ORIGINAL RESEARCH

# Assessment of descending aortic blood flow velocities with continuous wave Doppler echocardiography among healthy Children in South East Nigeria

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## Abstract

**Background**

The descending aorta velocity is important predictor of aortic disease in children and can be very helpful in some clinical and surgical decision making.

**Aim**

The purpose of this study is to assess the normative values of descending aorta velocity among children from South-East Nigeria. It also aimed to assess the correlation between age, body surface area and mean velocity across the descending aorta.

**Methods**

This is a cross-sectional study where the descending aorta velocity of one hundred and eleven children were enrolled consecutively using digitized two-dimensional and Doppler echocardiography.

**Results**

A total of 111 children had echocardiography to study their cardiac structures and compute their mean scores of their descending aorta velocity. The mean velocity across the descending aorta was 1.3±0.2m/s with maximum and minimum velocities of 2.06 and 0.84cm respectively. The mean descending aorta velocity in males (1.37±0.24 m/s) was significantly higher than that in females (1.24±0.18); (Student T test 3.09, p = 0.03). There was no correlation between age and mean velocity across the descending aorta (Pearson correlation coefficient; -0.03, p = 0.7) nor between body surface area and descending aorta velocity (correlation coefficient 0.01, p= 0.8).

**Conclusions**

The presented normalized values of the descending aorta velocity using a digitized two-dimensional and Doppler echocardiography among healthy children will serve as a reference values for further studies and can be applied for clinical and surgical use in children with various cardiac anomalies.

**Keywords:** Digitalized two-dimensional echocardiography; Doppler echocardiography; children, South-East Nigeria; descending aorta velocity

## Introduction

The descending aorta plays a vital role in the anatomy of the cardiovascular system. The left ventricular ejection yields a continuous flow due to the elastic buffering of the descending aorta which transmits the pulsatile effect[1]. Aortic enlargement and impaired aortic bioelastic function is a sequel of cardiac and non-cardiac diseases in children[2-4]. This sequel is of clinical importance as it can lead to cardiovascular complications such as left ventricular hypertrophy, aneurysmal anomalies of great vessels and myocardial infarction[5-7].

It is noteworthy that aortic pulse wave velocity (PWV) and aortic distensibility which correlates with the descending bioelastic function of the aorta serve as pathogenic markers in the disease of the cardiovascular disease[8]. The rate of blood flow at the descending aorta is crucial as it helps to understand the mechanism and the evolution of cardiovascular diseases caused by a disturbance of the aortic flow hemodynamics in children[8]. The use of echocardiography has shown immense benefit in the analysis of hemodynamic aortic flow dysfunction in cardiovascular disease[9]. Echocardiography remains the goal standard in estimating the descending aorta velocity, it is reproducible, economical and reliable. Evaluation of the aortic function using the 4D flow MRI are expensive and unaffordable in a developing economy like ours[10]. Vam et al[11] in their study on aortic hemodynamics, noted significant correlations between age and peak systolic velocity. A study had shown that despite having a similar diameter of the ascending aortic dimensions, the descending aorta velocity still remains different for gender[12]. It is important to note that age and gender influences the compliance and elasticity of the descending aorta, this they do by influencing the biomechanical tissue properties (compliance and elasticity) in healthy subjects by affecting the pulse wave velocity along the aorta[11]. Besides, females



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have a smaller aortic dimensions than males with increased risk of aortic events in aging[12].

The impact of age and gender on aortic hemodynamics indicates the importance of age and gender-matched control for the assessment of cardiovascular disease on aortic blood flow. There is an inverse relationship of descending aorta velocity with the fetal heart. Ursem et al[13] had noted in their study that from the gestational age of 10 to 20 weeks, there is a notable increase of descending aorta peak systolic and time-averaged velocities with a decrease in the fetal heart rate. Estimation of the descending aorta velocity will assist the clinician to know when the normal values are exceeded. This will help in clinical and surgical decision making. For instance, Wyse et al[14] noted a significantly higher peak descending aortic blood flow velocities among 30 children with aortic coarctation compared to control with a positive correlation with the systolic blood pressure gradient[14].

