Time-Resolved Contrast-Enhanced Imaging Using 3D HYPR VIPR Reconstruction with Adaptive Composite Window

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Introduction

Many MR applications require both high temporal and spatial resolution. The recently proposed HighlY constrained backPRojection (HYPR) technique [1] allows reconstruction of diagnostic quality images with dramatic acceleration factors. It was demonstrated [2] that in phase contrast (PC) imaging, HYPR processing combined with 3D radial VIPR [3] acquisition produce artifact-free images without significant loss of SNR for undersampling factors up to 930. We apply the HYPR algorithm to contrast enhanced (CE) imaging with VIPR acquisition and study the resulting temporal and spatial resolution. This poses an additional challenge in dealing with the rapidly changing dynamics of the contrast uptake which may affect the image quality. This concern arises from the fact that HYPR backprojection is constrained by the composite image which is reconstructed from the projections comprising several consecutive time frames. In our reconstruction, we form the composite image using an adaptive technique that preserves temporal behavior of the resulting time series.

Theory and Methods

The data for HYPR VIPR are acquired in the form of temporally interleaved isotropically distributed radial projections. For each time frame, a composite image is reconstructed using filtered backprojection (FBP) or regridding followed by 3D Fourier transform. Time frame images are then reconstructed by unfiltered backprojection using corresponding composite images as the constraints. The standard HYPR algorithm suggests the use of a sliding window composite image centered at each time frame. This way the composite images for frames immediately preceding the arrival of contrast will contain some of the post-contrast acquired projections, hence the contrast may show up too early in the HYPR reconstruction series. We employ an alternative adaptive technique for reconstruction of the composite images. First, we reconstruct low resolution versions of each time frame image from the central *k*-space region of undersampled data. Then, we look at the cross-correlations of the low resolution images and use data from the time frames with the highest correlation coefficients to form the composite image for the given time frame. Such an adaptive procedure ensures that time frames prior and post contrast arrival are reconstructed using composite images formed with projections acquired before and after contrast arrival, respectively, and the temporal behavior of the reconstructed time series correctly represents the contrast uptake.

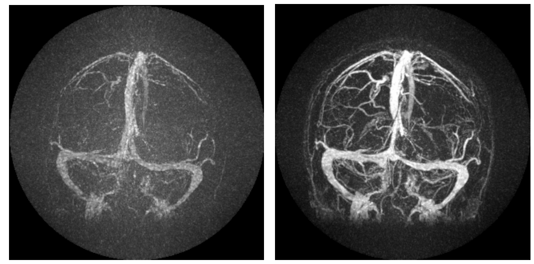

Figure 1 Comparison of a single time frame obtained with (a) FBP, (b) HYPR

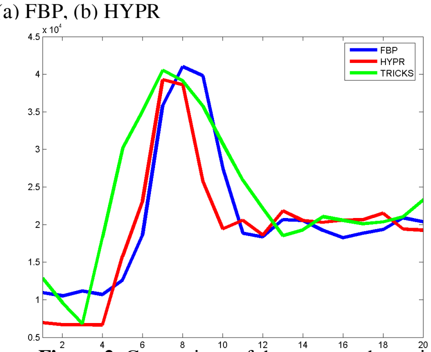

Figure 2 Comparison of the contrast dynamics in the carotid artery for FBP (blue), HYPR (red), and TRICKS (green) reconstruction

Results and Discussion

Imaging was performed on a 3T clinical scanner (GE HealthCare, Milwaukee, WI). CE images were acquired, using 10,000 total projections, 20 distinct interleaved projection sets, a 20x20x20cm FOV, and 0.625 isotropic spatial resolution during a contrast injection (20cc Omniscan@2cc/s). The time series of 20 time frames with the temporal resolution of 3 sec/frame was reconstructed using HYPR method with the adaptive composite window comprising data from 5 time frames. The number of projections per time frame was 500 resulting in the undersampling factor of 320 relative to the Nyquist criterion. We compare the results of HYPR reconstruction with FBP reconstruction from the same data. Figure 1 shows comparison of the reconstruction results for the peak arterial frame reconstructed with HYPR and FBP. Despite the fact that undersampled FBP reconstruction produces poor image quality, it provides adequate representation of the contrast dynamics. Figure 2 shows that the time series behavior for an ROI inside the carotid artery obtained with FBP, HYPR, and product TRICKS sequence used in clinical practice. The HYPR waveform is in good agreement with that of the FBP reconstruction. We believe that the FBP reconstruction overestimates the signal in the initial time frames prior to contrast arrival due to heavy streaking artifacts. The duration of the TRICKS exam was 70 sec and the resulting 20 frame time series had in-plane spatial resolution of .85mm, slice thickness of 4mm, and interpolated temporal resolution of 3.5 sec. We hypothesize that the TRICKS waveform differs from the other two reconstruction methods because it has lower spatial resolution and its temporal resolution is frequency dependent.

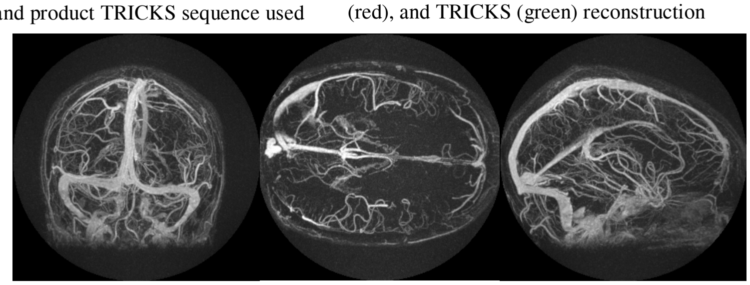

Figure 3 Coronal, axial, and saggital MIPs of the all-inclusive composite image

Conclusions

HYPR with adaptive composite window is a feasible imaging technique to be used in rapid contrast enhanced imaging. 3D HYPR VIPR permits high isotropic spatial resolution without compromising temporal resolution or significant SNR loss. Initial experiments suggest that it is possible to double the current undersampling factor of 320 in order to increase temporal resolution to about 1.5 sec. For diagnostic purposes, CE HYPR VIPR also allows for a high-quality all inclusive composite image, shown in Figure 3, which may be used for further investigation of suspicious vessels and/or veins.

Acknowledgements

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References

1. Mistretta CA *et al., MRM* 2006; **55**: 30-40.
2. Velikina JV *et al.,* abstract 92, ISMRM 2006, Seattle, WA
3. Barger AV *et al., MRM* 2002; **48**: 297-305.