Rapid Evaluation of Cardiac Function Using Undersampled Radial TrueFISP with GRAPPA

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Introduction

Real time functional cardiac imaging is one of the most challenging MR applications in terms of imaging speed due to the rapid movement of the heart, especially during stress. The application of parallel imaging in this area has been especially beneficial, since it can increase the image acceleration by a factor of 2-3 with little effort [1-2]. Another potential option is undersampled radial acquisitions [3]. This type of sampling scheme has been proposed as a way to rapidly acquire functional cardiac images without the use of parallel imaging. Ideally, one could combine these two methods to obtain the best of both worlds. However, most normal parallel imaging reconstructions are designed for Cartesian sampling patterns. In general, the parallel imaging reconstruction problem is orders of magnitude more difficult for non-Cartesian sampling patterns, such as radial sampling [4]. Several solutions to this general problem have been proposed [4-6] which are able to reconstruct radially sampled images in a reasonable time. In this abstract, we apply the recently proposed direct radial GRAPPA reconstruction [6] to the problem of real-time imaging of cardiac function. It is shown that GRAPPA provides a good image quality with substantially reduced artifacts compared to the undersampled radial reconstructions without GRAPPA. Parallel imaging accelerations of 3-6 were obtained, corresponding to a factor of 8-16 compared to full Cartesian sampling.

Methods

Real time radial cardiac imaging was performed on a 1.5 T Siemens Quantum Symphony using two standard 6-channel array coils (anterior/posterior) combined to 8 receiver channels. A radial TrueFISP sequence was used for readout. This sequence used a TR of 3.86 ms for 256 readout points at a bandwidth of 686 Hz/pix. The FOV used was 400 mm^2. Each frame of the reduced image acquisition consisted of 16-32 projections covering 180º. Ten 96 projection images were acquired for coil sensitivity calibration before the real time acquisition.

Following acquisition, the individual frames were reconstructed using the direct GRAPPA method proposed in [6]. The method can be summarized as follows. Each frame of the radially sampled data is reordered into a hybrid space corresponding to the FT of the sinogram of the object along the readout direction. These data are then segmented along the readout direction. Each segment is then passed to a normal GRAPPA reconstruction. After each segment is processed, the data is combined to form the final image. For the images shown here, 16 segments were used. The method was implemented in Matlab 6.1 on a 2.7 GHz Pentium 4 processor with 512 MB RAM. The final image reconstruction was performed using the filtered back-projection routine provided by Matlab.

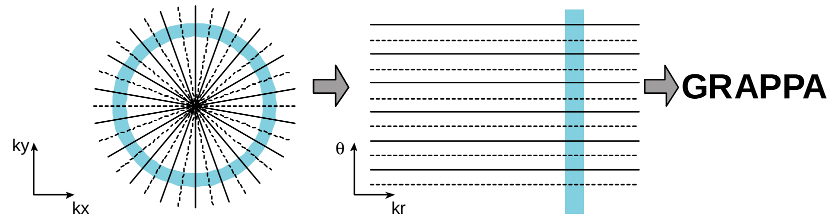

Figure 1. Schematic of reconstruction process. Each frame of the radial acquisition is reordered into a hybrid space, which corresponds to the FT of the sinogram of the object along readout. These data are then segmented along the readout direction (blue). Each segment is then passed to a normal Cartesian GRAPPA reconstruction.

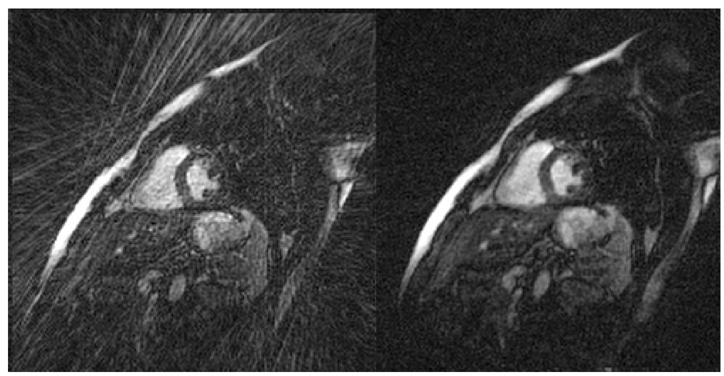

Figure 2: (left) Undersampled PR reconstruction from 32x256 projections (right) 3X GRAPPA reconstruction up to 96x256 projections. No obvious streaking artifacts remain in the GRAPPA image.

Results

The direct GRAPPA reconstruction provided reduced aliasing artifacts in every case tested so far. The reconstruction time for the first frame was 24s while later frames required only 12s. Of this time, 8s was required for the back-projection alone, indicating that the reconstruction time would probably be dominated by the back-projection/ regridding time for subsequent frames. For comparison, a CG-SENSE [4] reconstruction required approximately 50s per image frame.

Figure 2 demonstrates the good image quality obtained with the GRAPPA reconstruction. In this case, 32 projections were reconstructed up to 96 projections using a 3x GRAPPA reconstruction with no echo sharing between frames. The GRAPPA reconstruction shows fewer aliasing artifacts compared to the undersampled image without GRAPPA while maintaining good image quality throughout the image. Figure 3 shows an example of 6x acceleration using 16 projections reconstructed up to 96. In this case, some blurring of the fine structures can be seen in these images. We have seen a similar loss in resolution using the CG-SENSE reconstruction at this level of acceleration, indicating that this is near the limit in terms of acceleration for this coil.

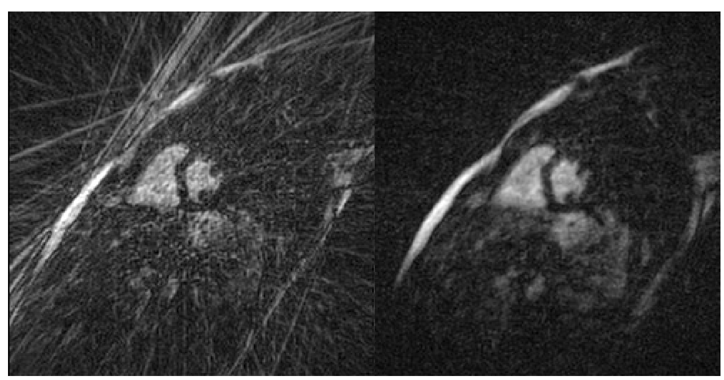

Figure 3: (left) Undersampled PR reconstruction from 16x256 projections (right) 6X GRAPPA reconstruction up to 96x256 projections. Some spatially dependent blurring can be noted in some areas of this image.

Conclusion

We have shown that it is possible to perform rapid real time cardiac functional imaging using an undersampled radial trajectory in combination with the GRAPPA parallel imaging reconstruction. GRAPPA improved image quality compared to the undersampled data set in each case tested to date. The coil calibration strategy based on a prescan of several fully sampled frames proved to be an easy and robust solution for this application. However, an interleaved sampling strategy based on a TSENSE/TGRAPPA [7-8] type of acquisition should bring even more benefits, especially in terms of the potential use of this method for interactive acquisitions.

References:

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