# Ultra low dose 4D contrast enhanced MRA using HYBRID HYPR technique

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## INTRODUCTION

Time resolved contrast-enhanced magnetic resonance angiography has been widely used to evaluate vascular hemodynamics. Due to recent concern of the NSF disease, eliminating or reducing Gadolinium-based contrast agent is desirable [1]. HYBRID HYPR [2] decouples the high spatial resolution and SNR, which require relative long scan time, from the high temporal resolution, which demands for fast data acquisitions. It used the HYPR constrained reconstruction to obtain high temporal resolution, high spatial resolution, and high SNR image series. The hypothesis of this work is that the contrast dose can be reduced using the HYBRID HYPR technique: the SNR of the HYPR images is primarily determined by the composite, which is generated using minimal mount of contrast agent (e.g. post contrast phase-contrast images) or can be acquired before contrast injection (e.g. Time-of-Flight images). High temporal and spatial resolution time resolved contrast-enhanced MRA can be obtained by using Low Dose HYBRID HYPR method with reduced contrast dose.

## METHODS

Low Dose HYBRID HYPR method had been tested on four normal volunteers and one AVM patient. Different amount of contrast agent have been used from 6ml (the patient) down to 1ml (three of four volunteers). Studies were conducted on a GE 3T scanner. We selected MultiHance (Bracco, Princeton, NJ) as the contrast agent for these studies. Following the low dose contrast injection, a CE-MRA examination of the head is performed using time resolved multi-echo VIPR (ME VIPR). Subsequently, PC VIPR acquisition is acquired and then used as a composite image for HYPR FLOW reconstruction. Imaging parameters for the ME VIPR were: FOV = 26x26x26cm$^3$, TR/TE = 3.1/0.4 ms, BW = 125 kHz, readout points were 64 per echo covering between the center to the edge of the k-space, frame update time was 0.5 s. The scan parameters for post contrast PC VIPR acquisition were: FOV = 20x20x20cm$^3$, TR/TE = 12.5/4.8 ms, BW = 62.5 kHz, 7000 projections. Flip angle was adjusted between 8 to 20 degrees based on the amount of contrast. Scan time is about 5 minutes. For three of the four volunteers, TOF images were acquired before contrast injection for the HYPR TOF reconstruction. Imaging parameters for the TOF were: FOV = 22x22x8.8 cm$^3$, slice thickness = 1 mm, 40 slices per slab, TR/TE = 24/2.7 ms, BW = 41.76 kHz, acquisition matrix: 512x256x40/slab, flip angel = 20$^o$, flow compensation and magnetization transfer were employed. Factor of two parallel imaging has been applied to reduce the scan time to within 5 minutes. The final images were approximated as a product of weighting images and the composite. The weighting images, which define the contrast kinetics, were obtained by convolving the dynamic images (acquired using ME VIPR) with a local blurring kernel. For intracranial MRA, typical kernel size is 10x10x10, resulting in very low noise variance in the weighting images. The SNR of the final images only depends on the composite images, which for HYPR FLOW study would be the post contrast phase contrast images and for HYPR TOF study would be the pre-contrast TOF images.

## RESULTS AND DISCUSSION

Figure 1 show 4 selected HYPR FLOW time frames in coronal plane (top) and axial plane (second row) from a normal volunteer using only 1 ml contrast. Numbers on the images are the corresponding time in seconds after the contrast injection. The temporal reconstruction window was 0.75 s and the spatial resolution was 0.7x0.7x0.7 mm3. Figure 2 show the cropped HYPR TOF images at the same time frames as Fig. 1. The spatial resolution was 0.43x0.86x1 mm3 before zero-filling. As shown in figure, higher in-plane spatial resolution provides excellent visualization of the distal vessels. Since the same weighting images have been used for both HYPR FLOW and HYPR TOF reconstructions, the temporal windows were same for both cases. However, HYPR FLOW images show better SNR than the HYPR TOF due to its larger coverage, zero background of the composite and the circulating contrast material.

