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Original Article

Normal Echocardiography Values of Aortic Arch Measurements in Neonates

Awdah A. Nawal, MD [1], Saleem. Irfan, MBBS [2], Alhamoud M Faisal CT [1], Alshaghrood A Alhanoof MD [1], Kariri M. Alanoud CT [1], SALIM. AHMAD, FCPS, MRCP [1]

[1]Department of Pediatric Cardiology, Prince Sultan Cardiac Center, Riyadh, Saudi Arabia.
[2]Department of Medicine, NHS Hospital, Essex, United Kingdom.

*Corresponding author: Dr Salim Ahmad FCPS, MRCP; *salimahmad19@gmail.com*

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Abstract

Background: Accurate evaluation of aortic arch dimensions in neonates is crucial for early identification of congenital cardiac anomalies such as aortic coarctation. Although echocardiography is widely used, region-specific normative data integrating anthropometric and anatomical variations remain limited. This study aimed to establish reference echocardiographic measurements of the neonatal aortic arch and examine their relationship with body size and arch branching patterns. ***Methods:*** A cross-sectional, retrospective study was conducted at Prince Sultan Cardiac Center between January and December 2023. The cohort consists of 99 neonates, having echocardiograms within the first week of life for different clinical indications and revealing no congenital heart disease. Standard echocardiographic measurements were obtained for the aortic annulus, sinus of Valsalva, sinotubular junction, ascending aorta, proximal and distal transverse arches, and isthmus. Data were analyzed using SPSS version 28. Pearson's correlation assessed associations between aortic dimensions and neonatal characteristics; linear regression identified predictors; one-way and two-way ANOVA evaluated differences across weight categories and arch types. ***Results:*** The mean gestational age was 37.99 ± 1.54 weeks, and the mean weight was 3.01 ± 0.60 kg. Echocardiographic assessment showed that the mean aortic annular diameter was 6.39 mm (SD = 0.69), the sinus of Valsalva measured 7.77 mm (SD = 0.88), and the sinotubular junction was 6.98 mm (SD = 0.75). The mean ascending aorta dimension was 7.88 mm (SD = 0.87), while the proximal transverse arch and distal transverse arch measured 6.73 mm (SD = 1.63) and 5.32 mm (SD = 0.85), respectively. The study showed that larger body weight was associated with greater proximal aortic dimensions. Two-way ANOVA revealed additional effects of arch type, where neonates with a common brachiocephalic trunk had larger ascending aortic dimensions than those with normal branching. ***Conclusion:*** This study establishes normative echocardiographic data for neonatal aortic arch dimensions and demonstrates that body weight and arch branching pattern significantly influence proximal aortic size. These findings enhance the precision of neonatal cardiac assessment and support early detection of structural variations and potential aortic abnormalities.

Keywords: ***Neonates; Echocardiography; Aortic arch; Normative values; Coarctation of the aorta; Anthropometric predictors; Common brachiocephalic trunk.***

Introduction

Echocardiography has become an indispensable tool in neonatal cardiology, offering non-invasive and reliable evaluation of cardiac structures and function during the critical early stages of life. In particular, the assessment of the aortic arch is of paramount importance, as it plays a central role in ensuring systemic blood flow. Accurate identification of normal dimensions is essential for differentiating between healthy and pathological states in neonates, especially those at risk of congenital heart disease (Tissot *et al*., 2017).

Over the last decades, efforts have been made to establish normative values, but variations in methodology, patient populations, and measurement techniques have contributed to inconsistencies in reported ranges (Dijkema *et al*., 2017).

Beyond immediate diagnostic concerns, echocardiographic evaluation of the aortic arch provides prognostic information relevant to surgical planning and long-term outcomes. Abarbanell *et al*. (2018) identified specific echocardiographic parameters predictive of surgical strategies in interrupted aortic arch, highlighting how subtle variations in measurement can alter clinical pathways.

We managed to study the normal values of aortic arch in neonates for the local population.

Methodology

Research Design

This study employed a single-center, retrospective observational design conducted at the Prince Sultan Cardiac Center, Riyadh, Saudi

Arabia. The primary aim was to establish normative echocardiographic values for aortic arch measurements in neonates and to examine their associations with demographic and anthropometric variables. The study was carried out over a 12-month period between 01 January 2023 and 31 December 2023.

Research Participants

The study population comprised 99 neonates screened to rule out congenital heart disease in Prince Sultan Cardiac Center within the first week of life during the period from January 2023 to December 2023. All neonates were from the postnatal ward who underwent transthoracic echocardiography (TTE) for different indications to rule out congenital heart disease within the first seven days of life.

