Cardiac function assessment without ECG using image-based navigation

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INTRODUCTION: 2D multislice retrospectively cardiac gated cine imaging based on an external ECG signals is commonly used to analyse cardiac function [1]. In order to avoid image quality degradation due to corrupted ECG signals self-navigator techniques have been proposed [2]. They either rely on k-space signal variations due to inflow effects and changes of the blood pool size or cross-correlation variations in selected region of interests. Therefore, they require a detectable periodic signal change in each slice. This requirement is not necessarily fulfilled for apical slices where the blood pool is only visible during late diastole. In addition, the complex blood flow close to the valve plane could also lead to inaccuracies of the self-navigator signal. Furthermore, these techniques obtain the gating signal from each slice individually and therefore, it is not guaranteed that the self-navigator signals are synchronised between different slices.

Here we present a new method which obtains an image and a navigator slice simultaneously using radial CAIPIRINHA (radCAIPI) [3] with a Golden Ratio sampling order. During the 2D multislice acquisition the navigator slice is kept at a constant position centred between apex and valve plane and the imaging slice is moved to cover the entire ventricle. Our approach guarantees that the same accurate navigator signal is available for all slices which avoids any position dependent variations. An image based navigator signal is obtained from the navigator slice and the data from the imaging slices are retrospectively reordered yielding multiple cine images with high spatial and temporal resolution.

METHODS: Sampling scheme: Data is acquired with a Golden radial trajectory. This allows for the retrospective combination of arbitrary radial lines and offers great flexibility for retrospective gated cine imaging [4]. RadCAIPI separates the signal from two simultaneously excited slices by alternating the phase of the RF pulse between 0 and π for adjacent radial lines for one slice and keeping it constant for the other slice. Due to the properties of the Golden Ratio alternating phases for successively acquired radial lines for a Golden radial sampling scheme leads to a similar distribution of phases (Fig. 1a). Therefore, the signal from two simultaneously excited slices can also be separated successfully (Fig. 1b).

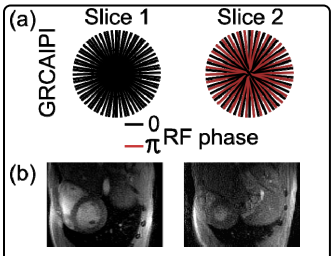

Fig. 1(a) Alternating the phase of successively acquired Golden radial lines for one slice allows for the separation of the signal of two simultaneously excited slices (b).

Image acquisition: RadCAIPI with a Golden Ratio trajectory was implemented on a 1.5T MRI scanner (Philips Healthcare). Nine short axis data sets were acquired in a healthy volunteer with the imaging slices covering the entire left ventricle and the navigator slice centred in the ventricle: T1 weighted fast field echo (FFE) sequence, FOV: 320mm^2, 2mm resolution in-plane, flip angle: 15°, TR/TE = 3.3/1.48ms, 8s breathhold/slice. All images were reconstructed using a non-Cartesian iterative SENSE reconstruction [5]. The necessary coil sensitivity maps were obtained from the data itself.

Gating signal: Real time images from the navigator slices were reconstructed with a temporal resolution of 37ms using a sliding window approach. From these images functional image-based cardiac navigator signals were obtained. This navigator signals were then used to retrospectively reorder the data from the corresponding image slices, i.e. data from different cardiac cycles but same cardiac phases was combined. That allowed for the reconstruction of 40 cardiac phases for each slice yielding high temporal and high spatial resolution cine images.

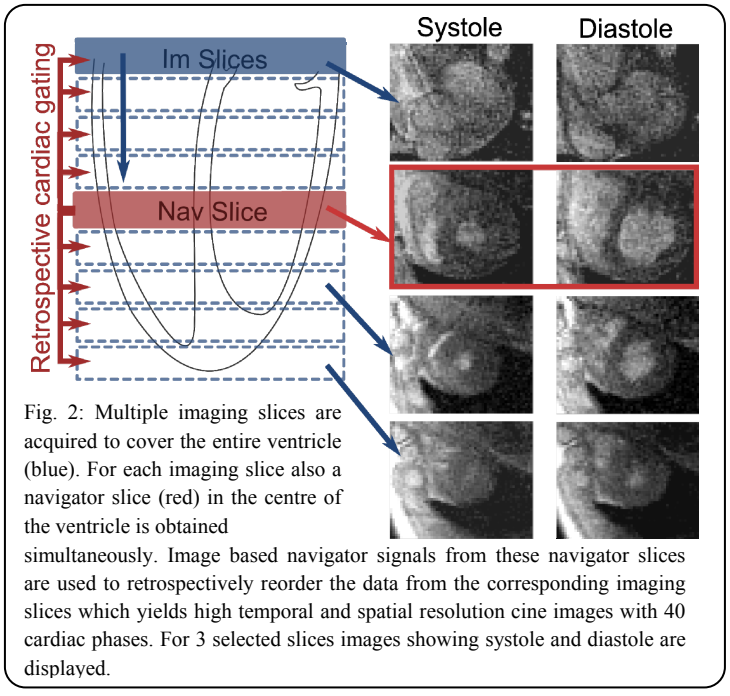

Fig. 2: Multiple imaging slices are acquired to cover the entire ventricle (blue). For each imaging slice also a navigator slice (red) in the centre of the ventricle is obtained simultaneously. Image based navigator signals from these navigator slices are used to retrospectively reorder the data from the corresponding imaging slices which yields high temporal and spatial resolution cine images with 40 cardiac phases. For 3 selected slices images showing systole and diastole are displayed.

RESULTS: The gating signal obtained from the blood pool showed a standard deviation of 15.8ms compared to a standard ECG signal and a variation of 7.9ms between different short axis data sets. Retrospectively gated cine images for several positions in the ventricle in systole and diastole are shown in Fig 2.

CONCLUSION: We have presented a new method which uses data from two excited slices to obtain both image and navigator information at different locations simultaneously. The image-based navigators obtained from the navigator slice showed high accuracies and little variation between different image slice positions. Nevertheless, also more advanced image analysis techniques can be applied to obtain a cardiac navigator signal. In addition respiratory navigation could be obtained from the same images. So far the method was used for FFE sequences. Future work will include an implementation for balanced SSFP imaging to improve SNR and image quality.

Our approach yields a cardiac navigator signal which is obtained from common navigator images allowing for slice positions which do not yield a reliable signal themselves. Although we demonstrated the image-based navigation for cardiac function, it can be used in a wide range of applications.

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