

Pulmonary Artery Diameters in Premature Infants: Normal Ranges

T H Tan, J T Heng, K Y Wong

ABSTRACT

The aim of this study is to establish the norms for pulmonary arterial diameters in the premature infants. One hundred and thirty cross-sectional echocardiograms were performed on 62 premature neonates (23.4 weeks to 36 weeks gestation) in the Neonatal Intensive Care Unit. Except for small atrial septal defects / patent foremen ovale (≤ 3 mm) or patent ductus arteriosus (PDA), babies with structural heart defects were excluded. The weight at echocardiography ranges from 470 grams to 2445 grams, with a mean of 1157 grams. The diameter of the pulmonary annulus (PA), left pulmonary artery (LPA) and right pulmonary artery (RPA) were measured at peak systole at predetermined sites. Sizes of the atrial septal defect and PDA were also measured, if present.

There was no difference in the diameter between the left and right pulmonary arteries ($p=0.254$, paired t-test) in the same patient. After controlling for weight, the mean diameters of the LPA and RPA were larger in patients with PDA ($p=0.002$) compared to those without PDA ($p=0.002$), while their pulmonary annulus were comparable in size ($p=0.691$).

Between the gestational ages of 23 and 36 weeks, the diameter of PA, LPA and RPA correlated linearly with weight (Pearson R = 0.84, 0.82, 0.65 and 0.71, respectively; $p<0.0005$). Prediction graphs and regression equations are given. These normal ranges can be used for assessment of pulmonary artery diameters in premature neonates.

Keywords: Prematurity, patent ductus arteriosus, regression equations, congenital heart disease

Singapore Med J 2001 Vol 42(3):102-106

INTRODUCTION

The diameters of the main pulmonary artery and its branches are of practical importance in decision making in congenital heart disease. For example, in Fallot tetralogy the need for a shunt, the size of the shunt to

be implanted or the option to go for a full surgical repair is based on this data. Although reference ranges are available for term infants and older children, there is little data for the premature neonates⁽¹⁾. Two-dimensional sector echocardiography has been documented to be an accurate method of determining the diameters of pulmonary arteries, with good correlation with measurements from cardiac catheterization studies⁽²⁾. We therefore embarked to establish the norms of pulmonary artery diameters in premature babies.

MATERIALS AND METHODS

Premature infants (≤ 36 weeks gestation) in the Neonatal Intensive Care Unit (NICU) who were referred for echocardiography between December 1998 and May 1999 were enrolled in this study. Except for small atrial septal defects / patent foremen ovale (≤ 3 mm diameter) and patent ductus arteriosus (PDA), patients with structural heart defects were excluded from the study. Patients with turbulent flow in the main, left and right pulmonary arteries (flow velocities ≥ 2 m/s) were also excluded.

Two-dimensional echocardiographic studies were performed in the NICU using HP2000 SONOS Phased Array Imaging System (Hewlett-Packard, Massachusetts, USA) equipped with a 7.5 MHz transducer. After complete echocardiographic examination to demonstrate normal cardiac structural anatomy, parasternal long- and short-axis cuts, as well as high parasternal views were used to obtain the following information:

1. Internal diameter of the pulmonary annulus (PA) - This was measured between the hinge points of the pulmonary valve leaflets, and the maximal diameter in systole was recorded (Fig. 1). The ECG was used to determine the duration of systole.
2. Internal diameter of the right pulmonary artery (RPA) and the left pulmonary artery (LPA). Measurements were taken at a distance of 0.5 to 1.0 mm distal to the bifurcation of MPA (Fig. 2). The maximal diameters at systole were recorded.
3. Internal diameter of the aortic annulus (AoA) - maximal systolic diameter measured between the hinge points of the aortic valve leaflets.

