Rapid Volumetric Body MRI: Feasibility Assessment of Highly Accelerated Parallel Imaging for Magnetic Resonance Urography

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Introduction In current clinical practice, the utilization of multidetector CT for body imaging dominates that of MRI. This is in part because some of the inherent advantages of MRI (e.g. lack of radiation exposure, flexibility of contrast mechanisms) are offset by the complexity of scan prescription and data acquisition. Highly accelerated parallel imaging has the potential to shift this balance, by enabling the acquisition of high-resolution images over comprehensive volumes in a single breath-hold. This capability can simplify existing protocols by replacing multiple targeted scans with a single accelerated acquisition. Furthermore, accelerated volumetric data sets may offer greater diagnostic value because they can be retrospectively reformatted to obtain multiple different views of any chosen region. As a case study of the value of highly accelerated imaging for body MRI, we are developing an accelerated protocol for magnetic resonance urography and renal mass evaluation that employs a 32-receiver imaging system. MR urography is a good candidate for accelerated imaging because it requires anatomical and vascular imaging of a large region that extends from the top of the kidneys to bottom of the bladder. Due to scan-time constraints in conventional MRI exams, this region is traditionally imaged by means of multiple targeted acquisitions with limited coverage or resolution in separated breath-holds. The aim of this work is to investigate the benefits of merging these targeted scans into single accelerated scans that cover the entire region of interest.

Methods The relevant portions of the conventional and accelerated protocols are displayed in Table 1 (with additional T_2-weighted and multi-echo T_1-weighted studies omitted for simplicity). Our conventional protocol consists of two sagittal 3D spoiled gradient echo (SPGR) volumes situated over each kidney (TR 4.6 ms, TE 2.2 ms, matrix size 288×90×44, FOV 36×25×13 cm), and a pair of coronal SPGR scans (matrix size 256×128×40, FOV 44×35×12 cm, TR 4.0 ms, TE 1.8 ms, flip angle 12°, or TR 4.9 ms, TE 1.8 ms, flip angle 45°) covering the abdomen. The higher flip angle of the second acquisition accentuates the post-contrast visibility of the ureters and bladder. Each scan is repeated before and after the administration of Gd-DTPA (Magnevist, Berlex Labs, USA). In the accelerated protocol, several scans are merged into a smaller number of SPGR acquisitions (matrix size 220×224×222, approximate FOV 34×40×44 cm, TR 4.2 ms, TE 1.7 ms, flip angle 12°, or TR 4.2 ms, TE 1.6 ms, flip angle 45°). Each accelerated acquisition is undersampled by a factor of 3 in the S/I direction and a factor of 4 left-to-right, yielding an overall factor of 12 and a scan duration of 22 s. Frequency encoding is oriented A/P. In some cases the 45° flip angle of the second scan was reduced slightly owing to SAR constraints.

Three healthy adult subjects (2 male, 1 female, ages 28, 45, 59 y) were imaged using both the conventional and accelerated protocols. Each pair of exams was completed during the same session, with the order of the protocols chosen randomly. In two cases, the accelerated protocol was performed first. The Institutional Committee on Clinical Investigations approved the research protocol and written informed consent was obtained from all subjects.

All data for the accelerated protocol were acquired using a specially modified 32-receiver GE Excite II system (GE Healthcare Technologies, Waukesha, WI, USA) and a 32-element body surface array (1). Image reconstructions were performed online using a Linux cluster (2) running a parallel C-based version of the generalized encoding matrix image reconstruction algorithm (3). Data for the standard protocol were acquired using a commercially available 8-element body array (GE Healthcare Technologies, Waukesha, WI, USA).

Images were presented to a radiologist for grading. Images of the kidneys, ureters, bladder, renal arteries, aorta, and iliacs were assessed for visualization, edge clarity, quality of regional fat saturation, presence of filling defects, and presence of artifacts obscuring anatomy on a 1-5 scale with 5 indicating best image quality. Filling defects were ranked on a confidence level: 1= definitely absent, 2 = probably absent, 3= indeterminant, 4= probably present, 5 = definitely present.

Table 1: Conventional and accelerated protocols

Conventional	Accelerated
Three plane scout	Coil Sensitivity Calibration
Sagittal SPGR right kidney	SPGR, 12° flip angle
Sagittal SPGR left kidney	
Coronal SPGR, 12° flip angle	
Coronal SPGR, 45° flip angle	SPGR, 45° flip
Bolus timing	Bolus timing
Coronal SPGR, 12°, multiphase	SPGR 12° flip (multiphase)
Sagittal SPGR right kidney	
Sagittal SPGR left kidney	
Coronal SPGR, 45° flip angle	SPGR 45° flip

Results and Discussion Fig. 1 shows a MIP of a background-subtracted post-contrast accelerated scan to illustrate the coverage of the accelerated protocol. Fig. 2 shows a comparison between urograms obtained using the standard and accelerated protocols. Fig. 3 compares an image obtained from a prospective targeted sagittal acquisition to a retrospectively reformatted accelerated scan having an equivalent slice thickness. The retrospective reformat appears to show better resolution and lower levels of Gibbs ringing while retaining comparable SNR. Image quality ratings are summarized in Table 2. Ratings in the first four columns have been averaged over the six anatomical classes listed above. Although no statistical conclusions can be drawn at this point given the small number of subjects, the preliminary results suggest that the accelerated protocol yields source images with somewhat lower SNR, but which are otherwise comparable to those from the standard protocol. We also note different confidence levels in the evaluation of ureteral filling defects (Table 2, last column), with possible influences from ureteral peristalsis in this healthy, asymptomatic population, perhaps owing to the higher isotropic resolution of the accelerated acquisition. As expected, the accelerated protocol is somewhat less time-consuming than the standard protocol. In the three volunteer studies, the minimum table time for completing the accelerated protocol was 18 min (26 min average), while for standard protocol the shortest exam was 26 min (32 min average).

Table 2: Image quality ratings.

Protocol	Grain	Visualization	Edge clarity	Artifact	Ureter filling defects
Standard	4.2	4.8	4.6	4.5	1
Accelerated	3.8	4.7	4.4	4.4	2.7

This pilot study will be extended to patients referred for MRU and/or evaluation of renal masses. Our current data indicate that highly accelerated parallel imaging may indeed provide a viable technique for fast, simplified body MRI, on the model of multi-detector CT but maintaining the advantages of MRI. Apart from the benefits of reduced scan time, this approach also offers the possibility of highly flexible retrospective image analysis through the acquisition of large-FOV, high-resolution volumetric data sets.

References

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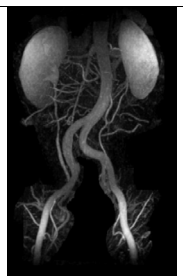

Fig. 1: MIP of a background subtracted post-contrast accelerated scan.

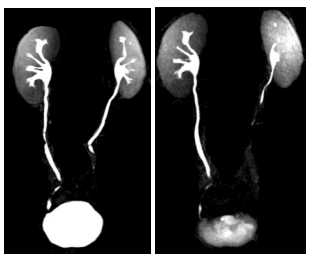

Fig. 2 Conventional (left) and accelerated (right) MR urogram.

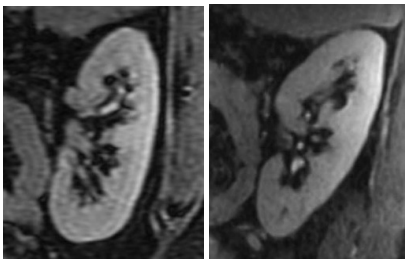

Fig 3. Prospective (left) and retrospectively reformatted (right) views of the right kidney.