Prospective synchronization of small animal cardiac MRI: a quantitative comparison of an optical device, pressure sensor and ECG

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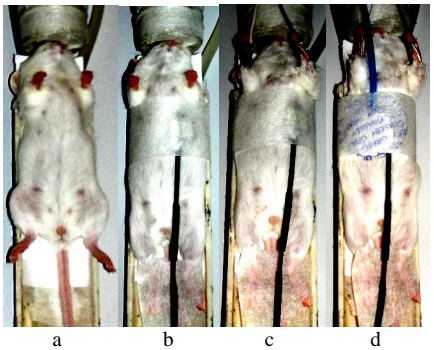
Introduction

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. 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 (1-4). For respiratory motion, an air cushion associated to a pressure sensor is commonly used and suffer from its relatively large dimension compared to mouse. By contrast with ECG and pressure, light propagation in thin optical fibers is free of any electromagnetic perturbations. In this context, this study aims to compare three different measures of heart beats and breathing using three types of sensors: (1) ECG, (2) pressure sensor via air cushion, (3) modulation of reflected light using optical fibers. Comparisons were assessed based on mouse cardiac MRI.

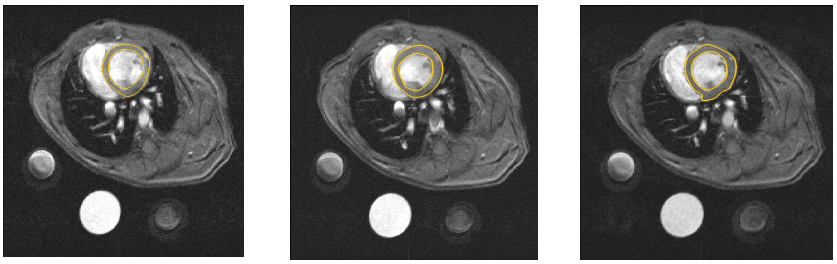
Material and Methods

An optical-based device designed to synchronize MRI acquisition on small animals was previously developed using a transmit-receive pair of optical fibers (5). 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 and pressure 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. Finally, the air cushion was placed above (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 x 30 mm2 FOV, 256 x 192 matrix, 4 averages; phase anti-aliasing = 2; TR/TE = 9/2.9 ms; 25° flip angle; 1 mm slice thickness. With a heart rate of 350 bpm, a total of 12 frames per heart cycle were obtained. 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). Significant differences between mean SNR values measured with three sensors were determined using a paired Student's t test (Excel, Microsoft, WA, USA).



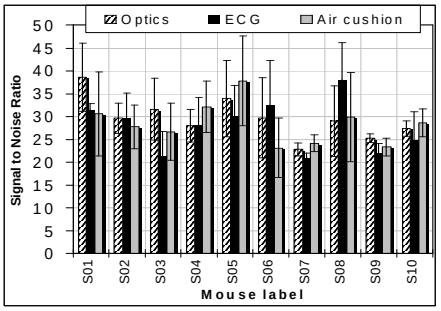
a b c d

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



a b c

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



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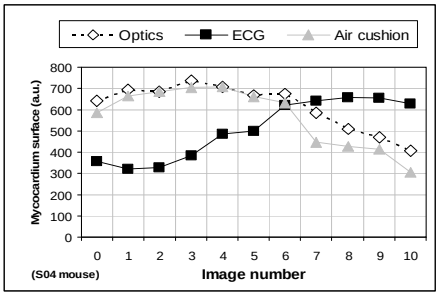

b

Fig. 3. (a) Mean SNR-values measured on myocardium wall for the three different sensors and for each mouse. (b) Example of evolution of the surface of myocardium wall with frame number and corresponding to different phases of the cardiac cycle, depending on sensor used.

Results

MR images of mice heart depict low visible motion artifacts with all three investigated signals used for triggering (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 sensors was 29.5 ± 4.5, 28 ± 5.5 and 28.5 ± 4.5 for optical, ECG and air pressure devices respectively. By contrast, the mean SNR measured on images without synchronization and performed only on a unique mouse was 16 ± 1. No significant SNR differences were found on images acquired with the three sensors. However, depending on device used, the triggering point (setting the beginning of the acquisition) does not correspond to the same instant of the cardiac cycle inducing a time shift between image series acquired with the three devices (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 and air pressure sensors investigated. The optical fiber-based device could be an attractive alternative to commercially available triggering devices for small animal MRI in difficult environments such as small volume available and fast gradients switching.

References

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