Department of
Paediatric Medicine
KK Women's &
Children's Hospital
100 Bukit Timah
Road
Singapore 229899

T H Tan, MBBS,
MMed, MRCP
Registrar

J T Heng, MBBS,
MMed
Consultant

K Y Wong, MBBS,
MMed
Senior Consultant &
Head

Correspondence to:
Dr Tan Teng Hong
Fax: (065) 394 1043
Email: tanth@
kkh.com.sg

4. Presence or absence of PDA - internal diameter of the PDA was recorded, if it was present.

For each parameter, a minimum of three measurements were taken and the average values were used in subsequent analysis. PA, RPA, LPA and AoA diameters were measured in grayscale echocardiogram while the colour-width of the PDA were measured. All examinations were done by one observer (THTan) and the examinations were recorded on videotape for later verification. To assess inter-observer variation, thirty-five recordings were randomly selected and the vessel diameters were independently measured by a second



Fig.1 Measurement of Pulmonary Annulus Diameter.

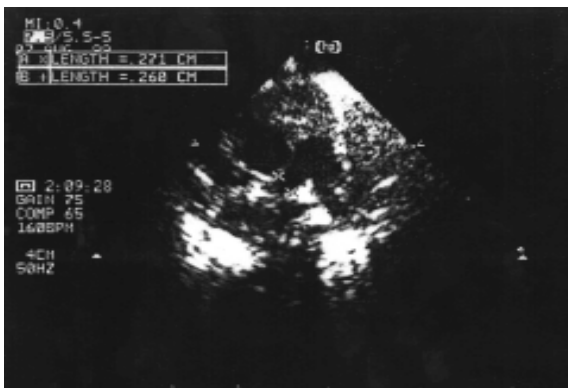


Fig.2 Measurement of Right and Left Pulmonary Artery Diameters.

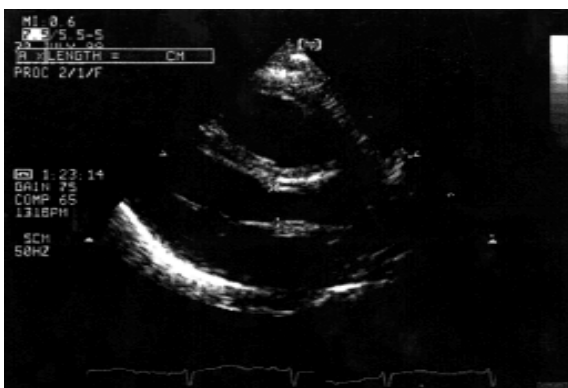


Fig. 3 Measurement of Aortic Annulus Diameter.

observer (JTHeng). These measurements were then compared to the original measurements.

Patients' biodata such as gestational age at birth, birth weight, gestational age and weight at echocardiographic examination, mode of ventilation and indication for echocardiography were also recorded. Gestational age at birth was calculated according to early dating ultrasound scan, maternal menstrual history or using the New Ballard Score⁽³⁾ and/or the Dubowitz scoring system⁽⁴⁾.

Statistical calculations and graphs were performed using SPSS 9.0 for Windows (SPSS Inc, Chicago, USA). Paired t-test was used to compare RPA vs LPA; analysis of covariance (ANCOVA) was used to compare RPA, LPA and PA diameters between patients with PDA and those without PDA, correcting for weight. Linear correlation analysis was used to determine correlation of RPA, LPA, PA and AoA with weight and gestational age. Linear regression analysis was used to derive the regression equations for the correlation.

RESULTS

During the 5-month period from December 1998 to May 1999, a total of 140 echocardiograms were performed on 69 premature infants (≤ 36 weeks gestation) with structurally normal heart, except for small ASD/PFO or PDA. Ten echocardiograms of seven patients were excluded from analysis as their ASD/PFO were more than 3 mm in size.

There was a slight excess of male representation (68% vs 32% female) and the mean gestational age at examination was 28.7 weeks (range 23 to 35.8 weeks). The weight of the patients at echocardiography ranged from 470 grams to 2445 grams, with a mean of 1157 grams. Postnatal age at echocardiography ranged from 2 days to 63 days, with a mean of 8.9 days.

