MR compatible Doppler-ultrasound device to trigger the heart frequency in Cardiac MRI: comparison to ECG

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Introduction

Cardiac MR imaging has rapidly developed in the past few years. 2D CINE steady-state free precession (SSFP) imaging is the most reliable and used technique for left ventricular (LV) function assessment whereas the electrocardiography (ECG) triggering technique is commonly used to synchronize the data acquisition with the cardiac cycle (1). However, ECG may carry different risks of interference with the MR system (2). Therefore a triggering alternative is an important issue for future studies. Recently, a new method based on a MRI compatible Doppler ultrasound (US) device has been successfully applied to trigger the heart frequency in cardiac MRI (3). However, the physiologic delay between electrical activation of the heart represented by the PQRS-complex and the measureable Doppler US signal has not been taken into account. As the trigger time point of the Doppler US signal is shifted in respect to the ECG signal, the observed heart cycle in cardiac MRI triggered cine sequences may not represent a complete cycle. In the presented study, ECG and Doppler US signals have been acquired simultaneously to determine the delay of the US signal. Subsequently cardiac MR imaging with triggering of the heart beat with the MRI compatible Doppler US device was performed and compared to conventional ECG triggering.

Material and Methods:

Doppler US and ECG

The US transducer (HP 15245A) of a standard CTG (model HP 8040A, Hewlett Packard, Palo Alto, USA) was employed for cardiac triggering and a 4-lead ECG for routine triggering. US trigger signals were determined using raw US Doppler signals from a modified CTG and processed using software written in MATLAB (MathWorks, Natick, MA). US, ECG and the generated US trigger were acquired simultaneously outside the MR room for 2 min using Biopac (BIOPAC Systems, Inc.) modules (Fig1 a)). The physiologic time delay was assessed using a peak detection algorithm and the occurrence of peaks in ECG and US signals were compared.

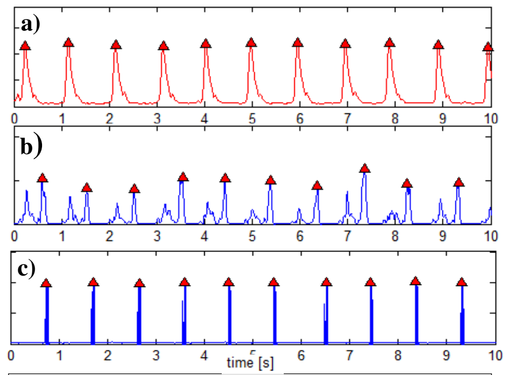

Figure 1 Shown are simultaneous acquired ECG (a) Doppler US (b) and generated trigger signal from Doppler US (c). The red triangle represents the detected peak by the peak detection algorithm.

MR Imaging

MR imaging was performed on 5 healthy subjects on a 1.5 T MR scanner (Philips Medical Systems, Best, Netherlands). The Doppler US transducer was placed on the chest above the heart. The determined US trigger signal was transferred to the ECG trigger unit of the MRI scanner and used for cardiac triggering. The CTG signal was protected against the electrical and magnetic fields' interference of the MRI, additionally an optical transmission and standardization of the heart signal was used to put the analogue signal back to the ECG-unit of the MRI. Cardiac MRI was performed using both triggering methods consecutively. For cardiac MRI cardiac triggered cine SSFP MRI sequences (TR 34.91 ms; TE 1.34 ms; Flip-angle 55°; slice thickness 3 mm) of the heart were achieved in short axis view, two and four chamber view and were adapted to the physiologic time delay for US Doppler triggering. From the short axis view the left ventricular volumes (LV) and ejection fraction (EF) were measured. MR images acquired with Doppler US and conventional ECG triggering were evaluated separately by two radiologists concerning image quality and functional assessment.

Results:

Cardiac MR imaging was possible in all examinations and the Doppler US signal was stable during the whole MRI measurement. The cardiac frequency was between 60-70 BPM in all subjects. Simultaneous measurements of ECG, Doppler US and generated US Trigger signal are correlating **(Fig 1.)** with a time delay of the Doppler US signal to the ECG of 394±9 ms. Additionally the US Trigger signal shows a time delay to the Doppler US signal by 40ms due to processing time. Using Doppler US for triggering image quality was comparable to ECG **(Fig 2.)**. All anatomical structures could be clearly evaluated. For functional evaluation the LV and the EF were assessed. There was no significant difference between both methods: LV 128 ±0.2 ml and EF 65 % for Doppler-US and LV 125±0.2 ml and 66 % for ECG.

Discussion and Conclusion:

The MR compatible Doppler US device is a new triggering method for cardiac MRI. The acquired Doppler US signals correlate with a constant time delay to ECG measurements. There was no difference between Doppler-US and ECG in the evaluation of anatomical structures and functional information. It might be faster and easier in the application compared to ECG and could be beneficial at higher magnetic field strengths.

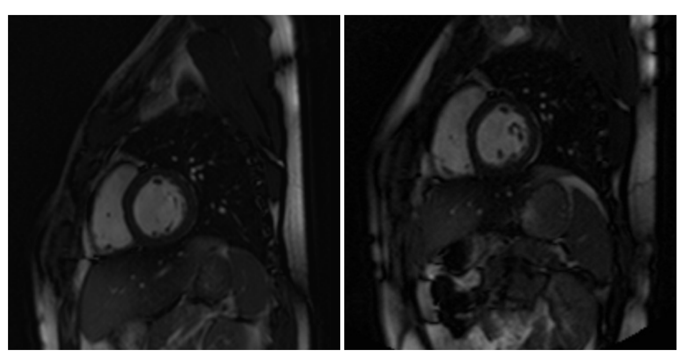

Figure 2 Illustrated are the ECG (a) and US Doppler triggered (b) images in short axis view of the heart in systole.

References:

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