Highly accelerated non-contrast enhanced MRA of the renal arteries using iterative reconstruction

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Purpose/Introduction: In non-contrast-enhanced 3D MR angiography (non-ce 3D MRA) of the renal arteries, long acquisition times are typically needed, which can impede clinical use. Recently proposed iterative methods offer the combination of parallel MRI with compressed sensing [1,2] for the reconstruction of highly undersampled data. The aim of this abstract is twofold: First to demonstrate the application of a dedicated undersampling pattern in combination with an optimized iterative reconstruction algorithm for non-ce 3D MRA of the renal arteries, and secondly to study the impact on image quality with increased acceleration. This is accomplished through evaluation of the sharpness, the contrast and the maximal visible blood length (MVL) [6] of the vessels.

Subjects and Methods: Experiments were performed in healthy volunteers on a clinical 3T MR Scanner (MAGNETOM Trio, A Tim System, Siemens AG, Healthcare Sector, Erlangen) using the 6 ch. body-matrix coil and 6 elements of the spine matrix. An IR-prepared 3D b-SSFP technique [3,4] was applied. The acquisition was respiratory-triggered, and imaging parameters included a full matrix of 240 x 240 x 120, and a FOV of 256mm x 256mm x 120mm, a TI of 1300ms, and a flip angle of 90°. The readout direction was chosen from left to right, and different undersampling factors (USF) were applied retrospectively in both partition and phase encoding direction. The chosen undersampling pattern has regular undersampling in the k-space center and a diverging density in partition and phase encoding direction, adapted to the length of the respective dimension. The reconstruction was done with an iterative method minimizing the data fidelity term (equation (1)). The reconstruction matrix A consists of the coil sensitivities, the projection matrix and the Fourier transform. The reconstruction finished after 6, resp. 8 (for USF 9 and 12) iterations of the quasi-newton solver. Sharpness and contrast of the right and left 1st and 2nd order renal artery branches were evaluated in different localizations (4 positions, 1st order, 6 positions, 2nd order) calculating the slope [5] and the signal intensity ratio between the inner region and the background. The MVL [6] was calculated using a region growing anatomy-adapted segmentation algorithm. (See fig. 1)

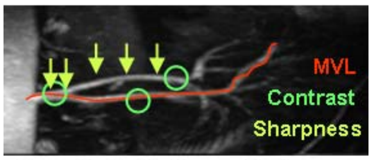

Figure 1: Evaluation method

$$(1)\quad f(x) = ||y - Ax||_2^2$$

Results: Figure 2 shows the results for dataset 1 as reconstructed with different USFs. Up to an USF of 12, the distal part of the main renal artery as well as the second and third order branches were delineated with a good sharpness. Figure 3 shows results of the quantitative evaluation for three consecutive volunteers. Sharpness and contrast stay at a high level for both USF 3 and 6, offering even slightly higher values than the reference due to the influence of the iterative method. All three quality measures decrease slowly but continuously with the USF increasing further to 9 and 12. The reconstruction results for USF 9 for dataset 2 and 3 are shown in fig. 4.

