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Evaluation of Normal Ranges of Aortic Elasticity Parameters Obtained From Ascending Aorta Diameter Using Transthoracic Echocardiography in Healthy Children: A Single-Center Study

Sağlıklı Çocuklarda Transtorasik Ekokardiyografi Kullanılarak Çıkan Aort Çapından Elde Edilen Aort Elastikiyet Parametrelerinin Normal Aralıklarının Değerlendirilmesi: Tek Merkezli Çalışma

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Abstract: In this study, we aimed to determine the normal distribution ranges of aortic elasticity parameters produced from data obtained from ascending aortic diameters according to age and sex and to analyze the factors affecting aortic elasticity parameters. Patients were grouped according to age and sex. In addition to the demographic data of all patients, the left ventricular systolic and diastolic functions, aortic diameters, and left ventricular masses were evaluated using transthoracic echocardiography. The aortic diameters, aortic strain, aortic stiffness, and aortic distensibility were obtained. A total of 215 patients (103 boys and 112 girls) were included in our study. In the study, the mean values of age and body surface area (BSA) were 8.49 (±5.37) years and 1.02 (±0.46) m2, respectively. The aortic strain, stiffness, and distensibility values were 23.13% (±16.03), 3.33 (±1.95), and 0.010 (±0.008) dyn-1*cm2*10-6, respectively. When compared according to sex, age, left ventricular function, aortic diameter, and aortic elasticity parameters were similar. A table of normal value ranges of aortic elasticity parameters was created according to age group and sex. There were varying degrees of correlations between aortic elasticity parameters and age, BSA, left ventricular function, aortic diameter, and blood pressure. The aortic elasticity parameters vary according to age and sex. Aortic elasticity parameters are affected by age, heart function, aortic diameter, blood pressure, and hormonal status, which change during puberty.
Keywords: Child, aortic strain, aortic stiffness, aortic distensibility, normal range

Özet: Çalışmamızda çıkan aorta çaplarından elde edilen verilerden üretilen aortik elastisite parametrelerinin yaş, cinsiyetlere göre normal dağılım aralıklarını belirmelemek ve aortik elastisite parametreleri üzerine etki eden faktörleri analiz etmek amaçlanmıştır. Tüm hastalar yaş gruplarına ve cinsiyetlere göre gruplandırılmıştır. Tüm hastaların demografik verilerinin yanında, transtorasik ekokardiyografi ile sol ventrikül sistolik ve diyastolik fonksiyonları, aortik çapları, sol ventrikül kütleleri değerlendirilmiştir. Aortik çaplardan; aortik strain, aortik stiffness, aortik distensibilite parametreleri elde edilmiştir. Çalışmamıza 215 hasta (erkek ve kız sırasıyla 103, 112) dahil edildi. Çalışmada yaş, vücut yüzey alanı (BSA) ortalama değerleri sırasıyla 8.49 (±5.37) yıl, 1.02 (±0.46) m2 idi. Aortik strain, stiffness, distensibilite değerleri sırasıyla %23.13 (±16.03), 3.33 (±1.95), 0.010 (±0.008) dyn-1*cm2*10-6 idi. Cinsiyete göre karşılaştırılma yapıldığında yaş, sol ventrikül fonksiyonları, aortik çaplar, aortik elastisite parametreleri benzer değerlerde bulundu. Yaş gruplarına ve cinsiyete göre aortik elastisite parametreleri normal değer aralıkları tablosu oluşturuldu. Aortik elastisite parametreleri ile yaş, BSA, sol ventrikül fonksiyonları, aortik çaplar ve kan basıncı ile değişen derecelerde korelasyon ilişkisi mevcuttu. Aortik elastisite parametreleri yaş gruplarına ve cinsiyetlere göre farklılık göstermektedir. Aortik elastisite parametreleri ile yaş, kalp fonksiyonları, aortik çaplar, kan basıncı ve pubertele birlikte değişen hormonal durum etki etmektedir.
Anahtar Kelimeler: Çocuk, aortik strain, aortik stiffness, aortik distensibilite, normal aralık

Ethics Committee Approval: The study was approved by Ethics in Research Committee at Diyarbakır Gazi Yaşargil Training and Research Hospital University Non-Interventional Clinical Research Ethics Committee (Decision no: 80, Date: 24.05.2024).

Informed Consent: The authors declared that it was not considered necessary to get consent from the patients because the study was a retrospective data analysis.

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1. Introduction

Structurally and functionally, the arterial system consists of large, elastic, and muscular arteries. Large elastic arteries store ejected blood during systole and ensure constant blood flow throughout the systolic and diastolic cycles. Muscular arteries modulate pressure waves by changing their tone (1).

