Model-based Reconstruction for Free-Breathing Cardiac CINE Imaging using GRICS

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INTRODUCTION

Physiological motions, such as breathing and heart beating, still remain a major source of artifacts in MRI. The Generalized Reconstruction by Inversion of Coupled Systems (GRICS) (1) has been developed from a mixed approach of motion correction (2) and parallel imaging (3) to correct them. This method is based on a motion model that is constrained by physiological signals, such as respiratory belt amplitude. Compared to other approaches, such as fast dynamic acquisition techniques in k-t space (4), including those involving a motion model (5), GRICS has the advantage of correcting for complex deformation fields in the whole field of view. The method was originally aimed at correcting respiratory motion in ECG triggered black blood images (1). Nevertheless, functional cardiac assessment plays a major role in cardiac MRI and 2D SSFP cardiac CINE sequences are generally used for this purpose. Therefore an extension of GRICS is described for 2D SSFP Cardiac CINE imaging in free-breathing, featuring a piecewise linear model for cardiac motion.

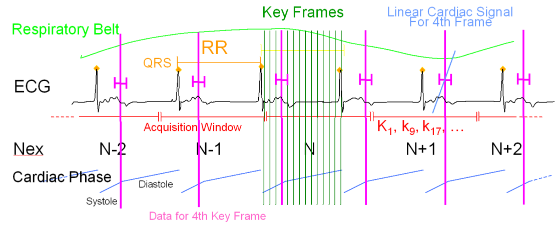

Figure 1: Multi phase data acquisition vs. physiological signals. For each R-R interval, a cardiac phase is defined and split into 14 key frames. Within the small time interval of a key frame, a linear cardiac signal is used in supplement to the two respiratory belts for GRICS reconstruction.

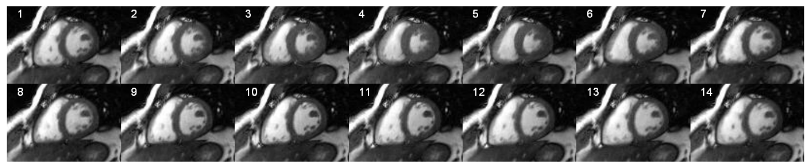

Figure 2: For one slice, a detail of the short axis left ventricle for all 14 key frames.

METHODS

To demonstrate the feasibility of a whole heart free-breathing cine imaging, 18 slices in main heart orientations were acquired on 1.5 T GE Signa HDx MR system (GE Healthcare, Milwaukee, WI). A free-breathing healthy volunteer underwent 18 multi phase balanced-SSFP sequences (TR 3.85ms, TE 1.68ms, 40cm FOV, 256x256 matrix, 45° flip angle, 8mm slice thickness, 40 temporal phases for a total of 40s). The sequence was modified with k-space acquisitions reordering for a more spread time distribution. The same slices were acquired in breath-hold using the conventional 2D balanced-SSFP. ECG and two respiratory belts (chest and abdomen) were collected using a patient monitoring system (Maglife^{TM}, Schiller Médical, Wissembourg, France) and combined with MR data for the reconstruction (6).

The proposed reconstruction (CINE-GRICS) involves, for each slice, the reconstruction of 14 cardiac phases, that we call key frames (Fig 1-2). Each key frame is reconstructed with standard GRICS, using 3 input signals in order to constrain the motion model, including two respiratory belts, and a cardiac phase signal derived from the ECG, accounting for small cardiac deformations within the frame. From these results, series of 32 cardiac phases in a chosen static respiratory position have been generated in DICOM format (Fig 3) and then compared with standard breath-hold acquisitions using dedicated software (Mass Analysis Plus, MEDIS medical imaging systems, Leiden, The Netherlands).

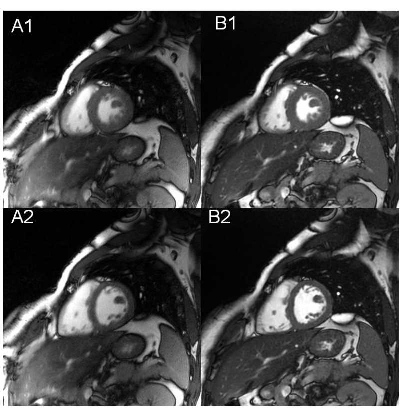

Figure 3: For a slice, a comparison between CINE-GRICS reconstruction (A) and standard clinical breath-hold acquisition (B).

RESULTS

The CINE-GRICS reconstruction provides as intermediate results 14 key images (Fig 2) and their corresponding deformation model parameter maps for each one of the 18 slices. The CINE reconstruction was also compared to a simple averaged Fourier reconstruction from the same raw data (Fig 4 A). Sharpness and fine details can be observed on the time-mode display of the CINE-GRICS reconstruction (Fig 4. D2). Functional parameters, such as left ventricle volumes or ejection fraction, were obtained from the 16 short axis slices with similar results to the breath-hold ones.

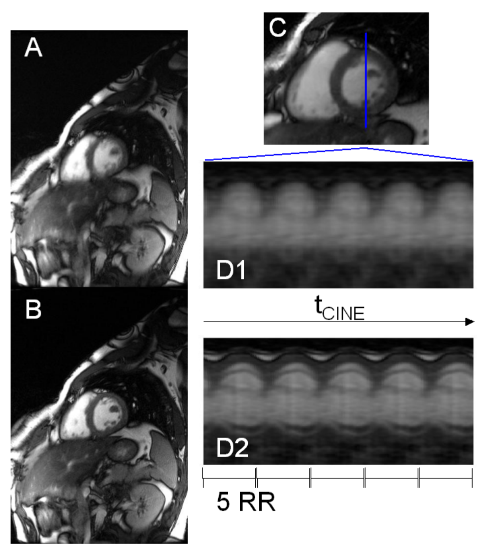

Figure 4: Slice comparison between simple averaged Fourier reconstruction (A) and CINE-GRICS reconstruction (B). In vertical long axis (C), their respective profile (D1 & 2) reproduced along 5 normalised RR intervals.

CONCLUSION

As in (1), CINE-GRICS images are sharper than averaged Fourier reconstruction. This result demonstrates the possibility of whole volume CINE cardiac imaging in free breathing using GRICS reconstruction algorithm with image quality surpassing standard Fourier averaging (Fig 4) in an acquisition time compatible with clinical constraints. The image quality is similar to breath-hold acquisition (Fig 3) and compatible with cardiac functional assessment.

REFERENCES

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