Cardiac and respiratory motion compensated reconstruction driven only by 1D navigators

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INTRODUCTION

Cardiac MRI requires compensation of respiratory and cardiac motion, which is usually performed by gating using an ECG and breathing signal. Recently, a motion compensated reconstruction of arbitrary physiological motion was proposed [1], that is based on a generalized reconstruction by inversion of coupled systems (GRICS) and uses a motion model and a reduced number of 1D input signals for driving this model. External motion sensors (e.g. respiratory bellows) were used to drive the model. Recently self-gated methods were also proposed by extracting respiratory [2] and ECG signal [3] from additionally acquired central k-space profiles. However, such navigator data are usually used for gating or slice tracking, assuming rigid body motion along the navigator profile (motion is described by a scalar value). This work focuses on the analysis of such 1D navigators, in the context of a multiple coil acquisition (providing localized information). Motion eigenmodes are determined from 1D navigators of a 32-channel coil array, which are then used as inputs for the GRICS motion compensated reconstruction. The approach was tested in cardiac function studies of healthy volunteers under free breathing and without using an external ECG-signal.

METHODS

Data from three volunteers were acquired on a 1.5 T Philips Achieva scanner (Philips Medical Systems, Best, The Netherlands), using a 32 channel cardiac coil. A balanced SSFP sequence for 3D cine acquisition was modified to obtain additional central k_0-profiles every 30 ms. For each coil, the resulting 1D+t profiles (one spatial dimension + time) were subjected to a nonrigid 1D registration (see Fig.1) using an optical flow algorithm. A principal component analysis of the resulting 1D+t motion fields from the whole coil array was then performed. The first eigenvectors were used as motion model inputs for the GRICS algorithm.

GRICS consists of simultaneously solving the motion compensated reconstruction problem and the optimization of the underlying motion model. For each cardiac phase to be reconstructed, data from neighboring cardiac phases were first selected (within a cardiac window of approximately 200 ms), based on an ECG-like signal obtained by filtering of the centre k-space data, using the method described in [3]. The selected data are then used for GRICS reconstruction, which thus corrects for both respiratory motion and cardiac motion within the cardiac window.

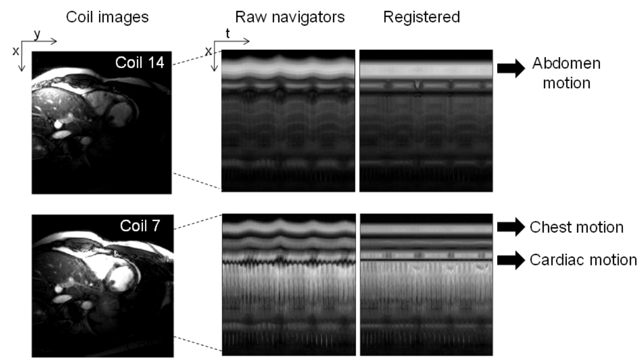

Fig.1. Coil images (left), corresponding central k-space profile navigator (middle), and registered profiles (right), using the optical flow 1D non-rigid registration. In this example motion from the abdomen (coil #14), chest and heart (coil#7) are extracted.

RESULTS

The use of parallel receivers provide information about motion from different regions of the body (abdomen, chest, heart...) as can been seen in Fig.1. Furthermore, the eigenmodes show the main components of motion in the field of view in terms of cardiac and/or respiratory components. The most significant eigenmodes were used in motion compensated reconstructions (Fig.2) which were compared to a breath-hold acquisition of the same slice. A significant decrease in motion artifacts was observed, in particular in the myocardial borders, which appear blurred without any correction. This shows the ability to compensate simultaneously for non-rigid cardiac and respiratory motion without the need for external sensors such as ECG.

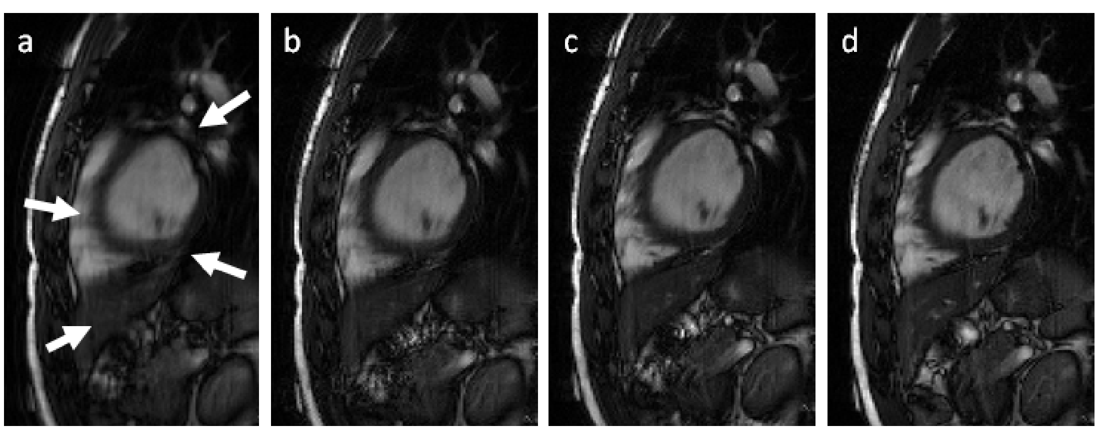

Fig.2. Reconstruction from cardiac data (sagittal slice) corrupted by respiratory motion and cardiac motion (within a 200 ms cardiac window): standard reconstruction (a); sensor-based GRICS, using ECG and 1 respiratory bellow (b); GRICS using navigator information only (c). Breath-hold cine image for reference (d).

CONCLUSION

The proposed processing of navigator data allows automatic analysis of the full navigator dataset. The main eigenmodes extracted from the dataset were shown to allow motion compensated cardiac reconstruction in free-breathing, and without the use of external ECG signal. Potentially, this approach allows the scanning of patients without any ECG-sensor or reconstruction of cardiac cine images if the external ECG signal is failing or is distorted at high magnetic field strengths.

REFERENCES

[1] F. Odille *et al.*, MRM 2008, 60:146-157 ; **[2]** S. Uribe *et al.*, MRM 2007, 57:606-613 ; **[3]** M. Buehrer *et al.*, MRM 2008, 60:683-690