Many diseases, such as inactive physical life, obesity, prematurity, hypertension, renal failure, diabetes mellitus, beta thalassemia major, and connective and systemic inflammatory diseases are risk factors for cardiovascular diseases (2-12). The endothelium plays an important role in maintaining homeostasis and cardiovascular functions (13, 14). Increased arterial stiffness has high predictive value for morbidity and mortality in cardiovascular diseases (15, 16). A relationship exists between central aortic stiffness and arterial stiffness (17).

In the evaluation of aortic elasticity, there are many imaging methods, such as transthoracic echocardiography, Doppler echocardiography, sonographic methods, carotid intima-media thickness, cardiac magnetic resonance imaging (MRI), and computed tomography (CT) (4, 18-21).

The aim of this study was to determine the normal value ranges of aortic elasticity parameters according to age and sex using data obtained from ascending aortic diameters, and to analyze the factors affecting this.

2. Materials and Methods

Patients who applied for any reason and no cardiac pathology was detected as a result of the evaluations were included in our study. Ethics committee approval for our study was obtained from the Gazi Yaşargil Training and Research Hospital Ethics Committee (decision number=80/2024). First, this was a retrospective study. The demographic data of the patients were obtained from their files, and echocardiographic examinations were performed offline. Patients with a family history of hypertension, early myocardial infarction, stroke, or chronic disease were excluded from this study. Foreign participants were excluded from this study. Based on studies evaluating normal aortic elasticity values of 165 and 168 healthy children, 215 healthy children were included in our study (22, 23).

The patients were grouped according to age and sex. They were grouped as boys and girls according to sex. Healthy children were grouped according to age (24, 25). According to age groups, they were categorized as under 1 year old, 1-5 years old, 5-9 years old, 9-13 years old, and 13-18 years old.

After all patients rested for 15 minutes, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured oscillometrically.

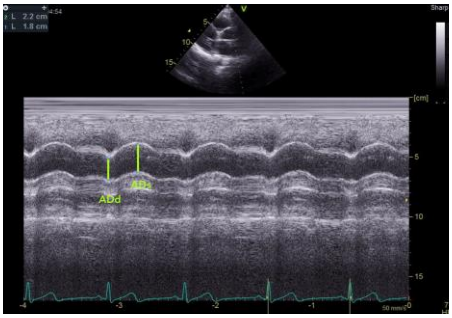
Patient age was expressed in decimal years, body weight in kilograms, height in centimeters, and body surface area in square meters (26). Body mass index (BMI) was calculated as the ratio of body weight (kg) to height squared (m^2). Children with BMI < 25 were included in this study (27).

All patients underwent transthoracic echocardiography after a detailed anamnesis and systemic examination. In line with the recommendations, 2D, color Doppler, and M-mode images were obtained. Left ventricular long-axis wall thicknesses and ejection fraction (EF) were calculated automatically using M-mode (28). Left ventricular mass (LVmass) was calculated using the formula derived from the left ventricular wall thickness. The ratio of LVmass to BSA was obtained as LVmass-index (LVmass-i) (29).

Ventricular early (E) and late (A) filling velocities were measured using pulsed-wave Doppler at the mitral valve tip in the apical four-chamber view (28).

Systolic (ADs) and diastolic (ADd) aortic diameters were measured by sectioning the left ventricle in the long-axis position with M-mode, 2-3 cm above the aortic valve (figure 1). Aortic strain (AS) was measured as (ADs-ADd)/(ADd). Aortic stiffness; [In (SBP/DBP)]/AS, distensibility, calculated as 2 × AS/(SBP-DBP) (28, 30).

The IBM SPSS (version 27) was used to analyze the data. The distribution of the data was expressed as mean, standard deviation, minimum-maximum value, 5th percentile, and 95th percentile. Continuous variables are expressed as mean±standard deviation or median (minimum, maximum), and categorical variables are expressed as percentages (%). Student’s t-test or Mann-Whitney test was used for continuous variables, depending on the homogeneity of the data, and the chi-square test was used for analysis of categorical variables. For the correlation analysis, the Pearson test or Spearman test was used, depending on the homogeneity of the data. Statistical significance was set at p value < 0.05.



ADs: systolic aortic diameter, ADd: diastolic aortic diameter

Figure 1. *Measurement of systolic and diastolic aortic diameters with M-mode*

3. Results

A total of 215 patients (47.90% boys and 52.10% girls) were included in our study. In our study, the average age, height, and weight BSA, BMI values were 8.49 (±5.37) years, 126.37 (±35.74) cm, 30.87 (±19.07) kg, 1.02 (±0.46) m^2, 16.76 (±2.94) kg/m^2, respectively.

The mean values of SBP and DBP were 106.40 (±14.29) and 60.69 (±7.97) mmHg, respectively.