Indication for echocardiography were:

- 47.5% To exclude PDA
- 31.9% Post Indomethacin therapy
- 11.3% Routine D2 echocardiogram
- 9.2% Others

Mode of ventilation at echocardiography were:

- 41.5% Continuous Positive Airway Pressure (CPAP)
- 40.8% Intermittent Mandatory Ventilation (IMV)
- 14.6% Room Air
- 2.3% High Frequency Oscillatory Ventilation (HFOV)
- 0.8% Oxygen Hood

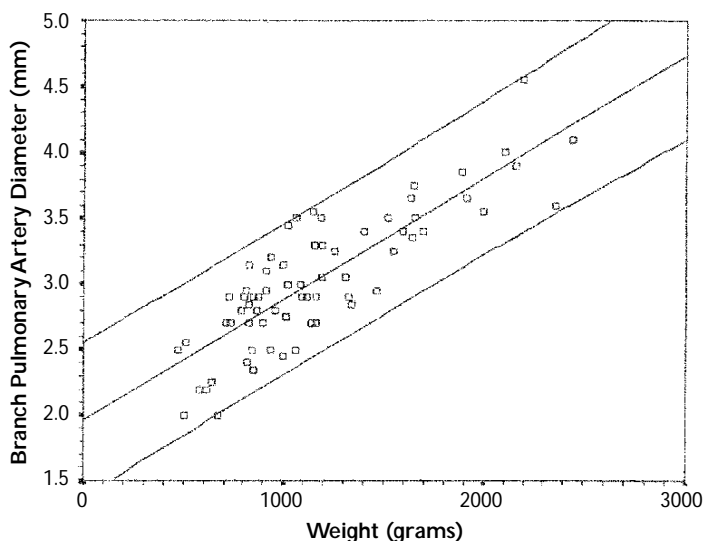
We found no significant difference when the LPA was compared to the RPA of the same patient ($p=0.254$, paired t-test). As such, the LPA and RPA were analysed together under the heading of branch pulmonary artery (BPA).

Table I. Statistics of BPA, PA and Ao measurements.

	Mean (mm)	Standard Deviation	Pearson Correlation Coefficient with Weight	PValue for Pearson Correlation	Regression Equation
Branch Pulmonary Artery (Without PDA)	3.04	0.51	0.833	< 0.0005	BPA = 1.96 + 0.92 (Weight)
Branch Pulmonary Artery (With PDA)	3.21	0.65	0.844	< 0.0005	BPA = 1.85 + 1.19 (Weight)
Pulmonary Annulus	5.47	0.97	0.819	< 0.0005	PA = 3.48 + 1.73 (Weight)
Aortic Annulus	5.03	0.80	0.840	< 0.0005	Ao = 3.33 + 1.47 (Weight)

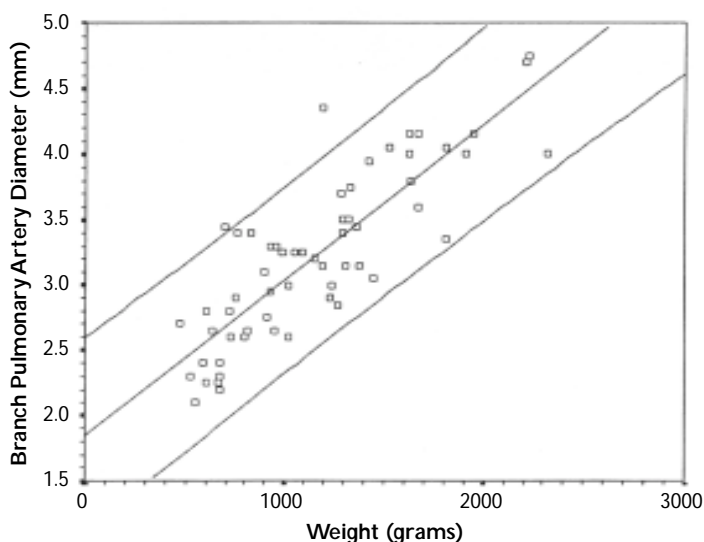
BPA: Branch pulmonary artery, PA: Pulmonary Annulus, Ao: Aortic Annulus, Weight: Weight of infant in kilograms. BPA, PA and AoA are measured in millimeters.

Fig. 4 Prediction graph of BPA Diameter Vs Weight (Patient without PDA).



Centre line is the mean; upper and lower line is the 97th centile prediction line.

