

Assessment and feasibility of the four landmarks of the aortic root in a cohort of very preterm infants

Sam Phillips¹, Koert A de Waal^{1,2}

¹University of Newcastle, ²Department of Neonatology, John Hunter Children's Hospital, Newcastle NSW, Australia

ABSTRACT

- Background** : The diameter of the aortic root is used as a parameter to calculate blood flow in very preterm infants. There are considerable differences in diameter of the four anatomical landmarks of the aortic root in children and adults, but limited data are available for the very preterm population. The aim of this study was to obtain reference and reliability data on two-dimensional measurements of the aortic root in very preterm infants <30 weeks gestation.
- Materials and Methods** : Fifty long axis echocardiograms were reviewed and re-analyzed for measurements at the four anatomical landmarks of the aortic root; the aortic annulus, sinus of Valsalva (SV), sinotubular junction, and the proximal ascending aorta (PAA). A subjective visual scoring system was developed to quantify image quality. A random sample of images was blindly re-measured to assess intra- and inter-observer reliability.
- Results** : Significant differences in diameter were found between the four landmarks, except between SV and PAA. Inter-observer coefficients showed marginal variation ranging from 5.0% to 8.2%, with slightly lower intra-observer variability. Overall image quality score was poorest for PAA on standard long axis images but improved when the probe was adjusted along the outflow tract.
- Conclusion** : We present reliability and reference values for all four anatomic landmarks of the aortic root in very preterm infants and demonstrated the importance of standardizing and reporting cardiac output measurements in preterm infants.
- Keywords** : Aortic root, echocardiography, preterm infants, reference values

INTRODUCTION

Accurate assessment of the circulatory function in the preterm infant has the ability to improve patient care. Doppler ultrasound measurements of blood flow can offer an understanding of the pathophysiology underlying common clinical presentations and can help to guide treatment choices.^[1] However, variability of blood flow measurements has been reported to be as high as 22%, with inter-observer variability even higher.^[2,3]

Vessel diameter, velocity time integral (Vti), heart rate, and body weight are the determinants of blood flow calculations, and the main cause of variability is found in the diameter measurements.^[4] Reducing this variability in diameter measurements could strengthen the role of blood flow measurements in clinical practice. When reviewing the current methodology of measuring blood

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Address for correspondence: Dr. Koert A de Waal, Neonatal Intensive Care Unit, John Hunter Children's Hospital, Lookout Road, New Lambton NSW 3205, Australia. E-mail: koert.dewaal@hnehealth.nsw.gov.au

flow, a large variety is found. This is, especially true for left ventricular output (LVO), where variation is found for both Vti measurements and diameter measurements.^[5-9] The aortic root diameter was often measured in M-mode, currently no longer recommended.^[10] Although superior in temporal resolution, M-mode measurements are susceptible to error. The M-mode beam has to be placed perpendicular to the vessel wall to produce accurate results, and this is not always possible. Furthermore, M-mode measurements of the aortic root do not prespecify what area is actually measured and used for calculation of LVO. The aortic root is an area stretching from the aortic annulus (AA) to the proximal ascending aorta (PAA), including the sinus of Valsalva (SV) and the sinotubular junction (STJ) [Figure 1]. There are considerable differences in diameter of the AA and SV in children and adults, but limited data are available for the preterm population.^[11,12] The aim of this study was to obtain reference and reliability data on two-dimensional (2D) measurements of the four landmarks of the aortic root in very preterm infants.

MATERIALS AND METHODS

The study population consisted of infants admitted to the John Hunter Hospital Neonatal Intensive Care Unit, Newcastle, Australia. Following ethics approval from the Hunter New England Human Research Ethics Committee, long axis ultrasound images of the aortic root obtained for clinical purposes and stored on the local server were retrospectively explored. The images were acquired using a Philips iE33 ultrasound machine with 12.5 MHz probe and performed by one investigator (KW). Images of stable preterm infants <30 week gestational age with a structural normal heart with or without the presence of a patent ductus arteriosus (PDA) or open foramen ovale were included.

