Study of Kidney SWI under Oxygenation Variation after Water Uptake - Initial Results

M. B. Mie[1], F. G. Zoellner[1], and L. R. Schad[1]
[1]Computer Assisted Clinical Medicine, Heidelberg University, Mannheim, Germany

Introduction:
Susceptibility weighted imaging (SWI) is a well established technique for brain imaging [1]. It can not only be used for imaging multiple sclerosis [2], stroke and hemorrhagic lesions [3], but is also a useful tool to visualize venous structures with diameters in the submillimeter range [4]. In the kidney, there are many diseases that may lead to an impaired function particularly longstanding diabetes mellitus, renal artery stenosis but also acute and chronic rejection after renal transplantation [5]. This is the reason why knowledge about the vessel structure and the degree of oxygenation is of great interest. SWI has not been established for renal imaging yet, but offers a valuable tool for abdominal measurements. Although it has recently been shown, that SWI is applicable to the abdomen [6], the technique is still in its infancy. Since SWI is based on the usage of blood as an intrinsic marker of blood oxygenation, it is very interesting to investigate the effect of an induced increase of blood flow, resulting in a higher blood oxygenation level dependent (BOLD) contrast. In this study, the higher kidney function and the accompanying higher blood flow are realized by water uptake. Images have been acquired before and after water uptake in constant time intervals. A quantitative comparison of the state before and after water uptake is possible by contrast-to-noise ratio (CNR) calculation.

Methods:
The well established imaging sequence parameters of brain measurements could not be used in the abdomen due to a long acquisition time. Some modifications compared to the brain measurement have to be made [6]. The used imaging sequence was a T2*-weighted 3D FLASH. To reduce scan time to allow for breath-hold acquisition, parallel imaging (GRAPPA acceleration factor 3, reference lines: 24) and phase and slice partial Fourier (6/8) were applied. Other imaging parameters were: TE/TR/FA=20ms/28ms/15°, matrix size=256x256, FoV= 231x231mm^2, slice thickness=1.8mm, BW=120Hz/Px, slices per slab=24, TA=28s. The measurements were performed on a 3T Siemens Magnetom Skyra (Siemens, Erlangen, Germany) using a 18 channel phased-array body coil. For data processing, a positive phase mask with a slope of $2/\pi$ and a multiplication factor m=4 has been applied. Because of the difficulties of renal imaging due to respiratory and bulk movement, a pixel-by-pixel analysis is not possible. Nevertheless, this problem can be solved by choosing a distinct vein in the kidney and investigate the variation of time of the signal contrast between this vein and the kidney cortex over the time.

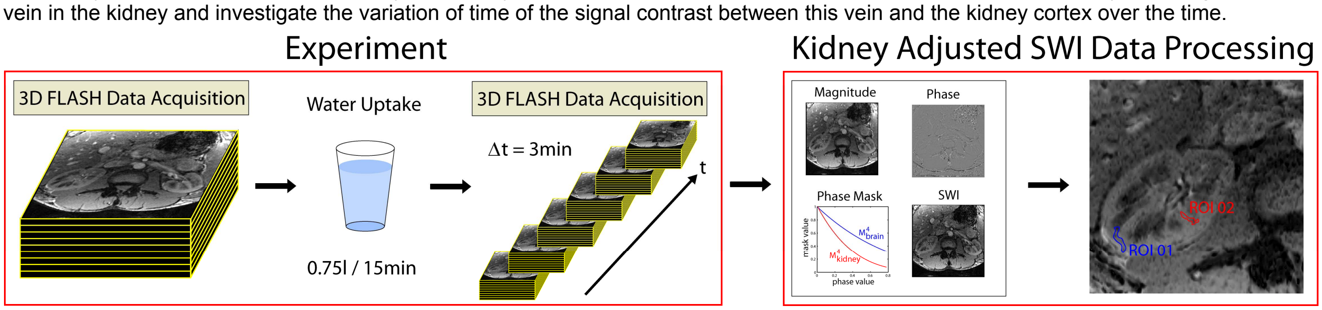
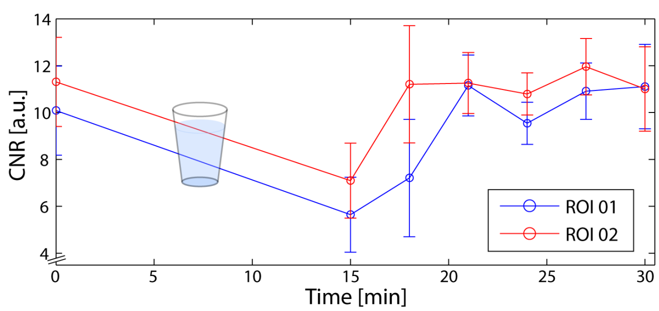


Figure 1. *Data acquisition and post processing. The experiment consists of multiple 3D FLASH acquisitions, one before and six after 15 minutes water uptake. The time interval between the post-water-uptake measurements was 3 minutes. For SWI, kidney adjusted data post processing with adjusted phase mask has been applied [6].*

Results:
Figure 2 shows the CNR results for two different regions of interest (ROIs) in the kidney, each representing an area of a venous structure. It can be observed, that for both ROIs the susceptibility weighted contrast first decreases and then increases again. This effect can be visualized by kidney SWI post processing.



t [min]	CNR_{01}	CNR_{02}
0	10.1±1.9	11.3±1.4
15	5.6±1.6	7.2±2.6
18	7.2±2.5	11.2±2.0
21	11.2±1.3	11.3±2.1
24	9.6±0.9	10.8±1.0
27	10.9±1.2	12.0±1.9
30	11.1±1.8	11.0±2.2

Figure 2. *CNR variation in time. During water uptake the CNR decreases and increases again. The absolute CNR value depends strongly on the choice of the ROIs.*

Discussion:
First results of abdominal SWI are very promising. The observable effect of kidney oxygen consumption can be measured by SWI analysis. In contrast to experiments were the blood flow is reduced and the SWI contrast has been increased [7], the opposite effect can be observed. This signal behaviour comes up to the expectations, whereas the blood flow is increased due to a higher oxygen consumption, resulting in a lower vessel contrast. After a certain time interval, the CNR increases, until the kidney has reached its equilibrium oxygenation state. Other studies showed that water diuresis led to a local T2* increase in the renal medulla [8]. This study could demonstrate the sensitivity of SWI to a higher blood flow induced by an increase of the kidney function. The relative contrast change could visualize the response of the veins due to a higher organ function. It has to be taken into account that a temporal signal variation of a region, that is affected by respiratory or bulk motion, is very difficult to observe. Moreover, the high oxygenation of the kidney in the resting state [9] makes SWI of this organ very difficult. In conclusion, the effect of the change of the oxygenation of the kidney is detectable by the SWI contrast.

References:
[1] Haacke EM et al. *Magn Reson Med* 52 (3): 612–618 (2004)
[2] Tan IL et al. *Am. J. Neuroradiol.* 21 (6): 1039–1042 (2000)
[3] Hermier M et al. *Stroke* 35 (8): 1989–1994 (2004)
[4] Reichenbach JR et al. *Radiology* 204 (1): 272–277 (1997)
[5] Schoenberg SO et al. *Der Radiologe* 37(8): 651-62 (1997)
[6] Mie MB et al. *Z Med Phys* 20: 143-150 (2010)
[7] Sedlacik J et al. *Neuroimage* 40: 11–18 (2008)
[8] Nissen JC et al. *Z Med Phys* 20: 88-100 (2010)
[9] Vaupel P et al. *Cancer Res.* 49(23): 6449-65 (1989)