PC HYPR Flow: a technique for rapid imaging of contrast dynamics

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Introduction

In contrast-enhanced (CE) time-resolved angiography it is desirable to obtain images with high spatial and temporal resolution as well as high signal-to-noise ratio (SNR). This is a challenging problem in MRI because rapid passage of the contrast agent limits the temporal window available for acquisition of each time frame. In Cartesian sampling schemes, limited acquisition time bounds the number of phase encodes which, in turn, leads to decreased spatial resolution or ghosting artifacts. Non-Cartesian acquisition schemes, such as radial or spiral, exhibit much less structures artifacts resulting from undersampling; however, the SNR of the reconstructed images is still proportional to the square root of acquisition time, making the noise level prohibitively high for rapid imaging applications. Use of view sharing or parallel imaging techniques addressed the spatial/temporal resolution trade off to a certain degree but still did not overcome the SNR limitation. We propose a novel method, PC HYPR Flow, that combines the benefits of rapid three dimensional radial acquisition and highly constrained backprojection reconstruction (HYPR) [1] to obtain a time series of 3D images with isotropic submillimeter spatial resolution, subsecond temporal resolution, and high SNR.

Methods

In the PC HYPR Flow technique, we modify the HYPR LR algorithm [2] to address the dilemma of providing high SNR and spatial resolution without sacrificing temporal resolution. Typically, in HYPR-based algorithms, the composite image is obtained from all or a subset of the projections collected in a time-resolved exam. Here, we propose to acquire the composite image in a separate, non-time-resolved PC scan [3]. Such a scheme splits the task of providing high spatial resolution/SNR and high temporal resolution between two scans: the high temporal resolution reflecting the flow dynamics is provided by the time-resolved CE exam, while high spatial resolution and high SNR result from the longer PC scan used to obtain a composite image and they are transferred into the reconstructed time series due to the properties of the HYPR LR.

The PC HYPR Flow exam consists of three continuously performed scans. Data acquisition starts with a pre-contrast scan, immediately followed by a contrast agent injection and a time-resolved first pass scan. These short exams (usually 30-60 sec long each) are instantly succeeded by a longer PC exam. The acquired time-resolved data are then reconstructed using HYPR LR processing with the composite image constraint obtained from the post-contrast PC exam.

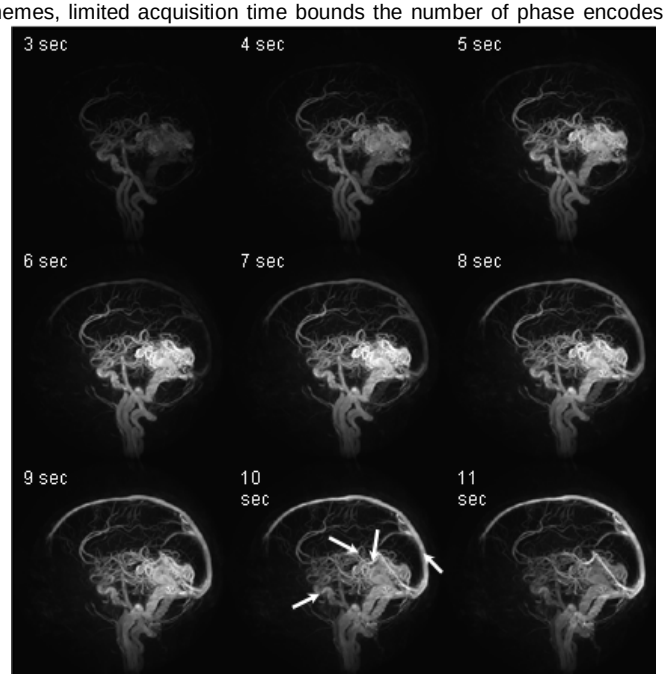

Figure 1. Sagittal MIPs of the PC HYPR Flow time series depicting contrast passage in an AVM patient during a time window of 3-11 sec after the contrast agent injection. Arrows indicate locations in which the temporal waveforms were measured.

Results

The feasibility of PC HYPR Flow technique was explored in a number of in-vivo exams of both healthy volunteers and patients with a brain AVM. The exams were performed on 3.0T GE Signa HD scanner (GE Healthcare, Waukesha, WI, USA). All exams had 260mm field of view. The time-resolved exams had a total duration of 60 sec with the 0.5 sec frame rate and a TR of 3.1 ms, resulting in the acquisition of 160 four half-echo projections in each time frame. The length of the PC VIPR exam was 300 sec during which about 7000 partial echo. Figure 1 shows a time series of sagittal MIPs from a PC HYPR Flow exam of an AVM patient. Note the good separation of the arterial and venous phases that is also illustrated by the plot of the temporal waveforms (see Figure 2) of the arterial and venous locations marked by arrows in Figure 1.

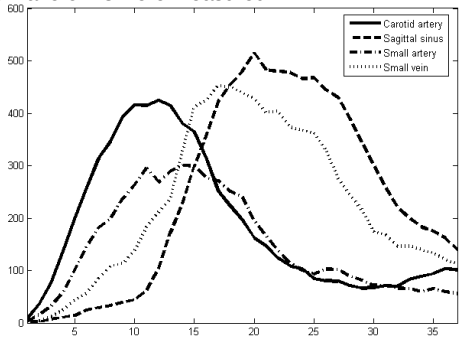

Figure 2. Temporal waveforms measured in the carotid artery (solid line), sagittal sinus (dashed line), a small artery feeding the AVM (dash-dot line), and a small draining vein (dotted line) of the image volumes obtained with PC HYPR Flow.

Conclusions

Initial trials in healthy volunteers and brain AVM patients indicate that PC HYPR Flow is a feasible technique that simultaneously provides 3D isotropic submillimeter spatial resolution, subsecond temporal reconstruction windows (including optional tornado filter view sharing) and high SNR level for contrast enhanced angiography. Clinically, PC HYPR Flow has potential to replace DSA in evaluation of AVM patients. Moreover, PC HYPR Flow is a promising technique for imaging intracranial stenoses. The applicability of PC HYPR Flow is not limited to intracranial angiography, it can be used for any anatomy which admits a PC VIPR exam. We believe that the use of PC HYPR Flow can benefit, in particular, peripheral angiography and imaging of any anatomical region where rapid flow dynamics currently limit spatial resolution or SNR.

References

1. Mistretta CA et al., MRM, 55(1): 30-40; 2006 2. Johnson KM et al., MRM, in press 3. Gu TL et al. AJNR, vol. 26, 743-9, 2005.