

# A novel, non-invasive method for the physiological monitoring of small mammals during high-field magnetic resonance studies

J.S. Thornton, <sup>†</sup>R.A. Page, D.A. West, M.E. Fry, R.J. Ordidge.

Department of Medical Physics and Bioengineering, University College London, London, U.K. and <sup>†</sup>Department of Clinical Neurosciences, Royal Free Hospital, London, U.K.

## Abstract

Signals induced by the motion of a small coil placed on the abdomen of mice studied in a 7T spectrometer were recorded for the purpose of physiological monitoring. A dominant signal component originated from respiratory motion, with smaller components, correlated with the cardiac cycle, also observed. The method has proved of great experimental utility, facilitating the safe maintenance of animals during long periods of inhalation anaesthesia. The technique is economical, simple to implement and entirely non-invasive. Further applications may include cardiac or respiratory gating of MR sequences, or fundamental studies of respiratory or cardiac dynamics.

## Background

High-field MR studies of small rodents are increasingly being reported, particularly those involving transgenic mice as models of human conditions such as Huntington's Disease<sup>1</sup>. Such studies, frequently longitudinal, require repeated examinations of the same animal, with each imaging/spectroscopy session ideally lasting for several hours. In order to safely maintain animals under anaesthesia for long durations, a robust method for physiological monitoring is required. This should be completely non-invasive to avoid injury to the animals, such as occurs with common monitoring techniques e.g. the use of subcutaneous ECG electrodes.

## Method

Experiments were performed using wild-type and transgenic mice studied under halothane inhalation anaesthesia in the bore of a 7T magnet. The animals were studied supine, loosely restrained by means of a tooth bar. Physiological motion was sensed electro-magnetically using a 1 cm diameter sensor consisting of 2 10-turn plane-wound coils connected in anti-phase and positioned on the animals' thorax. Voltages of the order of 1 mV were induced across the coils proportional to their rate of motion. The 2 coils were connected so as to provide differential signals allowing common-mode rejection of electrical interference. Signals were passed through a low-pass filter in the wall of the screened scanner room and observed by one of 2 methods: For routine monitoring purposes, the coil was connected directly to the input of a standard clinical ECG unit (Cardiorator CR7, Cardiac Recorders Ltd, London, England) producing signals of similar magnitude to those obtained using standard ECG electrodes. To allow continuous recording of signals and for more detailed analysis, a 2-channel instrumentation amplifier (Gain 59dB) was constructed<sup>2</sup> the output of which was digitised at a sampling rate of 1 kHz using a National Instruments 6024E data-acquisition card (National Instruments, Austin, Texas.).

In a small number of studies, in order to elucidate the physiological origins of the motion-induced signals, a standard 3-lead ECG waveform obtained using subcutaneous electrodes was digitised simultaneously using the second amplifier channel.

## Results

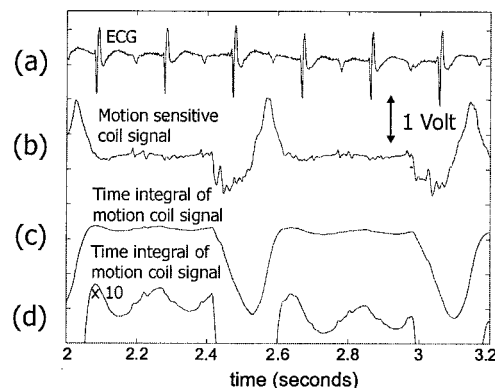
Fig. 1 shows a typical trace obtained from a wild-type mouse. The motion-sensor signal (Fig. 1(b)) is dominated by a characteristic waveform repeating with a frequency of 1.8 Hz. Integration of this yields a signal proportional to displacement of the sensor (Fig 1(c)) which we believe largely represents respiratory motion of the abdominal wall. The signal indicates a respiratory cycle duration of about 550 ms, consistent with data published elsewhere<sup>3</sup>. The heart rate of this animal was approximately 5 Hz (Fig. 1(a)). Further amplification of the motion-sensor signal (Fig. 1(d)) reveals an underlying sinusoidal variation occurring at the same frequency as the ECG suggesting that this component originates from cardiac motion. Closer inspection reveals other small perturbations in the motion-sensor signal apparently correlated with features in the ECG waveform and worthy of further investigation.

## Discussion

The ability to non-invasively monitor respiratory rate has allowed us to successfully control the depth of anaesthesia during over 100 MR studies of mice, each of duration more than 2 hours, such that the animals were recovered without apparent harm. The signal obtained contains information regarding both respiratory and cardiac motion and could potentially be used to trigger scanner sequences in such applications as cardiac MR or diffusion studies. As signals are obtained with no electrical contact with the subject, the method may also prove attractive for monitoring human subjects in high-field systems.

## References

1. Mangiarini L, et al. *Cell*.1996; 87: 493-506.
2. J.G. Webster (ed.), *Medical Instrumentation: Application and Design*, Houghton Mifflin Company, Boston. p325, 1992
3. Burnet, H., et al., *J. NeuroSci.* v21, p5212, 200



**Fig. 1** Signal acquired using the monitoring method from an anaesthetised mouse, with a simultaneously acquired conventional ECG signal for comparison.