Preliminary results demonstrate the feasibility of achieving high temporal and spatial resolution angiograms with ultra low contrast dose (~1ml). The high spatial resolution and SNR would be recovered from the composite images, which can be acquired with relatively longer scan time (~5 mins), but with less dependence upon the contrast (e.g. TOF, phase-contrast, ASL etc.). Reducing the contrast dose could reduce the NSF risk and overall medical cost. It also provides possibility to have multiple injections if needed. It is flexible to choose the composite to be used for the HYBRID HYPR reconstruction based on the interest of the task, sequence availability and so on, as long as the composite image provides vascular structure with high spatial resolution and high SNR. One potential issue of the HYBRID HYPR is mis-registration between the two scans. We have demonstrated that an automatic linear registration before HYPR reconstruction would address the issue [2]. Another potential issue is saturation effect in the composite due to slow or complex flow. Low dose HYBRID HYPR also provides a possibility to split a single dose into two injections: a small amount of contrast is used for the dynamic acquisition, whereas the rest amount of dose can be used for a fluoro-trigged high spatial resolution CE images to generate the composite.

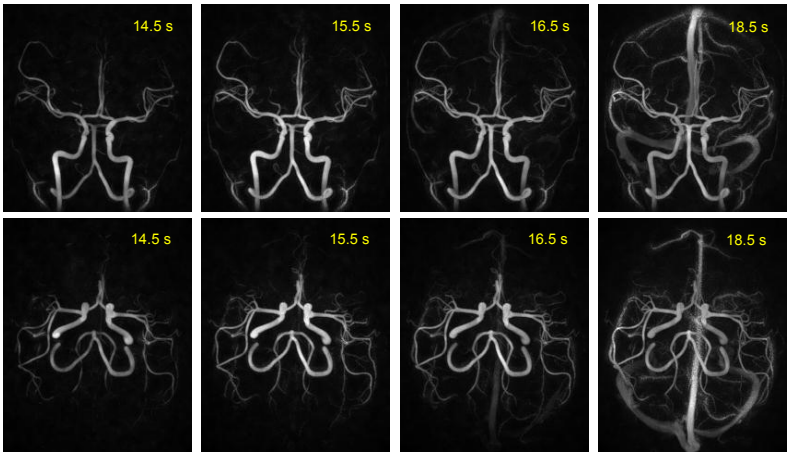


Figure 1 Four selected HYPR FLOW time frames in coronal plane (top) and axial plane (second row) from a normal volunteer using only 1 ml contrast. Numbers on the images are the corresponding time in seconds after the contrast injection.

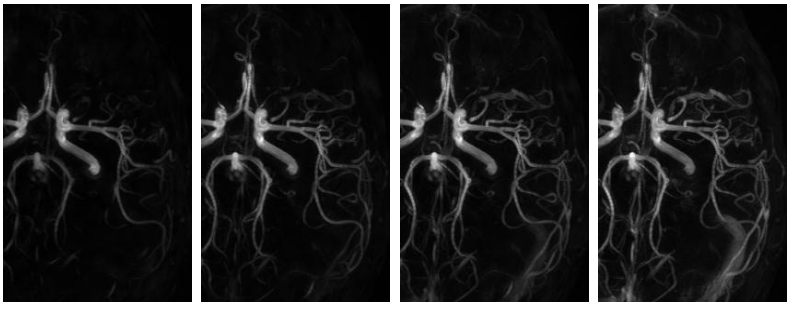

Figure 2 Cropped HYPR TOF time frames using the same weighting images as in Fig.1 (1 ml contrast in total), but with the pre-contrast TOF as the composite.

## CONCLUSIONS

Low dose HYBRID HYPR is able to provide high resolution 4D MRA with contrast as low as 1ml.

## REFERENCES

1. Laub G, et al, Proc. 17th Annual Meeting of ISMRM 2009, P276 *2. Wu YJ, et al,* Proc. 17th Annual Meeting of ISMRM 2009, *P3257.*

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