An optical based device for dual cardiac and respiratory synchronization for small animal MRI

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Introduction

Magnetic resonance imaging (MRI) on living organism involves the monitoring of both respiratory and heart motions in the thoracic and abdominal regions in order to synchronize acquisitions to reduce the motion artifacts. The electrocardiograph (ECG) signal is conventionally used to measure cardiac cycle. However, induced signals created by the gradient switching and RF pulses during MRI acquisition are disturbing original ECG signal [1-4]. It is not always possible to restore an uncorrupted ECG signal especially for weak ECG signals recorded on mouse and at a very high magnetic field. The goal of this work was to develop a fully optical-based device able to monitor the respiratory and heart cycles using fiber optics for mice.

Methods and materials

Two 200 µm optical fibers were used: one for transmission and the other for detection of light. The two fibers were optically insulated to decrease the ambient light noise. The tip of both fibers was stripped on a 2 cm length. The fiber's tips were bundled together with epoxy glue. The fiber tips were cleaved and polished to maximize light detection. Collimated continuous-wave light from a 650 nm laser diode was focused into the transmit fiber using an optical lens. As light from the transmit fiber impinged upon a moving surface (such as animal thorax skin), the amount of diffusely reflected and backscattered light detected by the receive fiber increases as the surface moves closer to the probe tip and decreases as it moves away. The detected light was carried by the receive fiber to a light-voltage amplified photodiode (Fig. 1).

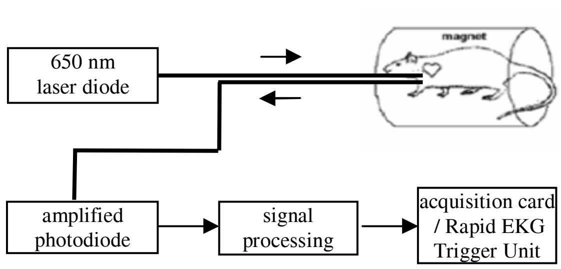

Fig. 1: Schematics of the fiber-optic monitoring device

The output voltage was proportional to the received light and was passed to a custom-built signal-processing circuit for further amplification and filtration. The signal was then recorded by an acquisition card (PMD-1208FS, Measurement Computing, Middleboro, MA 02346, USA) for signal display and adjustments of gating levels (cardiac and respiratory) using Labview programming interface (National Instruments Corporation, USA). Also for a synchronized MRI acquisition, the device was interconnected with a Rapid Biomedical ECG Trigger Unit HR V2.0 (Rapid Biomedical GmbH, Rimpar, Germany). The gating level, cardiac and respiratory, was adjusted at the necessary level to generate a trigger signal for MRI acquisition.

The MRI acquisition was performed on a Bruker 4.7T Biospec system (Bruker, Ettlingen, Germany) for mice liver examination. Gaseous anesthesia was performed on adult mice using an induction box with a mixed gas of air (30% oxygen) at a concentration of 4% isoflurane. The mice were then placed in supine position on a dedicated plastic bed and the fiber optical pair was fixed using soft medical adhesive tape on thorax skin.

Results

The recorded optical-based signals were well correlated with both respiratory and heart motions. Because only optical devices were used inside the MRI bore (coil and gradients), the signal was totally unaffected by RF and gradients. Signal amplitude was large enough to perform an easy adjustment of gating level with good differentiation between cardiac and respiratory signal (Fig. 2). The fiber optical pair was placed in various locations on the thorax and the variation of signal amplitude was independent of location. The adjustable amplifier gain offers compatibility with different ambient light condition. Interfaced with Rapid ECG Trigger Unit, the gating level was adjusted either for respiratory synchronized MRI acquisition, either for dual, respiratory and cardiac, synchronized MRI acquisition. The acquired MRI images of mice liver reveals no moving artifacts.

Conclusions

Full optical-based signal from heart and respiratory motion were recorded on mouse and where used for respiratory synchronization of MRI hepatic acquisitions. The adjustments of gating level can be performed, via the acquisition card using real-time software or via the Rapid ECG Trigger unit, for respiratory and/or cardiac motion depending of the needs of MRI acquisition.

The fiber optical pair is extremely thin, under 1 mm diameter and is very easy to install even within small volume MRI coil. This optical-based trigger device is fully operational and will be now carefully compared to other methods based on ECG or pressure for liver imaging on small animal.

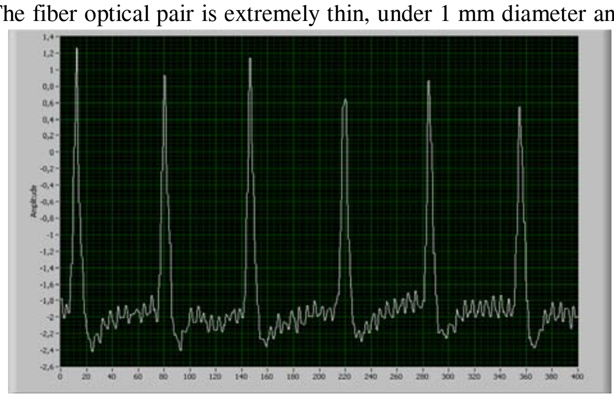

Fig. 2: The optical-based signal. The largest peaks are attributed to respiratory cycle and the small oscillations are attributed to heart motion.

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