MR Angiography using Fractional Contrast Doses with VIPR and HYPR

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Purpose: Inspired by concern over the link between gadolinium-based contrast agents and nephrogenic systemic fibrosis (NSF) in patients with impaired renal function, this work explores the feasibility of performing time-resolved, contrast-enhanced MRA exams of the peripheral vasculature with a fraction of a single dose of contrast material (<0.1 mmol/kg). To achieve this, we exploit the benefits of both the vastly undersampled isotropic projection reconstruction (VIPR) [1] k-space trajectory and the highly constrained back projection (HYPR) [2] reconstruction method. Due to the nature of the VIPR trajectory, high undersampling factors can be achieved with relatively benign undersampling artifacts and SNR penalties. Undersampling factors as high as 240 yield VIPR time frames (reconstructed by gridding and Fourier transform only, i.e. no HYPR reconstruction) of peripheral MRA exams with surprisingly high SNR. This observation motivated an investigation into the capability of performing peripheral MRA exams with a decreased dose of contrast material. As expected, the SNR of VIPR time frames decreases with contrast material doses of less than 0.1 mmol/kg due to the small voxel size (1.0 mm^3) and high undersampling factors. In the exams we performed, the SNR of a VIPR time frame became prohibitively low using a contrast material dose of 0.025 mmol/kg in healthy volunteers. However, one main advantage of the HYPR reconstruction method is the characteristic that the SNR of the final HYPR image is dependant on the SNR of the composite and weighting images, both of which have higher SNR than the corresponding VIPR time frame. Combining these attributes of VIPR data acquisition and HYPR reconstruction allows for time-resolved, contrast enhanced MR angiography exams with low doses of contrast material.

Methods: Data from four healthy volunteers and one patient with known peripheral vascular disease were acquired on a 3T MR750 scanner (GE Healthcare, Waukesha, WI) using a 32-channel torso coil (NeoCoil, Pewaukee, WI). Subjects were intravenously administered a gadolinium-based contrast agent (MultiHance, Bracco Diagnostics Inc, USA) at a rate of 3 ml/s. Data was collected from each volunteer after an injection of a quarter dose of contrast (0.025 mmol/kg), a half dose of contrast (0.05 mmol/kg), and a full dose of contrast (0.1 mmol/kg) in this order. The total amount of contrast material administered during the exam did not exceed a triple dose, or 0.3 mmol/kg.
Scan parameters for all subjects were as follows: 1.0 mm isotropic spatial resolution; 480 mm isotropic field of view; 80% fractional echo; TR/TE/FA/BW = 4.9ms/1.2ms/20°/±125kHz; 1,500 projections per time frame; 7.35 second temporal resolution. HYPR reconstruction was performed using a composite image consisting of all the scan data (45,000 projections).

Results: Results from a healthy volunteer after full, half and quarter dose contrast injections are shown in Figure 1 (15.4 ml, 7.7 ml and 4.0 ml, respectively for this volunteer). The top row of Figure 1 displays a single VIPR arterial time frame for each contrast dose (no HYPR reconstruction). (Note that data was acquired bilaterally and the space between the legs was cropped out for space considerations.) It is clear that the SNR of these VIPR images decreases with each reduction of contrast dose.

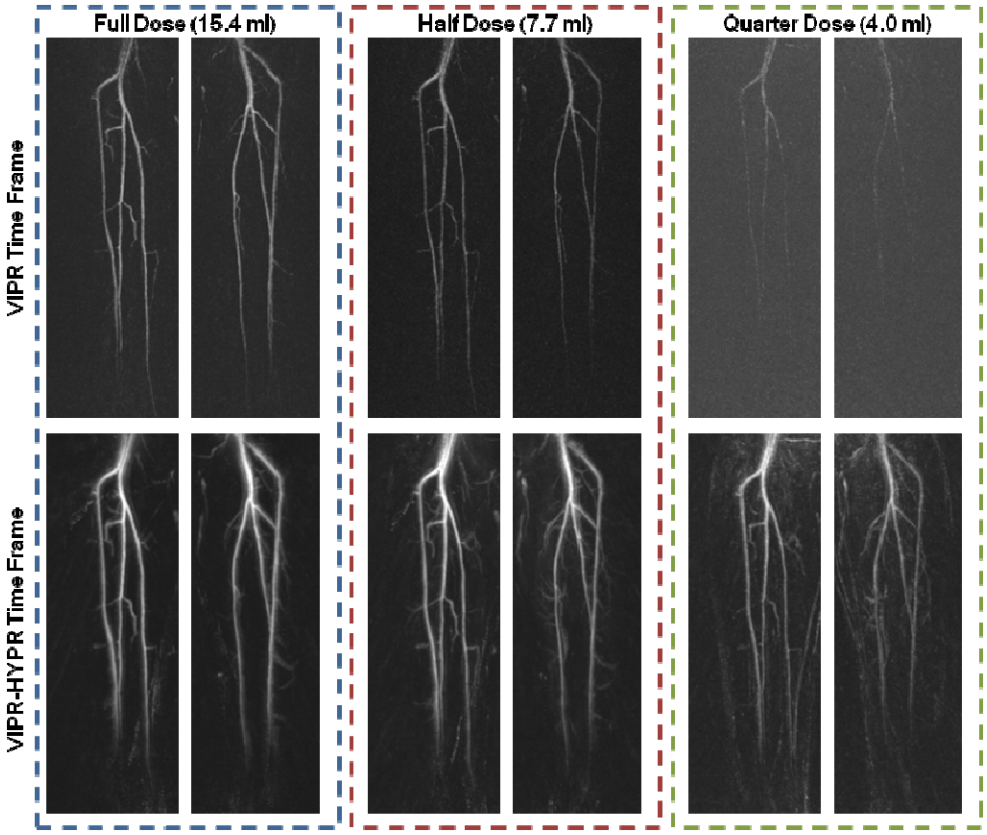

Figure 1: Single time frames after VIPR (top row) and VIPR-HYPR (bottom row) reconstructions from a healthy volunteer using full, half and quarter contrast material doses (15.4 ml, 7.7 ml, 4.0 ml, respectively). Imaging parameters: 1.0 mm isotropic resolution, 1,500 projections per time frame, acceleration factor of 240, 7.35 second temporal resolution

The bottom row of Figure 1 shows the corresponding time frames after HYPR reconstruction. Here, the SNR penalties due to decreased contrast dose are less dramatic. Notice small arteries branching off the major arteries are still discernable after only 0.025 mmol/kg of contrast.

Imaging patients with severe disease poses challenges, such as complex flow and short artery-venous transit times. Figure 2 shows a single time frame reconstructed with VIPR-HYPR from a patient after 0.05 mmol/kg of contrast was injected (7.0 ml for this patient with known peripheral vascular disease and diabetes). The data was acquired bilaterally and cropped to a single leg for space considerations. HYPR processing permits a reduction in contrast material dose while retaining SNR despite the added challenge of a very short artery-venous transit time in this patient.

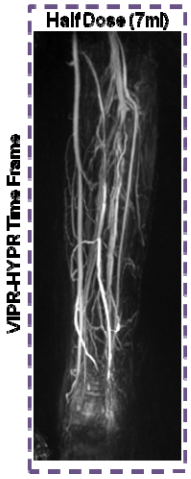

Figure 2: Single VIPR-HYPR time frame from a patient after a half contrast material dose (7.0 ml). Image cropped to show a single leg.

References: [1] Barger AV, *et al*. MRM. 2002:48:297-305. [2] Mistretta CA, *et al*. MRM. 2006:55:30-40.
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