

# Quantification of Aortic Pulse Wave Velocity in neonates to assess impact of PDA

Kathryn M Broadhouse<sup>1</sup>, Anthony N Price<sup>1</sup>, Giuliana Durighel<sup>1</sup>, Anna E Finnemore<sup>1</sup>, David J Cox<sup>1</sup>, Alan M Groves<sup>1</sup>, A David Edwards<sup>1</sup>, and Jo V Hajnal<sup>1</sup>  
<sup>1</sup>Robert Steiner Unit, Imaging Sciences Department, MRC Clinical Sciences Centre, Hammersmith Hospital, Imperial College, London, United Kingdom

## Background

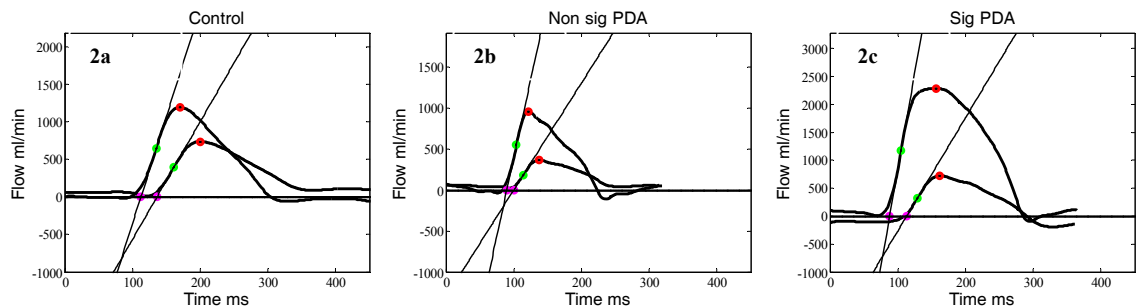
Persistent Patent Ductus Arteriosus (PDA) (a shunt remnant of fetal circulation) remains a common clinical presentation in preterm infants, but true hemodynamic impact of PDA shunt on total systemic blood flow remains poorly understood<sup>1</sup>. Using phase contrast MRI we have previously shown that shunt volumes can be up to 74% of cardiac output<sup>2</sup> (CO), that even in the presence of large shunt volumes total systemic blood flow can be maintained and that it is done so by a significantly increased CO. In this initial study we have utilized phase contrast (PC) MRI data to quantify pulse wave velocity (PWV) in order to better understand the hemodynamic impact of this increase of CO. Aortic PWV, the velocity of the systolic wave front propagating along the aorta, has traditionally been used as a marker for aortic stiffness and as an indicator of future cardiovascular events<sup>3</sup>, but it is also an indicator of vascular impedance<sup>4</sup>. Intra-vascular pressure measurements provide the most accurate PWV measurements but this invasive technique is not suitable for many patients. PC MRI provides an accurate, non invasive measure of blood flow in vessels of sufficient calibre with sufficient temporal resolution to calculate PWV. Quantification of PWV using PC sequences has been validated and applied in many adult studies<sup>5</sup>. This study looks at the feasibility of measuring PWV in neonates and seeks to identify any changes in PWV associated with PDA.

## Methods

All scans were performed with a Philips 3T Achieva MR scanner and a dedicated pediatric body coil. Infants were scanned with ear protection, routine monitoring and without sedation or anesthesia. No respiratory compensation techniques were used. This study was approved by the North West London Research Ethics Committee (06/Q0406/137) and written informed parental consent was obtained in all cases. Two 2D PC MR sequences (spatial resolution = 0.6/0.6/4mm, temporal resolution = 11.8ms, TR/TE = 5.9/3.1ms, slice thickness = 4mm, cardiac phases = 20) were used to quantify through plane blood flow at the aortic valve (LVO) and in the descending aorta (DAo) at the level of the diaphragm (Figure 1a and b respectively). Three methods were used to determine systolic wave front time delay between LVO and DAo. The first method used arrival time defined as the intercept of the line tangential to the maximum gradient of the upstroke of the time axis. The second used the time of maximum gradient of the upstroke and the third used the time of peak flow. All results were then normalized by length of the infant measured directly after the scan. All infants received an echocardiography scan within 24 hours of MRI and PDA infants were classed as either significant (sig PDA) (duct diameter  $\geq 1.5$ mm) or non significant (non sig PDA) (duct diameter  $<1.5$ mm). An unpaired Student's t-test was used to compare PWV in control and all PDA infants and in just the sig PDA infants in each method. Significance was determined by a p value of less than 0.05. Blood flow quantification was performed using Philips ViewForum, graphical analysis and calculation of PWV was carried out using MathWorks Matlab.

