Imaging the Kidneys at 7T using 8Tx/32Rx Abdominal Coil and RF Shimming of Individual Slices

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Introduction and Purpose

Abdominal MRI at field strengths up to 3 Tesla is used in many clinical applications including MR angiography of the arterial vasculature or tumor and metastasis screening. In particular, functional imaging of the kidney has evolved into a clinical tool by combining the assessment of renal artery patency with functional measurements of the renal parenchyma [1]. Recently, the BOLD contrast has been utilized to measure renal filtration non-invasively [2], a technique that is especially suited for high-field MRI at 7 T or higher due to the field-strength dependency of the parameter T2*.

However, imaging human subjects at 7 T is challenging due to SAR constraints, RF inhomogeneity and, in the abdomen, due to the lack of body resonators for RF transmission. Therefore, dedicated local transmit (Tx) coils are necessary. In addition, RF inhomogeneity can be effectively addressed using parallel transmission (pTx) techniques [3]. This pilot study is using a novel 8Tx/32Rx coil to compare RF shimming with individual RF shim settings for each slice to a quasi-CP mode to improve renal MRI at 7 T.

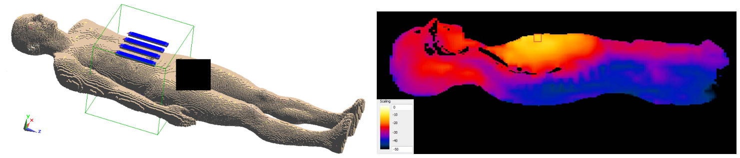

Fig.1: Voxel model of virtual human and placement of anterior transmit elements (left). Local SAR distribution of a single Tx element, 10 cm³ average (right).

Methods

For abdominal MRI at 7T, an 8Tx/32Rx RF coil (QED, Mayfield Village, OH) was used, consisting of an anterior and a posterior part. Each part comprises 4 parallel strip line Tx elements oriented in head-foot-direction, and 16 Rx coils in loop design, arranged in a 4x4 array.

The coil was modeled in SEMCAD X (Schmid & Partner Engineering AG, Zürich, Switzerland) with in-plane resolution of ≤ 0.5 mm and ≤ 2 mm in z-direction, together with the whole body virtual human Duke (Virtual Family [4], IT'IS Foundation) with ≤ 3 mm isotropic resolution (Fig. 1 left). The local SAR for each element was simulated and averaged over 10 cm³ (Fig. 1 right). The coil was connected to a 7T MR system equipped with an 8-channel pTx console (Siemens Healthcare, Erlangen, Germany). For volunteer imaging, the coil halves were placed at the level of the kidneys and coronal B1-maps were acquired [5] using a pre-saturated TurboFLASH sequence [6] with TR=5000 ms/TE=1.9 ms. A magnitude least squares algorithm was used to calculate amplitude and phase of individual transmit channels [7]. Homogeneity was assessed for acquired B_1^+ maps using mean magnitude distance (standard deviation) from flat target profile. A 2D FLASH sequence was applied with TR=50 ms and 12 echoes at TE=2.27, 4.99, …, 32.19 ms, from which T2* maps were calculated by fitting a mono-exponential decay to the data, after thresholding at 3% signal level and smoothing with a Gaussian kernel.

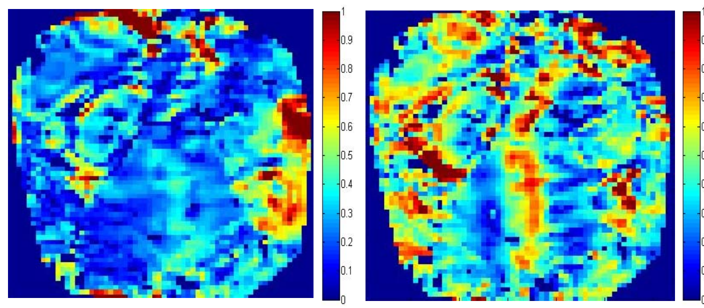

Fig. 2: Measured combined B_1^+ maps of different shimming methods: CP mode (left) and RF shim (right).

Results

Imposing the IEC limits of 10 W/kg maximum local SAR, a power limit of 0.15 W per channel (10 s) and 0.30 W (6 min) per channel were obtained assuming a worst-case electric field superposition. Fig. 2 depicts the CP mode (left) and RF shimmed (right) experimentally combined B_1^+ maps. Standard deviation of RF shimmed B_1^+ map was 40% less compared to CP shimmed B_1^+.Fig 3 shows one coronal slice containing the kidneys, comparing the different RF shim settings at identical image scaling. RF shimming improves the image quality, which is most notable in the spine. The T2* maps (Fig. 4) also reflect the more homogeneous signal distribution for the RF shim, as is again visible in the spine region. Also, a better differentiation of T2* values in renal medulla and cortex is seen for the RF shimmed excitation.

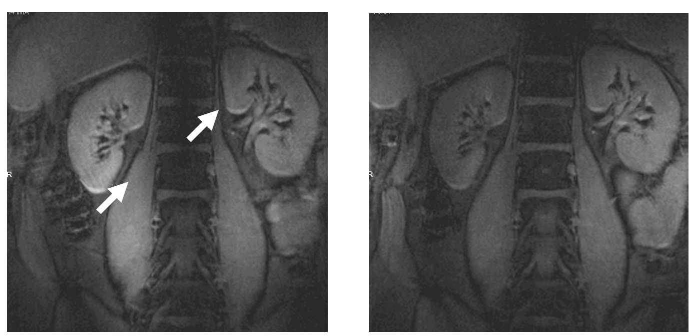

Fig. 3: Comparison of different coil operation modes: CP mode (left, hyper- and hypointense regions marked by arrows), and RF shim (right)

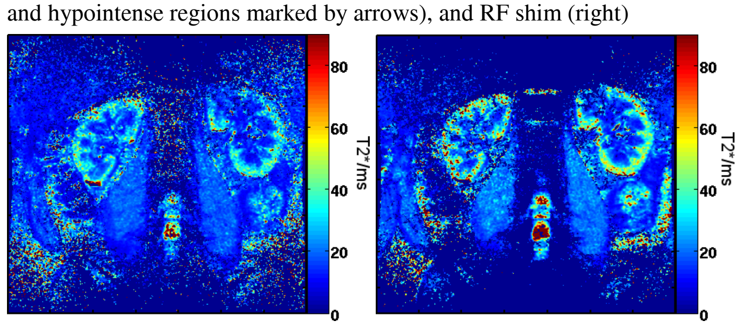

Fig. 4: T2* maps CP mode (left), RF shim (right).

Conclusion

B1 field inhomogeneity at 7T can be reduced in abdominal imaging by varying the phase and amplitude of individual channels of the 8Tx/32Rx RF coil.

References:- [1] Michaely HJ et al., Invest Radiol 2004;39(11):698. [2] Li LP et al., Magn Reson Imag Clin N Am 2008;16(4):613, viii. [3] Ibrahim TS et al., Magn Reson Imag 2001;19 (10):1339.[4] Christ A et al., Phys Med Biol 2010;55, N23. [5] Curtis AT et al., Magn Reson Med 2012;68:1109. [6] Fautz HP et al., Proc ISMRM 2008; p1247. [7] Setsompop K et al., Magn Reson Med 2008;59:908.

Acknowledgments:-Support in the implementation of the SAR calculations by the QED team (H. Fujita and M. Finnerty) is gratefully acknowledged. The study was supported by the (INUMAC) project (BMBF grant 13N9208 and 01 EQ0605).