

## In utero fetal electrocardiogram gating: technical feasibility

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### Introduction

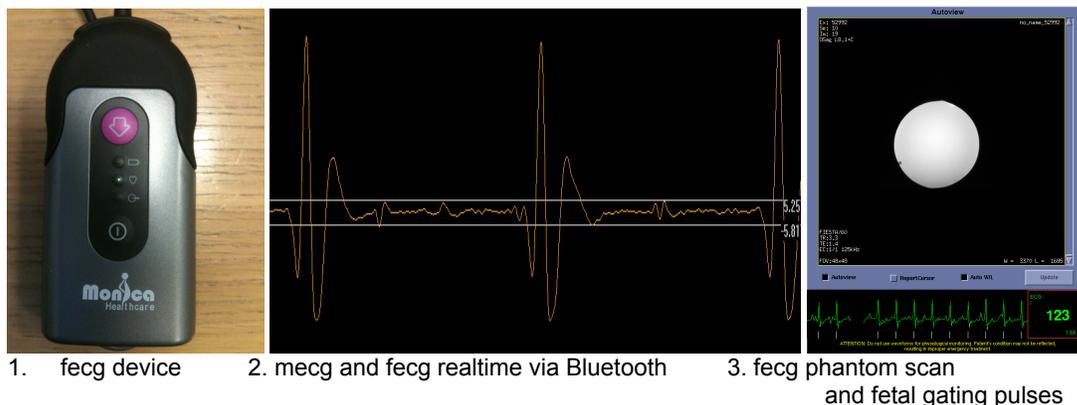
There are many possible causes for intra-uterine growth restriction (IUGR) in fetuses but one of the leading causes is placental dysfunction, often resulting in poor blood supply to the fetus. This can have significant adverse effects on fetal brain growth and development. An important clinical problem is deciding when a fetus with IUGR should be delivered, balancing the two rival risks of premature delivery against staying in a (potentially) damaging in utero environment. We plan to measure blood flow in the umbilical vessels and within the mothers's uterine blood vessels at all stages of the fetal cardiac cycle. Phase-contrast MR angiography (PCMRA) requires gating in order to get time-resolved information throughout the cardiac cycle. This can be performed on the maternal circulation but the blood flow in the umbilical vessels is driven by the fetal heart and as such is not accessible using current technology. The aim of the study was to perform both safety and gating performance tests in advance of in vivo studies using a compact maternal (mecg) and fetal (fecg) monitoring system.

### Methods

A compact monitoring device (Fig 1) with advanced software capable of reliably detecting both the mecg and fecg traces simultaneously was modified by the manufacturer to provide an external TTL trigger signal from the detected fecg signal. Six metre long high resistance carbon ECG leads were fed through waveguides into the MR scan room from the device. The leads were attached to MR compatible electrodes and placed on a large torso shaped imaging test object in locations similar to those which would be used for fetal gating. The surface of the test object was covered with conducting gel as used for the electrodes to provide a circuit for any possible RF pickup. A worst case single shot fast spin echo (SSFSE) sequence was run with the same imaging parameters as used for clinical in-utero scanning using the body transmit coil. The leads were attached to the ECG system outside the MR scan room and the radiofrequency voltage generated at 64MHz was measured across the leads using a digital oscilloscope. To test gating performance, the trigger signal was attenuated and fed back into the standard MR ECG system. A .wav file voltage from a laptop simulating the mecg and fecg was used to gate the signal during image acquisition (FIESTA, SLT=5mm, in-plane resolution =2mm, NEX=1, TR/TE=3.3/1.4ms).

### Results

RF voltages measured across the leads were always less than +/-1V peak to peak which is much lower than would produce a radiofrequency burn. The electrodes were relocated within the RF body coil several times with similar results. Images were acquired with the electrodes in place and there was no evidence of RF or B<sub>0</sub> interference. Images were then acquired at the fetal heart rate (123 bpm) to demonstrate the rapid gating capability (Fig 3). The fecg signal was 10 $\mu$ V and the mecg 100 $\mu$ V measured using the Bluetooth interface (Fig 2).



### Discussion

It is possible to safely trigger the MR scanner using a fecg monitor and carbon fibre lead system which is MR compatible. It is also possible to observe the mecg and fecg signals realtime using a Bluetooth interface on the device. We are currently applying for ethical approval for a clinical volunteer study to investigate reliability of fecg signal detection inside the MR system.