Echocardiographic assessment of left ventricular outflow tract diameter in preterm infants

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Abstract

Introduction: Left ventricular output (LVO) measurement is an important part of the echocardiographic assessment of cardiac function in preterm infants. The accurate measurement of left ventricular outflow tract diameter (LVOD) is key to the calculation of LVO. Given the lack of an appropriate gold standard, we used right ventricular output (RVO) as the comparator and sought to identify the most accurate method of determining LVO in preterm infants.

Methods: We studied stable preterm infants without significant cardiac shunts. LVOD was measured at the aortic valve, the aortic sinus and at the sinotubular junction. LVOs were calculated and the precision and accuracy of each was determined relative to the RVO using the Bland-Altman method.

Results: 52 infants were included in this analysis. The mean difference between RVO and LVO was largest when LVOD was measured at the aortic valve and aortic sinus, +106 and -115 ml/kg/min, respectively, and smallest when measured at the sinotubular junction, 9 ml/kg/min. Limits of agreement between RVO and LVO were narrowest when LVOD was measured at the STJ.

Conclusion: LVOD measurement at the sinotubular junction provides more precise and accurate measurement of LVO, in comparison to RVO, than measurement at the aortic valve or the aortic sinus.

Keywords: Bland Altman Plot, cardiac output, left ventricular outflow tract, precision, preterm infant.

Introduction

Echocardiography is the preferred bedside technique to assess cardiac function and guide therapy in preterm infants.[1–4] The American Society of Echocardiography and the European Association of Echocardiography recommend targeted echocardiography to measure LVO in infants without cardiac shunts.[2,5] Calculation of the LVO relies on accurate measurement of the left ventricular outflow tract diameter (LVOD) and correct Doppler trace acquisition. There is no consensus about the most appropriate position to measure the LVOD within the ascending aorta.[6,7]

Measurement of LVOD is reported at three locations; between the hinges of the aortic valve (AV),[8–11] in 2D and M-mode, at the aortic sinus (AS)[12–14] in 2D and M-mode and at the sinotubular junction (STJ).[15,16] In comparison, measurement of RVO is well standardised and known to be accurate.[9,17] We measured the LVOD at the AV, AS and the STJ and calculated precision and accuracy of the resulting three measurements of LVO compared with RVO in infants without significant cardiac shunts.

Participants and methods

This study is a post hoc analysis of data collected between December 2011 and August 2012 during a study of the effects of nasal continuous positive airway pressure (nCPAP) on cardiac function in premature infants. This study was approved by the Royal Women's Hospital Human Research Ethics Committee and is registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12611001057976).

Infants with a postmenstrual age of 28–34 weeks who were stable on nCPAP were included. Infants were excluded if they were on inotropic support, had a significant structural anomaly or a significant shunt such as a PDA, atrial septal defect (ASD)/persistent foramen ovale (PFO) or any ventricular septal defect (VSD). We defined a significant ASD/PFO as having a diameter of greater than 3 mm measured with colour flow Doppler. A significant PDA was more than 1.5 mm in diameter with a flow velocity of less than 3 m/s and/or a pulsatile flow pattern. Infants were excluded if they were treated with fractional inspired oxygen (FiO2) of more than 0.4, or a PEEP higher than 7 cmH2O, or nasal intermittent mandatory ventilation.

Sucrose was used to settle the infants if required. Parents gave written informed consent before enrolment into the study.

Echocardiographic measurements were performed by a single examiner (FB) with a GE Vivid-I portable cardiac ultrasound machine

