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Weight corrected percentiles for blood vessel diameters used in flow measurements in preterm infants

Koert de Waal [a,*], Martin Kluckow [b], Nick Evans [c]

[a] Department of Newborn Care, John Hunter Children's Hospital and University of Newcastle, NSW, Australia
[b] Department of Neonatology, Royal North Shore Hospital and University of Sydney, NSW, Australia
[c] RPA Newborn Care, Royal Prince Alfred Hospital and University of Sydney, NSW, Australia

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ABSTRACT

Background: Blood flow measurements are an integral part of haemodynamic assessment of the newborn infant. Most variability of Doppler derived blood flow is caused by diameter measurements. Population based percentiles of diameter measurements would be useful for training of clinicians undertaking blood flow measurements and allow rapid identification of outliers.

Methods: Diameter measurements of pulmonary valve annulus, ascending aorta and the superior vena cava using standardised methodology were collected retrospectively from 9 prospective studies on transitional haemodynamics in preterm infants. Data were analysed to calculate weight corrected percentiles of diameters used for blood flow measurements.

Results: We analysed 2870 measurements in 694 preterm infants less than 1750 g. The median gestational age was 27 weeks (range 23 to 34 weeks) and the median time of measurement was 22 h after birth (range 0.5 h to 70 days). 76% of measurements were performed while the infant received mechanical ventilation and 20% received cardiovascular support. Mean diameters increased with weight and standard deviations were comparable over the weight range.

Conclusion: Data from this large combined series provide a reference range for blood vessel diameters in the population most often measured. The data permits recognition of outliers and could be used to trigger review of measurements that fall outside the normal range.

1. Introduction

The pediatric and neonatal intensivist is often faced with clinical haemodynamic dilemmas that are challenging to interpret and manage due to a lack of basic haemodynamic physiologic information. This is especially true for the preterm newborn, where small size limits the use of invasive haemodynamic monitoring. In most neonatal intensive care units, cardiovascular function is monitored only by continuous heart rate, invasive blood pressure monitoring, and inaccurate clinical signs such as capillary refill time [1]. Although these parameters give important information, they provide only indirect and frequently limited insight into the complexities of cardiac function and the transitional circulation of the neonate. Doppler ultrasound measurements offer a clearer understanding of the pathophysiology underlying the clinical presentations and can help guide treatment choices [2,3]. The most studied parameters are left ventricular output (LVO), right ventricular output (RVO), and more recently, flow in the superior vena cava (SVC flow) [4,5]. These blood flow (BF) measurements combined with assessment of ductal shunt and shunt through the foramen ovale provide information on global cardiac function and distribution of blood flow between the pulmonary and systemic circulation.

For clinical practice, longitudinal measurements are most informative due to the physiological and pathological changes in BF during transition and thereafter. However, intra-observer variability for RVO, LVO and SVC flow has been reported to be as high as 12%, 22% and 17% respectively [5–8]. The inter-observer variability is generally higher. This potential measurement variability makes interpretation of changes in BF difficult.

Diameter, velocity time integral (Vti), heart rate and body weight are the determinants of BF calculations. Diameter measurement is the main cause of variability [5–7], as this is more difficult to measure accurately. Reducing variability in diameter measurement could strengthen the role of BF measurements in clinical practice. Providing tools for training of clinicians undertaking blood flow measurements could assist in this goal. The aim of this study is to provide a range of diameters with weight corrected percentiles used to calculate BF from a large prospectively collected dataset, to help recognize outliers and trigger review of measurements that fall outside the normal range.

* Corresponding author at: Department of Neonatology, John Hunter Hospital, Lookout road, New Lambton NSW 3205, Australia. Tel.: +61 2 49214362; fax: +61 2 49214408.
E-mail address: koert.dewaal@hnehealth.nsw.gov.au (K. de Waal).

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2. Methods

This is a retrospective analysis of prospectively collected BF measurements used for various purposes. The data are collected from 9 original studies [9–17], published over 17 papers between 1995 and 2011. All 5 original investigators used the methodology as taught by Evans et al. [4,5,9]. The majority of measurements were performed with a 128/XP Acuson and 7 Mhz probe. In 1 study (90 infants) an Acuson Aspen was used, and in 3 studies (106 infants) an Acuson/Siemens Sequoia. One study (68 infants) measured using the Philips iE33 with 12.5 Mhz probe.

The ventriculo–pulmonary junction was imaged with the transducer in the mid-parasternal view in a minor anticlockwise rotation from the parasternal short axis view, with the transducer directed slightly upwards in the direction of the blood flow. The pulmonary valve annulus was then measured at the hinge points in end-systole, and used as the diameter for RVO calculations. The aortic root was imaged using the long axis view, where the internal diameter of the aorta was measured in between the supra-aortic ridge and the proximal ascending aorta in end-systole and used as the diameter for LVO calculations. For one study, 101 images of the aortic root were reanalysed as the aorta annulus was initially used in this study [15]. The SVC diameter was imaged using the high parasternal view. Minimum and maximum SVC diameters were taken at the point where the SVC starts to open up into the right atrium, and then averaged for calculation of flow.

All measurements performed within a 24 h time period were averaged to minimise the effect of extreme values, ie. all diameter measurements on day 1 were averaged. The final dataset contained 1710 measurements in 694 infants less than 1750 g. Changes in weight and measured diameter were explored using histogram analysis, scatterplots and linear regression.

For ease of use in clinical practice, we calculated the median and percentiles of the population per 250 g weight increase.