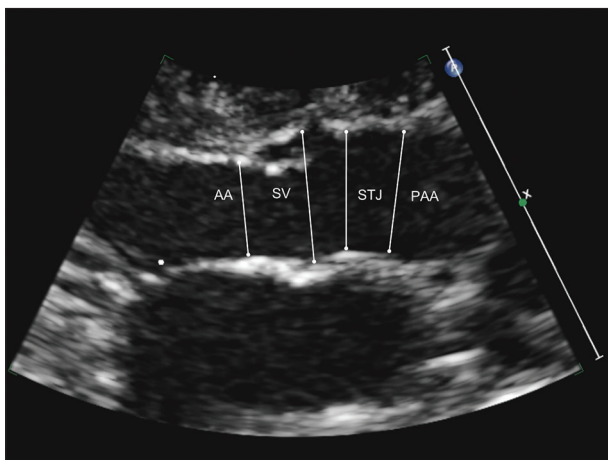


Figure 1: Parasternal long axis view of the aortic root in a 1000 g infant. AA: Aortic annulus, SV: Sinus of Valsalva, STJ: Sinotubular junction, PAA: Proximal ascending aorta

The images were analyzed according to a predefined protocol. A subjective visual scoring system was developed to quantify image quality and score clarity of the anterior and posterior hinge points, walls, and distinct anatomical reference points. Clear visualization of each of the landmark reference points [Table 1] of the aortic root was scored as yes or no, and a maximum score of 12 could be obtained.

Images were measured using the inner diameter (inner edge to inner edge) at the four anatomical landmarks of the aortic root; the AA, SV, STJ, and the PAA. The mean of three diameter measurements for both the maximum and minimum diameter for each anatomical point was recorded.

We estimated a sample of 50 scans that would be sufficient to provide initial reference values. The difference in diameter between the four anatomical landmarks was assessed with *t*-tests, and linear regression was used to explore relationships between diameters and weight.

A sample of 8 (16%) scans was blindly re-measured by both investigators to establish reliability data. To assess intra- and inter-observer reliability a Bland-Altman approach was used to calculate bias and limits of agreement. The coefficient of variation (COV) (the standard deviation of the difference of the two samples divided by the average of the two samples) was also calculated.

RESULTS

Fifty scans in 48 stable preterm infants were included in the analysis. The median gestational age was 27 weeks

Table 1: Visual image quality scoring system

Anatomic reference point	Item scored	Percentage
AA	Clear visibility of the anterior hinge point	96
	Clear visibility of the posterior hinge point	52
SV	Clear visibility of the anterior wall	96
	Clear visibility of the posterior wall	92
	Clearly visible dilatation representing the sinus	82
STJ	Clear visibility of the anterior wall	96
	Clear visibility of the posterior wall	98
	Clearly visible narrowing distal to the sinus	74
PAA	Clear visibility of the anterior wall	74
	Clear visibility of the posterior wall	46
	Clearly visible dilatation distal to the STJ	36
	More than one image used to visualize all 8 reference points	20

AA: Aortic annulus, SV: Sinus of Valsalva, STJ: Sinotubular junction, PAA: Proximal ascending aorta

(range 24-29) with a birth weight of 1000 g (range 560-1670). Most scans (86%) were performed while the infants were on nasal continuous positive airways pressure, and four scans when on mechanical ventilation for respiratory distress syndrome. The median FiO₂ and mean airway pressure was 21% (range 21-35) and 6 cm H₂O (range 0-8), respectively.

Twenty infants had a PDA >1.5 mm and 31 a foramen ovale >2.0 mm at the time of the scan.

Image quality of the included images is presented in Table 1. The exact position of the posterior hinge point of the aortic valve was only clearly visible in just over half the images. The anterior and posterior wall of the SV and STJ could be easily visualized, but distinct anatomical features were not always present. The PAA scored lowest overall. In 10 scans, the PAA could not be analyzed from the same image where AV, SV, and STJ were analyzed.

The maximum and minimum diameters for each anatomical point are presented in Table 2. Significant differences were found between the four landmark diameters, except between SV and PAA (paired sample *t*-test *P* < 0.001). All diameters increased with weight at time of measurement (*r*² = 0.23-0.43, *P* < 0.001).

The intra- and inter-observer variability are presented in Table 3. Inter-observer COV ranged from 5.0% to 8.2%, with slightly lower intra-observer variability. Maximal SV diameters showed the lowest COV, and minimum AA diameter the highest, but the difference was marginal and probably not of clinical importance.

Table 2: Minimum and maximum diameters at the 4 landmarks of the aortic root

Anatomic reference point	Minimum diameter (mm)	Maximum diameter (mm)
AA	4.2 (0.6)	4.7 (0.6)
SV	5.5 (0.9)	5.8 (0.9)
STJ	4.9 (0.8)	5.2 (0.9)
PAA	5.3 (0.7)	5.6 (0.8)

Data presented as mean (SD). SD: Standard deviation, AA: Aortic annulus, SV: Sinus of Valsalva, STJ: Sinotubular junction, PAA: Proximal ascending aorta

Table 3: Inter- and intra-observer variability of minimum and maximum diameters of the aortic root