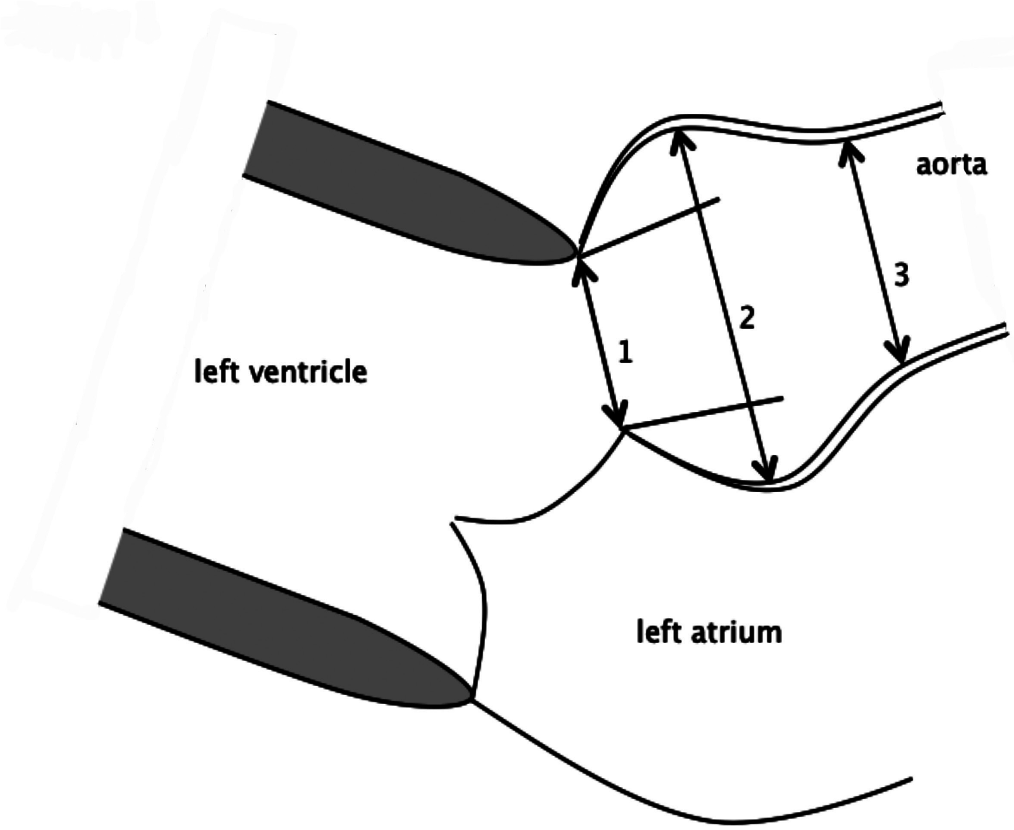

Figure 1: Aortic diameters measured in two – dimensional echocardiography from a high parasternal long axis view at the height of the AV (1), the AS (2), and the STJ (3).

(General Electric, Fairfield, Connecticut) using an 8 or 10 megahertz sector array transducer incorporating colour flow and pulsed wave Doppler. The LVOD was measured at three sites in 2D: between the hinges of the AV, at the widest point at the AS, and at the STJ. Each diameter measurement was repeated three times and the average was used for calculation. The aortic pulse wave Doppler trace was obtained from an apical view demonstrating the LVOD. The right ventricular outflow tract diameter was measured in mid-to-end-systole in 2D from a high parasternal view at the hinges of the pulmonary valve. The pulmonary pulse wave Doppler trace was obtained from a high parasternal view demonstrating the pulmonary outflow tract.[3,16,17] The gate range was placed just distal to the aortic and pulmonary valve. CO is measured in ml/kg/min and calculated as follows: CO (ml/kg/min) = VTI (cm) x HR (min-1) x CSA (cm^2) / w (kg) where VTI is velocity time integral, HR is heart rate, CSA is cross sectional area at the point of velocity measurement, and w is weight.[2,17,18] VTI is measured with pulsed Doppler measurement of the flow, the CSA is calculated from the diameter of the vessel. CSA = Diameter2 x π/4. CO was calculated after all measurements of ventricular outflow tract diameter and Doppler trace analysis were completed.

The Bland-Altman method was used to compare RVO with the LVOs calculated using the LVOD measured at the AV, the AS and the STJ. The mean difference indicates accuracy of estimates of LVO relative to RVO and limits of agreement (± 2 SD of differences) and standard error (limits of agreement/mean value) indicate precision.[18,19]

The demographics of study population are presented as median (interquartile range (IQR)), blood flow presented as mean (standard deviation (SD)), unless indicated otherwise.

Results

Study population

Of 98 parents approached for consent, 52 infants were included in the study investigating the effects of nCPAP on cardiac function in premature infants. The data of all 52 infants were utilised for the post hoc analysis presented here. The median (IQR) corrected gestational age was 30 (29,32) weeks and the median (IQR) weight was 1.4 (1.1, 1.6) kg at the time of the study. The median (IQR) postnatal age was 11 (3, 43) days. Of 52 infants, 31 had a PDA and/or PFO that was insignificant. The O2 requirement was 21% (21, 28)

Comparison of left and right ventricular output

LVOs were calculated with LVOD measured at the AV (224 ± 71 ml/kg/min), the AS (436 ± 134 ml/kg/min) and STJ (321 ± 121 ml/kg/min). Mean RVO was 330±-118 ml/kg/min. The mean difference between RVO and LVO was largest when LVD was measured at AV and AS, +106 and -115 ml/kg/min, respectively. The most accurate measurement of LVO was achieved with LVD at the STJ, +9 ml/kg/min. Limits of agreement (percentage error) between RVO and LVO were -28, 240 ml/kg/min (40.1%) when LVD was measured at AV, -295, 65 ml/kg/min (54.5%) when LVD was measured at AS, and -100, 117 ml/kg/min (32.2%) when measured at STJ.

