Improving Radial Sliding Window Cotrast-Enhanced Intracranial MRA using HYPR

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Introduction:

In contrast-enhanced magnetic resonance angiography (CE-MRA), high signal-to-noise ratio (SNR) is desired to visualize small arteries. At the same time, sufficient temporal resolution is required to image the dynamics of the blood flow, which may be critical for accurate diagnosis and treatment for various vascular diseases, such as intracranial arteriovenous malformations (AVMs) or aneurysms.

We have previously utilized partial Fourier and radial sliding window reconstruction to achieve frame rates comparable to X-Ray DSA (1). However, in comparison to X-Ray, the MRA still has inferior SNR and suffers from temporal blurring due to lengthy acquisition time to capture one complete time frame. In this study we propose a method to increase the SNR of the Radial Sliding Window MRA using HighlY Constrained Projection Reconstruction (HYPR) (2) with sliding composite.

Materials and Methods:

Simulations

Computer simulations were performed using Matlab (Mathworks, Natick, MA). A bolus of contrast agent was modeled using a step function, moving in a straight line across the field of view. This was chosen because the functions can be modeled as a product of three separable *rect* functions in x, y, and z dimension and can be analytically transformed back and forth in k-space and image space so that we have a truth image to compare the different reconstruction methods. 128 projections were acquired for each image. HYPR reconstruction was performed using 4, 8, 16, 32, 64, and 128 projections with sliding composite, where composite is an average of some number of frames behind and in front of the current frame. 128 projection sliding window images without HYPR were also reconstructed for comparison.

In order to quantify the quality of images reconstructed, image error was measured using the following equation, modified from the original equation by Peters et al(3): $$\text{ImageError} = 100 \times \sqrt{\sum_{x,y} \left[I_{truth}(x,y) - I_{HYPR}(x,y) \right]^2}$$

Signal vs. time curves were plotted for appropriate regions of interest (see Figure 1) to compare the temporal profiles of truth, radial sliding window reconstruction with and without HYPR processing.

In Vivo Imaging

In this ongoing study of MRA of AVM patients, we have 6 volunteers with angiographically confirmed AVMs. The raw data was acquired on Siemens 3T Trio (Siemens Medical Solutions, Erlangen, Germany) using 3D spoiled gradient echo sequence typically with following protocol: FOV=220x220mm, TR/TE=2.7/1.3ms, N_{proj}=192, N_{RO}=192, N_{slice}=20, readout/slice partial Fourier factors=75%/75%, receiver BW=1300 Hz/Px, Flip Angle=25°. Images were reconstructed offline using Matlab. Reconstruction was done with 6 and full 192 projections for comparison. HYPR processing with sliding composite, which is a time average of about 5 seconds ahead of the current frame and 10 seconds, was applied. Signal-to-noise ratio was calculated by averaging signal inside an ROI over an artery and dividing by standard deviation of noise. SNR and temporal profiles were compared for each different reconstruction schemes, including 192 projection sliding window without HYPR.

Results:

Simulations

Simulations showed that the average image error was greatest for 4-projection HYPR and decreased as more projections were used to reconstruct the images. The standard deviation of the image error over time was also greatest for 4-projection HYPR. Qualitatively, in the images, this is manifested as flashing of the image due to fluctuations in artifact levels. The temporal profile also reflected the fluctuations in artifact levels, characterized by spiky shape rather than a smooth curve. However, as more projections were used, temporal blurring was observed.

In Vivo Imaging

Temporal profiles in human volunteers with AVMs showed results similar to those from simulations. The 6-projection HYPR images had spiky temporal profiles, though it seemed to have overall shape closer to true bolus dynamics. The 192-projection HYPR had temporal profile very close to that of 192-projection image without HYPR, but was significantly higher in SNR. (Figure 1)

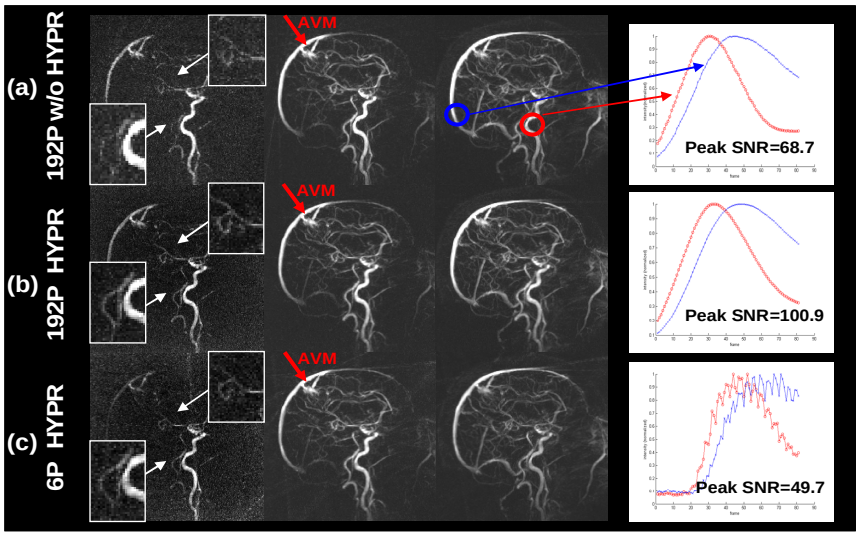

Figure 1: comparison of 192-projection with (b) and without HYPR(a) and 6-projection HYPR(c). Sliding composite was used for HYPR images. The images from left to right are each taken 6 seconds apart from a dynamic series. Note areas indicated by white arrows where benefits of HYPR can be observed.

Discussion:

HYPR was initially developed by Mistretta et al (2) as a way to achieve acceleration in dynamic contrast enhanced MRA using limited projections. However, even with full 192 projection images, with an appropriate composite, significant SNR gains (up to ~47%) was observed without significant changes in temporal profiles.

References: 1. Cashen TA et al. MRM, 2007. 2. Mistretta CA et al. MRM, 2006. 3. Peters DC et al. MRM, 2006.