3. Results

The initial dataset contained 2910 measurements in 720 infants. We excluded the data from infants who weighed over 1750 g due to the limited data available, leaving 2870 measurements in 694 infants. The median gestational age at birth was 27 weeks (range 23 to 34 weeks) with a median weight at measurement of 956 g (374 to 1748 g). The median time of measurement was 22 h (0.5 h to 70 days). Seventy-six percent of the measurements were performed while the infant received mechanical ventilation and 20% were randomized to cardiovascular support (dopamine, dobutamine, milrinone or placebo). In 38% of the measurements the diameter of the ductus arteriosus was >1.5 mm.

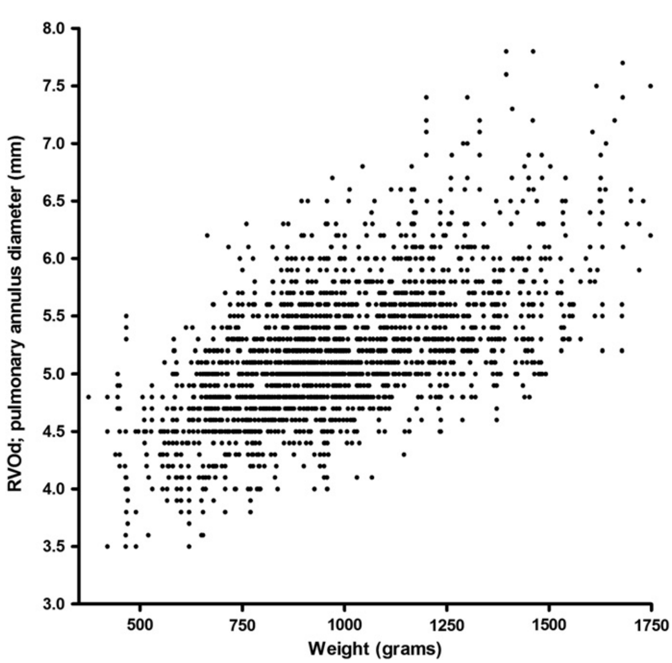

Fig. 1. Scatterplot of measurements of the hinge points of the pulmonary valve annulus in end-systole (RVO diameter).

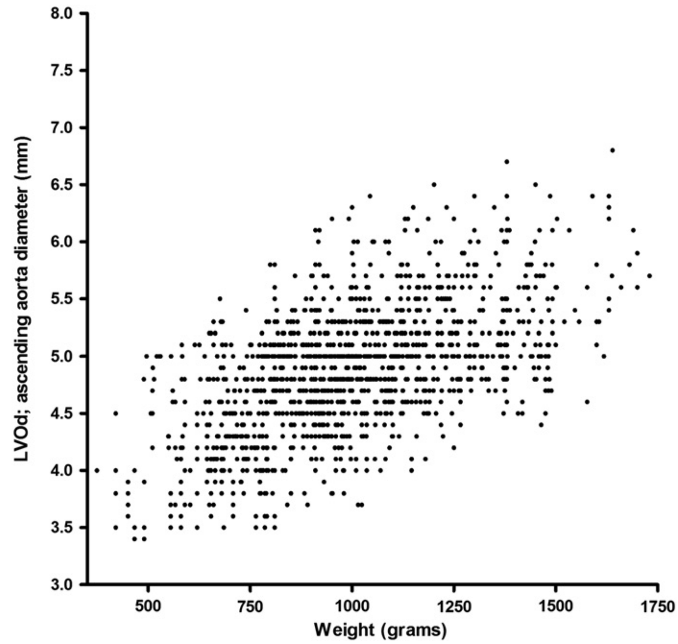

Fig. 2. Scatterplot of measurements of the internal diameter of the aorta in between the supra-aortic ridge and the proximal ascending aorta in end-systole (LVO diameter).

Histogram analysis showed a normal distribution of the data. The dataset is presented in Figs. 1 to 3. For each parameter the diameter increased with increase in weight (R^2 0.38, 0.34 and 0.15 for measured RVO, LVO and SVC diameters respectively, $p < 0.001$). The median

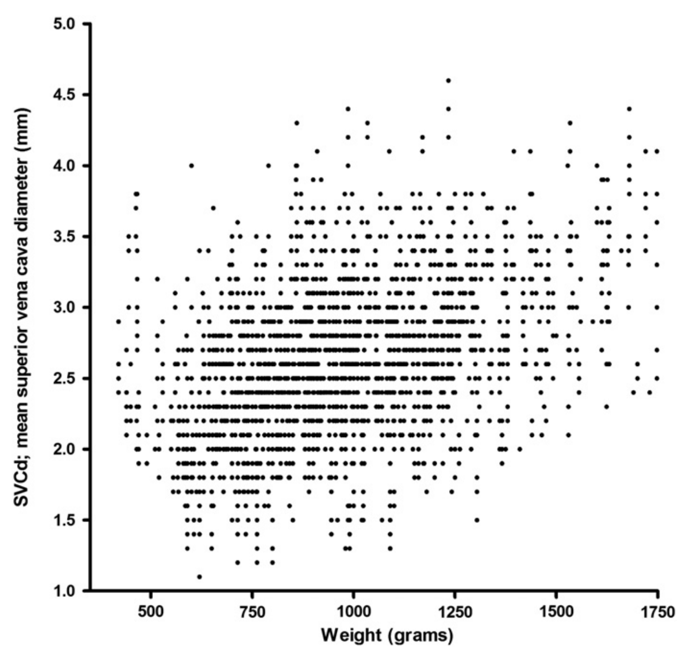

Fig. 3. Scatterplot of measurements of averaged minimum and maximum internal SVC diameter at the point where the SVC starts to open up into the right atrium (SVC diameter).