Investigation of Spatial and Temporal Fidelity of HYPR Processing Using a Motion Phantom

L. Keith[1], M. Rahimi[2], J. Holmes[3], K. Wang[3], J. Brittain[3], and F. Korosec[1,4]

[1]*Medical Physics, University of Wisconsin-Madison, Madison, WI, United States,* [2]*Biomedical Engineering, University of Wisconsin - Madison, Madison, WI, United States,* [3]*Global Applied Science Laboratory, GE Healthcare,* [4]*Radiology, University of Wisconsin - Madison, Madison, WI, United States*

Purpose: Since the HYPR [1] algorithm was introduced, many authors have investigated the temporal and spatial accuracy of the algorithm using computer simulations in two dimensions [2-4]. While those studies were instructive and necessary to understand the general characteristics of the technique, it is just as necessary to study temporal and spatial accuracy using real, acquired 3D data [5]. When acquiring angiography data from human subjects, the exact input function is unknown so it is difficult to draw conclusions regarding the fidelity of the reconstruction algorithm. In this work, an experimental setup has been designed to mimic the sparsity and image characteristics found in angiography.

Methods: A computer-controlled motion stage was used to translate an object through the imaging FOV during data acquisition in an attempt to mimic a bolus of contrast material traveling through vasculature. The motion control stage and sharp edges of the phantom were chosen to provide well-defined inputs to the HYPR processing. Two experiments were conducted: *Experiment 1* investigated the temporal and spatial fidelity of HYPR processing; *Experiment 2* compared the fidelity of HYPR against that of a clinically used, time-resolved Cartesian view-sharing MRA technique [5]. Two saline-filled acrylic tubes – *Tube A* (narrow: 6.35 mm) and *Tube B* (wide: 15.8 mm) – were attached to a motion stage (software: Motion Planner, Parker Hannifin) and traversed through the FOV at a velocity of 5.0 mm/s. A second 6.35mm saline-filled tube remained static in the imaging FOV along with a spherical phantom. *Figure 1* illustrates the experimental set-up. The start of data acquisition was triggered by the motion stage once the programmed velocity was reached.

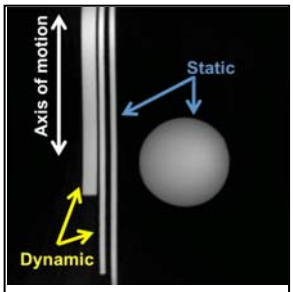

Figure 1: Phantom set-up

Data for HYPR processing were acquired with the VIPR [7] trajectory. Imaging parameters for the experiments included: 1.0 mm isotropic spatial resolution; TE/TR: 1.1/4.1ms; FA: 20°; BW: ±125kHz. Images were reconstructed in two ways: 1) from the undersampled data using a gridding algorithm and a 3D Fourier transform alone (i.e. no view-sharing or HYPR reconstruction) – referred to as *RAW* time frames and 2) from the *same data* as the RAW time frames with the addition of HYPR LR [8] processing – referred to as *HYPR* time frames. The undersampling factors for RAW and HYPR images are 314 (512 projections/frame, 2.04 s/frame) for *Experiment 1* and 157 (1024 projections/frame, 4.08 s/frame) for *Experiment 2* to match the temporal update rate of a clinical Cartesian view-sharing method. HYPR composite image length for both experiments was 84 s. The clinical MRA parameters include: 1.25x1.33x2.0 mm resolution; SENSE-based parallel imaging R=2; 4.3 second update rate; 25.8 second temporal footprint.

Results: To assess the temporal fidelity (i.e. the amount of signal crosstalk from the composite image into the HYPR time frame) and the temporal impact of a long footprint (the composite image), profiles of the individual components of the HYPR algorithm are shown in *Figure 2*. There is evidence of small amounts of signal crosstalk in *Figure 2*; the HYPR profile (blue) has slightly heightened signal intensity beyond the leading edge that mimics the composite image profile (see dashed box in plot). However this crosstalk signal is ≈10% of the mean signal within each tube - very small in comparison to the noise floor of RAW profiles, which is ≈50% of the mean tube signal. (Note that due to the sharp edges of the phantom, streak artifacts in the RAW images are more prevalent than what is typically observed *in vivo*.)

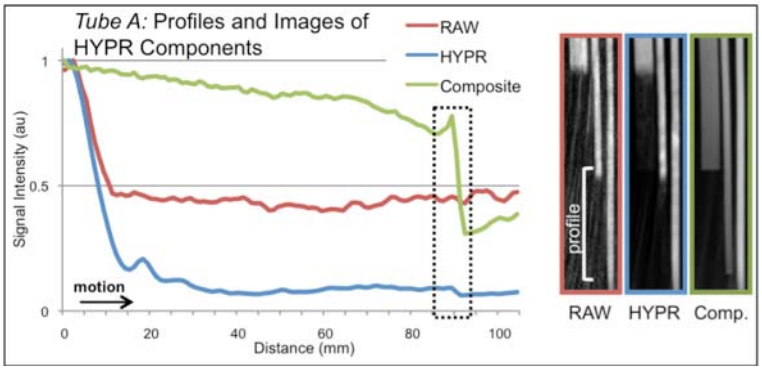

Figure 2: Profiles and enlarged MIPs for components in the HYPR processing algorithm – see legend. Imaging/Reconstruction parameters: 1.0 mm isotropic spatial resolution; 512 projections/frame; 2.04 secs/frame; 84 secs/composite image.

To assess the spatial fidelity of the HYPR process, profiles through the leading edge of *Tube A* are enlarged and compared for RAW and HYPR images in *Figure 3*. Note some blur is expected due to the motion of the phantom during data acquisition and this blur is observed in the leading edge of the RAW profiles (red). The dashed-gray vertical lines in *Figure 3* mark the distance the tube is expected to travel during the data acquisition for the displayed time frame: 10.4 mm. Spatial infidelity resulting from the HYPR process would manifest as greater blur in the leading edge as compared to the profile from the RAW images (i.e. a more shallow slope of the leading edge profile). In this case additional blur introduced by the HYPR algorithm is minimal.

Figure 4 shows profiles and MIPs for HYPR and Cartesian view-shared images. Again, HYPR processing introduces minimal additional blur of the leading edge.

Discussion: HYPR was shown to maintain high spatial and temporal fidelity in this experiment designed to mimic a contrast bolus. Although the temporal footprint of the HYPR composite image is long (84 seconds), HYPR images demonstrate higher temporal fidelity than Cartesian view-shared techniques with shorter temporal footprints.

References: [1] Mistretta, *et al.* MRM.2006:55:30-40. [2] Wu, *et al.* MRM.2008:59:1090-1098. [3] Keith, *et al.* MRM:2008:60:398-404. [4]Huang, *et al.* MRM:2007:58:316-325. [5] Holmes, *et al.* MRM.2009:62:1543-1556. [6] Korosec, *et al.* MRM.1996:36:345-351. [7] Barger, *et al.* MRM.2002:48:297-305. [8] Johnson. *et al.* MRM.2008:59:456-462.

Figure 3 (near right): Profiles of 30 mm at the leading edge of *Tube A* from RAW and HYPR images. Gray dashed lines show the distance the tube traveled during the 2.04s of data acquisition for

Figure 4 (far right): Profiles and enlarged MIPs for HYPR and clinical MRA time frames. HYPR parameters: 1.0 mm isotropic resolution; 4.08 sec/frame; 84 sec/composite image. Clinical MRA parameters: 1.25x1.33x2.0 mm spatial resolution; 4.3s update rate; 25.8s temporal footprint.