The descending aorta blood flow also has clinical implications in that it is a direct measure of the cardiac index[15]. Seear[15] et al noted that the mean aortic blood flow in the descending aorta was directly proportional to cardiac index. They postulated that the mean aortic flow velocity has an important marker and an indicator of cardiac output. This can be used as prognostication in children with heart failure. Knowledge of the normative values of descending aorta velocity is crucial especially in the management of children with congenital and acquired cardiovascular disorders. Normal data for aortic velocity in children have been reported but much is not documented on the normalization of the descending aorta velocity to body surface area in our setting[15].

The dilatation or coarctation of the descending aorta and impaired bioelasticity are important markers of cardiac and extra cardiac diseases as they may lead to cardiovascular complications. Besides, the reference ranges from early childhood to adolescence are rare in our locale. The aim of this study is to document normative values of the descending aorta velocity with Doppler echocardiography among apparently healthy children form South-east Nigeria. This work will form a data base in our locale where such work is grossly lacking.

### *What previous studies on this topic have shown*

Normal data for aortic velocity in children have been reported and widely used in the western world. For instance, Poutanen et al[16] documented normal values for aortic dimensions and aortic flow velocities in healthy children . Their findings served as a reference data and template for future studies and clinical decision making in children with various cardiac abnormalities.

### *Why this study is still needed*

The descending aorta blood flow also has clinical implications in that it is a direct measure of the cardiac index. Descending aorta velocimetry can also be used for prognostication in children with heart failure. Knowledge of the normative values of descending aorta velocity is crucial in this locale especially in the management of children with congenital and acquired cardiovascular disorder. Normal data for aortic velocity in children have been reported but much is not documented on the normalization of the descending aorta velocity to body surface area in our setting. Besides, the reference ranges from early childhood to adolescence are rare in our locale. This work will also form a data base in our locale where such work is grossly lacking.

## Methods

### *Study Design*

This was a prospective cross -sectional observational study.

### *Study Population*

These were children from the age of one year to eighteen years. Children who were apparently well, who had no obstructive lesion or any congenital, or acquired cardiac defects or anaemic heart disease were selected consecutively into the study. This study was conducted in four private hospitals in Enugu metropolis involving a total of 111 apparently healthy children. These health facility provide services in the treatment of children with cardiac illnesses. The hospital of study also reviews children who came for checks who have recovered fully after treatment for common childhood illnesses . Children referred to the paediatric clinics for suspected cardiac disease but who had normal echocardiographic reports were recruited into the study.

### *Study Area*

This study was carried out in 4 institutions across the Enugu metropolis, namely the University of Nigeria Teaching Hospital (UNTH) Ituku-Ozalla Enugu, State University Teaching Hospital, Triple care specialist hospital and Blessed children specialist hospital. These hospitals provide specialized services in the management of children and also review review children who present for routine follow-up, and who are apparently well after treatment for minor illnesses.

### *Study Duration*

The study was undertaken for over a 4-year period, from May 2020 to April 2023. Besides there were quality controls taken at intervals to reduce bias.

### *Echocardiographic determination of the Descending Aorta Velocity.*

The descending aorta velocity was assessed by means of echocardiography. The Echo Hewlett-Packard (HP) SONO 2000 Ultrasound model was used with a very high frequency. Descending aorta velocimetry was defined as the descending aorta blood flow rate per unit second[17]. This was measured in a supra-sternal long-axis view. Descending aortic flow velocity is usually measured with continuous or pulsed wave Doppler ultrasound as far as there is no obstruction or regurgitation. The use of the continuous wave Doppler method is advantageous over the pulse wave method in that it measures limitless values of descending aorta velocity. Continuous wave Doppler velocities can also measure other systolic high velocity jets in children and neonates especially among those seen in mitral blood flow velocities in the aorta[18]. The pulse wave velocity is limited when there is an obstruction to blood flow velocities[18]. Besides, aortic regurgitation is well calculated by the continuous wave Doppler ultrasound recording across the aortic valve[19]. Descending aortic flow velocities are best measured and calculated using the suprasternal notch in the suprasternal long axis-view[19]. The descending aortic flow velocity was obtained by means of the cosine of the angle between the ultrasound beam and the velocity derived from the frequency shift by the Doppler equation[19]. To avoid underestimation of velocity, angles of the cursor were placed between twenty degrees and zero degree.

