Highly Accelerated Abdominal CE-MRA with 3D Timing Scan

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Introduction In abdominal CE-MRA high spatial resolution is necessary for accurate diagnosis of renal artery stenosis and other vascular pathologies. Obtaining images with both high spatial resolution and high SNR is particularly challenging in the abdomen due to limited scan time, typically a breath hold (~20 sec), and often the need to image over a large FOV. Furthermore, high frame rate time-resolved imaging may be desired to obtain temporal information useful for the understanding of abnormal flow and filling patterns. Although parallel imaging has been used to decrease scan time or improve spatial resolution in abdominal CE-MRA[1-3], highly accelerated (R>4) acquisitions have yet to be effectively applied. The purpose of this work is to develop an abdominal CE-MRA method that achieves high temporal and spatial resolution imaging of the abdominal vasculature using a single split dose of contrast material. To obtain this, the CAPR [4] sampling method, high (R=8) 2D SENSE accelerations and specialized receiver coil arrays were implemented. The imaging protocol consists of: (a) a low-dose time-resolved 3D CAPR acquisition that serves as a timing bolus and (b) a subsequent high spatial resolution renal 3D MRA. The high spatial resolution scan can optionally be repeated to image the venous phase. We hypothesize that the time-resolved 3D low-dose (2 ml) timing scan can provide accurate timing information for the renal MRA and also serve as a diagnostic overview of the structure and dynamics of the vasculature. Furthermore, highly accelerated (R=8) imaging of the abdominal vasculature can provide high quality imaging over a large FOV.

Methods ***Acquisition.*** The two acquisitions were based on the CAPR pulse sequence and implemented with a 2D SENSE acceleration factor of 8 (R_Y=4, R_Z=2). ***In Vivo Studies***. 18 volunteer studies and 5 patient studies have been performed. A coronal acquisition was used with frequency S/I, phase L/R, and slice encoding A/P. The FOV was modified on a volunteer-specific basis in order to encompass the entire central abdomen L/R and A/P. The acquisition parameters are shown in Table 1. All scans were performed during end-expiration breath hold. The matrix size for the high spatial resolution renal MRA was adjusted based upon breath hold capability. ***Contrast Dose***. The injection protocol for the low-dose time-resolved exam consisted of 2 ml Multihance at 3 ml/sec followed by 20 ml saline at 3 ml/sec. For the high resolution scan 18 ml of Multihance was injected at 3 ml/sec followed by 20 ml saline at 3 ml/sec. ***Receiver Coil***. A circumferential modular coil array with 8-16 elements has been developed for accelerated abdominal imaging. The element size is 14.3 x 27.2 cm^2. The modular array readily allows the number of elements used to be determined by volunteer size; 10 elements was generally appropriate. ***Reconstruction***. The images were automatically reconstructed using custom hardware and sent back to the scanner console within two minutes of the completion of the scan, making it clinically feasible to use CAPR as a timing bolus.

Table 1: CAPR Abdominal CE-MRA Parameters

	Timing Bolus	High Resolution MRA
FOV (cm^3)	30-38 x 35-40 x 25.6-28.8	30-38 x 35-40 x 25.6-28.8
Matrix	80-192 x 96-192 x 72-120	256-320 x 256-320 x 180-256
Spatial Resolution (mm^3)	2.0-4.5 x 2.0-4.5 x 2.4-4.0	1.0-1.5 x 1.0-1.5 x 1.0-1.6
SENSE Acceleration	R_Y = 4, R_Z = 2	R_Y = 4, R_Z = 2
Frame Time (sec)	0.73 - 1.77	17.3-28.2

Results The highly accelerated CAPR timing scan with sub-second temporal resolution well portrayed the transit of the test bolus through the abdominal vasculature with high SNR. In 22/23 studies accurate timing was determined, and the single phase angiograms provided sharp depiction of the arterial vasculature over the full abdominal FOV. Representative results are shown in Fig. 1. Fig. 1 (A-C) show three consecutive 0.73 sec time frames from a time-resolved CAPR scan depicting the arrival of the contrast bolus to the abdominal aorta and progressive filling of the vasculature. This scan provides dynamic information, an overview of the vasculature, and serves as a timing scan. Fig. 1 (D) coronal MIP of the full S/I FOV and (E-G) zoom MIPs from the subsequent renal angiogram show the excellent depiction of the celiac trunk (E), renal arteries (F) and branching mesenteric vessels (G).

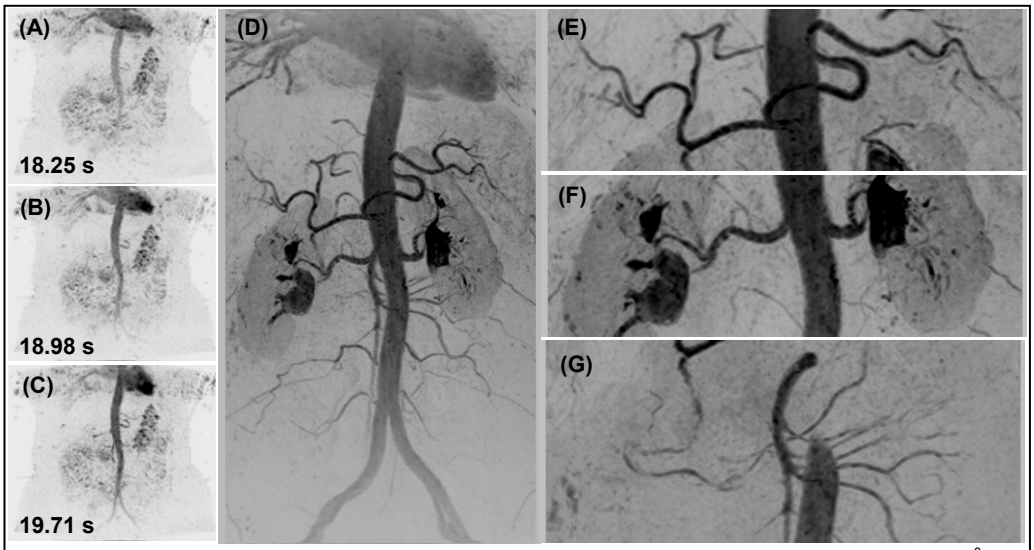

Figure 1: Consecutive coronal MIPs from CAPR timing scan (A-C) with spatial resolution 4.25x4.25x4.0 mm^3 and frame time of 0.73 sec. Coronal MIP of renal MRA over the full S/I FOV (D) and targeted MIPs of celiac trunk (E), renal arteries (F), and superior mesenteric artery and its branches(G).

Conclusions Using a single 20 ml contrast agent dose, both a time-resolved acquisition and a high spatial resolution renal MRA can be obtained by implementing variations of the CAPR sequence with high (R=8) 2D SENSE accelerations. The low-dose time-resolved CAPR acquisition serves as an accurate timing scan for the renal MRA and compared to a standard 2D single slice timing bolus has the additional benefit of providing a 3D structural and functional overview of the vasculature and renal parenchyma. This work suggests that high quality MR angiograms of the abdominal vasculature can be obtained with highly accelerated (R=8) acquisition techniques. This technique may be applied for high resolution MRA in patients who are marginal breath holders or venography of mesenteric/portal system or hepatic veins/IVC. The time-resolved scan may be used for visualization of vascular malformations as well as for measurement of renal/hepatic tissue perfusion.

References [1] Chen, Rad231:893(2004) [2] Born, JMRI 22:559(2005) [3] Muthupillai, JMRI 31:149(2010) [4] Haider, MRM 60:749(2008)