Development and Validation of 3 Tesla Functional Cardiac Magnetic Resonance Imaging in Preterm and Term Newborns

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Background and Aims: Circulatory failure causes significant mortality and morbidity in newborn infants. Improvements in clinical circulatory care are limited by the paucity of accurate cardiovascular biomarker outcome measures for clinical trials in this population. Currently available echocardiographic techniques cannot reliably detect changes in blood flow volume in the neonate of less than 30-40%[1], and cannot reliably calculate ejection fraction[2]. We have installed a magnetic resonance scanner within our neonatal intensive care unit to allow us to study extremely preterm infants while maintaining circulatory, respiratory and thermal stability[3].The aim of this study was to develop and validate cardiac magnetic resonance (CMR) imaging techniques to assess ventricular function and systemic perfusion in preterm and term newborns, and to compare techniques to echocardiographic methods.

Methods: All scans were performed with a Philips 3-Tesla MR scanner. Infants were fed and allowed to fall into natural sleep without the use of sedation or anaesthesia. Infants were laid in a custom made cradle, with ear protection and routine monitoring. A Flex-M two-channel surface receiver coil was placed over the chest with elements anterior and posterior. No respiratory compensation techniques were used. Phase contrast (PC) assessments of flow were performed immediately distal to the aortic and pulmonary valves, as well as in the superior vena cava (SVC) and descending aorta (DAo). External validation of the phase contrast measures was performed with a flow phantom. Balanced fast field echo (bFFE) sequences were applied for 2 chamber, 4 chamber and short axis views (Figure 1). A short axis stack of 5-7 slices covered the left ventricle from base to apex. Left ventricular filling and function was assessed using CMR Tools (Cardiovascular Imaging Solutions, London, UK) processing software.

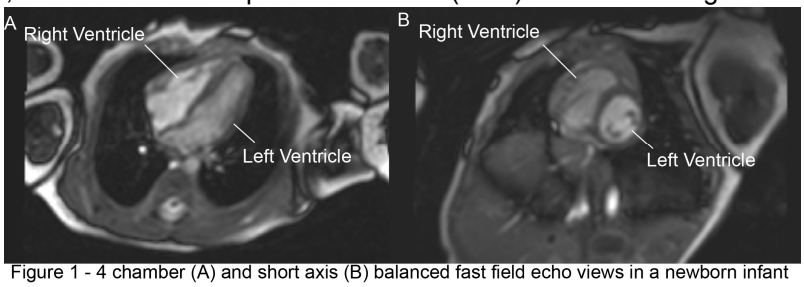

Figure 1 - 4 chamber (A) and short axis (B) balanced fast field echo views in a newborn infant

Results: 108 newborn infants with median birth weight 1627 (580-4140) grams, gestation 32 (25-42) weeks were studied. Optimised parameters for phase contrast and cine imaging were identified (Table).

	TR (msec)	TE (msec)	Flip Angle	Slice thickness (mm)	Voxel size (recon,mm)	Phases/cycle	Sequence duration (sec)	Local SAR (W/kg)
bFFE	4.1	2.0	45^0	5	0.87	32	29	9.4
PC	8.4	4.9	10^0	4	0.98	20	57	0.5

Phase contrast quantification of flow in an external phantom was highly correlated with actual measured flow (r^2=0.995). Limits of agreement (LOA) and repeatability index (RI; LOA/mean flow) for repeated PC assessment of left and right ventricular outputs, SVC flow and DAo flow were LVO ±50.2 (22.2%), RVO ±55.5 (22.5%), SVC ±20.9 (20.0%) and DAo ±26.2 (19.4%) ml.kg^{-1}.min^{-1}(Figure 2). Mean flow volumes in 28 stable infants were LVO 222, RVO 219, SVC 95 and DAo 126 ml.kg^{-1}.min^{-1}, with flow being higher at lower gestational age. LOA (RI) for cine assessment of LVO was ±58.3 (22.1%) ml.kg^{-1}.min^{-1}, and for left ventricular ejection fraction was 7.4 (10.8%). Mean LVO in 75 stable infants was 245 ml.kg^{-1}.min^{-1}. LOA (RI) for repeated echocardiographic assessment of LVO were ±108.9 (49.2%) ml.kg^{-1}.min^{-1}.

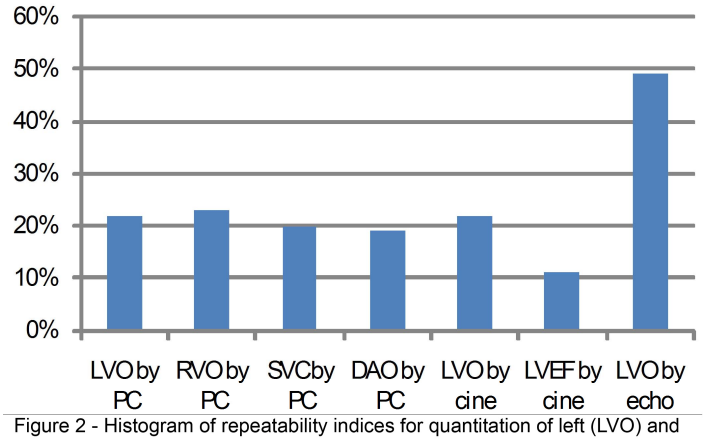

Figure 2 - Histogram of repeatability indices for quantitation of left (LVO) and right (RVO) ventricular output, superior vena caval (SVC) and descending aortic (DAo) flow, and left ventricular ejection fraction (LVEF); by phase contrast (PC), cine CMR and echocardiographic techniques in newborn infants

Conclusions: Magnetic resonance assessments of cardiac ejection fraction, cardiac output and systemic perfusion are feasible in newborn infants. CMR can reliably detect changes in cardiac output and systemic perfusion of around 20% in newborn infants, which is a significant improvement on existing echocardiographic methods.

References: 1 - Chew et al. Intensive Care Med. 2003;29:1889-1894, 2 - Lee et al. J Pediatr. 1992;120:114-119, 3 - Merchant et al. Early Human Development, in press