**Table 1: Socio-demographic characteristics of respondents**

| Variable | Frequency (n = 111) | Percentage (%) | |
|---|---|---|---|
| Gender | | | |
| Male | 58 | 52.3 | |
| Female | 53 | 47.7 | |
| Mean Age of respondents in years | | Student t-test | p-value |
| Male | 8.1±4.9 | -0.19 | 0.9 |
| Female | 8.2±5.0 | | |

**Table 2: Correlation between mean velocity across the descending aorta and age and Body surface area**

| Correlation between mean velocity across the descending aorta and | Sample size (n) | Pearson p value correlation (r) | P-value |
|---|---|---|---|
| Age | n=111 | -0.03 | p = 0.7 |
| Body surface area | n=111 | 0.01 | 0.8 |
| | | | |
| Mean Velocity | | Student t-test | p-value |
| Male | 1.37±0.24 m/ | 3.09 | p = 0.03 |
| Female | 1.24±0.18 | | |

Several cursor positions were taken to help reduce bias so as to establish the signal with the highest frequencies[20]. This method also reduces to the barest minimum the difference between the use of pulsed and continuous wave Doppler methods[20]. The descending aorta velocity was ascertained with a very high frequency wave with high intensity to get a pure and well delineated jet[20]. The recording was done from the jet, at a small angle, so as to achieve a maximal velocity[20]. Every obstructive lesion in any course of the cardiac chambers or valvar obstructions along the cardiac chambers towards the ascending and descending aorta were all excluded. All values of the descending aorta velocity were documented in meters per second[20].

### *Measurement of body surface area*

### *Body surface Area*

This was measured using the Mosteller formula

(Height [cm] × Weight [kg]/3600)½

### *Sample Size Estimation*

To achieve 5% precision at a 95% confidence interval for a population >5,000 a minimum sample size of 100 was determined from Glenn's Table of sample sizes. 21 Attrition rate of 11% was considered and this brought the sample size to 111.

### *Ethical Approval and Consent to participate*

The approval was obtained by the Health Research Ethics Committee of the University of Nigeria Teaching Hospital, Enugu with registration number NHREC/05/01/2008B-FWA00002458-1R00002323. We obtained oral informed consent for echocardiography from parents or caregivers of the subjects,however those who are above 7 years had assent obtained form them. The oral informed consent was also contained in the approval letter of the ethical approval by the the Health Research Ethics Committee of the University of Nigeria Teaching Hospital, Enugu.

### *Data analysis*

Data were analyzed with SPSS version 20 software (IBM Armonk, NY). Categorical variables such as gender were summarized and presented as tables while discrete variables such as age were summarized as means and standard deviation. Comparison between means of descending aorta velocity and gender were analysed using the independent Student T-test. The relationship between descending aorta velocity with age and gender was analysed with the Pearson correlation coefficient. The P-value was set at p< 0.05.

## Results

A total of 111 children had echocardiography to study their cardiac structures and compute their mean scores of their descending aorta velocity. The participants comprised of 58 (52.3%) males and 53 (47.7%) females. Male to female ratio is 1.1:1. Table 1

The mean age of participants was 8.1±5.0 years. The mean age of the males (8.1±4.9) was comparable with that of the females (8.2±5.0) years; (T test= -0.19, p= 0.9). The mean weight in kilograms was 29.8±18.2 with minimum and maximum weights of 2.0 and 83.0 kg. The mean velocity across the descending aorta was 1.3±0.2m/s with maximum and minimum velocities of 2.06 and 0.84cm respectively.

The mean descending aorta velocity in males (1.37±0.24 m/s) was significantly higher than that in females (1.24±0.18c); (Student T test 3.09, p = 0.03). There was no correlation between age and mean velocity across the descending aorta (Pearson correlation coefficient; -0.03, p = 0.7) nor between body surface area and descending aorta velocity (correlation coefficient 0.01, p= 0.8).

## Discussion

The knowledge of descending aorta velocimetry and its hemodynamics is important in the evaluation of children with abnormalities of the aortic root and its branches such as aortic root dilatation, coarctation of the aorta and interrupted aortic arch[22]. The continuous wave Doppler technique was used in this study because of its several advantages. Firstly, the velocities were elicited all along the ultrasonic beam and high velocities were captured in the study. Changes in blood flow volume can also be assessed with continuous wave as changes in volume flow cause an increase in the velocity since velocity decreases with a decrease in flow[22].

