Improved Cardiac MRI of Preterm Infants using Retrospective Cardiac and Respiratory Gating

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Introduction: Circulatory failure is responsible for a high proportion of neonatal mortality [1]. Cardiovascular physiology in preterm infants is poorly understood and may differ significantly from older children, thus research to enhance the understanding of neonatal circulatory failure is a priority [2]. Conventional CMR in adults and children usually relies on patient cooperation in the form of breath-holding to produce optimal images. Alternatively, navigators or respiratory bellows can be used to compensate for or reject diaphragmatic movement. Unfortunately, most of these techniques are difficult to achieve in neonatal CMR due to rapid and inconsistent breathing patterns. In addition rapid heart rates (typically 120-180 bpm) and the much smaller distances between diaphragm and heart mean MR navigators can compromise scan quality or lengthen acquisition times substantially.

In this study we have measured respiratory patterns and bulk body motion in preterm infants using real time MRI and an apnea pressure sensor placed on the abdomen. Knowledge of how diaphragm position is represented by the respiratory pressure trace has allowed for retrospective analysis of cine data, improving image quality and allowing for cardiac cine data to be resolved through the respiratory cycle.

Methods: All scans were performed on a Philips (Best, Netherlands) 3-Tesla Achieva MR scanner using an 8-element paediatric cardiac receive-coil. Infants were scanned with ear protection, routine monitoring and without sedation or anaesthesia. ECG and respiratory traces were recorded alongside sequence event markers in order to retrospectively reconstruct images offline in Matlab.

Real time MR was performed using a balanced SSFP sequence with acquired resolution of 2x2x5 mm, using SENSE (R=2.5) and half Fourier acquisition with temporal resolution of 66 ms per frame (FA/TE/TR=25/1.6/3.2ms). Short axis, 2-chamber and 4-chamber cardiac views were acquired for 200 repeated dynamics resulting in ~13 secs of recorded cardiac and respiratory motion. Real time CMR data has been collected on 30 preterm infants with gestational ages (GA) ranging 26 to 39 weeks and body weights (BW) of 780 to 3760g

Cardiac cine MRI was performed on 19 preterm infants (GA: 26-39 weeks, BW: 880-3760g) using a retrospective gated balanced SSFP sequence acquiring 30 cardiac phases at 1x1 mm resolution in-plane (2.5 or 4mm thickness) with multiple averages acquired serially. Individual slices were acquired in approximately 1.5 minutes for 8 averages (FA/TE/TR=45/2.5/5ms).
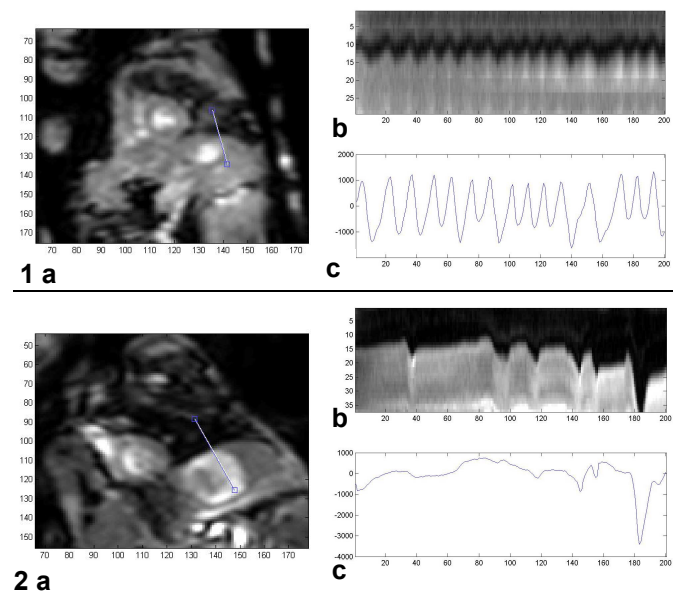

