Contrast-enhanced and non-contrast-enhanced renal vessel imaging at 7 Tesla

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Target audience: Clinicians and supporting scientists interested in clinical MRI at ultra-high magnetic field strength.

Introduction: Conventional x-ray digital subtraction angiography is still the standard of reference for the evaluation of arterial diseases. However, over the last years contrast-enhanced MR Angiography (MRA) has been accepted as a non-invasive alternative. Although Gadolinium-based contrast agents have long enjoyed an outstanding safety record, recent reports in renal failure patients have associated the administration of Gadolinium with nephrogenic systemic fibrosis [1]. Owing to this development, scientific attention has recently focused on Gadolinium dosage studies [2] and non-contrast-enhanced techniques for angiography [3,4]. Since MRA is one of the applications that may benefit dramatically from the increase of the magnetic field strength [5,6], the aim of this study is the evaluation of diagnostic quality of renal MRA at 7T in non-contrast-enhanced (ne) TOF versus contrast-enhanced (ce) FLASH imaging under reduction of contrast agent dosage to one-half and one-quarter of the standard dosage.

Methods: 15 healthy volunteers (9 f, 6 m) were imaged at 7T (Magnetom 7T, Siemens Healthcare) using an eight-channel transmit-receive body coil in CP$^+$ mode. The imaging protocol consisted of a ne TOF sequence in transversal orientation with TR/TE/flip angle of 17 ms / 4.7 ms / 60°, resolution 1.6x0.8x2.5 mm^3, and TA = 33 s. Additionally, a T1w 3D FLASH (spoiled gradient echo) sequence was obtained in coronal orientation with TR/TE/FA = 2.9 ms / 1.0 ms / 25°, resolution 1.3x1.3x1.6 mm^3, TA = 27 s before administration of 1.0 M Gadobutrol (Gadovist ®, Bayer Healthcare), as well as 20 s, 70s, 120s, and 300 s after contrast agent injection. Each volunteer was imaged with three dosages of the contrast agent with at least 48 h between each scan at different dosages: (i) standard/high dosage of 0.1 mmol / kg body weight (BW), (ii) half/intermediate dosage of 0.05 mmol / kg BW, and (iii) quarter/low dosage of 0.025 mmol / kg BW. The images were evaluated qualitatively regarding vessel delineation and diagnostic quality as well as quantitatively by calculating contrast ratios (CR) between ce and ne measurements [CR = (ce - ne)/(ce + ne)] in the abdominal aorta and the right/left renal arteries. For comparison with TOF images CR was also calculated between vessel and background tissue.

Results: 7T ce MRA allowed high-quality vessel depiction with all three applied dosages (Fig. 1). Mean contrast ratios were similar for all three dosages in the renal artery, but clearly higher for the intermediate dosage in the aorta (0.22) compared to the low (0.12) and high dosages (0.15); see Table 1. The relatively low contrast ratios reflect that arteries already appear hyperintense in non-enhanced FLASH images at 7T, which results in limitations in the subtraction imaging between ce and ne measurements typically performed at clinical field strengths (Fig. 2c). Venous overlay was observed mainly in ce measurements, regardless of applied dosage (Fig. 1). Non-enhanced TOF MRA allowed high-quality vessel depiction at 7T and was rated qualitatively similar to the ce measurements. Strong background suppression resulted in highest contrast ratios for the TOF MRA compared to ce MRA.

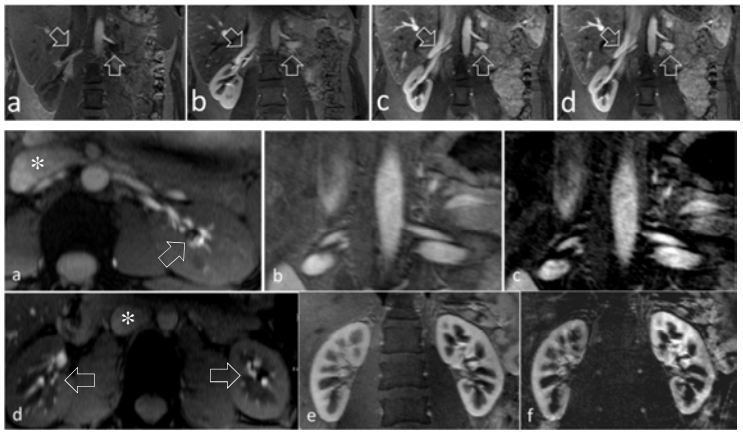

Figure 1: Non-enhanced (a) and ce FLASH images acquired with increasing contrast agent dosages of 0.025 mmol/kg BW (b), 0.05 mmol/kg BW (c), and 0.1 mmol/kg BW (d) show vessel delineation of similar quality, with slight improvements for the intermediate and high dosage. However, venous contamination was found at all dosages (arrows), rendering ne imaging advantageous in this case.

Figure 2: Comparison of transversal ne TOF MRA (a, d) and coronal ce FLASH MRA (b, e), as well as subtraction images (ce-ne FLASH; c, f). Diagnostic quality of vessel delineation was found to be equal per se in both imaging sequences with moderate venous overlay being apparent also in the ne TOF images (a, d; star). Due to the intermediately hyperintense native vessel signal, subtraction images render no additional value (c). Superiority of the TOF sequence can be appreciated in the strong background suppression, rendering excellent depiction of peripheral renal arteries in the corticomedullar region (arrows in a, d) without an overlay of the renal cortex as in ce FLASH MRA (e, f).

	CR aorta		CR renal artery	
	(ce/ne)	(aorta/bgr.)	(ce/ne)	(r.a./bgr.)
0.1 mmol/kg BW	0.12	0.22	0.11	0.28
0.05 mmol/kg BW	0.22	0.24	0.15	0.26
0.025 mmol/kg BW	0.15	0.16	0.13	0.26
ne TOF		0.38		0.44

Table 1: Mean contrast ratios (CR) calculated between ce and ne measurements with different contrast agent dosages in the abdominal aorta and renal artery (r.a.). For comparison with ne TOF datasets, CR was calculated between vessel signal and background (bgr.) tissue.

Discussion: Advantages of ce FLASH MRA lie in the higher spatial and temporal resolution compared to ne TOF MRA. Reduction of the applied contrast agent dosage is possible at 7T without compromising diagnostic quality. Non-enhanced TOF MRA is superior in its very strong background suppression and in the high conspicuity of corticomedullary arteries. The possibility to perform high-quality native and low-dose vessel imaging may be of high clinical importance for patients with renal insufficiency.

References: 1. Grobner, Kidney Int. 2007;72:260-264 2. Habibi, Radiology 2008;248:680-92 3. Lanzman, Rofo. 2010;182:861-867
4. Hodnett, Radiology 2011;260:282-93 5. Metzger, MRM 2013;69:114-26 6. Umutlu, Invest.Radiol. 2011;46:425-433