Time-Resolved Contrast-Enhanced Peripheral MRA in Patients with Low Contrast Doses Using VIPR-HYPR

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Introduction: As a result of the suspected link between high doses (>0.1mmol/kg) of gadolinium-based contrast agents and the risk of nephrogenic systemic fibrosis (NSF) in patients with renal failure, a great deal of work has been focused on the development of low-dose MRI and MRA techniques [1-2]. We have previously introduced a method for acquisition of time-resolved contrast-enhanced MR angiography of the peripheral vasculature using fractional doses of contrast material (<0.1 mmol/kg) [3]. Undersampled 3D radial k-space trajectories (VIPR) [4] and HYPR image processing [5] have been combined to provide distal time-resolved MRA with high spatial and temporal resolution while maintaining good image quality with contrast material injections as little as 0.025 mmol/kg in healthy volunteers. Here, we extend past work to a population of patients with known peripheral vascular disease with the aim of quantifying the image quality and reader confidence of these low contrast material dose exams.

Methods: The VIPR k-space trajectory is an undersampled 3D radial acquisition pattern. Undersampling artifacts – albeit structured – are distributed in three dimensions so they resemble noise rather than coherent streak artifact. This behavior facilitates high undersampling factors with relatively benign artifacts. Further, the VIPR k-space trajectory samples the center of k-space every projection. Signal averaging of the lowest spatial frequencies yields high SNR performance. Lastly, VIPR acquisitions have isotropic spatial resolution, which allows for multi-planar reformation of images into any orientation. Despite these advantages, the SNR of VIPR images (gridding and Fourier transform with no additional processing) is degraded with low-dose imagining.

To regain SNR, HYPR processing is utilized. HYPR is a constrained reconstruction technique that improves SNR and decreases undersampling artifacts while retaining high temporal fidelity. This occurs because the SNR of a HYPR time frame depends on the SNR of the well-sampled composite image, while the temporal information is maintained from the undersampled, high temporal resolution weighting image.

Data were collected from six patients with known peripheral vascular disease and normal renal function using a 3T MR750 scanner (GE Healthcare, Waukesha, WI) and a 32 channel phased array abdominal coil (NeoCoil, Pewaukee, WI) in accordance with our institutional review board guidelines. Gadobenate dimeglumine (MultiHance, Bracco Diagnostics INC, USA) was intravenously administered at a rate of 3.0 ml/s (IV in antecubital fossa) or 2.5 ml/s (IV in hand). Data were collected from each patient after injection of 0.025 mmol/kg, 0.05 mmol/kg and 0.1 mmol/kg of contrast material, followed by a 20 ml saline flush after each injection. The lower dose injections (0.025 and 0.05 mmol/kg) were diluted with saline solution to match the volume of the single dose injection. A period of 15-20 minutes between acquisitions was useed to allow for contrast material elimination via the kidneys. Scan parameters included: 400 - 480 mm FOV; FA/TE/TR/BW: 20°/1.3ms/4.2-4.5ms/±125.0kHz; 1.0 x 1.0 x 1.0 mm spatial resolution; HYPR weighting image temporal resolution: 4.5 – 6.75 seconds/image; HYPR composite image acquisition duration: 126 – 189 seconds; effective temporal resolution: 4.5-6.75 seconds/frame.

Arterial frames from each contrast dose acquisition of each patient were read by two experienced cardiovascular radiologists. Scores were assigned to describe the level of image quality and qualitative SNR for seven vessel segments in each leg. The level of stenosis present in each vessel segment was also assessed along with the level of confidence in each stenosis grade. Cohen's kappa coefficients were calculated to assess the agreement of stenosis grade between full, half and quarter contrast dose acquisitions.