Comparison of left and right ventricular output in infants without detectable shunt

In infants without any detectable residual shunts (n = 21) the mean difference between RVO and LVO measured at AV, AS and STJ were 102, -118, and 12 ml/kg/min, respectively. Limits of agreement between RVO and LVO were -23, 227 ml/kg/min

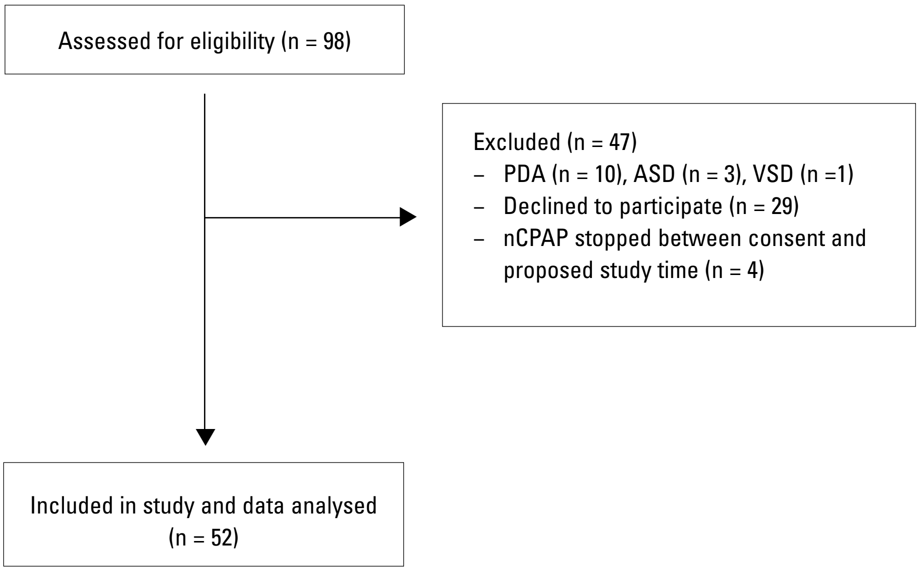

Figure 2: Infants recruited for the study.

