in vivo T1ρ Study on Human Kidney

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Introduction: In biological tissues, the T1ρ relaxation rate, which is sensitive to the spin-lattice relaxation in the rotating frame, may reflect contributions from multiple interactions, such as dipole-dipole, chemical exchange and scalar coupling. Although T1ρ imaging has been successfully applied to the characterization of various neurological diseases (Alzheimer's, Parkinson's (1), brain tumor (2), cerebral ischemia (3), myocardial metabolism (4), and knee cartilage degradation (5), T1ρ imaging has not been used to study kidney function or disease. Kidney is crucial for water filtration (to remove metabolic waste) and re-absorption (to conserve water by urine concentration). In particular, active tubular re-absorption in renal medulla demands high oxygen consumption, as shown by renal BOLD MRI measurements (6). Since T1ρ is sensitive to the tissue compositions and interactions, and unaffected by field inhomogeneities created by the blood within the microvasculature, it may provide complementary information on renal function. In this study, we have developed a T1ρ sequence to generate kidney T1ρ maps on healthy human volunteers, and compared them with conventional renal T1, T2 and T2* maps.

Methods: All experiments were performed on 3T Siemens Trio scanner using a body transmit RF coil and spine/body matrix coils. Five studies were conducted on healthy volunteer subjects. Previously reported T1ρ preparation technique (4) was further modified to minimize sensitivity to both B0 and B1 field inhomogeneities. Instead of utilizing a single non-selective 180 degree refocusing RF pulse, two refocusing pulses were employed, as shown in Fig. 1. Each 180 degree pulse was configured with composite refocusing pulses to further reduce artifacts from B0 and B1 imperfection. The time of spin-lock (TSL) value varied from 10 to 120 msec. In one study, renal T1ρ dispersion curve was acquired with spin-lock B1 ranging from 2 μT to 12 μT. Since no significant difference was found with use of B1 higher than 8 μT, B1 was set at 8 μT (350 Hz). MR parameters for True-FISP single shot data acquisition were: FOV of 320x320 mm^2; slice thickness of 8 mm; in plane resolution of 1.7x1.7 mm^2; TR of 4.5 s; TE of 1.43 ms; and centric reordering, acquisition time of 3 mins with 40 repetitions. In the scanning session, subjects were instructed to conduct short timed breath holding (about 1 sec) during each image acquisition stage.

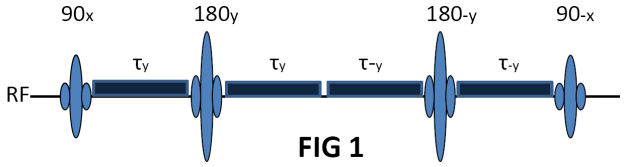
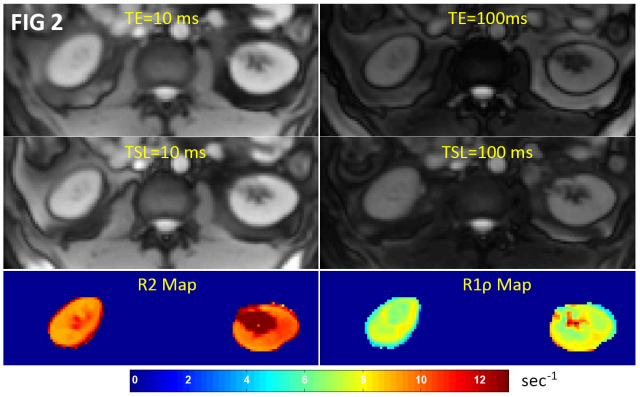
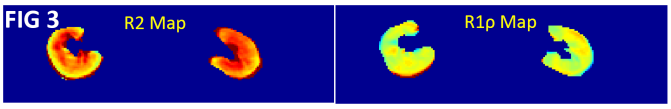
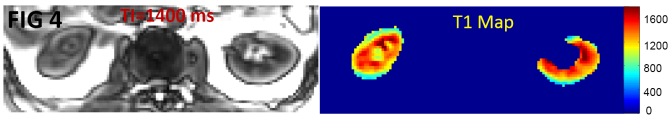


FIG 1







Results: Top two rows of Fig.2 show the typical T2- and T1ρ-weighted renal images acquired from a subject at TE or TSL of 10 and 100 ms. No apparent artifacts in the kidney area were noted. T2-weighted images were acquired by setting B1 to be zero in the T1ρ preparation. The calculated relaxation rate maps for T2 and T1ρ are also displayed in Fig. 2. The estimated T2 values of the renal cortex and medulla for this subject were similar around 90 ms, with T2 of medulla being slightly higher. The intrarenal T2 contrast was more apparent in a different subject (Fig. 3). In all five studies, the T1ρ contrast between renal cortex and medulla was well differentiated and consistent. The mean T1ρ in the cortex was about 120 ms, while it was higher around 160 ms in the medulla. The T1 map of the kidney is shown in Fig. 4 from the same study as Fig.2. The T1 measured around 1200 ms in the cortex and 1500 ms in medulla. Higher T1 and T1ρ value of medulla may suggest a higher interstitial and intra-tubular water content. The larger difference between the T1ρ and T2 value in medulla may also be a result of a higher oxygen extraction fraction (deoxygenated blood in capillaries affects both T2 and T2* of the tissue), consistent with its higher oxygen metabolism.

Discussion: In this study, we improved the T1ρ sequence to compensate for both B0 and B1 field imperfections and applied this technique for T1ρ-weighted imaging and T1ρ mapping of in vivo human kidneys. We believe the T1ρ signal of the kidney may provide additional information regarding the underlying structure of the kidney beyond the traditional T1, T2 and T2* measurements. For example, since the kidney is highly vascularized with abundant capillaries, both T2 and T2* of kidney parenchyma are strongly associated with the blood oxygenation level. In contrast, T1ρ is relatively unaffected by the renal vascularity and may serve as an important imaging biomarker for quantitative functional MRI of kidney. Additionally, the sensitivity of T1ρ to tissue compositions and interactions may broaden our understanding and detection of renal pathologies.

References: **1.** Haris, *et al.*, JNeurol. 2010; **2.** Aronen, *et al.*, MRI 1999;17:1001; **3.** Jokivarsi, *et al.*, Stroke 2010;41:2335; **4.** McCommis, *et al.*, MRM 2010;63:1442 ; **5.** Regatte, *et al.*, AcadRadiol 2004;11:741; **6.** Prasad, Nephron Clin Pract 2006;103:c58.