McKinnon-Bates Sparsification for Accelerated Phase Contrast Imaging

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INTRODUCTION

High spatial and temporal resolution flow measurements with two-dimensional phase contrast (PC) imaging require >20-40s of scan time, which is challenging for patients. Spatial and/or temporal resolution is often sacrificed to allow for scans with feasible breath hold times. Shorter scan times have been achieved with sparsity-based reconstructions such as compressed sensing [1] and k-t BLAST [2]. While effective, these techniques require substantial processing time and can lead to unpredictable artifacts and/or variable performance, especially when utilizing non-Cartesian trajectories. Radial undersampling techniques have also allowed for reduced scan times in 2D PC imaging [3], but suffer from streak artifacts with high acceleration. In this work, we investigate sparsifying preprocessing techniques to improve the performance of image reconstruction. We apply this processing to 2D radially sampled data to allow for reconstruction of highly undersampled 2D PC images.

THEORY & METHODS

The algorithm for this technique is summarized in Figure 1. Similar to the McKinnon-Bates reconstruction algorithm [4], this algorithm relies on relatively artifact-free composite images to subtract static tissue components. First, velocity images reconstructed using standard gridding techniques are utilized to obtain the probability that each voxel is representative of background tissue. This is performed using measurements of acceleration and cross-correlation with expected flow patterns.

A composite image was created from all projections over time to represent a fully sampled temporally averaged image. Utilizing the above mask and composite image, expected signal from static tissue is then subtracted from each original time frame. Coils were combined with Parallel Imaging with Localized Sensitivities (PILS) processing [5].

To test the algorithm, a radially acquired 2D PC slice was acquired in the aorta at the level of the pulmonary artery with retrospective gating on a 3T scanner. A total of 1,350 projections were acquired with pseudo-random sampling such that the number of projections could be sorted into any number of time frames. The above processing was performed on projections parsed into two cases: (1) 30 time frames with 45 projections per time frame; (2) 100 time frames with 14 projections per time frame.

Flow measurements in the ascending aorta were compared and plotted over the cardiac cycle for both original images and images processed with the McKinnon-Bates sparsification processing using 45 projections per time frame. Flow measurements from a sliding window reconstruction with 45 projections per time frame were also plotted for comparison.

RESULTS

Artifacts were substantially reduced in images processed with the McKinnon-Bates sparsification processing (Figure 2 B, D, F, H) both for images with 14 and 45 projections. Flow measurements from the images processed with the McKinnon-Bates sparsification were similar in magnitude and in temporal characteristics relative to flow measurements from the unprocessed images (Figure 3). Flow measurements from the sliding window reconstruction showed marked temporal blurring.

DISCUSSION & CONCLUSIONS

With the McKinnon-Bates sparsification processing we have reconstructed highly accelerated 2D PC data with reduced streak artifacts. Despite the low number of projections, temporal resolution, image quality, and flow information of reconstructed time frames were preserved. This algorithm may be useful for reducing the scan time for 2D PC data or improving temporal resolution.

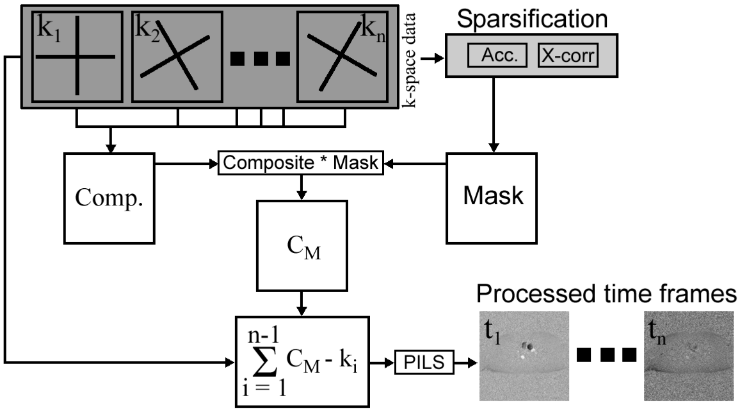

Figure 1. Schematic of the McKinnon-Bates sparsifying algorithm. Original k-space data are shaded in dark grey. Comp = composite; Acc = acceleration; X-corr = cross-correlation.

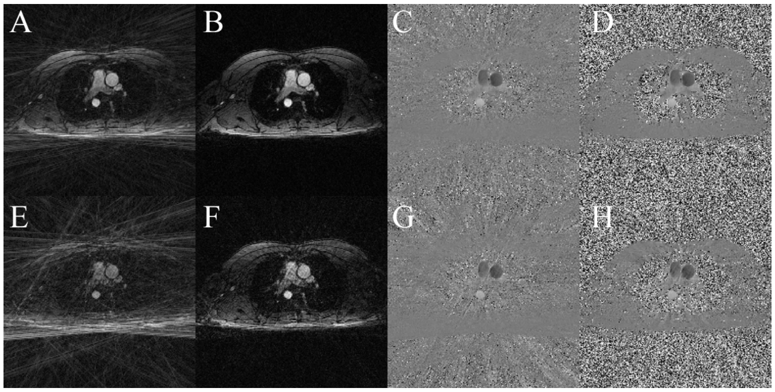

Figure 2. Peak systolic time frame for images reconstructed with 45 (**A-D**) and 14 (**E-H**) projections. Original magnitude (**A**,**E**) and velocity (**C**,**G**) images show streak artifacts. The McKinnon-Bates sparsification processing produces images with substantially less noise in both magnitude (**B**,**F**) and velocity (**D**,**H**) images.

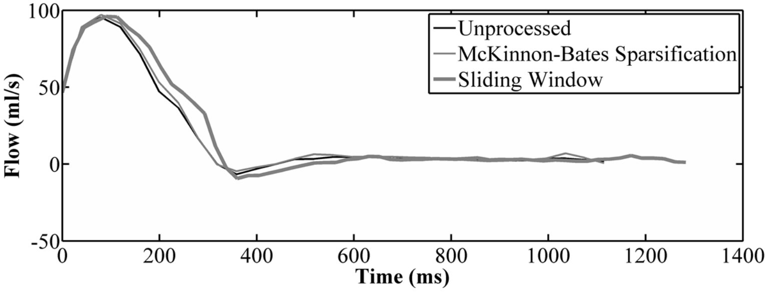

Figure 3. Ascending aortic flow measurements over the cardiac cycle as measured from images reconstructed with 45 projections. Flow curves were measured from unprocessed time frames, as well as with the McKinnon-Bates sparsification process and with a sliding window approach.

Similar to previous experiences, flow measurements even with highly undersampled radial 2D PC data are still reliable [3]. As seen in Figure 3, flow measurements from both unprocessed and McKinnon-Bates processing were very similar. While this is to be expected given our past experiences, it is encouraging that the McKinnon-Bates sparsification processing proposed in this study provides both similar flow measurements and significant improvements in image quality.

The success of this algorithm depends on the quality of the sparsification mask. While 14 projections were sufficient to obtain images of good quality, further reductions in the number of projections may lead to streak artifacts that obscure the vessels and therefore deteriorate the cross-correlation. Nevertheless, the current sparsification algorithm was robust with an undersampling factor of 30.

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