Fig. 5 Prediction Graph of BPA Diameter Vs Weight (Patient without PDA).



Centre line is the mean; upper and lower line is the 97th centile prediction line.

PDA was present in 46% of echocardiography. After controlling for weight, the BPA diameter tended to be larger in patients with PDA ($p=0.001$, ANCOVA). However, there was no difference in PA size between those with and without PDA after adjusting for weight ($p=0.619$, ANCOVA).

The BPA and PA show good linear correlation with weight, with the Pearson's correlation coefficients above 0.8 in each case ($p < 0.0005$). The means, standard deviations, Pearson correlation indices with weight, and regression equations of BPA, PA and AoA are summarized in Table I. Prediction graphs are given in Fig. 4 to Fig. 7.

The "growing velocities" of the pulmonary arteries can also be derived from the regression equations. The "growing velocities" of the BPA, PA and AoA in this study were 1.04 mm, 1.73 mm and 1.47 mm per kilogram weight gain, respectively.

In terms of inter-observer agreement, the mean differences between the two observers for PA, RPA and LPA were 0.59 ± 0.44 mm, 0.28 ± 0.26 mm and 0.27 ± 0.26 mm, respectively (values given as mean + standard deviation). There were good correlations between the measurements of the two observers, with correlation coefficients of 0.82, 0.82 and 0.84 for PA, RPA and LPA ($p < 0.005$ in each case), respectively.

DISCUSSION

With rapid technological improvements and increasing expertise in the care of the premature babies, survival of these premature infants has greatly improved. The limit of viability or the perception of such limit has also been lowered dramatically. As such, cardiologists are seeing more patients with congenital heart defect who are premature. Although surgical repair for complex congenital heart defects are still not available for small premature babies, with improved surgical techniques and cardiopulmonary bypass technology, correction or palliative surgery might be extended to such tiny babies. The dimensions and anatomy of the pulmonary vasculature are

important prognostic factors for the repair of congenital heart defects such as Fallot tetralogy, pulmonary atresia, tricuspid atresia or any complex lesions that necessitate Fontan-type procedures. Various indices with regard to pulmonary artery size had also been developed to prognosticate the success of such operations^(5,6).

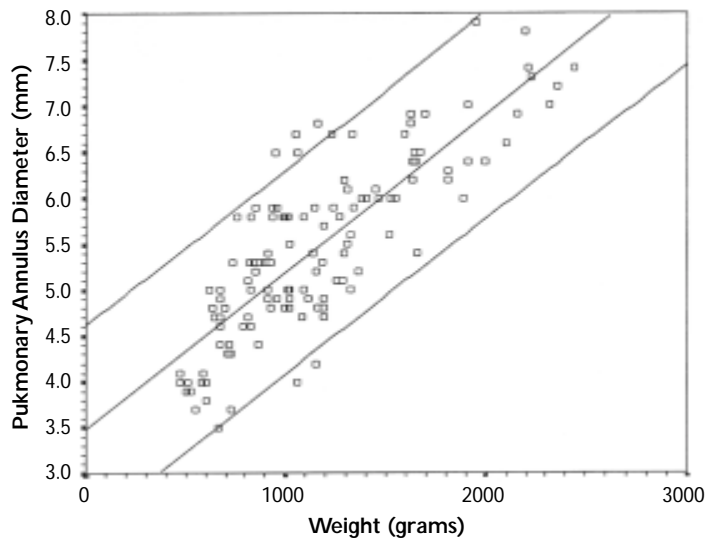
Peripheral pulmonary artery stenosis or hypoplasia can occur in isolation or in association with other cardiac defects such as pulmonary valvular stenosis, ventricular septal defect, Fallot tetralogy or transposition of great vessels. It can also occur as part of William Syndrome, Noonan Syndrome, Alagille Syndrome, cutis laxa, and Ehlers-Danlos syndrome. Having normal reference ranges of pulmonary artery sizes is important in the diagnosis of peripheral pulmonary artery stenosis, especially in milder bilateral diffuse hypoplasia of the pulmonary arteries.

