Susceptibility Weighted Imaging (SWI) of the Kidney at 3T – Initial Results

M. Mie[1], J. C. Nissen[2], F. G. Zöllner[1], M. Heilmann[1], H. J. Michaely[2], S. O. Schönberg[2], and L. R. Schad[1]
[1]Department of Computer Assisted Clinical Medicine, Heidelberg University, Mannheim, Germany, [2]Institute of Clinical Radiology and Nuclear Medicine, Heidelberg University, Mannheim, Germany

Introduction:

The kidney is important for the control of the blood pressure as well as for the homeostasis by selectively excreting or retaining various substances [1]. There are many diseases leading to an impaired function of the kidney particularly longstanding diabetes mellitus, renal artery stenosis but also acute and chronic rejection after renal transplantation [2]. Magnetic resonance imaging is a tool in the diagnostic work-up of kidney diseases also allowing for assessment of the organ function. The susceptibility differences in the kidney can be represented in susceptibility weighted imaging (SWI) by using phase imaging in addition to the magnitude imaging [3]. Usually, SWI is performed in imaging of the cerebrum, primarily in enhancing the venous vessels, but also in strokes, hemorrhages and cerebral tumours [4]. Implementation of SWI on the kidney requires different problems to be solved: Respiratory and bulk motion due to peristaltics leading to pronounced artifacts and require acquisition time as short as possible. On the other hand, the kidney shows a different oxygen consumption with a higher oxygen fraction in the venous vessel system than in the cerebral veins. Thus, the susceptibility difference between the venous vessels and the surrounding tissue is not as pronounced as in the brain. The aim of this work was to implement SWI on the kidney assuming that through variation of the phase mask small susceptibility difference might be fostered.

Methods:

In a first step a comparison between abdominal and brain images has been performed with well established imaging parameters (TE/TR/FA=20ms/28ms/15°, slice thickness=1.5mm, FoV=162.5x200mm^2, matrix size=260x320, BW=120Hz/px, slices per slab=56, TA=9 min). To transfer this imaging protocol to abdominal imaging several parameters had to be adapted to reduce motion artifacts in the image and therefore, allowing for breath-hold acquisition. To reduce scan time, parallel imaging (GRAPPA acceleration factor 2) and partial Fourier-imaging (6/8) were applied, resulting in a total scan time of TA=67s. In addition, to even more shorten the acquisition time, the field of view (FoV) was kept as small as possible covering one kidney and avoiding infolding artifacts. Other important imaging parameters (TE, FA) were kept constant. In summary, the abdominal SWI protocol comprises the following parameters: TE/TR/FA=20ms/28ms/15°, slice thickness=1.8mm, FoV=220x220mm², matrix size=256x256, BW=120Hz/px, slices per slab=52, TA=67s.

Results:

Figure 1 shows that there are larger phase changes in the brain (Fig. 1a) than in the kidney data (Fig. 1b), because of a lower oxygen extraction fraction (OEF) in the kidney (0.08-0.1, [5]) than in the brain (white matter 0.25-0.35, gray matter 0.45-0.5, [5]). The corresponding abdominal magnitude image and the resulting SW image can be seen in Figures 2a and 2b. The SW contrast enhanced abdominal images created with the standard (brain) phase mask were of poor image quality, as hardly any obvious and visually detectable contrast enhancement was observed. It is either useful to change the phase mask, or to increase the number of multiplications *n* with the phase mask *M*. In this work, both possibilities were investigated. At first, different mask multiplications (*n*=4, *n*=8) were compared. Fig. 2b and 2c show the different weighted SW images. It can be observed that a higher number of multiplications visually increases the contrast in the image. Next, we created a new phase mask altering the slope of the previously used mask. The given corresponding magnitude image and SW images are shown in Figure 2a and 2d. The SW image shows some areas where venous structures can be seen. To evaluate the contrast enhancement by our new post-processing, we calculated the contrast-to-noise ratio (CNR) in carefully selected regions-of-interest. The CNR of the original post-processing was 15.31, whereas for the higher number of multiplications a CNR of 24.13 was obtained. The modified phase mask leads to almost the same value. Small black lines enhanced by the phase mask could be identified and interpreted as small renal veins.

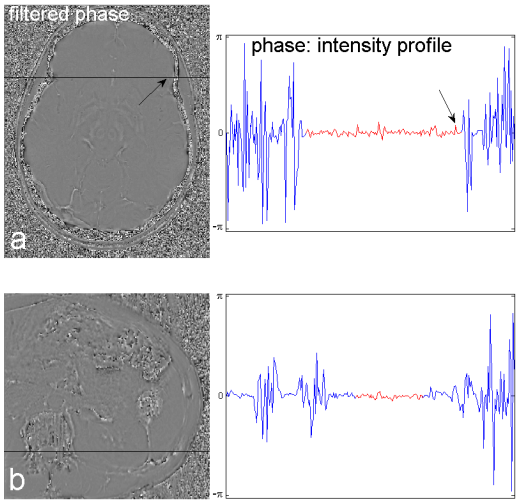

Figure 1: *(a) Filtered phase image of the brain (left) and corresponding phase values along the black line. The red part of the plot shows the phase values of the brain. The arrow marks a venous vessel (b) Filtered phase image and phase values of the abdomen. The red part of the curve shows the phase values of the left kidney.*

Discussion:

CNR analysis showed that within the kidney structures an increase in contrast of a factor 1.5 could be obtained.The acquisition time of 67s may be acceptable for certain healthy volunteers and was sufficient for the aim of this pilot study but of course is not clinically feasible. The acquisition time must be further shortened to allow for breath-hold examinations in patients, or navigator or trigging techniques must be implemented to reduce motion artifacts in images at longer scan times. In summary, the results represent initial experiences with the SWI for abdominal imaging which proof the principal feasibility. However, further research has do be performed to make this technology applicable in clinical abdominal MRI.

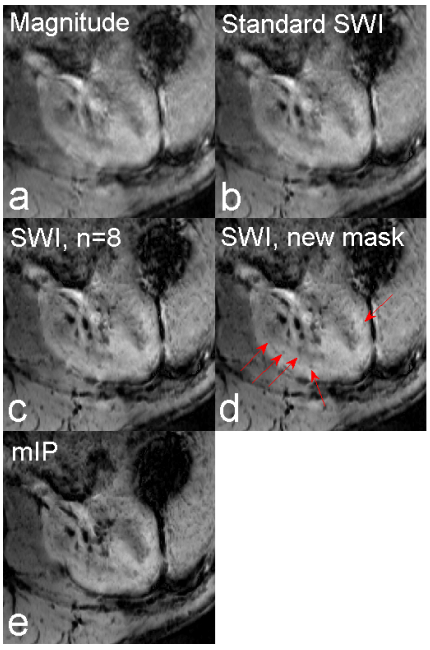

Figure 2: *(a) Magnitude image and (b) corresponding SW image reconstructed with standard phase mask using n=4, (c) n=8 and (d) modified phase mask with n=4. The red arrows mark the spots where venous structures can be seen. (e) Minimum intensity projection (mIP) of 3 slices.*

References:

[1] Schoenberg et al. *Der Radiologe*, 37(8):651-62 (1997) [2] Michaely et al. *Der Radiologe*, 48(2):185-200; (2008), [3] Haacke et al. *Magn Reson Med.*, 52(3):612-8 (2004), [4] Barth et al. *Invest Radiol.*, 38(7):409-14 (2003), [5] Vaupel et al. *Cancer Res.*, 1;49(23):6449-65 (1989)