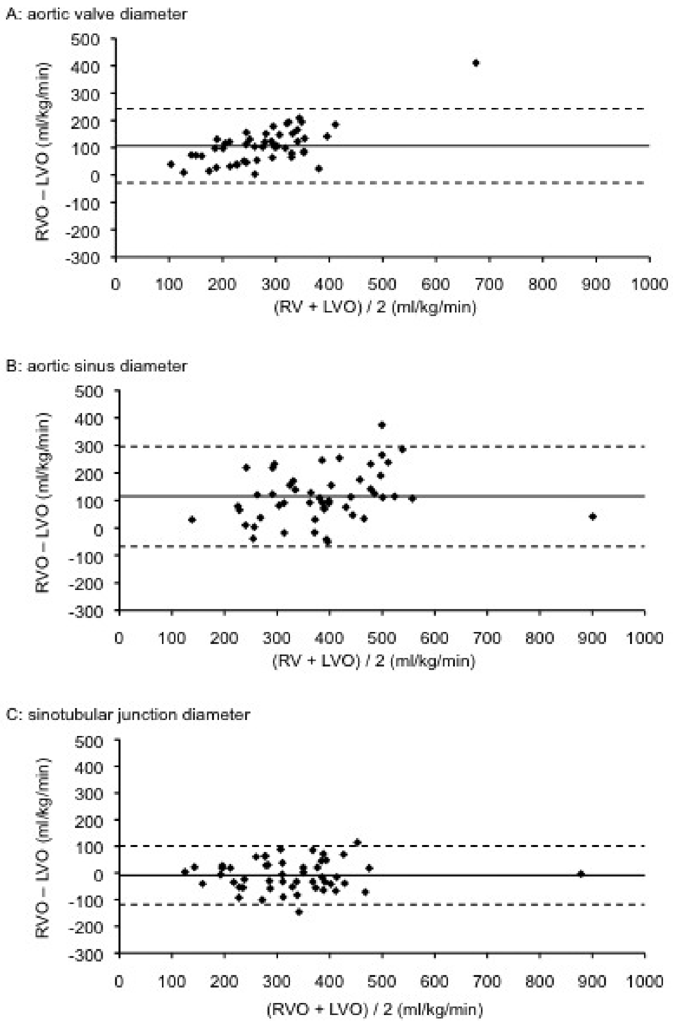

Figure 3: Bland Altman Plot: LVO calculated with AV (A), AS (B), and STJ (C) diameter compared to RVO. The continuous line represents the mean difference between LVO and RVO, the dotted lines represent the limits of agreement.

when LVD was measured at AV, -265, 29 ml/kg/min when LVD was measured at AS, and -86, 111 ml/kg/min when measured at STJ.

Discussion

We demonstrate in our study that LV output is underestimated when measuring the LVOD at the AV and overestimated when measured at the AS. Our results indicate that measurement of the LVOD at the STJ is the most precise and accurate when compared to RV outflow measured in infants without significant shunts.

Significant differences between RVO and LVO have previously been reported in infants without any significant cardiac shunts. Sloot, *et al.* measured the LVOD between at the AV and found the LVO to be 68% of the RVO in infants at the age of 7 and 14 days.[8] Patel, *et al.* measured LVOD from an M-mode recording at the AS and demonstrated that RVO was 57 ml/kg/min greater than LVO.[13] These differences were mainly attributed to difficulties insonating the aorta. Insonation of the pulmonary artery, and therefore calculation of RVO, is technically straightforward through a high parasternal view. In comparison, the left ventricular outflow tract is directed towards the right shoulder and the probe is usually placed over the cardiac apex, pointing upwards and anterior. Alignment of the Doppler beam with the LVOD is more challenging and prone to error. In our study we attempted to keep the angle of insonation at less than 20 degrees. Using the same method (AV diameter), the ratio of LVO/RVO is identical i.e. 0.68, in our study and the study of Sloot, *et al.*[8] We believe that differences in measurements of LVO occur more because of different measurements of the LVOD rather than differences in angle of insonation.

Accurate measurement of the LVOD is crucial as the absolute diameter is small, and assessment is prone to variation. A 1 mm difference in measured outflow tract diameter will change calculated ventricular output by around 120 ml/kg/min. This is because the measurement errors are amplified by the exponent used in the area calculation.[9,20] In our study, the LV outflow tract diameter is significantly larger when measured at the STJ compared to measurement at the AV. However, in M-mode, the AS diameter is challenging to measure as the line of intersection is static, while the AS moves along the longitudinal axis of the aorta with each heart beat. 2D images lack clear contrast at the AS and measurement is made even more difficult by the presence of the coronary arteries that are sometimes intersected as they come off the AS.

Our study is limited by the lack of a true gold standard measure of cardiac output in this population. Echocardiographic LVO measurements were previously compared to thermodilution in term babies and older infants and best agreement was found when the LVOD was measured at the STJ.[15] A recent study compared echocardiographic LVO measurements with MRI findings and concluded that the AV diameter seemed to be the most accurate.[11] However, in comparison to LVOD measurement, the diameter of right ventricular outflow tract is consistently obtained at the basal attachment of the leaflets of the pulmonary valve from a frozen image. This method has been demonstrated to have high inter- and intra-observer repeatability as compared to measurements at other points in the right ventricular outflow tract.[9,15] Therefore, we are confident that our measurement of RVO represents a reasonable comparator to determine the best method of calculating LVO.

Placement of the Doppler range gate poses another challenge. The length of the sampling area in our study was 2 mm, a standard setting for pulsed wave Doppler measurements. Conventionally the gate is placed just distal to the valve measured. Given that the length of the aortic sinus is about 2–3 mm in premature infants 28–34 weeks, the sampling area extends from the coronary sinus into the ascending aorta. Therefore, sampled flow velocities combine measurements from regions with different diameters. It is possible that the diameter measured at the leaflets of the aortic valve is not the most appropriate parameter for ventricular outflow tract assessment. It is difficult to place the Doppler range gate exactly at the place where the diameter is measured.

As calls for bedside evaluation of the cardiac function of NICU patients become louder it is critical that the measurements on which important clinical decisions are made are robust.[21–23] Our study demonstrates the importance of correctly standardising the measurement of LVO in preterm infants using echocardiography. We 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 RVO in preterm infants.

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