Pulmonary artery size for term neonate and older children have been well studied and normal ranges for this group of children from autopsy study and echocardiographic studies have been published^(2,7-11). The diameter of pulmonary artery in term infant and older children has been found to correlate linearly with weight and body surface area^(5,6). However, non-linear relationships were found in other studies - either as a function of the natural logarithm of the body weight⁽²⁾, or as a linear relation to the square root of the body surface area^(7,8). In this study, we found that the diameter of the branch pulmonary arteries, pulmonary annulus and aortic annulus correlated linearly with the weight of the baby at echocardiography. Body surface area was not used, as body length was not routinely measured, neither could it be accurately measured in this group of sick premature infants.

We also found that the BPA and PA diameter correlated linearly with the babies' gestational age at echocardiography. However, these correlations with gestational age (Pearson's correlation coefficients of 0.702 and 0.735, respectively) were not as strong as that with weight. There was also a much greater dispersion of points about the mean. This was not unexpected as gestational age was not as precise a measurement as weight.

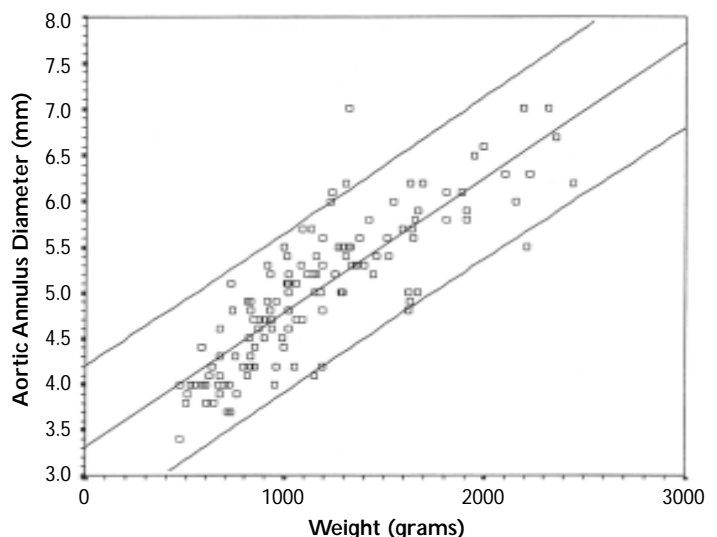
The "growing-velocities" of the large vessels in premature babies at 23 weeks to 36 weeks gestation were much greater than that of term babies during the first 3 years of life (as found by Trowitzsch et al)⁽⁵⁾. In our study, the BPA, PA and AoA grew by 1.04 mm per 1 kg weight gain, 1.73 mm per 1 kg weight gain and 1.47 mm per 1 kg weight gain, respectively, between the gestational age of 23 weeks to 36 weeks. Contrast these values with those obtained by Trowitzsch et al: 0.33 mm/kg for RPA, 0.35 mm/kg for LPA, 0.5 mm/kg for PA and 0.43 mm/kg for ascending aorta.

Fig. 6 Prediction Graph of PA Diameter Vs Weight.



Centre line is the mean; upper and lower line is the 97th centile prediction line.

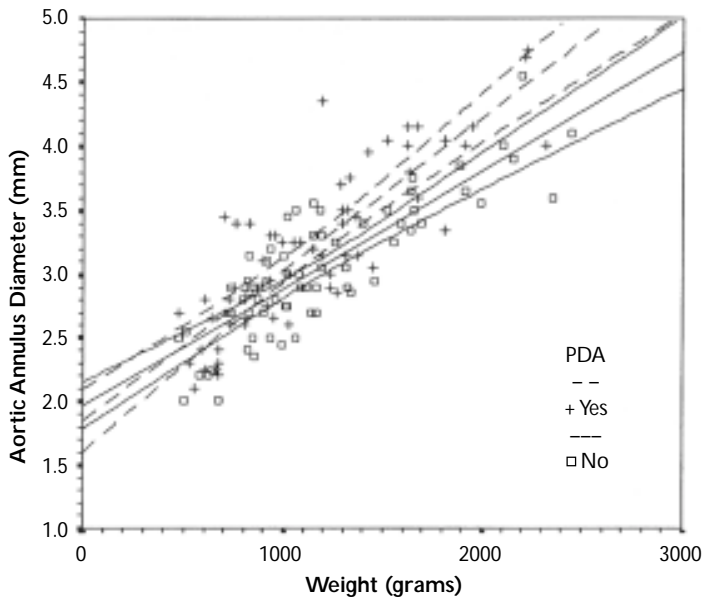
Fig. 7 Prediction Graph of Aortic Annulus Diameter Vs Weight.



