

Mouse cardiac MRI: comparison of prospective synchronization using optical and ECG signals with a retrospective technique

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Introduction

Prospective synchronization on living organisms of MRI acquisitions to reduce the motion artifacts involves the monitoring of both respiratory and heart motions in the thorax and abdominal region. The signal conventionally used to measure cardiac cycle is the electrocardiograph (ECG) signal. Respiratory motion can be derived from low frequency modulation of ECG signal [1]. Because of the weak amplitude of the ECG signal recorded on small animals, to obtain an uncorrupted ECG (RF pulses and gradient switching) is challenging [2-4]. By contrast with ECG, light propagation in thin optical fibers is free of any electromagnetic perturbation. On another hand, retrospective techniques based on navigated-echoes do not require sensors and are well suited with CINE FLASH sequences. In this context, this study aims to compare the prospective techniques of heart beats and breathing monitoring using two types of sensors: (a) modulation of reflected light using optical fibers and (b) ECG with (c) a retrospectives technique. Comparisons were assessed based on mouse cardiac CINE FLASH MRI.

Material and Methods

An optical-based device designed to synchronize MRI acquisitions on small animals was previously developed using a transmit-receive pair of optical fibers [5]. To characterize this optical device, response from photo detector to an ECG-like signal and the transfer function between 0.1 and 100 Hz were measured (data not shown). Briefly, the light from a laser diode was focused into the transmit fiber and impinged upon the moving skin. The reflected light was detected by the receive fiber and then carried to a light-voltage amplified photodiode. After proper filtering and amplification, the output signal was interconnected with a commercial trigger unit (Rapid Biomedical, Würzburg, Germany) for gating purpose. The efficiency of the optical device as well as ECG sensor were assessed on 10 mice (6 weeks old OF1 with 26 ± 2 g average weight). Ethical guidelines for experimental investigations with animals were followed, and the experimental protocol was approved by the Animal Ethics Committee of our institution. The fiber optical pair was first fixed using soft medical adhesive tape on thorax skin. Then ECG electrodes were placed on the front legs (see figure 1). The experiments were performed on a Bruker 4.7T Biospec system (Bruker, Ettlingen, Germany). A quadrature 32 mm inner diameter birdcage coil (Rapid Biomedical, Würzburg, Germany) was used. Short axis-orientation images of the heart were obtained using a CINE FLASH sequence with the following parameters: 30×30 mm² FOV, 256×192 matrix, 1 mm slice thickness; TR/TE = 10.3/4.2 ms; 25° flip angle. With a heart rate of 350 bpm, a total of 12 frames per heart cycle were obtained. For prospective gating, a FLASH method was used with 8 averages and 12 frames. For retrospective gating, the IntraGateFLASH method (Bruker) was implemented with 200 repetitions. On every single CINE image, a region of interest (ROI) corresponding to the myocardium wall of left ventricle was drawn manually using CreaContour (laboratory-developed software) and the mean SNR of each data set is calculated for each mouse and for each of the three methods. Significant differences between mean SNR values were determined using a paired Student's t test (Excel, Microsoft, USA).

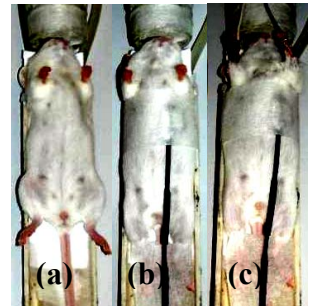


Fig. 1: Sensors mounting procedure on the anesthetized mouse: (a) before and (b) after optical fiber pair fixation on thorax and (c) electrodes placements on the front legs.

Fig 2. MRI images acquired on a mouse using a CINE FLASH sequence corresponding approximately to the same cardiac phase with: (a) optical device, (b) ECG and (c) IntraGate. The images displayed do not correspond necessarily to the same frame in the CINE movie.

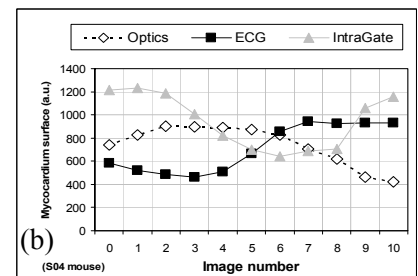
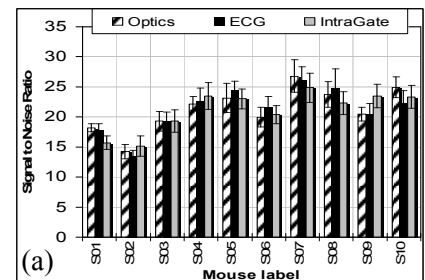
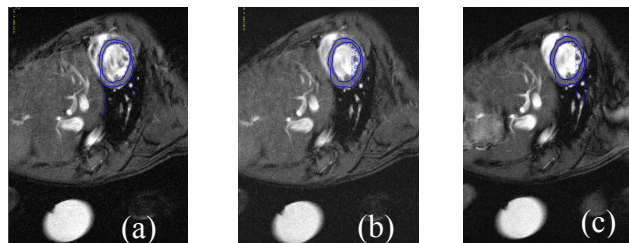


Fig. 3. (a) Mean SNR-values measured on the 12 frames in the myocardium wall for the three different methods and for each mouse. (b) Example of evolution of the surface of heart versus frame number and corresponding to different phases of the cardiac cycle, depending on method used.

Results

MR images of mice heart depict low visible motion artifacts with all three investigated methods used for triggering or/and post-processing (Fig. 2). Fig. 3a shows for each mouse, the mean SNR measured in the myocardium wall for all frames of the CINE acquisition. The mean Signal-to-Noise Ratio (SNR) averaged for all mice with the three methods was 21.3 ± 3.6 , 22.3 ± 3.8 and 21.1 ± 3.4 for optical, ECG and IntraGate respectively. No significant SNR differences were found on images acquired with all data sets. However, depending on device or method used, the triggering point does not correspond to the same instant of the cardiac cycle inducing a time shift between image series acquired with optics, ECG and IntraGate (Fig. 3b).

Conclusions

Full fiber optical-based signal derived from heart and respiratory motion was suitable for prospective triggering for heart MR imaging. The fiber optic device performed as well as the ECG. The optical fiber-based device could be an attractive alternative to commercially available triggering devices for small animal MRI, when IntraGate method is inappropriate, in difficult environments such as small volume available, high field magnets and fast gradients switching.

References

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