Robust generation of cardiac gating and trigger signals in small animals.

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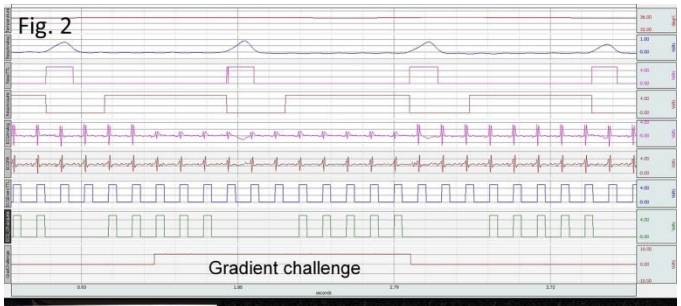
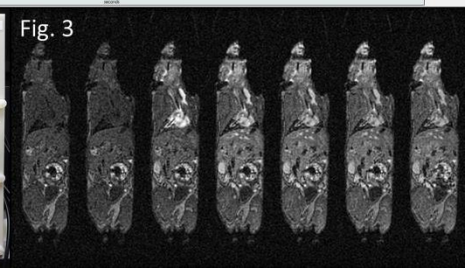
Introduction A reliable means of generating R-wave synchronization for a comprehensive range of MRI scan modes for use in the mouse is not commercially available. We describe a simple-to-build programmable unit that achieves this, and which incorporates respiration synchronisation control.

Methods CBA mice were anaesthetised (1-3% isoflurane in air/O_2) and placed in a cradle with temperature and respiration maintained at 35-36˚C and 40-60 breaths/minute respectively. ECG was detected using subcutaneously-implanted platinum needle electrodes and respiration with a pressure balloon. Signals were amplified (ECG100CMRI and DA100C, Biopac Inc, respectively) and passed to the gating controller unit which consisted of a casing, a voltage shifting module, 3 Arduino controllers, arrays of level-adjustment switches and dials, and I/O ports, as shown in Fig. 1. ECG gating signals were generated 1 ms after the peak of the filtered R-wave signal and respiration gating signals were generated using threshold detection.

Gradient challenges were applied at 125, 250, 500, 1000 and 2000 Hz at 20 G/cm, and at 3000 and 6000 Hz at 15 G/cm. ECG was monitored before, during and after the challenge. DCE-MRI at 420µm isotropic resolution was performed at 7 T using a constant TR, 3D gradient echo scan which incorporated cardio-respiratory synchronization and the automatic reacquisition of data acquired at the entry to the breath. 64 centre-out fast phase-encode lines were acquired per successful R-wave giving a scan time of ca. 10-15 s/frame. Contrast agent (100 µl, Gadospin-P, Viscover) was infused over 15 s at the start of frame 11/50.





Results The gating control unit is based around the Arduino microprocessor unit, and can be assembled with little specific electronic engineering expertise.

ECG traces and gating signals, acquired in the presence of 20 G/cm gradients applied at 2000 Hz are shown in Fig. 2. Similar results were found at lower frequencies, but at 125 Hz gradient noise was seen. The signal propagation delay was 6 ms. Whole-body DCE-MRI performed using cardiorespiratory gating showing the uptake of Gd is shown in Fig. 3; 7 consecutive frames acquired from 2 frames before Gd-delivery are displayed.

Conclusion.

Robust ECG detection in the presence of fierce imaging gradients is possible and a simple-to-build assembly for performing cardio-respiratory synchronization with minimum user interaction has been developed.