Fig. 1 Real time MRI of steady breathing in a 29 week (970g) preterm infant, and Fig. 2 an example of bulk motion in a 34 week (1.63kg) preterm infant showing a) a single dynamic frame with line used for b) x-t plots over all 200 dynamics alongside c) the respiratory trace from the apnea pressure monitor pad.
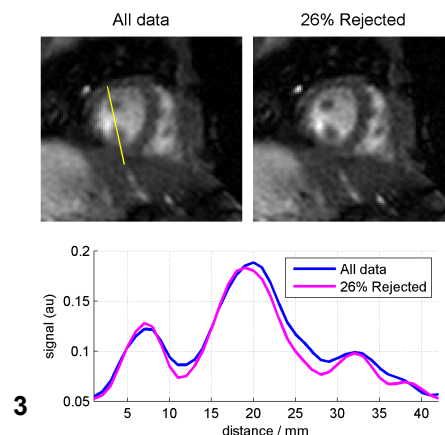Fig. 3 end-diastole frame of cine data from a 29 week infant comparing the average of all acquired data with rejection of 26% of the same data based on respiratory trace thresh-holding on a k-space line by line basis (2.5mm slice thickness).
Fig. 4 End-diastole frame from cardiac and respiratory resolved data with 20 cardiac phases at 3 different sections of the respiratory cycle (slice thickness 4mm).

Results and discussion: Real time MRI examples are shown from two typical scenarios faced when imaging preterm infants. In Fig. 1 rapid shallow breathing is characteristic of a settled infant during scanning, whereas more erratic breathing and bulk body movements which often occur with un-sedated infants are shown in Fig. 2. In both situations the respiratory pressure sensor traces closely match the actual diaphragm and heart movements, especially for steady breathing.

In Fig.3 an example data set using all 8 averages is shown alongside images reconstructed with 26% of k-space lines rejected based on manual thresh-holding of the respiratory traces and corresponding k-space lines prior to retrospective cardiac binning. The signal plots of the line shown in Fig.3 demonstrate the enhancement of contrast and edge definition at the edges of the blood pool and myocardium. An advantage to retrospective cardiac and respiratory gating of cine data is the ability to resolve the cardiac cycle at as many respiratory positions as the data acquired will allow. Fig. 4 shows a short axis cine with 8 averages/slice binned into 20 cardiac and 3 respiratory phases. The three respiratory phases are depicted for the same cardiac phase (end-diastole); the red line and blue region of interest are drawn to align with the diaphragm and a papillary muscle at end expiration, then replicated in the other respiratory views to provide reference indices for displacement. This provides clear evidence that finer anatomical detail is lost in the averaged data set, even in this example of a rapid shallow breathing infant.
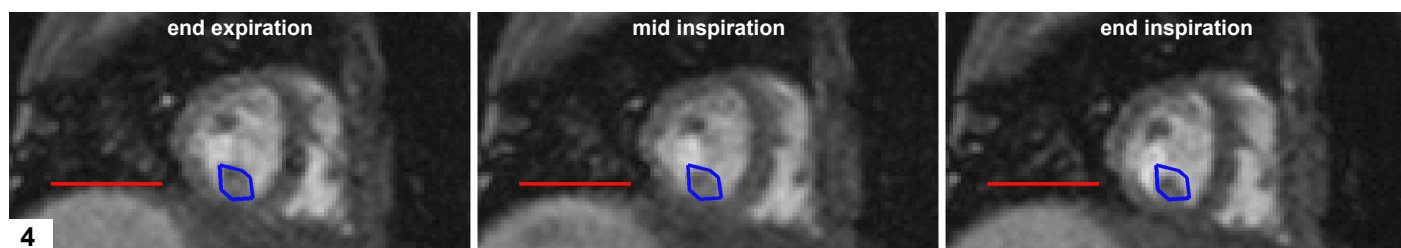
Conclusion: This preliminary work has shown that retrospective processing of multiple-averaged neonatal cardiac MR data can further improve image quality and should enable extraction of respiratory gated information to provide new insight into neonatal circulatory function.

References: [1] Doyle et al. J Paediatr Child Health. 1999;35:255-9. [2] Jobe AH. J Perinatol. 2006 Jul;26 Suppl 2:S5-7