Centre line is the mean; upper and lower line is the 97th centile prediction line.

In this study, we also found that the presence of a PDA increases the size of the branch pulmonary arteries. This is interesting as it reflects volume load to the pulmonary arterial system incurred by the presence of patent ductus arteriosus. Overlapping Fig. 4 and Fig. 5 (Fig. 8), we found that this difference in mean branch pulmonary artery sizes is more pronounced in the heavier babies and converges in those under 1000 grams. Given the small size of the differences and the large degree of overlapping, it is unlikely that this difference in branch pulmonary sizes can be used to predict the occurrence of symptomatic patent ductus arteriosus. Unlike that for the BPA, the presence or absence of PDA did not change the PA diameter significantly; this is explained by the annulus

Fig. 8 Branch pulmonary artery diameter in babies with and without PDA.



Centre lines are the mean; upper and lower lines are the 95th percent confidence limit for the mean.

being a less distensible structure compared to the branch pulmonary arteries, which is more influenced by the ductal flow.

CONCLUSION

We have established reference ranges for the large pulmonary artery diameters in premature babies from gestational age of 23 weeks to 36 weeks. The prediction

graphs and regression equations will serve as useful guides to determine abnormalities of the pulmonary artery size in premature babies.

REFERENCES

1. Toshiro Imai, Gengi Satomi, Satoshi Yasukochi, et al. Normal values for cardiac and great arterial dimensions in premature infants by cross-sectional echocardiography. *Cardiol Young* 1995; 5:319-25.
2. Hofstetter R, Engelhardt W, Prunte K, Rother A, von Bernuth G. Sector echocardiographic determination of the diameter of the large arteries of the heart in children. *Z Kardiol* 1987; 76:38-43.
3. Ballard JL, Khoury JC, Wedig K, Wang L, Eilers-Walsman BL, Lipp R. New Ballard Score, expanded to include extremely premature infants. *J Pediatr*; 119:417-23.
4. Dubowitz LM, Dubowitz V, Goldberg C. Clinical assessment of gestational age in the newborn infant. *J Pediatr*; 77:1-10.
5. McGoon C, Baird DK, Davis GD. Surgical management of large bronchial collateral arteries with pulmonary stenosis or atresia. *Circulation* 1975; 52:109-18.
6. Nakata S, Imai Y, Takanashi Y, et al. A new method for the quantitative standardization of cross-sectional areas of the pulmonary arteries in congenital heart disease with decreased pulmonary blood flow. *J Thorac Cardiovasc Surg* 1984; 88(4):610-9.
7. Trowitzsch E, Berger T, Stute M. The diameter of the large arteries in the first 3 years of life: An echocardiographic study. *Monatsschr Kinderheilkd* 1991; 139:355-9.
8. Hanseus K, Bjorkhem G, Lundstrom NR. Dimensions of cardiac chambers and great vessels by cross-sectional echocardiography in infants and children. *Pediatr Cardiol* 1998; 9:7-15.
9. Snider AR, Enderlein MA, Teitel DF, Juster RP. Two-dimensional echocardiographic determination of aortic and pulmonary artery sizes from infancy to adulthood in normal subjects. *Am J Cardiol* 1984; 53:218-24.
10. Ichida F, Aubert A, Deneff B, Dumoulin M, Van der Hauwaert LG. Cross sectional echocardiographic assessment of great artery diameters in infants and children. *Br Heart J* 1987; 58:627-34.
11. Van Meurs-Van Woezik H, Debets T, Klein HW. Growth of the internal diameters in the pulmonary arterial tree in infants and children. *J Anat* 1987; 151:107-15.