Cardiac Functional Assessment without ECG using Physiological Self-Navigation

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INTRODUCTION: Electrocardiogram (ECG) gated cine MRI provides highly accurate functional information on the heart [1]. Nevertheless, a reliable ECG signal is not always available due to patient's electrophysiology or high MR field strengths [2].

Here we present a novel two-step framework to assess cardiac function by retrospective gating using physiological cardiac gating (PCG) signals obtained from the same acquired data. First, real-time images are reconstructed to obtain a cardiac gating signal describing blood volume changes in the left ventricle (LV). This physiological information is used to retrospectively reorder the data and to reconstruct cine MR images. Secondly, the closure of the mitral valve (MV) in these images is used to synchronise different slices and avoid potential issues of asynchronous contraction of the heart in different slices.

The approach utilises the properties of a Golden Angle (GA) radial sampling scheme [3] to reconstruct both real-time and retrospectively reordered cine images with different temporal resolutions from the same acquired data.

METHODS: Image acquisition (Fig 1a-b): A 2D GA radial sampling scheme was implemented on a 1.5T MRI scanner (Philips Healthcare). 12 radial long axis (LAX) slices covering the entire LV were acquired over a 10s/slice breathhold in 5 volunteers: balanced SSFP sequence, FOV: $320mm^2$, $2x2x8mm^3$ resolution, FA: 60^o, TR/TE: 3/1.5ms. All images were reconstructed using a non-Cartesian iterative SENSE reconstruction [4].

Image-based Cardiac gating signal (Fig 1b-c): Real-time images (1 to 400) were reconstructed from the GA data. A cardiac gating signal was determined in these images as the temporal changes of the LV blood pool width (red arrows+curve) [5]. Different reconstruction windows (12 – 90 ms temporal resolution) were tested in one volunteer and the accuracy of this image-based cardiac gating signal was assessed by comparing it to an external ECG signal in one volunteer.

Retrospectively gated cine images (Fig 1d): The temporal resolution leading to the highest accuracy of the image-based cardiac gating signal was applied to all volunteers and retrospectively reordered cine images comprising 30 cardiac phases (1 to 30) were reconstructed. These images were compared to standard Cartesian ECG-gated cine MRI with similar scan parameters.

Functional assessment – Synchronisation (Fig 1e): The closure of MV (T_{VC}) was determined in all slices and used to synchronise the cine LAX images. This information on MV can only be accurately detected in retrospectively reordered images with high spatial resolution, i.e. not in real-time images. The accuracy of T_{VC} was assessed by comparing it to an external ECG signal. A functional assessment of the LV was carried out comparing the proposed PCG approach to a standard Cartesian ECG-gated 2D multi-slice short-axis method.

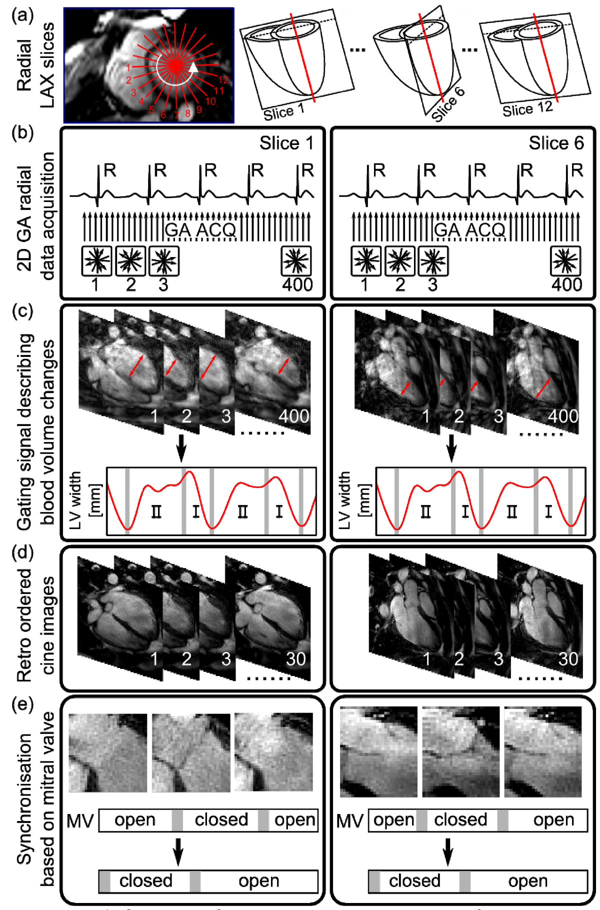

Figure 1: Overview of proposed physiological gating framework. Details in METHODS section

Figure 2: Results of proposed framework (PCG) for two cardiac phases (Diastole and Systole). Temporal profiles show great correlation with standard Cartesian approach (Cart).

RESULTS: The image-based cardiac gating signal clearly shows ventricular ejection (I) and filling (II) phases (Fig. 1c). The highest accuracy was achieved for real-time images with a temporal resolution of 24ms. Over all five volunteers this led to a deviation of less than 20ms between the image-based cardiac gating signal and ECG. Cine images obtained with the proposed PCG method are shown in Fig. 2. Spatial-temporal plots from our PCG approach and a standard ECG-gated Cartesian method (Cart) show great correlation (black arrows: papillary muscles). A functional assessment showed a difference of less than 5% between the proposed PCG and a Cartesian ECG-gated short-axis reference method.

CONCLUSION: We have presented a novel framework which allows for cardiac functional assessment using only physiological information obtained directly from the acquired images utilising the properties of a GA sampling scheme. The obtained physiological gating and synchronisation signals showed accurate correlation with an external ECG. The real-time images can also be used to detect and compensate for respiratory motion [6] which would add another physiological component. This framework shows great potential for reliable cine imaging of foetuses, of cardiac patients with electrophysiological problems and in high-field cardiac MR applications.

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