *Parameter maps of one exemplary volunteer after the water charge:* ***Upper row:*** *T_2- (left) and T_2^* (right) maps.* ***Lower row:*** *Corresponding adjusted R^2 maps.*

Sequence: Each examination included a standard 3D FLASH measurement to acquire T_2^* data and a True FISP measurement with a preceding T_2 preparation [6]. The T_2 preparation consists of a $90_x°$ rectangular excitation pulse which flips the magnetization on the transversal plane where it is subject to relaxation. The magnetization is refocused by an MLEV-4 composite pulse train. After the refocusing pulses a $90_{-x}°$ tip-up pulse flips the magnetization back on the longitudinal axis. The strength of the T_2 weighting can be varied by changing the preparation time. After the $90_{-x}°$ tip-up pulse a spoiler dephases remaining transverse magnetization. TE = 0 was achieved by omitting the preparation module. Images were acquired with a matrix size of 96x240 and a subsequent resolution of 1.6 mm in-plane and a slice thickness of 5 mm for both sequences. Eight echoes with TE between 3.3 ms and 21.1 ms were acquired for each time point with the FLASH-sequence. For the TrueFISP, repetition time was set to 4.3 ms and data were acquired from 5 different echo times [0/20/40/80/160 ms] as shown in Fig. 1. T_{acq} for one image amounted to approximately one second.

Measurements: Two healthy volunteers (both male) were included in our pilot study with an average age of 31 years. Every subject had to undergo a 10h diet without any food or drink intake prior to the examinations to maximize the effect. The pre-waterload measurement was performed before a standardized break of 5 minutes in which each subject drank 1.0 litre of water while remaining in the head first supine position in the scanner to preserve geometric conformity. After this break, six post measurements followed the waterload in intervals of 5 minutes. The whole study was performed on a Siemens 3T Magnetom Skyra (Siemens Healthcare, Erlangen, Germany). Each measurement was acquired in one breathhold.

Post-processing: T_2- and T_2^*-maps were created by fitting the monoexponential relaxation equation pixelwise to the acquired data. To assess fit quality, goodness of fit maps were created using the adjusted R^2 parameter. Three regions of interest (ROI) were drawn in the cortex of each kidney and data were averaged creating the time curves shown in Fig. 3 for each volunteer. By supplementing the selected relaxation time values with their goodness of fit, it was assured that only values over a threshold of 0.9 of the corresponding goodness of fit value were taken into account.

Results

Fig. 2 shows the calculated T_2 and T_2^* maps and the corresponding adjusted R^2 maps for the measurements directly after the water charge. The upper row depicts the very homogeneous T_2 map (left) and the corresponding T_2^* map. In contrast to comparable T_2^* maps, the T_2 maps show a more uniform distribution of the T_2 values. The fit error maps in the lower row also show a better fit quality in the T_2 examinations. N.b., the colormap for the fit errors was selected in a way that values below the threshold of 0.9 are coded in yellow or blue. Fig. 3 illustrates the time curves acquired with the ROI-readout for each measurement time point (1 pre, 6 successive post measurements) for each volunteer. Especially the rise in the T_2 time from the pre to the first post measurement is clearly outlined, whereas the T_2^*- measurements are marked by a large variety. Since the rise in the T_2^*- relaxation time induced by the water charge is well inside the overlapping error range the measurement of the effect is ambiguous. The average value in the cortical tissue of Volunteer 1 (2) starts with $T_{2,\,pre}$ = 62.2±1.9 ms (60.0±1.9 ms) and rises up to a peak of $T_{2,\,post2}$ = 78.9±1.7 ms ($T_{2,\,post1}$ = 68.6±3.8 ms).

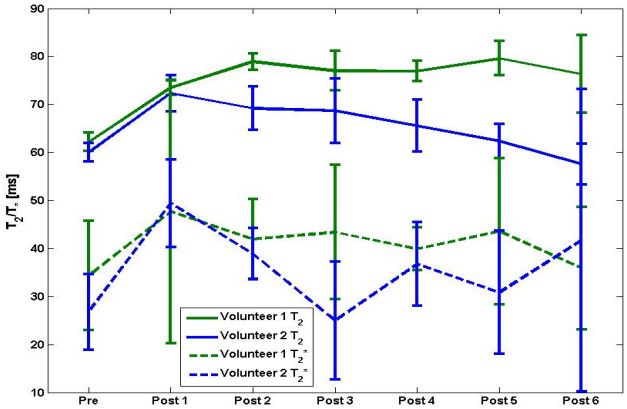

Figure 3. *Time curves of the two examined volunteers. Each volunteer showed a significant increase in the relaxation times after the oral administration of one liter of water.*

Discussion

Signal changes in the renal cortex triggered by the water intake could be sufficiently followed acquiring 5 echoes with the T_2-prepared TrueFISP sequence. Results showed very homogeneous parametric maps, allowing for the measurement of the relatively small effect in the cortical tissue. A future study with more subjects is scheduled to verify the initial results. In conclusion, the presented T_2-MRI is feasible. In contrast to conventional T_2^*-BOLD-techniques, the T_2 measurement produces more consistent and reliable results characterizing kidney function during a waterload experiment.

References
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