Inclusion criteria: All neonates who did not have any congenital heart disease during the study period were included in the study.

Exclusion Criteria: Neonates with hemodynamically significant congenital heart defects, or body weight less than 2 kg were excluded.

Echocardiographic examinations were performed by trained pediatric echocardiographers and cardiologists using two-dimensional echocardiography. Measurements were obtained in accordance with established pediatric echocardiographic guidelines, utilizing the leading edge-to-leading edge technique to ensure accuracy and reproducibility, Tissot C , 2017, The following aortic arch parameters were assessed: ascending aorta, transverse aorta, and aortic isthmus diameters as well as the whole aortic root measurements including aortic annulus, sinus of Valsalva and sinotubular junction. Each measurement was taken at least twice, and the average value was recorded to minimize intra-observer variability.

Data Collection

Data was collected retrospectively from a total of 99 neonates who met the eligibility criteria in the Prince Sultan Cardiac Center during the study period. For each participant, demographic and clinical information was recorded, including gestational age (weeks), birth weight (grams), age at examination (days), and body surface area (m^2), which was calculated using standard pediatric formulas.

Ethical Considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and the institutional research policies of Prince Sultan Military Medical City. Ethical approval-IRB # 1704 was obtained from the Research Center at Prince Sultan Military Medical City prior to study initiation. Confidentiality and anonymity of participants were strictly maintained by assigning unique study codes and storing all data in password-protected files accessible only to the research team. No personal identifiers were included in the final dataset or publications.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 28. Descriptive statistics were employed to summarize demographic and echocardiographic characteristics, with continuous variables such as gestational age, birth weight, height, body surface area, and aortic arch measurements presented as means and standard deviations. Categorical variables, including type of aortic arch and weight categories, were expressed as frequencies and percentages. Associations between aortic arch measurements (aortic annulus, sinus of Valsalva, sinotubular junction, ascending aorta, transverse arches, and isthmus) and neonatal characteristics (gestational age, weight, height, and body surface area) were assessed using Pearson's correlation coefficients. Linear regression analyses were conducted to identify independent predictors of aortic dimensions, with gestational age, weight, and body surface area entered as predictor variables. To compare mean aortic dimensions across weight categories (2.0–2.5 kg, 2.5–3.0 kg, and >3.0 kg), one-way ANOVA was performed, followed by post hoc comparisons when appropriate. Additionally, a two-way ANOVA was conducted to examine the main and interaction effects of weight category and aortic arch type on each aortic measurement. All statistical tests were two-tailed, and a p-value less than 0.05 was considered statistically significant.

Results

The study included 99 neonates with a mean age of 1.87 days (SD = 1.44) and a mean gestational age of 37.99 weeks (SD = 1.54) at the time of echocardiography. The mean birth weight was 3.01 kg (SD = 0.60), with a mean height of 49.84 cm (SD = 2.47) and a mean body surface area of 0.20 m^2 (SD = 0.03). Echocardiographic assessment showed that the mean aortic annular diameter was 6.39 mm (SD = 0.69), the sinus of Valsalva measured 7.77 mm (SD = 0.88), and the sinotubular junction was 6.98 mm (SD = 0.75). The mean ascending aorta dimension was 7.88 mm (SD = 0.87), while the proximal transverse arch and distal transverse arch measured 6.73 mm (SD = 1.63) and 5.32 mm (SD = 0.85), respectively. Finally, the mean isthmus area was 4.23 mm (SD = 0.55).

Table 1: Demographic and Echocardiographic Measurements of the Study Population (n = 99)

Variable	Mean ± SD
Age (days)	1.87 ± 1.44
Gestational age (weeks)	37.99 ± 1.54
Weight (kg)	3.01 ± 0.60
Height (cm)	49.84 ± 2.47
Body surface area (m^2)	0.20 ± 0.03
Aortic annular diameter (mm)	6.39 ± 0.69
Sinus of Valsalva (mm)	7.77 ± 0.88
Sinotubular junction (mm)	6.98 ± 0.75
Ascending aorta (mm)	7.88 ± 0.87
Proximal transverse arch (mm)	6.73 ± 1.63
Distal transverse arch (mm)	5.32 ± 0.85
Isthmus area (mm)	4.23 ± 0.55

As shown in Table 2, most neonates (72.7%) had left aortic arch with normal branching. Additionally, 25.3% demonstrated a left aortic arch with a common brachiocephalic trunk, while only 2.0% presented with a left aortic arch and an aberrant right subclavian artery.

