Quantification of Aortic Pulse Wave Velocity in Preterm Infants using 4D Phase Contrast MRI

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Target Audience

Neonatologists, Cardiologists.

Background

Mechanical compliance within the healthy and diseased aorta has been well documented in adults and paediatrics [1][2]. Pulse wave velocity (PWV) of the systolic wave front propagating along the aorta, is an inverse measure of vessel compliance and marker for vessel stiffness. Metafratzi et al [1] reported a PWV range from 4 to 10 ms^{-1} in the healthy adult aorta, whilst Vulliemoz et al found a mean PWV of 4.4 ms^{-1} [3]. A significant increase in PWV has been found in paediatric subjects born prematurely at low birth weight when studied at ~8yrs and may explain the increase in cardiac disease in this population[2]. However PWV data does not extend back to preterm infants. Preterm circulatory physiology differs significantly from healthy infants born at term. However the consequential impact of this immature cardiovascular system on circulation is very complex and still poorly understood. PC MRI provides an accurate, non invasive measure of blood flow in vessels of sufficient calibre with sufficient temporal resolution. Recent studies in adults have used PC MRI flow data to determine PWV[4]. We previously showed that 2D PC MRI is capable of accurately determining flow rates and can be used to estimate PWV when combined with a separately measured aortic distance.

Objective

Assess feasibility of measuring aortic PWV in preterm and term infants using 4D PC MRI, in order to establish a normative range in this population and facilitate comparison with adult values.

Methods

4D phase contrast (PC) MRI sequences providing full coverage of the aortic arch were acquired in neonates. Aortic PWV was then calculated from flow measurements taken at 5 to 8 locations along the arch and the aortic length between each location. Neonatal PWV values were compared with previously published adult values. Scans were performed on a Philips 3T MR scanner using a specialised 8 channel pediatric body receive coil for infants above 2kg and a small extremity receive coil for infants below 2kg. Infants were scanned with ear protection, routine monitoring and without sedation/anesthesia[5]. 4D PC sequences (spatial resolution = 1mm isotropic, TR/TE = 5.6/3.1 cardiac phases = 20) were aligned near sagittal over the aortic arch. The velocity encoding was calibrated for the range of -150cm/s to +150cm/s and acquisition time ranged between 7 and 10 minutes depending on size and heart rate of the infant. Analysis was performed using commercially available software (EnSight; CEI, Apex, NC, USA) to define cut planes orthogonal to the lumen at 5 to 8 locations along the aorta from aortic valve to descending aorta at the level of the diaphragm (Figure 1). Flow was then quantified at these locations using flow_tool[6], (MathWorks Matlab). Time delays were calculated by performing a least squares fit (using MathWorks Matlab) between 1st and scaled upslope profiles obtained from consecutive planes (defined as time between 15% and 90% of upstroke flow). The aortic length was determined from interpolation between the centre of the lumen's spatial coordinates of each plane (using MathWorks Matlab). Aortic distance from the 1st to subsequent planes was plotted against time delay. PWV (defined as aortic length/time delay) was then obtained from the gradient of the resulting graph.

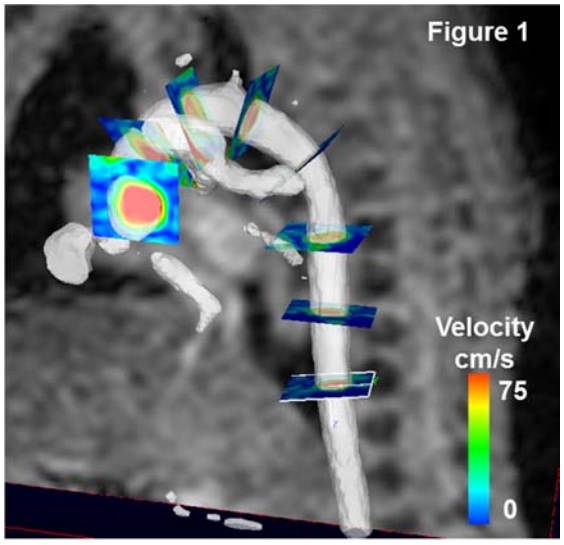

Figure 1 – location of 8 clip planes are shown with iso-volume rendering of aorta in an 960g infant.

Results

9 infants median (range) corrected GA 32(30^{+4}-36^{+5}) weeks and weight at scan 1330(875–2070) grams were studied. Mean (range) PWV was found to be 3.2(2.3-5.1)ms^{-1}.

Conclusion

This initial study confirms that 4D PC MRI is capable of determining PWV in premature neonates and the velocity so determined was found to be at the lower end of reported adult ranges.

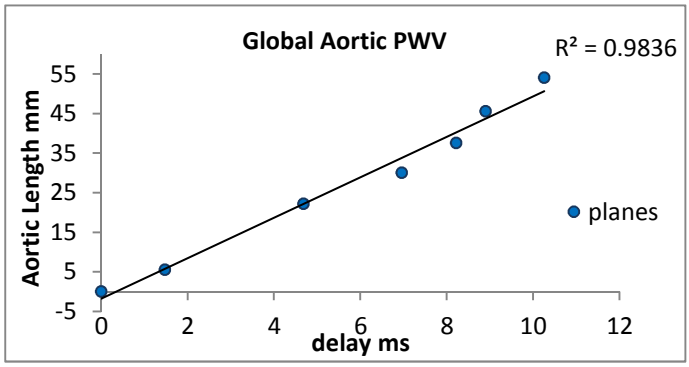

Figure 2 – Time delay plotted against aortic distance between the 1st and consecutive planes. PWV (defined as aortic length/time delay) obtained from the gradient of the slope.

References

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