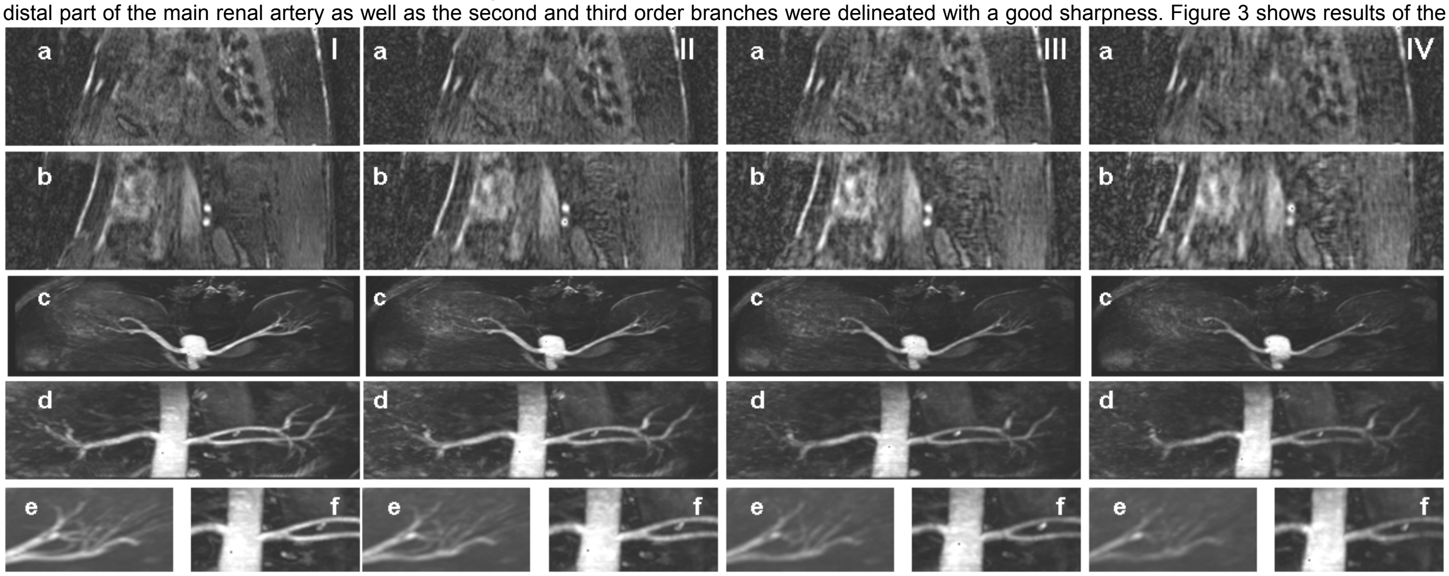

Figure 2: Reconstruction results for I) USF 3.06, II) USF 6, III) USF 9.06, IV) USF 12; a),b) individual slices, c) coronar MIP, d) transverse MIP, e),f) zoom

Sampling	Sharpness (1st/2nd)	Contrast (1st/2nd)	MVL (V. 1/2/3)
Reference	0.153/0.163	53.4/71.3	150/167/152
US 3.06	0.163/0.171	62.3/82.1	147/166/151
US 6	0.160/0.166	58.7/74.3	142/162/148
US 9.06	0.144/0.155	56.1/71.4	135/162/147
US 12.09	0.138/0.149	53.9/65.9	135/159/145

Figure 3: Quantitative evaluation

Discussion/Conclusion: The developed and implemented quantitative measures reflect visual image appearance and are therefore a suitable approach for quality control. The results demonstrate that the proposed combination of a dedicated 3D undersampling pattern and the optimized iterative reconstruction algorithm support high USF of up to 12 in non-ce enhanced renal angiography, while maintaining high level of sharpness and contrast. With suitable reordering schemes, it should be possible to translate these high USF directly into corresponding reduction of total acquisition time, leading to scan durations of only 1-2min and, hence, less motion artifacts, improved patient comfort, and higher patient throughput.

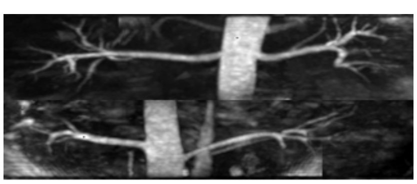

Figure 4: Reconstruction results USF 9

References: [1] Pruessmann et al., MRM 2001; 46:638 [2] Donoho, IEEE Trans. 2006; 52:1289 [3] Katoh et al., Kidney International 2004; 66:1272 [4] Wyttenbach et al., Radiology 2007; 245:186 [5] Li et al; Radiology 2001; 219:270 [6] Herborn et al, Radiology 2006; 239:263

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