Table 2: Distribution of Aortic Arch Types (n = 99)

Arch Type	Frequency	Percentage (%)
Left aortic arch with normal branching	72	72.7
Left aortic arch with common brachiocephalic trunk	25	25.3
Left aortic arch with aberrant right subclavian artery	2	2.0

As presented in Table 3, several significant correlations were observed between neonatal characteristics and aortic arch measurements. Aortic annular diameter was positively correlated with gestational age (r = 0.25, p = .012), weight (r = 0.41, p < .001), height (r = 0.29, p = .004), and body surface area (r = 0.42, p < .001). Similarly, the sinus of Valsalva showed significant positive correlations with gestational age (r = 0.28, p = .005), weight (r = 0.39, p < .001), height (r = 0.25, p = .011), and body surface area (r = 0.34, p = .001). The sinotubular junction was significantly associated with weight (r = 0.29, p = .004), height (r = 0.29, p = .004), and body surface area (r = 0.32, p = .001), but not with gestational age (p = .109). Ascending aorta dimensions correlated positively with gestational age (r = 0.26, p = .010), weight (r = 0.30, p = .003), height (r = 0.33, p = .001), and body surface area (r = 0.31, p = .002). In contrast, no significant correlations were found between neonatal characteristics and the proximal transverse arch, distal transverse arch (except for weight, r = 0.22, p = .030), or isthmus area (all p > .05).

Table 3: Correlations between Aortic Arch Measurements and Neonatal Characteristics (n = 99)

Measurement	Gestational Age (r, p)	Weight (r, p)	Height (r, p)	Body Surface Area (r, p)
Aortic annular diameter (mm)	r=0.25, p = 0.012*	r=0.41, p < 0.001**	r=0.29, p = 0.004**	r=0.42, p < 0.001**
Sinus of Valsalva (mm)	r=0.28, p = 0.005**	r=0.39, p < 0.001**	r=0.25, p = 0.011*	r=0.34, p = 0.001**
Sinotubular junction (mm)	r=0.16, p = 0.109 (ns)	r=0.29, p = 0.004**	r=0.29, p = 0.004**	r=0.32, p = 0.001**
Ascending aorta (mm)	r=0.26, p = 0.010*	r=0.30, p = 0.003**	r=0.33, p = 0.001**	r=0.31, p = 0.002**
Proximal transverse arch (mm)	0.05, p = 0.593 (ns)	0.18, p = 0.081 (ns)	0.13, p = 0.204 (ns)	0.15, p = 0.132 (ns)
Distal transverse arch (mm)	r=0.11, p = 0.259 (ns)	r=0.22, p = 0.030*	r=0.15, p = 0.135 (ns)	r=0.15, p = 0.150 (ns)
Isthmus area (mm)	r=0.17, p = 0.087 (ns)	r=0.20, p = 0.053 (ns)	r=0.16, p = 0.117 (ns)	r=0.11, p = 0.300 (ns)

*Significant correlations are marked with *p < 0.05 and **p < 0.01.*

As shown in Table 4, regression analyses were performed to examine the predictive value of neonatal characteristics on aortic arch dimensions. Overall, the models explained a modest proportion of variance, with R^2 values ranging from .04 to .19. Gestational age, weight, and body surface area did not significantly predict aortic annular diameter, sinus of Valsalva, sinotubular junction, ascending aorta, proximal transverse arch, or distal transverse arch dimensions (all p > .05). However, weight emerged as a significant predictor of isthmus area (B = 0.431, p = .041), indicating that greater neonatal weight was associated with larger isthmus dimensions. Body surface area showed a trend toward significance in predicting isthmus area (B = -9.131, p = .066) and distal transverse arch (B = -9.745, p = .202), though these associations did not reach statistical significance. These findings suggest that among the neonatal characteristics assessed, weight was the most consistent predictor, particularly for the isthmus area.

