Real-time cardiovascular imaging using a combination of HYPR, McKinnon-Bates, and COM gating algorithms

L. A. Keith[1], D. C. Peters[2], and J. V. Velikina[3]

[1]Physics, University of Wisconsin - Madison, Madison, WI, United States, [2]Harvard University, [3]Medical Physics, University of Wisconsin - Madison, Madison, WI, United States

INTRODUCTION

Real-time cardiovascular MR (CMR) is a clinical tool for assessment of cardiac function in patients without a regular rhythm, and is used experimentally for guiding interventions. The temporal resolution achieved by real-time imaging of the heart is about 70-120 ms and the spatial resolution is 3 - 4 mm. Improvement of the temporal and spatial resolution is an important goal in CMR because it will allow better assessment of real-time cardiac function. In this work we achieve 1.8 mm spatial resolution and 100 ms temporal resolution with improved signal-to-noise ratio (SNR) and artifact level by combining radial acquisition [1] with constrained reconstruction using HYPR [2] and McKinnon-Bates [3] algorithms and retrospective self-gating using the center of mass (COM) approach.

MATERIALS AND METHODS

A 2D balanced SSFP real-time radial sequence was used to acquire a time-resolved series of short-axis images of cardiac function on a 1.5 T Philips Achieva (Best, NL) using a 16 channel coil (Invivo Corporation, Pewaukee, WI). Scan parameters were: TR/TE/flip= 3.1/1.5/60°, 300 mm FOV, 8 mm slice thickness, 160 x 26 projections. Radial acquisitions of consecutive time frames were scheduled using bit reversal ordering of 8 temporal interleaves. The acquired data were then self-gated by calculating the COM value for each projection. In real-time imaging, self-gating helps to determine the cardiac dynamics which is especially important in patients without a regular rhythm. Figure 1 shows a COM determined curve of the cardiac dynamics. All acquired projections were assigned into groups according to their COM values. These groups roughly correspond to different cardiac phases.

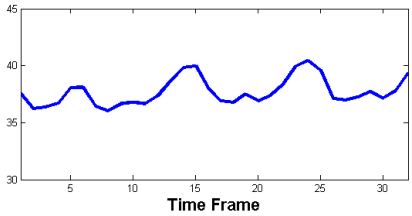

Figure 1. Cardiac dynamics curve determined using COM self-gating.

Therefore, we use images reconstructed from the projections in each group as composite images to constrain HYPR reconstruction of the individual time frames for each dynamical phase. Because of the irregular cardiac rhythm, the number of projections in each group may vary. In our experiments, this number typically was 50-80 which is not sufficient to reconstruct an artifact-free image with adequate SNR using the standard filtered backprojection algorithm (FBP). Instead, we employed the McKinnon-Bates algorithm [3] to reduce the appearance of streaks and noise in the reconstructed composite images. This is important because in HYPR reconstruction the SNR of individual time frames is primarily determined by the SNR of the composite image used to constrain the reconstruction.

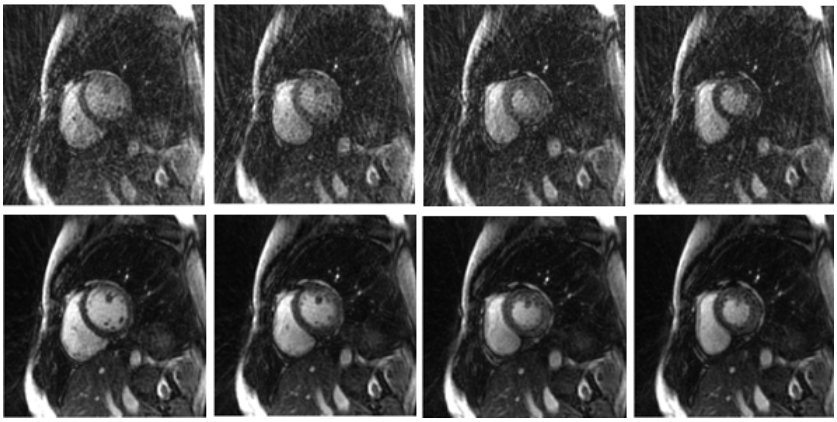

Figure 2. Consecutive frames in a time series reconstructed using FBP (top row) and a combination of HYPR and McKinnon-Bates algorithms (bottom row).

RESULTS AND DISCUSSION

Figure 2 compares the reconstruction results of several consecutive frames in a time series using the FBP algorithm (top row) and the combination of HYPR and McKinnon-Bates algorithms with the COM self-gating technique described above (bottom row). Each image was reconstructed from 26 radial projections which corresponds to an undersampling factor of about 10 relative to the Nyquist criterion. At such a high undersampling level, the FBP algorithm produce images with prohibitively high artifact and noise level, as exemplified in Figure 2. Images reconstructed with HYPR avoid this problem due to the ability of HYPR to transfer the SNR and spatial resolution of the composite images to individual time frames. Note also that the HYPR technique does not compromise temporal resolution of the reconstructed time series due to the COM processing performed for the composite images which minimized the amount of temporal blurring in the composites.

CONCLUSIONS

The combination of HYPR, COM gating, and McKinnon-Bates algorithms is a promising technique for real-time CMR imaging that can produce relatively artifact-free images with high SNR while increasing spatial resolution to 1.8 x 1.8 mm and providing temporal resolution of 100 ms. Initial investigations also indicate that a further increase in temporal resolution is possible without compromising image quality.

REFERENCES

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