Contrast-enhanced kidney MRI at 7Tesla: initial results

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Introduction

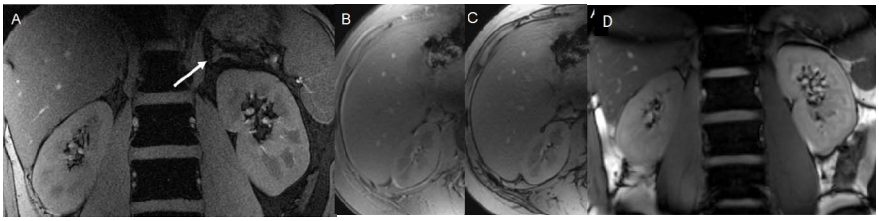
Numerous approaches in neuro- and musculoskeletal imaging at 7T have demonstrated the successful transformation of the associated higher SNR into a higher spatiotemporal resolution, enabling an improvement in the assessment of anatomical details as well as an increased accuracy for the depiction of pathological findings. With the introduction of ultra highfield imaging at 7T to whole body applications (1,2), the interest has aroused to assess the feasibility of dedicated kidney MRI at 7T with optimization and implementation of a dedicated examination protocol.

Methods

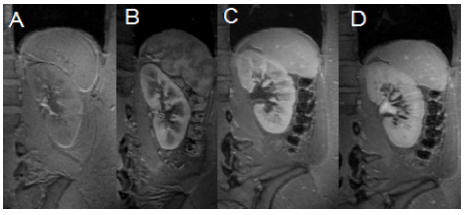
In vivo 7T measurements were performed in eight healthy volunteers (average age: 29.3 years, range 26-33 years). Examinations were conducted in supine position on a 7T whole-body MR system (Magnetom 7T, Siemens Healthcare Sector, Erlangen, Germany). For image acquisition, a custom-built 8-channel RF transmit/receive body coil was used, constructed of two arrays with 4 elements each placed ventrally and dorsally on the upper half of the abdomen. The examination protocol included 1) fatsaturated 2D FLASH sequence (TR/TE = 130/3.57ms, FOV 400 x 400 mm, flip 70°, BW 410 Hz/pixel, 13 slices, matrix 512 x 512 interpolated to 1024 x 1024, resulting in an uninterpolated in-plane resolution of 0.8 x 0.8 mm2, a slice thickness of 2 mm, and an acquisition time of 31 sec), 2) fatsaturated 3D FLASH sequence (TR/TE = 2.9/1.02 ms, FOV 400 x 400mm, flip 10°, BW 920Hz/pixel, 27 slices, matrix 320 x 320 interpolated to 640 x 640, resulting in an uninterpolated in-plane resolution 1.3x1.3mm2, a slice thickness of 1.6 mm, and an acquisition time of 27 sec) 3) T1w in and opposed phase imaging (TR/TE = 140/2.04 / 3.57 ms, FOV 340 x 255mm, flip 65°, BW 920 / 980 Hz/pixel, 20 slices, matrix 320 x 240 interpolated to 640 x 480, resulting in an uninterpolated in-plane resolution 1.1 x 1.1 mm2, a slice thickness of 3 mm, and an acquisition time of 20 sec) 4) TRUEFISP imaging (TR/TE = 3.48/1.53 ms, FOV 400 x 400 mm, flip 50°, BW 977 Hz/pixel, 21 slices, matrix 320 x 256 interpolated to 640 x 512, resulting in an uninterpolated in-plane resolution 1.3 x 1.6 mm2, a slice thickness of 4 mm, and an acquisition time of 19 sec) and 5) T2w TSE imaging (TR/TE = 3060/99 ms, FOV 350 x 240 mm, flip 120°, BW 130 Hz/pixel, 16 slices, matrix 256 x 176 interpolated to 512 x 382, resulting in an uninterpolated in-plane resolution 1.4 x 1.4 mm2, a slice thickness of 5.5 mm, and an acquisition time of 34 sec). Visual evaluation of the image quality for each sequence type was performed by two senior radiologists with 11 and 8 years experience in abdominal MRI using a three-point scale (1 = poor, 2 = moderate, 3 = good quality). The evaluation was based on (1) the corticomedullar differentation and the delineation of (2) adrenal glands, (3) proximal ureter, (4) renal arteries, and (5) renal veins. The presence of artifacts was assessed using a three-point scale (1 = strong impairment 2 = slight impairment of image quality, 3 = no artifact present or insignificant). For statistical analysis, a Wilcoxon rank test was used. A p-value <0.05 was considered statistically significant different. For dynamic imaging Gadobutrol (Gadovist®, Bayer Schering Pharma) was injected intravenously at a dose of 0.1 mmol / kg body weight. T1w 3D spoiled gradient-echo sequences were obtained pre contrast and at 20 sec, 70 sec and 120 sec delay. Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) of the renal cortex / medulla were measured for all time-points.

Results

Best overall image quality was found for the 2D FLASH sequence with an average score of 2.45. This value was significantly higher compared to the 3D FLASH (1.86), TrueFISP (1.46), and the T2-weighted sequence (1.38) with p values < 0.0005. The 2D FLASH sequence also proved to be least prone to artifacts (mean score: 2.64) and showed statistically significant less impairment by artifacts than the T2-weighted sequence. T2w TSE imaging showed the strongest impairment of all evaluated sequences, with a mean value of 1.43 and an average image quality index of 1.38. In the dynamic series SNR for cortex and medulla showed a continuous increase in 6/8 subjects with maximum values for the equilibrium phase. Best corticomedullar contrast was detected during the arterial phase with a mean CNR of 18.9 (vs. 8.9 for the pre contrast scan).



2D FLASH images (A) showed excellent delineation of small anatomical structures such as the adrenal glands (arrow) due to very good fatsaturation. Fig C shows out-of-phase imagnig with typical black rims around organs with a fat / water interface (B in-phase imaging). TrueFISP imaging (D) provided good anatomical overview.



Dynamic 3D FLASH shows homogeneous enhancement of renal cortex and medulla at 4 different measurement point (A: non-enhanced; B: arterial, C: portal venous; D: equilibrium phase).

Discussion

This first attempt at dedicated contrast-enhanced 7T kidney imaging reveals the diagnostic potential, but also the challenges and restrictions of ultra-high-field abdominal MRI. The initial imaging results demonstrate the successful transformation of the increased SNR into a high spatiotemporal resolution, yielding highly defined non-enhanced anatomical images while maintaining data acquisition within the window of a breathhold with parallel imaging. Further optimization of RF technology and dedicated coil concepts can be expected to better surmount the physical effects linked to high magnetic field strength and enable the acquisition of even higher image quality with corresponding clinical diagnostic value.

References:

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