Table 4: Linear Regression Predicting Aortic Arch Dimensions from Neonatal Characteristics (n = 99)

Dependent Variable (mm)	Predictor	B (Unstandardized)	SE	95% CI for B	p-value	R^2
Aortic annular diameter	Gestational age	0.039	0.048	-0.057 – 0.134	0.424	0.19
	Weight (kg)	0.187	0.246	-0.302 – 0.675	0.450	
	BSA	6.305	5.798	-5.210 – 17.819	0.280	
Sinus of Valsalva	Gestational age	0.088	0.061	-0.034 – 0.209	0.157	0.17
	Weight (kg)	0.579	0.315	-0.046 – 1.204	0.069	
	BSA	-2.641	7.425	-17.386 – 12.104	0.723	
Sinotubular junction	Gestational age	0.010	0.054	-0.098 – 0.118	0.857	0.11
	Weight (kg)	0.000	0.278	-0.553 – 0.552	0.999	
	BSA	6.262	6.567	-6.780 – 19.304	0.343	
Ascending aorta	Gestational age	0.084	0.061	-0.039 – 0.206	0.177	0.15
	Weight (kg)	0.084	0.315	-0.542 – 0.711	0.789	
	BSA	2.378	7.436	-12.388 – 17.144	0.750	
Proximal transverse arch	Gestational age	-0.015	0.123	-0.259 – 0.229	0.903	0.04
	Weight (kg)	0.531	0.630	-0.720 – 1.783	0.401	
	BSA	-2.945	14.863	-32.459 – 26.570	0.843	
Distal transverse arch	Gestational age	0.009	0.063	-0.115 – 0.134	0.883	0.07
	Weight (kg)	0.623	0.321	-0.015 – 1.261	0.056	
	BSA	-9.745	7.579	-24.795 – 5.306	0.202	
Isthmus area	Gestational age	0.044	0.041	-0.037 – 0.125	0.281	0.09
	Weight (kg)	0.431	0.208	0.017 – 0.844	0.041*	
	BSA	-9.131	4.909	-18.879 – 0.617	0.066	

As presented in Table 5, there were statistically significant differences in several aortic arch dimensions across the three neonatal weight categories. The mean aortic annular diameter increased progressively with higher weight, measuring 5.97 mm (SD = 0.54) in neonates weighing 2.0–2.5 kg, 6.32 mm (SD = 0.64) in those weighing 2.5–3.0 kg, and 6.62 mm (SD = 0.70) in neonates weighing more than 3.0 kg, F (2, 96) = 7.33, p = .001. A similar trend was observed for the sinus of Valsalva, which increased from 7.24 mm (SD = 0.87) in the lowest weight group to 8.04 mm (SD = 0.86) in the heaviest group, F (2, 96) = 6.72, p = .002. Significant weight-related differences were also found in the sinotubular junction, F (2, 96) = 4.17, p = .018, and ascending aorta, F(2, 96) = 4.06, p = .020, with both measurements increasing as neonatal weight increased. In contrast, no significant differences were found in the proximal transverse arch (p = .432), distal transverse arch (p = .098), or isthmus area (p = .247). Overall, the results indicate that higher neonatal body weight is associated with larger proximal aortic dimensions, whereas distal segments of the arch remain relatively stable across weight categories.

Table 5: Comparison of Aortic Arch Measurements Across Neonatal Weight Categories (n = 99)

Measurement	2.0–2.5 kg (n = 20) Mean ± SD	2.5–3.0 kg (n = 31) Mean ± SD	> 3.0 kg (n = 48) Mean ± SD	F	p-value
Aortic annular diameter (mm)	5.97 ± 0.54	6.32 ± 0.64	6.62 ± 0.70	7.33	.001**
Sinus of Valsalva (mm)	7.24 ± 0.87	7.71 ± 0.76	8.04 ± 0.86	6.72	.002**
Sinotubular junction (mm)	6.60 ± 0.72	6.96 ± 0.68	7.16 ± 0.76	4.17	.018*
Ascending aorta (mm)	7.49 ± 0.96	7.78 ± 0.86	8.10 ± 0.77	4.06	.020*
Proximal transverse arch (mm)	6.32 ± 1.48	6.79 ± 1.65	6.87 ± 1.68	0.85	.432
Distal transverse arch (mm)	5.00 ± 0.77	5.30 ± 0.80	5.48 ± 0.88	2.38	.098
Isthmus area (mm)	4.06 ± 0.58	4.23 ± 0.54	4.30 ± 0.54	1.42	.247