Diameter	Anatomic reference point	Inter-observer variability				Intra-observer variability			
		Bias	LLA	ULA	COV	Bias	LLA	ULA	COV
Minimum (mm)	AA	-0.1	-0.8	0.6	7.9	0.2	-0.3	0.8	6.5
	SV	-0.4	-1.1	0.4	6.6	-0.2	-0.6	0.2	3.6
	STJ	0.2	-0.7	1.0	8.2	-0.1	-0.7	0.6	6.2
	PAA	0.1	-0.6	0.7	6.4	-0.1	-0.7	0.6	5.8
Maximum (mm)	AA	-0.2	-1.0	0.5	7.4	0.1	-0.5	0.7	6.1
	SV	-0.4	-1.0	0.2	5.0	-0.2	-0.5	0.2	2.6
	STJ	-0.2	-0.8	0.4	5.5	0.0	-0.5	0.4	4.4
	PAA	-0.2	-1.0	0.7	7.1	0.0	-0.6	0.6	5.5

LLA: Lower limit of agreement; ULA: Upper limit of agreement; COV: Coefficient of variation (%), AA: Aortic annulus, SV: Sinus of Valsalva, STJ: Sinotubular junction, PAA: Proximal ascending aorta

DISCUSSION

This study provides reliability and reference values for aortic root dimensions using 2D parasternal long axis echocardiography for infants <30 weeks gestational age. Reliable and accurate cardiac output measurements are essential for the hemodynamic assessment of sick newborns. Small variations in diameter, especially in this specific population of very small size, can have a large impact on the cardiac output as the diameter is squared in the formula to calculate cardiac output. Our data show that using an aortic root diameter needs further specification on where exactly is measured, as diameters between the four anatomical landmarks varied significantly and the differences were large enough to be of clinical importance.

The marginal differences in variability found between the four landmarks indicate that there is no "preferred" diameter. Each landmark had its own advantages and limitations. The exact position of the posterior hinge point of the annulus could not frequently be determined, but we feel this does not influence annulus diameter measurement as the valve was merely positioned flat against the wall. The PAA was best visualized with alternative image acquisition compared to the conventional long axis view. Movement of the probe slightly upward along the ascending aorta could best visualize the PAA. From a physiological point of view, it would be most appropriate to measure the smallest diameter before the sinus for true LVO, or the smallest diameter after the sinus to represent blood flow to the body minus coronary blood flow.

We cannot comment on which parameter is the most accurate, as no gold standard for LVO was used in this study. Mellander *et al.* compared echocardiography and thermodilution LVO measurements in infants and children and found the internal diameter of the AA as most accurate.^[7] Ficial *et al.* studied the validity of systemic blood flow measurements in 49 preterm infants with magnetic resonance imaging (MRI) as alternative imaging mode.^[13] Echocardiographic assessment of calculated LVO showed a strong correlation with MRI

assessment. However, the Doppler measurements took place at the AA and the MRI measurements at the SV. The lower diameters with echocardiography were compensated by higher Vti to produce comparable LVO, but the study does not provide evidence on what area of the aortic root is most accurate. For optimal cardiac output measurements, the pulsed Doppler sample volume has to be placed exactly at the same level where the diameter was measured.

There are minimal published data on aortic root diameters in very preterm infants. We previously reported on 2D measurements of the PAA in a large cohort of very preterm infants.^[4] Other existing data were obtained by M-mode and mean diameters varied between 5.3 and 7.3 mm in the population under 1500 g.^[6,14,15] As mentioned, M-mode measurements do not specify what area is measured. If the recommendations by Sahn are followed, then is it likely that the widest area at the SV was measured.^[16] Current recommendations for measurements of the aortic root refer to 2D measurements at the SV, with separate measures described for the AA, STJ, and PAA.^[10] Beker *et al.* found that estimation of LVO with diameter measurement at the STJ is more precise and accurate than measurement at the AV or the AS, when compared to right ventricular output (RVO) in preterm infants.^[17] The study compared a calculated LVO using heart rate, Vti, and diameter, to predict RVO assuming a LVO: RVO ratio of 1. Infants with minimal shunt over a PDA and/or foramen ovale were included in the study, making interpretation difficult. Vti measurements usually have low measurement variability, but the presence of a small PDA can produce turbulent blood flow in the right ventricular outflow tract obscuring the borders of the Doppler blood flow velocity trace. Even a small open foramen ovale can alter the LVO: RVO ratio up to 50%.^[18] Both this study and ours demonstrate the importance of correctly standardizing and reporting LVO measurements in preterm infants.

CONCLUSION

We present reliability and reference values for all four anatomic landmarks of the aortic root. The SV had the highest image quality score, closely followed by STJ. Differences in measurement variability between the landmarks were marginal. The data are limited by the relative small sample size but can help strengthen the role of blood flow measurements in clinical practice.

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Conflicts of interest

There are no conflicts of interest.

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