Improved waveform fidelity of Hybrid HYPR with Compressed Sensing technique

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INTRODUCTION

Hybrid HYPR-MRA utilizes a separately acquired high spatial resolution static MRA as a spatial constraint to reconstruct highly undersampled dynamic MRA to achieve high temporal and spatial resolution simultenously [1]. However, for extremely high undersampling factor (>100) or/with reduced sparsity, severe undersampling artifacts not only contaminate the image, but also cause signal "crosstalk" from distant vessels, which appears as early enhanced veins or prolonged enhanced arteries. Current implementations with HYPR-MRA do not exploit parallel imaging or Compressed Sensing (CS) techniques, which have been proved to be effective removing undersampling artifacts. In this project, we propose to integrate Parallel imaging and CS to eliminate undersampling artifacts before HYPR algorithm, such that the waveform fidelity of small vessels can be improved, at the same time, CS related artifacts and SNR can be improved by Hybrid HYPR technique.

METHODS

In regular Hybrid HYPR algorithm, undersampled dynamic images are spatially filtered to generate the dynamic weighting images. The filtering process reduces undersampling artifacts and increases SNR, but reduces the spatial resolution. The amount of filtering is chosen based on the undersampling factor and the avoidance of the signal crosstalk from neighboring vessels. For 3D Projection Reconstruction (VIPR) sampling trajectory, the undersampling artifacts appear as background noise, which is preferable for HYPR reconstruction, however, even with the minimum filtering some signal contamination occurs especially with non-zero background images. To eliminate the need for spatial filtering and subsequently reduce background contamination, we propose to utilize a combination of parallel imaging and CS to reconstruct undersampled time frames before HYPR processing. In our particular implementation, we utilize Non-Cartesian SENSE [2] with an L1-norm of image as a regularization, which is solved using iteratively reweighted least squares. In order to improve the final SNR and spatial resolution, the obtained CS images are then fed to the regular Hybrid HYPR algorithm to form the final images.

The proposed reconstruction scheme (CS Hybrid HYPR) was tested on HYPR FLOW [3] datasets and compared to the regular HYPR FLOW results. spatial filtering was used on both algorithms.

RESULTS AND DISCUSSION

Figure 1 shows a venous phase image reconstructed using regular HYPR FLOW (middle) and CS HYPR FLOW (right) and compared to the one using gridding method (left). Both HYPR FLOW images have improved SNR and spatial resolution compared to the gridding method. However, CS HYPR shows better correlation with the original gridding image (left) than the regular HYPR, due to the fact that the CS procedure reduces undersampling artifacts superimposed in the background. Waveform comparisons from vessels marked in Figure 1 using the solid arrow and hollow arrow are shown in Fig 2a and b respectively. Both plots demonstrate the improved waveform fidelity of HYPR FLOW by adding CS before the processing. Figure 2a also demonstrates that CS procedure doesn't change waveforms from the actual vessel (curve cs vs. gridding), but only changes the background signals (curve cs-bg vs gridding-bg). Such changes result in the final waveform improvement of the vessel (curve cs-hf vs hf).

In this study, the motivation of using CS is to eliminate the undersampling artifacts. The spatial resolution and SNR will be further improved by the following HYPR FLOW procedure. This makes the final results less sensitive to selection of the CS parameters. In this study, waveforms were compared to those from the gridding images, which may also be biased by undersmapling artifacts. More phantom study should be conducted where the real truth can be established and compared with.

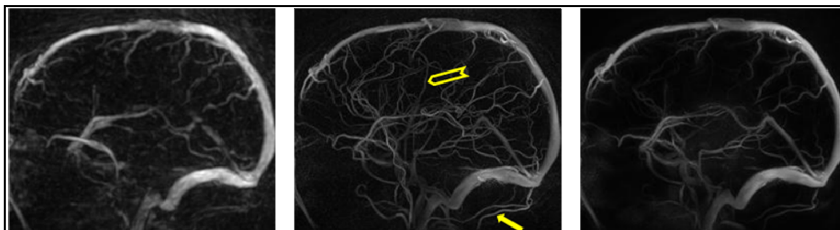

Figure 1 A venous phase Image reconstructed using different methods: left: gridding, middle: regular HYPR FLOW, and right: proposed CS HYPR FLOW. The hollow arrow and solid arrow on the regular HYPR FLOW image show early appearance of a small vein and prolonged arterial phase respectively, when compared to the gridding image on the left, whereas on the CS HYPR FLOW image, the signal intensity of these vessels matches better to the gridding image.

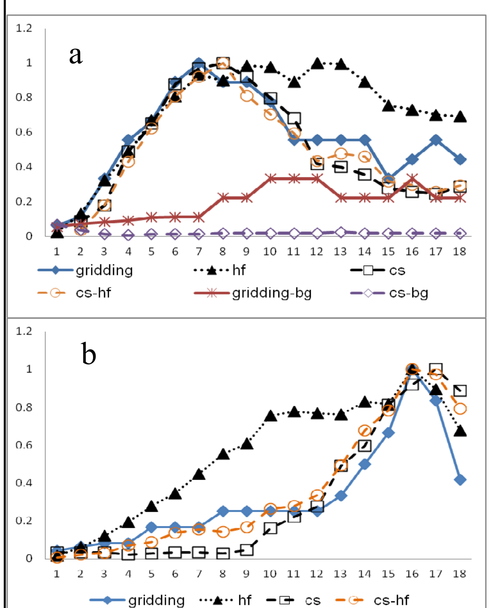

Figure 2 Waveform comparisons from small vessels marked in Fig.1 using solid arrow (a) and hollow arrow (b) among different reconstruction methods. "gridding": regular gridding technique; "hf": regular HYPR FLOW, where the spatially filtering applied on the gridding images; "cs": compressed sensing method only; "cs-hf": CS HYPR FLOW, where the filtering applied on the cs images; "gridding-bg": background signal from the gridding images; "cs-bg": background signal from the cs images. Waveforms from CS HYPR FLOW (cs-hf) match to the gridding method better than the regular HYPR FLOW due to the cleaner background signals after the CS procedure.

CONCLUSIONS

Signal crosstalk in Hybird HYPR-MRA are mainly observed on the small vessels after the peak arterial phase when the undersampling artifacts are getting severe. CS procedure effectively removes these undersampling artifacts, such that the further HYPR procedure is able to improve spatial resolution and SNR without sacrificing the waveform fidelity.

REFERENCES

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