As summarized in Table 6, two-way ANOVA (weight category × arch type) showed that the aortic annular diameter varied significantly by weight, $F(2, 91) = 3.46$, $p = .035$, and by arch type, $F(1, 91) = 8.68$, $p = .004$, with no interaction, $F(2, 91) = 0.85$, $p = .432$; for example, in the 2.0–2.5 kg group, means were lower with normal branching (M = 5.79 mm, SD = 0.46) than with a common brachiocephalic trunk (M = 6.48 mm, SD = 0.45). The sinus of Valsalva also differed by weight, $F(2, 91) = 3.66$, $p = .030$, and showed a significant interaction, $F(2, 91) = 4.23$, $p = .018$, indicating that the weight–sinus relationship depended on arch type (e.g., in 2.0–2.5 kg, common brachiocephalic > normal; in 2.5–3.0 kg, normal > common; >3.0 kg, similar means). For the sinotubular junction, there was a main effect of arch type, $F(1, 91) = 4.54$, $p = .036$, and an interaction, $F(2, 91) = 3.64$, $p = .030$, whereas weight alone was nonsignificant, $F(2, 91) = 0.80$, $p = .451$. No effects were detected for the ascending aorta (all $p > .05$), while the proximal transverse arch showed a robust arch-type effect, $F(1, 91) = 29.90$, $p < .001$ (e.g., >3.0 kg: normal M = 6.26 mm vs. common M = 8.25 mm), with nonsignificant weight and interaction terms. The distal transverse arch and isthmus area did not differ by weight, arch type, or their interaction (all $p > .05$). Levene's tests supported homogeneity of variances for all outcomes (all $p \geq .06$), indicating model assumptions were largely met (**see Table 6**).

Table 6: Descriptive and Inferential Statistics for Aortic Arch Measurements by Weight Category and Type of Arch (n = 97)

Measurement	Weight Category	Type of Arch	Mean ± SD (mm)	Main Effect of Weight (*p*)	Main Effect of Arch (*p*)	Interaction (*p*)	Partial η²
Aortic annular diameter	2.0–2.5 kg	Normal*	5.79 ± 0.46	.035*	.004**	.432	.202
		Common**	6.48 ± 0.45				
	2.5–3.0 kg	Normal	6.22 ± 0.58				
		Common	6.70 ± 0.76				
	>3.0 kg	Normal	6.53 ± 0.73				
		Common	6.75 ± 0.54				
Sinus of Valsalva	2.0–2.5 kg	Normal	7.00 ± 0.77	.030*	.632	.018*	.194
		Common	7.96 ± 0.81				
	2.5–3.0 kg	Normal	7.84 ± 0.73				
		Common	7.21 ± 0.73				
	>3.0 kg	Normal	8.04 ± 0.85				
		Common	8.00 ± 0.92				
Sinotubular junction	2.0–2.5 kg	Normal	6.34 ± 0.56	.451	.036*	.030*	.162
		Common	7.38 ± 0.57				
	2.5–3.0 kg	Normal	6.88 ± 0.65				
		Common	7.09 ± 0.73				
	>3.0 kg	Normal	7.18 ± 0.79				
		Common	7.06 ± 0.71				
Ascending aorta	2.0–2.5 kg	Normal	7.41 ± 0.83	.060	.546	.781	.087
		Common	7.72 ± 1.36				
	2.5–3.0 kg	Normal	7.80 ± 1.00				
		Common	7.71 ± 0.20				
	>3.0 kg	Normal	8.06 ± 0.82				
		Common	8.22 ± 0.69				
Proximal transverse arch	2.0–2.5 kg	Normal	5.91 ± 0.98	.344	.000**	.857	.296
		Common	7.52 ± 2.14				
	2.5–3.0 kg	Normal	6.31 ± 0.96				
		Common	8.43 ± 2.49				
	>3.0 kg	Normal	6.26 ± 1.10				
		Common	8.25 ± 2.00				
Distal transverse arch	2.0–2.5 kg	Normal	4.97 ± 0.74	.440	.451	.157	.103
		Common	5.08 ± 0.94				
	2.5–3.0 kg	Normal	5.31 ± 0.74				
		Common	5.39 ± 1.00				

	>3.0 kg	Normal	5.64 ± 0.94				
		Common	4.99 ± 0.43				
Isthmus area	2.0–2.5 kg	Normal	4.05 ± 0.50	.517	.124	.491	.074
		Common	4.06 ± 0.86				
	2.5–3.0 kg	Normal	4.34 ± 0.55				
		Common	3.91 ± 0.43				
	>3.0 kg	Normal	4.34 ± 0.49				
		Common	4.13 ± 0.61				

**Left aortic arch with normal branching; **Left aortic arch with common brachiocephalic branch*

Discussion

The present study established normative data for aortic arch dimensions in neonates, providing a comprehensive overview of how these parameters relate to somatic characteristics such as gestational age, weight, height, and body surface area. Strong positive correlations were observed between neonatal anthropometric variables and several proximal aortic dimensions, including the annulus, sinus of Valsalva, sinotubular junction, and ascending aorta. These findings are consistent with prior research demonstrating that cardiac and vascular dimensions scale proportionally with body growth in early life (Dijkema *et al*., 2017; Abushaban *et al*., 2018; Singh *et al*., 2023). The significant correlations found for body surface area and weight reinforce the premise that cardiac structure size is largely influenced by overall body size, underscoring the clinical importance of incorporating body metrics when interpreting neonatal echocardiographic data.