Results and Discussion: An example from one patient is shown in Figure 1 after injections of 0.025 mmol/kg (1a), 0.05 mmol/kg (1b) and 0.1 mmol/kg (1c) of contrast material, which corresponds to 3.7, 7.4 and 14.8 ml of contrast respectively for this patient (patient weight: 162.8 lbs/74 kg). Coronal MIPs of the best arterial frame are shown for the three contrast doses. Patient motion during the half dose exam degraded the apparent spatial resolution of b). High quality images were obtained in patients with the administration of small doses of contrast material (0.025 mmol/kg), similar to the results previously shown for healthy volunteers [3]. Disease is clearly visible in all three images (see arrows).

Though more subjects are needed to improve to statistical power of the correlation coefficients, initial results showed moderate to substantial agreement between the stenosis grades from 0.1 mmol/kg dose and both low dose regimens. Further, diagnostic confidence grades were not significantly impacted for low dose exams.

Conclusions: These results indicate that with VIPR acquisition and HYPR processing, it is possible to decease the dose of gadolinium-based contrast agents for time-resolved, contrast-enhanced peripheral MRA while maintaining high image quality and diagnostic confidence.

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References: [1] Habibi, *et al.* Radiology. 2008. 248:680-692. [2] Nael *et al.* Eur J of Rad. 2011. 80:2-8. [3] Keith *et al.* Procs 20th ISMRM. 2011. [4] Barger, *et al.* MRM. 2002.48:297-305. [5] Mistretta, *et al.* MRM. 2006. 55:30-40.

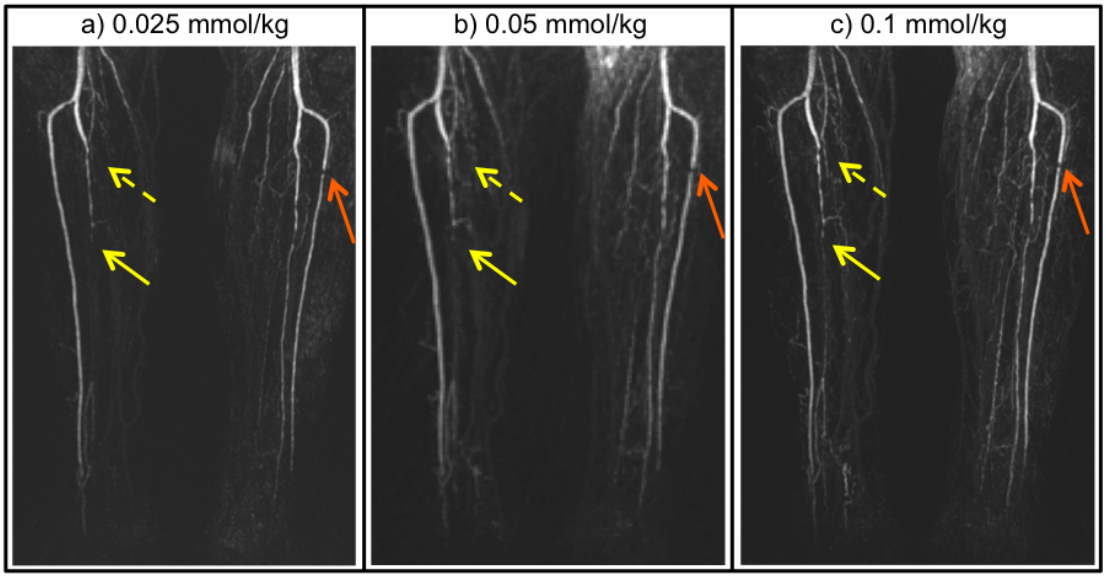

Figure 1: Coronal MIPs of arterial HYPR time frames at increasing contrast dosing (a) 0.025 mmol/kg, b) 0.05 mmol/kg, c) 0.1 mmol/kg) *Image specifications:* 1.0 mm isotropic resolution, 4.5 second weighting image temporal resolution, 480 mm FOV, undersampling factor ≈ 360. In the subject's right leg, occlusions of the peroneal (solid yellow arrow) and posterior tibial (dashed yellow arrow) arteries are well seen in all images. The severe stenosis of the proximal anterior tibial artery in the left leg is also visable (orange arrow).