

Feasibility of In-vivo Quantitative Susceptibility Mapping (QSM) in the Kidneys

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Introduction: Quantitative susceptibility mapping (QSM) offers a novel anatomical contrast proportional to the underlying susceptibility of the tissue (1,2). The majority of the QSM applications have been in the brain as a result of the lengthy 3D multi-echo gradient echo (mGRE) acquisition. In this study, we have implemented a cross-pair prospective navigator technique to allow 3D mGRE acquisition of the kidney during free-breathing.

Methods: The cross-pair navigator consists of a pair of selective 90° and 180° radio frequency (RF) pulses resulting in a 1-D spin-echo projection. Only spins in the intersecting region of the two RF pulses (Figure 1a), excited by the 90° and refocused with the 180° RF, contribute to the navigator signal. The navigator was positioned over the right hemidiaphragm (Figure 1b). Special precautions were taken to prevent the RF planar slabs from intersecting the kidneys. The data collection and navigator acquisition occurred within the same TR. Only data collected within the user-specified acceptance window was used in the final reconstruction. An example of a 20 sec navigator profile is shown in Figure 1c. The navigator parameters were: field of view = 400mm, acceptance window = 4mm, search window = 30mm, RF band thickness = 10mm.

Data were acquired in 5 healthy volunteers with the approval from our institutional review board. All experiments were performed on a 3T MRI system (MAGNETOM Verio, Siemens Healthcare, Erlangen, Germany) equipped with high performance gradient coils (45 mT/m maximum gradient strength, 200 mT/m/ms slew rate). The body and spine phased array coil were used for data acquisition.

The QSM acquisition was performed using a 3D T2*-weighted, multi-echo spoiled gradient echo sequence. The imaging volume was positioned in the oblique coronal plane to fully cover both kidneys. Eight echoes were acquired with even spacing. The imaging parameters were: TE [min, max] = [4.03, 22.99] ms; TR = 78 ms; flip angle = 15°; bandwidth = 781 Hz/Pixel; field of view = 360 mm, acquisition matrix = 256x256; slice thickness = 2.5 mm; number of slab encodings = 24 - 32; iPAT = 2; 6/8 Partial Fourier along the slab encoding direction. The scan time ranged from 5.9 to 8.3 minutes depending on the subject's respiratory pattern. The QSM images were reconstructed offline using a morphology-enabled dipole inversion (MEDI) algorithm (3).

Results: A representative single slice from the data in a healthy male volunteer (age of 50) is illustrated in Figure 2: a) magnitude image at TE = 9.69ms showing cortico-medullary contrast; b) calculated local field map (4); c) QSM reconstruction; d) R2* map; e) QSM overlaid on top of the magnitude image; f) R2* map overlaid on top of the magnitude image. Susceptibility and R2* values were spatially well correlated in the kidney and both values were higher in the renal medulla than cortex. The averaged susceptibility value was -0.04 ± 0.02 ppm in the renal cortex, and 0.09 ± 0.03 ppm in the renal medulla.

Conclusions: We have demonstrated the preliminary feasibility of obtaining QSM maps of the kidney using a prospective navigator-gated approach. Different susceptibility values were observed consistent with the renal anatomy. Further studies are warranted to demonstrate whether the source of the susceptibility difference between renal medulla and cortex is related to local blood oxygenation (BOLD effect). The following limitations should be noted. The mGRE sequence was not flow-compensated and artifacts were apparent around renal arteries. Regions with strong off-resonance effects and/or affected by the residual bowel motion can significantly degrade image quality.

Reference: 1) Shmueli et al. Magn Reson Med. 2009. 2) Rochefort et al. Magn Reson Med. 2010. 3) Liu et al. Magn Reson Med. 2011. 4) Liu et al. NMR Biomed. 2011.

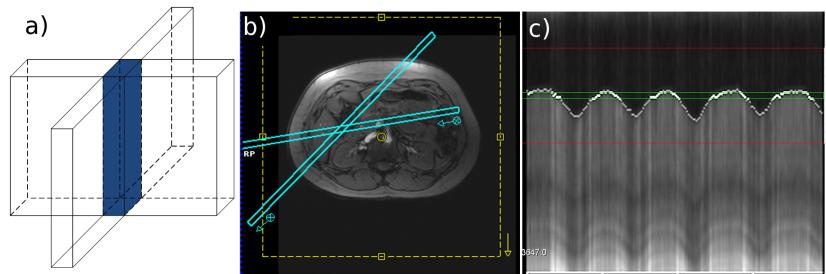


Figure 1. a) cross-pair navigator RF illustrations. b) navigator position. c) a 20-second navigator profile.

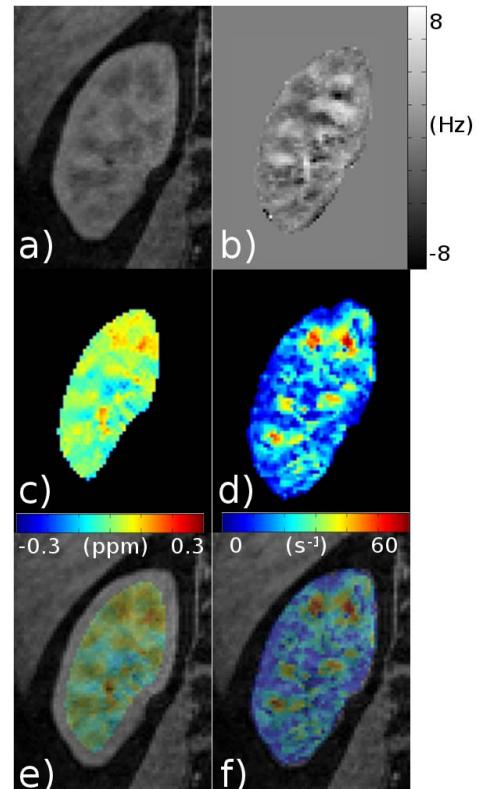


Figure 2. Renal QSM results.