## Results

Twenty nine infants were scanned with median (range) corrected gestational age at scan  $33^{+3}_{-6}$  to  $38^{+6}_{-6}$  weeks and weight at scan 1580(660 to 3780) grams. Of the infants scanned 3 had a significant PDA and 5 had a non significant PDA. Figure 2a, b and c show examples of LVO and DAo flow curves from a control, non sig PDA and sig PDA infant respectively. Arrival time, time of maximum gradient and time of peak flow are marked in pink, green and red respectively. There was no significant difference found between the PWV in control and PDA infants in any of the three methods. Mean and standard deviation (SD) of PWV values in control, non sig PDA and sig PDA infants for all 3 methods are shown in figure 3.



## Discussion

We have demonstrated the feasibility of carrying out PC PWV calculations in neonates, Figure 2a, b and c demonstrates the temporal delay between the arrival of the systolic wave front at the aortic valve and DAo plane and in all but 1 infant a delay was detected. Due to the higher heart rate of neonates the temporal resolution of 11.8ms may not be high enough to accurately determine the start of the upstroke; the time of maximum gradient may be a better measure in this case. In this initial study the temporal delay was normalized to the length of each infant with the assumption that the length of the infant is proportional to the aorta. Although the results are comparable in this study, for a true measure of PWV the length of aorta between the two imaging planes taken from the midline of the vessel is needed. The results show that there is no significant difference between the systolic wave front propagation in control and PDA infants. This is consistent with our previous work which showed that in many infants with a PDA total systemic blood flow is maintained. We would therefore expect PWV to be similar in both groups. Although only 1 example is shown, all the control and non sig PDA infants have very similar flow profile characteristics. However, there is a lot of variation in the LVO flow profile between individual sig PDA infants and these can be quite distinct from the other two groups. The PDA infants have LVO flow curves with broader peaks than control infants (Figure 2a and c); this acts to decrease the measured delay and is reflected in the peak flow PWV measurements (see figure 3, mean and SD of peak flow method). This could be due to the increased CO in PDA infants or to differences in the temporal flow pattern through the PDA or the impedance of the PDA, which is difficult to measure directly by MRI.

## Conclusion

We have demonstrated that PC PWV is feasible in neonates and that there is no significant difference in systolic wave front propagation between control and PDA infants. This is consistent with our previous study<sup>2</sup> and demonstrates that in these infants the cardiovascular system increases output in attempt to maintain systemic blood flow.

## References

- 1] – Wyllie. J. *Seminars in Neonatology*. 2003. 8:425-432. 2] – Broadhouse. K. M. *et al.* Submitted to *Pediatrics*, 3] – Grotenhuis. H. B. *et al.* *J MRI*. 2009. 30:521-526. 4] – Vulliemoz. S. *et al.* *MR Me*. 2002. 47:649-654.

3	Arrival time		Max gradient		Peak flow	
	mean	SD	mean	SD	mean	SD
Controls	3.38	1.44	3.70	2.73	2.28	1.56
Sig PDA	4.37	2.57	4.19	2.20	5.25	4.55
Non sig PDA	3.26	1.54	3.88	2.70	2.10	0.93