Quantification of Ductus Arteriosus Shunt Volume in Preterm Infants using Phase Contrast CMR

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Background

Persistent Patent Ductus Arteriosus (PDA) remains a common clinical presentation in preterm infants. Shunt through the PDA may cause both pulmonary hyper-perfusion and systemic hypo-perfusion, however the true impact of PDA shunt on total systemic blood flow remains poorly understood. Lack of insight into the true shunt pattern has produced considerable controversy over treatment approach, with some clinicians advocating invasive therapy to force closure while others recommend leaving the PDA to close naturally. Typically echocardiographic techniques are used to assess significance of a PDA from measurements of duct diameter and flow profile (a duct tends to be considered significant if diameter >1.5mm and retrograde flow is present in the post-ductal aorta). However, echo is unable to reliably quantify the volume of ductal shunt or effect of ductal shunt on systemic perfusion. It is thought that the volume of flow through the duct and its effect on systemic perfusion can vary considerably and it may be important to directly assess these to determine and evaluate appropriate treatment. We have explored the application of 2D phase contrast (PC) MRI for this task. PC MRI provides repeatable quantifications of left ventricular output (LVO), volume of upper body (superior vena cava (SVC)) and lower body (descending aorta (DAo)) blood flow[1]. We hypothesised that in the absence of ductal shunting the sum of SVC and DAo flow (total systemic flow) would equal LVO, with any difference between LVO and total systemic flow equating to volume of shunt; and that PC MRI techniques could reliably assess volume of total systemic flow to define the impact of PDA shunt on true systemic perfusion.

Methods

All scans were performed with a Philips 3-Tesla MR scanner and pediatric cardiac coil. Infants were scanned with ear protection, routine monitoring and without sedation or anesthesia. No respiratory compensation techniques were used. 2D PC MR sequences (resolution - 0.6/0.6/4mm, TR/TE - 5.9/3.1ms) were used to quantify LVO, SVC and DAo through plane flow at the levels of the aortic valve, pulmonary trunk and diaphragm respectively. Due to population anatomic variation in the azygous system there is often significant contribution to SVC flow from the lumbar and pelvic veins, therefore volume of azygous flow was quantified at the level of the diaphragm and subtracted from the SVC flow to evaluate upper body flow. Data quantification was performed using Philips ViewForum. LVO and total systemic blood flow were compared using a Bland-Altman plot. LVO, SVC and DAo flow were plotted against corrected gestational age to detect effects of PDA on systemic perfusion.

Results and Discussion

Nineteen preterm infants, mean birth weight 1780(780-3760) grams, gestation 33(26-39) weeks were scanned. Three infants had a PDA demonstrated on echo, one 'significant' PDA (2.4mm, non-restrictive flow, dilated left atrium and reversed diastolic DAo flow), two 'non-significant' PDA (1.0mm and 1.1mm, restrictive flow, no left atrial dilatation and forward diastolic DAo flow observed in both). Mean and range of SVC, DAo and azygous flow for the 16 infants without PDA were 100, 128 and 14ml/kg/min respectively. In infants without PDA total systemic flow closely matched LVO (mean difference +5ml/min, limits of agreement -51 - +61ml/min) (Figure 1). All three infants with PDA had lower body and upper body perfusion values within the group 95% confidence limits (Figure 2a 2b). The infants with non-significant PDA had LVO within the group 95% confidence limits (Figure 2c). However the infant with significant PDA had dramatically increased LVO (>12 standard deviations above the mean (Figure 2c)). In this infant the volume of ductal shunt was estimated as 62% of LVO. Despite this, total systemic perfusion was maintained, presumably due to increase in LVO.

Figure 1

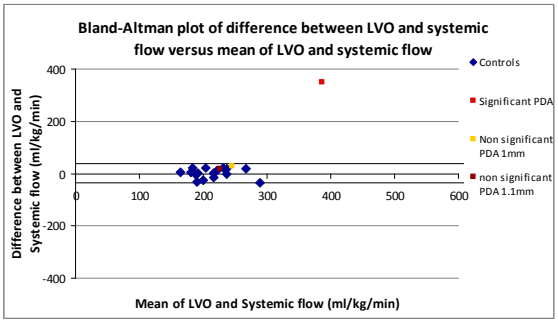

Figure 1-Bland-Altman plot showing relationship between LVO and volume of total systemic flow in 19 infants.

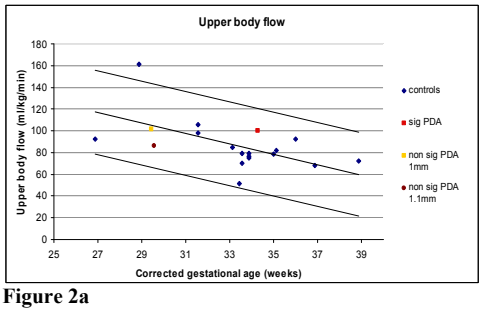

Figure 2a

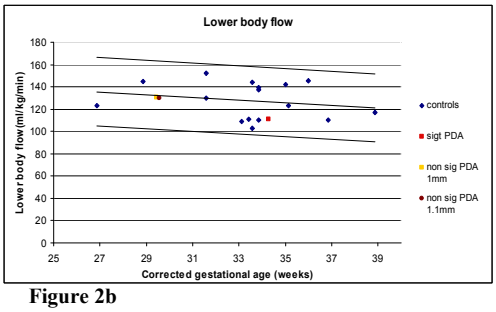

Figure 2b

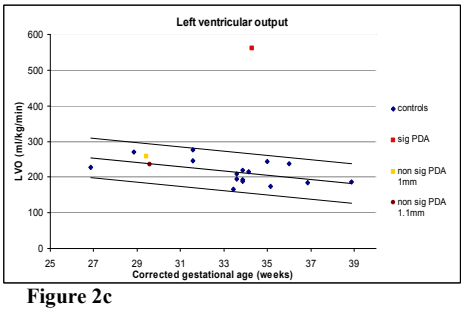

Figure 2c

Figure 2a – upper body flow. 2b - lower body flow. 2c - LVO flow

Conclusions: We have demonstrated that 2D PC-MRI can reliably quantify LVO and total systemic flow, can be used to evaluate volume of ductal shunt in preterm infants and can quantify the effect of the ductal shunt on systemic perfusion; potentially providing more accurate evaluation of haemodynamic significance of shunt. We have also demonstrated that a significant PDA determined by classical measures may not always cause systemic hypo-perfusion.

References

1- A Groves *et al*. Arch Dis Child Fetal Neonatal Ed. 2010 Oct 21