HYPR reconstruction with automatic detection of contrast arrival

A. Carrillo[1], J. H. Brittain[2], J. V. Velikina[3], Y. Wu[4], F. R. Korosec[3,5], O. Wieben[3,5], and C. A. Mistretta[3,5]

[1]Global Applied Science Laboratory, GE Healthcare, Evanston, IL, United States, [2]Global Applied Science Laboratory, GE Healthcare, Madison, WI, United States, [3]Department of Medical Physics, University of Wisconsin, Madison, WI, United States, [4]Department of Electrical and Computer Engineering, University of Wisconsin, Madison, WI, United States, [5]Radiology, University of Wisconsin, Madison, WI, United States

Introduction:

Recently, highly constrained backprojection (HYPR) [1], was proposed as a reconstruction method to enable large increases in MR scan efficiency for a variety of applications. Time resolved contrast-enhaced MR Angiography (CE-MRA) using HYPR allows for a dramatic increase in the reconstructed temporal frame rate without the normal penalties in SNR and/or spatial resolution. Unfortunately, this increase in data throughput can result in long reconstruction times, reducing the clinical viability of the technique.

During a typical time-resolved CE-MRA examination, data acquisition is started prior to the arrival of the extrinsic contrast agent at the vasculature of interest and data acquisition continues into the venous phase. The clinically relevant information starts with the arrival of the bolus, with the requirements for temporal resolution in the arterial phase being significantly higher than that in the venous phase. Carroll et al. [2] suggested the analysis of raw k-space data for the detection of contrast arrival and the reconstruction of an optimal 3D volume for a single time frame. We propose to adapt this technique to the HYPR method to tailor both the starting point and the temporal resolution of the reconstruction based on a k-space contrast uptake curve. Our technique will eliminate the reconstruction of baseline images with no vascular information and will significantly reduce the number of images reconstructed during the venous phase.

Methods:

Following informed consent, HYPR datasets were acquired from healthy volunteers on a clinical 1.5 T system (GE Healthcare, Waukesha, WI). Different anatomical regions were acquired for multiple volunteers, including the lower extremities and the head. Prior to the reconstruction of the HYPR images, the projections for each HYPR time frame were averaged, and the central 10% region of k-space was used to generate the corresponding time point on the contrast uptake curve.

The arrival of contrast at the vasculature of interest was defined as the point in the uptake curve with 5% of the peak amplitude. We considered several methods to determine the peak arterial phase and the start of the venous phase, such as searching for the maximum gradient of the contrast uptake curve starting a full composite after the arrival of the contrast or simply using the characteristic transit times for the anatomy being imaged. The HYPR dataset was reconstructed two ways: 1) all acquired data was reconstructed using the HYPR method and 2) using the information gathered in the uptake curve to start the reconstruction half a composite before the predicted contrast arrival time frame, using the full temporal resolution of the data through half a composite after the predicted start of the venous phase and then reconstructing the remainder of the data with half the maximum possible temporal resolution. Reconstruction times were noted in both cases with the time necessary for the generation of the uptake curve included in the measurement for the tailored reconstruction. Images from the tailored reconstruction and the full reconstruction were compared to verify that the arrival of the contrast was not missed and the acceptability of the lower temporal resolution of the images during the venous phase.

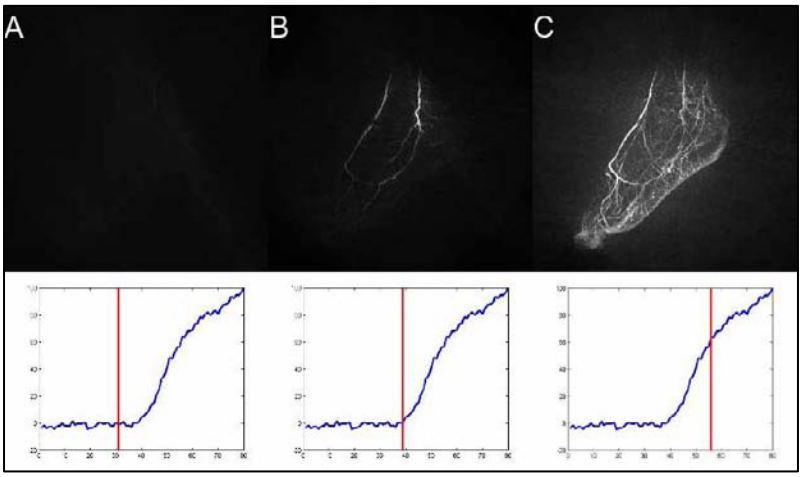

Figure 1. Three time frames of a HYPR MRA acquisition of the foot. The upper row shows the HYPR time frame at the time indicated by the vertical line on the contrast uptake curve in the bottom row. The uptake curve was reconstructed using the central 10% of the raw k-space data for each time frame. Figure A shows the reconstruction at the time the algorithm predicted as just prior to the arrival of contrast. Figure B shows an image during the arterial phase and Figure C shows an image at the predicted start of the venous phase.

Anatomy	Volume Dimensions	Recon Time	Tailored Recon	Contrast Arrival	Venous Phase
Phantom	256x256x12 16 projections/time frame 160 time frames 1 receiver	7 min	5.1 min	Time frame 29	Time frame 48
Foot	512x512x52 16 projections/time frame 96 time frames 4 receivers	146 min	76 min	Time frame 46	Time frame 74
Calf	512x512x96 16 projections/time frame 80 time frames 4 receivers	237 min	164 min	Time frame 32	Time frame 62

Table 1. Comparison of full and tailored HYPR reconstruction for different anatomical regions. Tailored HYPR reconstruction starts at the predicted contrast arrival frame, using the full resolution until the predicted start of the venous phase. The remainder of the data is reconstructed at half the maximum temporal resolution possible.

Results:

Figure 1 shows four HYPR time frames from a foot MRA generated using the complete dataset and their corresponding position on the contrast uptake curve. Observe that the algorithm correctly predicts the position of the contrast arrival and the start of the venous phase. Table 1 shows the reconstruction time using the full dataset and the tailored reconstruction for several datasets.

Discussion and conclusion:

The use of HYPR MRA provides clinicians with temporal resolution up to a 100 times better than traditional CE-MRA methods [3, 4]. However, the large data volumes prolong reconstruction times and increase data management and storage requirements, making routine use of the technique challenging in typical clinical practices. The proposed tailored HYPR reconstruction method reduces the necessary reconstruction time of the complete dataset without sacrificing any clinically relevant information. Further reduction in the temporal resolution of the venous phase might be possible, but additional investigation is necessary to determine the best reconstruction parameters, which will possibly vary with the vascular region of interest. It is important to note that the full temporal resolution of the venous phase can be provided retrospectively if it is deemed clinically necessary. While the use of the tailored reconstruction results in a significant reduction in processing time, reconstruction still takes too long for routine clinical use. Combinations of the proposed technique with other methods such as parallel processing will continue to bring the clinical application of HYPR closer to reality.

References:

[1] Mistretta, C et al; MRM 55:20-40. 2006 [2]Carroll, T et al; MRM 44:817-820. 2000 [3] Wieben, O et al ISMRM 2006, 688 [4] Velikina, J et al ISMRM 2006, 692