Detection of embryonic heart motion in the mouse using self-gated MRI

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Introduction

Elimination of motion artifact or capture of physiological motion dynamics in MRI traditionally requires the use of peripheral devices such as ECG and respiratory billows. However, alternative motion detection methods are available that derive motion information either directly from the imaging signal or from an additional data acquisition interleaved with the image data. In methods of "self-gated" imaging [1], this motion sensitive data is acquired without any additional radiofrequency or gradient pulses, thereby minimizing or eliminating potential time or image SNR penalties. The use of MR-based methods to detect motion presents an exciting opportunity to extend the capabilities of MRI to applications where it is otherwise difficult to monitor tissue motion.

In mouse embryo imaging, self-gated imaging methods are particularly attractive since ECG traces are not available for *in utero* gating. To date, self-gated imaging methods in the mouse have been demonstrated for cardiac and respiratory gating in the adult mouse, primarily for cardiac imaging. In this study, we sought to probe the sensitivity of self-gated MRI method and determine if self-gated methods are able to detect embryonic cardiac events *in utero*.

Methods

A modified a standard Cartesian 3D gradient-echo sequence is shown in Figure 1 in which gating data is acquired in the read direction[2]. In the present study, two waveforms representing physiological motion were derived from this gating signal: (1) maternal respiratory waveforms were generated from the early unencoded portion of the gating signal (by quantifying deviation from the median levels); and (2) an embryonic heart waveform was calculated (by performing a two-dimensional correlation with one space and one time dimension). All MRI data were collected on a 7.0T magnet using a Bruker Biospin Avance II console. For our initial investigation, we used a coarse resolution (matrix size 128x128x24 and field-of-view 25.6x25.6x4.8 mm) and image parameters TE/TR = 2.5 / 35 ms, with a 17 degree flip angle.

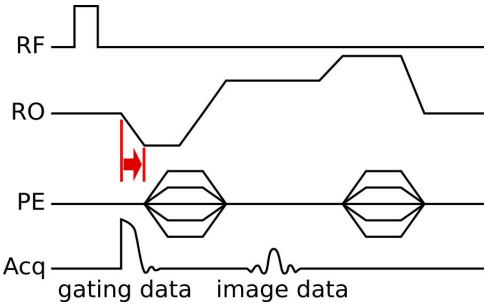

Figure 1: Modified gradient echo pulse sequence. The red arrow indicates the temporal shift in phase encode lobes.

Results

In figure 2, we show the physiological traces calculated from the MR-gating signal, including one to represent maternal respiration and another to represent the embryonic heart. In addition, we used these waveforms to reconstructed a low-resolution cine loop of the E16 mouse heart with 8 frames per cycle. While the resolution in our initial experiments was not prescribed for detailed anatomical visualization, the images do show that the derived embryonic waveform is correlated with the embryonic heart cycle.

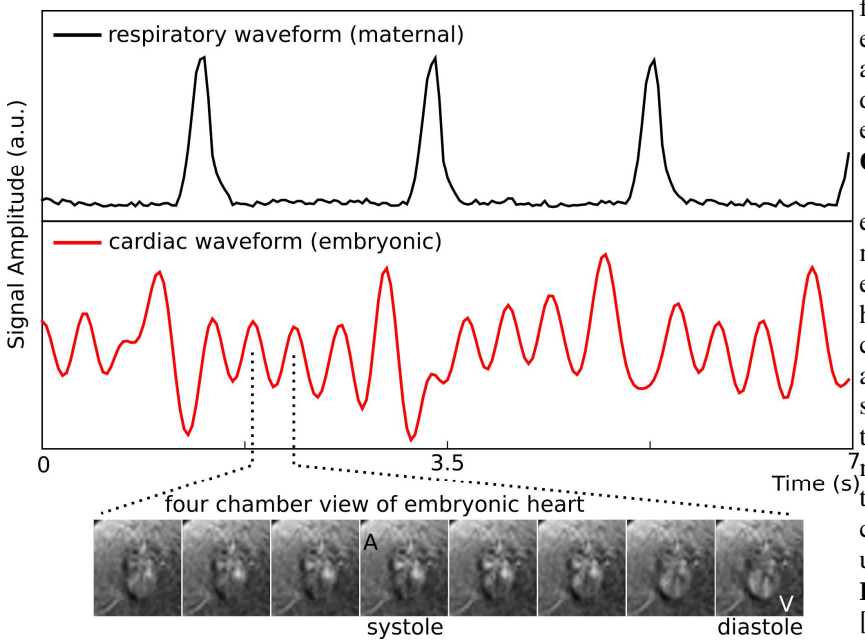

Figure 2: MR-derived physiological traces of the embryonic heart beat. Maternal respiration and embryonic cardiac events were calculated from gating data. To verify the latter, a low-resolution time course was reconstructed showing correlation between the embryonic heart cycle and the gating signal.

Conclusions

We have shown a simple proof-of-principle experiment that demonstrates that self-gated imaging methods can be sufficiently sensitive to detect murine embryonic heart motion in utero. Furthermore, we have described a method for deriving an embryonic cardiac waveform that can be used for gating during an MR imaging session. These results suggest that self-gated imaging methods are sufficiently sensitive to be used in some applications where external monitoring methods are unavailable and furthermore that, with additional development for high-resolution capability, cine imaging of the embryonic heart in utero can be achieved using MRI.

References

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