Combining nonrigid motion correction and partial Fourier for 3D high resolution cardiac imaging

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INTRODUCTION

Partial Fourier techniques use asymmetric sampling of k-space to save scan time. A dedicated reconstruction is necessary: (i) the symmetrically sampled data in the center of k-space are used to estimate a low resolution phase map; (ii) this phase map is then used to constrain the reconstruction of the full image. Such strategies apply to a wide range of iterative reconstruction schemes including partial Fourier SENSE [1].
Generalized reconstruction schemes have been described in order to compensate for complex, nonrigid motion retrospectively, e.g. for free-breathing cardiac imaging [2,3]. Modifying those iterative algorithms to include a phase constraint is straightforward. The main difficulty lies in the estimation of an accurate low resolution phase map. Since they are constructed from central k-space data from the same motion-corrupted sequence, they are also corrupted by motion which leads to corrupted phase maps and therefore residual artifacts. Here we describe a method to integrate a motion-compensated low-resolution phase map within the GRICS motion correction framework. The technique is applied to free-breathing 3D cardiac imaging using partial Fourier and parallel imaging (myocardial viability sequence).

METHODS

The GRICS framework solves jointly for a motion-compensated image and a nonrigid motion model (here a respiratory motion model). The algorithm has a multi-resolution implementation, which means in the first stage only the central k-space data are used to reconstruct a low resolution image and motion model. A phase constraint is not required at this stage because it only uses symmetrically sampled central k-space data. After that, the phase of the image is taken and upsampled to the next resolution level, using zero-filling and windowing to avoid ringing artifacts (taped-cosine window, as commonly used in partial Fourier techniques). The remaining resolution levels of GRICS are solved using a phase constraint in each image reconstruction step as described in [1].
Data from 3 healthy volunteers were acquired on a 1.5T scanner (General Electric, Milwaukee, WI, USA). We used a pulse sequence used clinically for myocardial scar imaging: IR-prepped fast gradient echo (3D-MDE) [4], TE/TR = 1.4/4 ms , 224x256 matrix, partial Fourier factor 0.6, SENSE factor 1 to 2, acquisition in diastole. Data were acquired without contrast agent injection (injection of healthy volunteers is not allowed in our country), therefore we used an inversion time TI of 300 to 400 in order not to fully null the signal from the myocardium. Data were acquired in breath-hold (8 to 10 mm resolution in the slice-encoding direction) and then during free breathing (3 to 5 mm resolution). The free breathing acquisition was repeated 3 times, providing extra excitations to compensate for the increased resolution in the slice-encoding direction and over-determination for the motion-compensated reconstruction. The signal from one respiratory belt was used to drive GRICS reconstructions.

RESULTS

Example images from one volunteer are shown in Fig 1. We compared standard breath-held images to free-breathing data with various reconstructions: averaged, partial Fourier GRICS using uncorrected/corrected low resolution phase maps. It can be seen that subtle changes in the phase map can lead to marked signal losses in the final image, e.g. at the interface between myocardium and blood.

CONCLUSION

Our results suggest that the construction of a good low resolution phase map can be critical when combining motion-compensated reconstruction techniques with partial Fourier. The application of GRICS in 3D allows motion to be corrected in 3D (including in-plane and through-plane motion). The scan time required for the 3D high resolution scan (i.e. the 3 free-breathing scans) was less than 2.5 min with parallel imaging (factor 2) and partial Fourier. This is acceptable for myocardial viability assessment, as a time window of roughly 5 min is available 10 to 15 min after injection for optimal contrast between scar, myocardium and blood. These results need to be confirmed by a patient study.

REFERENCES

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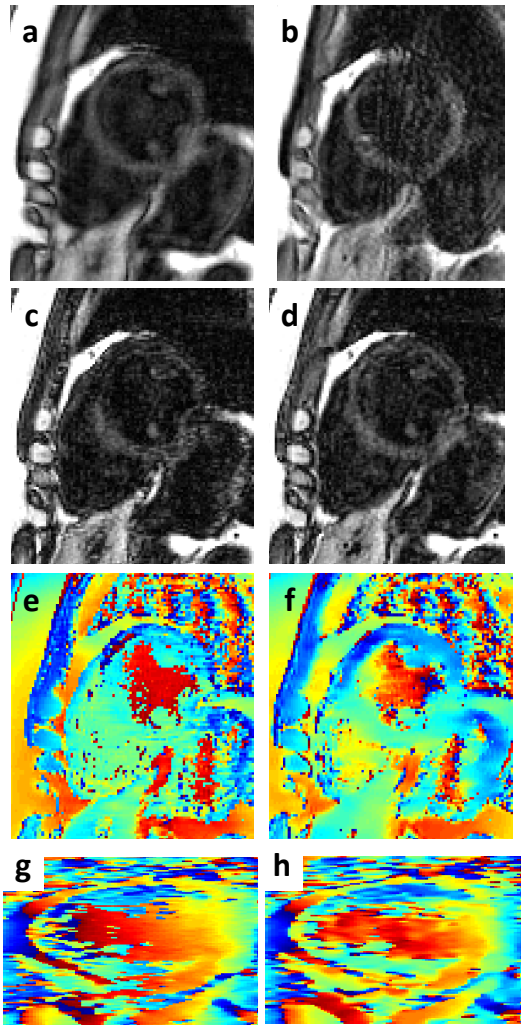

Fig.1 Data from a healthy volunteer acquired with a 3D myocardial viability sequence (without injection) with partial Fourier: (a) free-breathing (FB) acquisition, averaged reconstruction; (b) breath-hold reference; (c) FB, partial Fourier GRICS reconstruction with uncorrected phase map (short-axis view in (e), vertical long-axis in (g)); (d) FB, partial Fourier GRICS reconstruction with motion-corrected phase map (short-axis view in (f), vertical long-axis in (h)).