The objective of these study were to document normative values of descending aorta velocity in apparently healthy Nigerian children, the study was also aimed at delineating gender and age correlates of descending aorta velocity among healthy Nigerian children. The mean value obtained for the descending aorta velocity as seen in this study was 1.3±0.2m/s. This was similar to that documented by Gabrielsen et al[23] who got the highest values of values of (1.28 +/- 0.18 m/s), and lowest values for the descending aorta (1.17 +/- 0.22 m/s)[20]. The value of descending aorta velocity in this study was also corroborated by Soon et al[24] who documented values of 1.29 ±0.13 m/sec in their reportage. Garcia et al[25] also noted a similar value in descending aorta blood flow as 1.32 ± 0.1m/s. Though the authors' sample frame were drawn from subjects aged 9 years to 78 years, the descending aorta blood flow was stratified according to age range with values of 1.32 ± 0.1m/s seen in children aged 9 to 15 years.

The study showed no significant correlation between descending aorta velocity with the body surface area. No study was documented in literature where descending aorta velocity was indexed to body surface area. Some work had rather indexed aortic annulus, sinus, and sinotubular junction to body surface area. For instance, Poutanen 16 and his cohorts using a doppler echocardiographic measurements had noted a positive correlation of aortic annulus, sinus, and sinotubular junction and body surface area. They reported that best predictor of aortic annulus, sinus, and sinotubular junction was BSA with r values over 0.84. The comprehensive measurements of the descending aorta velocity and other cardiac structures and function remain crucial in managing children with congenital and acquired cardiac anomalies[26,27]. There may be need for further research into this finding where a very large cohort of subjects will be recruited and followed over time.

Decisions on the type of cardiac lesion located at the descending aorta and its branches and the accurate timing of interventions often rely to a large extent on these measurements[27]. For instance, aortic anomalies including native coarctation, catheter-guided interventions, dilatation of the aortic root associated with aortic valve disease and connective tissue diseases such as Marfan syndrome, anomalies arising from congenital heart disease, such as the arterial switch operation or the Ross procedure may dictate the choice of descending aorta repair[27-32].

This study showed that the mean descending aorta velocity in males was significantly higher than that of females. However, Kocher at al [26] using 623 healthy children noted no significant gender differences in their study. Similarly, Garcia et al[25] documented similar gender values of the descending aorta velocity. Weng et al[32] also noted that the higher descending aorta blood flow seen in females in their reportage may be explained possibly by the less elastic stiffness of the smooth muscles seen in the blood vessels of females[32]. It was also noted that stiffness of the arterial walls increases after-load of the left ventricle, females have lower arterial stiffness than males, thus higher descending aorta blood velocity[32]. There is an interplay of sex hormones surge with reduced stiffness and increase blood flow and function[32]. Females have this surge, especially during puberty[31].

There was no correlation between descending aorta velocity and age in this study. Poutanen et al[16] also noted that the descending aorta velocity were inversely proportional to age. Garcie et al[25] stratified the descending aorta velocity into different age groups among 98 adults and noted that age was significantly associated with aortic diameter velocity and they vary significantly between age groups. They noted the diameter of descending aorta velocity changes with age due to an increase in the aortic valve size with age[32]. The age range of the participants in the two studies may have contributed to the difference.

Besides, it is important to note that age and gender differences can affect altered aortic blood flow that may be associated with disease. Some studies have evaluated the effect of aging and gender on the morphology of the descending aorta[33-35]. For instance, it is known that age influences the compliance and elasticity of the descending aorta[34]. This they do by affecting the pulse wave velocity along the aorta and the left ventricular flow36-41.

The analysis of velocity magnitude across the descending aorta has provided baseline metrics for characterizing flow behavior in healthy children across gender and age in this locale. This may facilitate its application in surgical and clinical decision making in Nigerian children.

## Limitation

This study was limited by the moderate sample size. A very large sample size would have made the study stronger.

## Conclusions

The presented values of the descending aorta velocity using a digitized two-dimensional and Doppler echocardiography among healthy children will serve as reference values for further studies and can be applied for clinical and surgical use in children with various cardiac anomalies.

## Consent for publication:

Not applicable.

## Availability of data and materials

Data are however available from the authors upon reasonable request and with permission of the corresponding Author.

## Competing Interest

The authors declare that they have no competing interests.

## Funding

This study was not funded by any organization. We bore all the expense that accrued from in study.

## Authors' contributions:

CJM conceived and designed this study while CJM, CAT, and OEN helped in critical revision of the article. CJM and OEN also did the Data analysis/interpretation. All authors have read and approved the manuscript.

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