Conjugate-Gradient HYPR of Intracranial AVMs

H. Jeong[1], T. J. Carroll[1,2], C. Getch[3], C. S. Eddleman[3], and M. A. Griswold[4]

[1]Biomedical Engineering, Northwestern University, Chicago, IL, United States, [2]Radiology, Northwestern University, Chicago, IL, United States, [3]Neurological Surgery, Northwestern University, Chicago, IL, United States, [4]Radiology, Case Western Reserve University, Cleveland, OH, United States

Introduction:

HighlY Constrained Projection Reconstruction (HYPR)(1) has recently been a topic of interest for magnetic resonance angiography (MRA). HYPR achieves high frame rate by using very few number of radial projections per image. Each limited projection image is enhanced by processing it with a high signal-to-noise ratio (SNR) composite image with little temporal information. The result is high temporal resolution with high SNR. However, there are artifacts associated with the HYPR images such as cross talk between objects due to limited projections, as well as temporal blurring from time-averaged composite image. Griswold et al. previously proposed a method for correction of these artifacts in HYPR processed images, using a iterative technique called conjugate-gradient (CG) method (2). In this study, we compare radial sliding window MRA (3) of arteriovenous malformations (AVMs) with HYPR and CG HYPR processing to X-Ray angiograms for accuracy in imaging the dynamic information of AVMs.

Materials and Methods:

CG-HYPR is an iterative process which determines the correct image by optimizing the agreement between the acquired input image and the reconstructed image. First raw data is initially reconstructed and HYPR processed. Because HYPR involves multiplication of composite and unfiltered backprojections, alterations from the original image are introduced such as early vein enhancement and cross-talk. The resulting HYPR image is then fed to a CG unit, where the image is updated using correction factors from the CG algorithm. The correction factors are also updated for next iteration, and the process is repeated until convergence.

6 volunteers with angiographically confirmed AVMs were recruited. 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. Conventional HYPR and CG HYPR images with limited projections were obtained, in addition to full 192-projection radial sliding window reconstruction with CG HYPR processing. 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. The images were also correlated to X-Ray angiograms for each of the volunteers.

Results and Discussion:

The temporal profiles and the images themselves showed full 192 projections reconstructed with radial sliding window and CG HYPR most closely resembled the XRA images. Using full 192 projections seems to help with eliminating cross-talk resulting from limited projections, and CG-HYPR seems to decrease the early enhancement of the vein caused by the composite (Figure 1).

The iteration was stopped when a pre-determined level of residual is met. We have observed in preliminary studies that the near optimal removal of temporal blurring occurs at a point where the residual has been reduced to 10% of its starting value. This is significantly larger (>5 orders of magnitude) than would be expected in other situations, such as CG-SENSE reconstructions of non-Cartesian sampled data. However, further iterations do little to improve the temporal information, but result in significant degradation of SNR.

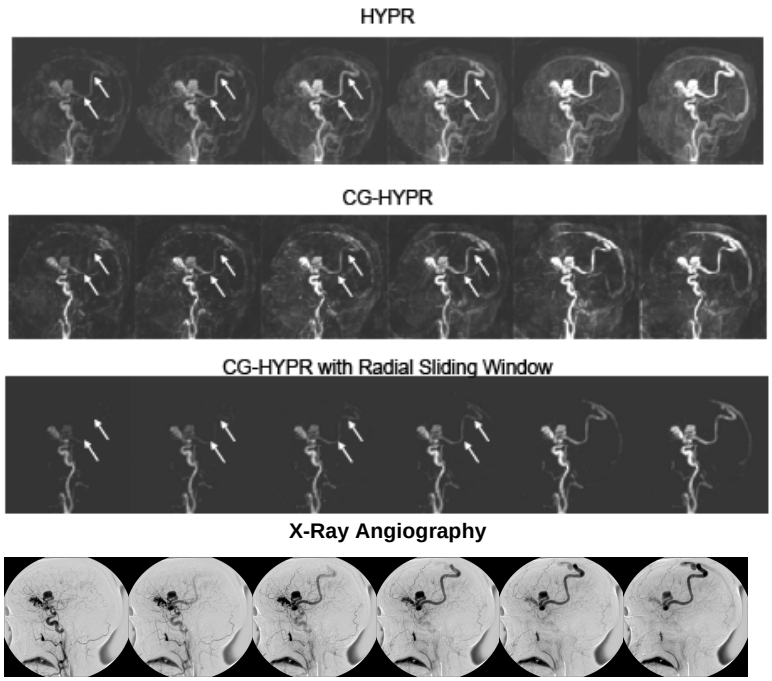

Figure 1: From top, HYPR, CG-HYPR, CG-HYPR with 192 projection radial sliding window, and XRA of an AVM patient. Note the time course of the late filling vein (arrows) is better represented when radial sliding window images are used as inputs to the CG-HYPR reconstruction.

Conclusion:

CG algorithm can improve HYPR by iteratively correcting the images for errors caused by HYPR processing. We have shown that with radial sliding window and CG-HYPR, we can obtain MRA images with temporal and spatial quality approaching those of XRA.

References:

1. Mistretta et al. MRM, 2006.
2. Griswold et al. ISMRM, 2007. 3. Cashen et al. MRM, 2007. 4. Huang and Wright, MRM, 2007