Regression analysis further demonstrated that neonatal weight was the most consistent predictor of aortic measurements, particularly the isthmus area, which increased with higher birth weight. This finding aligns with previous reports emphasizing the role of weight as a key determinant of cardiovascular dimensions in neonates (Singh *et al*., 2023). Weight is a readily available clinical measure, and its predictive value suggests that it may serve as a practical surrogate for more complex parameters such as body surface area in settings with limited resources. These observations also support the recommendations of Parikh *et al*. (2021), who highlighted that adjusting aortic dimensions for body size improves diagnostic precision when identifying conditions such as aortic arch hypoplasia or coarctation.

The analysis of aortic arch dimensions across weight categories revealed significant increases in the aortic annular diameter, sinus of Valsalva, sinotubular junction, and ascending aorta with greater body weight, confirming that larger neonates tend to have proportionally larger proximal aortic structures. In contrast, the proximal and distal transverse arch segments and the isthmus area exhibited minimal variation across weight groups, suggesting that distal segments of the aortic arch may mature or expand more uniformly, independent of overall somatic growth. These findings mirror those of Arya *et al*. (2016) and Tuo *et al*. (2022), who observed that proximal aortic structures exhibit more pronounced growth variability than distal segments, likely due to differential hemodynamic loading patterns in early postnatal life.

When assessing the influence of aortic arch branching patterns, significant differences emerged in several key dimensions. Neonates with a common brachiocephalic branch exhibited significantly larger aortic annular diameters, sinotubular junctions, and proximal transverse arches compared with those having normal branching. These structural variations may reflect compensatory remodeling associated with altered flow distribution across the arch vessels. Previous echocardiographic and surgical series have shown that such branching anomalies, though often incidental, can influence aortic geometry and complicate surgical or catheter-based interventions (Campanale *et al*., 2019; Van Poppel *et al*., 2022; Onalan *et al*., 2021). The interaction observed between weight and arch type for the sinus of Valsalva and sinotubular junction also suggests that both growth and anatomical configuration jointly contribute to the variability of proximal aortic measurements.

Overall, the results underscore the importance of recognizing anatomical variations in the aortic arch during neonatal echocardiography. Consistent with prior literature, echocardiography remains the gold standard for noninvasive assessment of neonatal cardiovascular anatomy because of its availability, safety, and ability to detect early structural differences (Vigneswaran *et al*., 2020; Nestaas, 2022; Van Laere *et al*., 2018). By incorporating body weight and branching morphology into the interpretation of aortic arch dimensions, clinicians can better distinguish normal developmental variation from true pathological hypoplasia. These findings contribute to establishing normative reference data for Saudi neonates and provide a foundation for developing localized nomograms to enhance diagnostic accuracy and early detection of congenital aortic arch anomalies.

Conclusion

In conclusion, this study provides comprehensive normative data for neonatal aortic arch dimensions and highlights the significant influence of anthropometric factors, particularly body weight, on aortic arch measurements. These findings contribute valuable reference data for neonatal echocardiography, supporting more accurate assessment and early detection of aortic abnormalities in clinical and research settings.

Declarations

Authorship contribution

Dr Salim Ahmad perceived the research idea and acted as mentor for the study and senior author for the manuscript writing and editing.

Dr Awadh A Nawal is the primary investigator and first author, who took the lead role in data collection and manuscript writing.

All coauthors played an active part in compilation of the study, manuscript writing and editing.

Conflict of interest

All authors have declared No conflict of interest.

Financial disclosure

The study did not receive any financial support.

Ethical approval

The study has been performed in accordance with ethical standards of the institutional research committee and with the 2013 Helsinki declaration of comparable ethical standards, The study has been approved by the institutional review board of Prince Sultan Cardiac Center, Riyadh, Saudi Arabia under IRB approval no: IR 1704. The need for written informed consent was waived by the IRB.

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