**Analysis of cardio-respiratory motion of the heart using GRICS (first insights)**

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# INTRODUCTION

Generalized Reconstruction by Inversion of Coupled Systems (GRICS) (1) is an approach aiming at correcting motion artifacts (2) and generalizing parallel imaging (3). It enables free-breathing MR Imaging of cardiac structures (4,5,6). This reconstruction process is constrained by physiological signals, such as respiratory belt amplitude and ECG (4). Other approaches have been proposed to improve imaging of moving structures by means of fast acquisition in k-t space (7,8), or using a motion model (9). However GRICS inherently defines a motion model which can be used to study local deformations.

Cardiac MR imaging is clinically established for functional cardiac assessment. 2D balanced-SSFP sequences are widely used for the functional assessment of the heart. However, local deformations can hardly be assessed with balanced-SSFP sequences. This is why other approaches are actively developed to evaluate cardiac motion including HARP, DENSE, SPAMM (10,11,12), however with lower spatial resolution or longer acquisition time. An extension of GRICS has been designed for 2D balanced-SSFP (4). Thanks to the motion model, mean local motion vectors can be computed for any given region of interest (ROI) within the thorax of a free-breathing subject. These vectors contain contributions from the so-called driving signals, derived from ECG leads and respiratory belts.

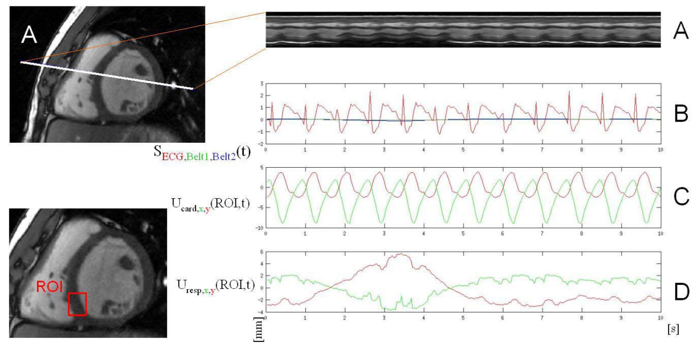


Figure 1: Cardiac and respiratory displacement vectors during a 10 seconds window showing correlation between average displacement in a rectangular ROI on the septum (left, bottom) and physiological signals. (A) time-mode display of the vertical section (shown top left) of the left ventricle (B) physiological recording at 25 Hz (red: ECG, blue and green: respiratory belts) (C) cardiac components and (D) respiratory components of the average displacement vector in the septal ROI (red: x component, green: y component).

# METHODS

Slices covering the heart in short axis, in vertical and in horizontal long axis orientations were acquired on a 1.5T Signa HDx MR system (GE Healthcare, Milwaukee, WI) using multi-phase balanced-SSFP sequences for 5 healthy subjects in free breathing (TR 3.85ms, TE 1.68ms, 40cm FOV, 256x256 matrix, 45° flip angle, 8mm slice thickness, 45 temporal phases for a total of 45s per location). The sequence was modified with k-space acquisition reordering to achieve a wider time distribution. Physiological signals were collected using a modified version of the Maglife monitoring system (Schiller Médical, Wissembourg, France) (13). To reconstruct the multi-phase data, three input signals were used, including two respiratory belts (thorax and abdomen). ECG recording was used to determine the R-waves and assign each k-space line to its correct cardiac phase. The CINE-GRICS reconstruction (4) involves, for each slice, the reconstruction of 14 cardiac phases, called key frames. Each key frame is reconstructed with standard GRICS (1), using respiratory belts, and a cardiac phase signal derived from the ECG, accounting for small cardiac deformations within the frame.

For each slice, the physiological recordings were resampled at 25 Hz, and used to create a dynamic sequence of corresponding frame rate (6). For each slice a region of interest (ROI) was drawn. Since the 14 key frames of the cardiac cycle were computed independently, a common reference frame was established on this ROI by tracking the mean cardiac phase motion. The linear motion model can be split into two contributions (respiratory belts and ECG), yielding two separate mean displacement vectors on the ROI (Fig 1: $U_{card}$ and $U_{resp}$).

# RESULTS

Reconstruction using GRICS produces several average key frames covering the cardiac cycle, and their corresponding displacement fields, at each slice location. From these optimizations, movies of the corresponding free-breathing acquisitions have been generated. A manually drawn line section across the left ventricle was chosen. The motion along the line match the corresponding physiological record (Fig 1: A and B). For each slice, an ROI was chosen and the two mean displacement fields were computed (Fig 1: C and D). Each component of the displacement fields is correlated with one of the physiological signals. A second larger ROI was defined, inside which a deformable checkboard was drawn (Fig 2: blue). The variation of the cardiac component of displacement fields (i.e. the component correlated with the ECG derived signal) was overlaid onto each tile of the checkboard for easier visualization (Fig 2: green arrows). The cardiac twist during systolic contraction is visible, looking at the arrows directions.

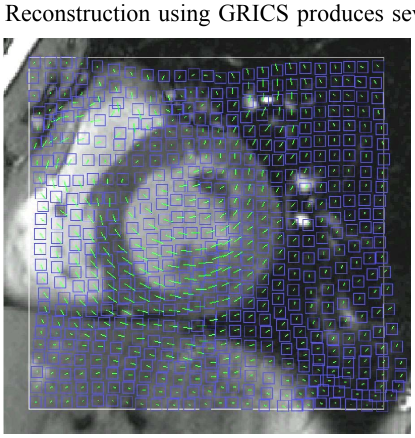

Figure 2: In an ROI covering the heart (white), the deformations inside a 24x24 checkboard (blue) were computed over a movie at 25 Hz of the beating heart. The variation of the cardiac component of motion (i.e. motion correlated with the ECG signal) during systolic contraction is displayed with green arrows..

# CONCLUSION

This result demonstrates the possibility to reconstitute from physiological recordings and MRI acquisitions, mean displacement vectors in arbitrary ROIs across the heart using GRICS reconstruction algorithm. This enables studying different contributions of the thoracic displacement which are correlated with physiological signals such as respiration or heart beat.

# REFERENCES

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