The average values of EF, LVmass, LVmass-i, E velocity, A velocity, E/A ratio are 69.93 (±6.59) %, 52.80 (±31.96) gr, 49.09 (±12.49) gr/m2, 1.05 (±0.17) m/s, 0.67 (±0.17) m/s and 1.64 (±0.45), respectively.

The average values of ADs, ADd, aortic strain, stiffness, and distensibility were 16.93 (±4.56) mm, 13.92 (±4.30) mm, 23.13 (±16.03) %, 3.33 (±1.95), and 0.010 (±0.008) $dyn^{-1}*cm^2*10^{-6}$, respectively (Table 1).

When grouped by gender, the median age values for boys and girls were 9.25 (0.04-17.83) and 7.66 (0.10-17.91) years respectively. The mean BSA values in boys and girls were 1.05 (±0.51) and 1.00 (±0.40) m2, respectively. The median BMI values for boys and girls were 16.09 (9.96-23.02) and 16.32 (11.44-23.97) kg/m^2, respectively. Age, BSA and BMI values were similar between boys and girls, and no statistical differences were detected.

SBP and DBP were similar when compared by sex.

The EF value was significantly higher in boys than in girls (p=0.01).

Although the LVmass value was similar in both sexes, LVmass-i was significantly higher in boys (p=0.009).

E and A velocities and E/A ratios were similar in both sexes.

ADs, ADd, aortic strain, stiffness, and distensibility values were similar in both sexes, and no statistical difference was detected (Table 2).

Table 3 shows the mean, standard deviation, minimum-maximum values, and 5th and 95th percentile values of age, aortic strain, stiffness, and distensibility values. The 5th percentile values of aortic strain in boys aged < 1 year, 1-5 years of age, 5-9 years of age, 9-13 years of age, and 13-18 years of age were 5.88, 9.09, 14.28, 5.55, and 6.13%, respectively. The 5th percentile values of aortic strain in girls under 1 year of age, 1-5 years of age, 5-9 years of age, 9-13 years of age, and 13-18 years of age were 6.66, 8.33, 6.82, 10.55, 8.33%, respectively. While aortic strain was higher in girls under the age of 1 year, it was higher in boys between the ages of 1 and 9 years, and was higher in girls aged 9 years. However, no statistical differences were detected according to age group.

Stiffness values in the boy age groups (<1y, 1-5y, 5-9y, 9-13y, 13-18y) and 95th percentile values were 7.46, 4.01, 4.25, 6.16, and 9.99, respectively, while in the girl age groups (<1y, 1- 5y, 5-9y, 9-13y, 13-18y) 95th percentile values were 7.21, 6.51, 8.12, 5.47, and 6.75. While the aortic stiffness value was higher in boys under the age of 1 year, it was higher in girls between the ages of 1 and 9 years, and was higher in boys aged 9 years. However, it was statistically insignificant across age groups.

Distensibility values in male age groups (<1y, 1-5y, 5-9y, 9-13y, 13-18y) while the 5th percentile values are 0.003, 0.003, 0.004, 0.002, and 0.002 $dyn^{-1}*cm^2*10^{-6}$, respectively. In the female age groups (<1y, 1-5y, 5-9y, 9-13y, 13-18y), the 5th percentile values were 0.003, 0.004, 0.002, 0.004, and 0.002 $dyn^{-1}*cm^2*10^{-6}$, respectively. The 5th percentile value of distensibility was higher in boys before the age of 9 years and girls after the age of 9 years. However, the distensibility value was statistically insignificant in the age groups according to sex.

The aortic elasticity parameters and their correlation relationships with various parameters are summarized in Table 4.

Aortic strain showed a correlation with other elasticity parameters, ADd, EF, and E/A ratio.

Aortic stiffness was significantly correlated with ADd, age, BSA, SBP, and the E/A ratio.

Aortic distensibility was significantly correlated with age, BSA, BMI, SBP, DBP, LVmass, ADs, ADd, EF, and E/A ratio.

Table 1. Table of mean, standard deviation, median and minimum-maximum values of demographic, echocardiographic parameters, aortic diameters and aortic elasticity parameters in all age groups

Parameters	Mean (n=215)	SD	Median	Range
Age (year)	8.49	5.37	8.33	0.04-17.91
Weight (kg)	30.87	19.07	27.20	3.00-89.00
Height (cm)	126.37	35.74	132	50-186
BSA (m^2)	1.02	0.46	0.99	0.20-2.14
BMI (kg/m^2)	16.76	2.94	16.12	9.96-23.97
SBP (mmHg)	106.40	14.29	108	60-135
DBP (mmHg)	60.69	7.97	60	36-82
EF (%)	69.93	6.59	70	57-88
LVmass (g)	52.80	31.96	48.16	6.39-174.52
LVmass-i (g/m^2)	49.09	12.49	47.92	20.63-90.63
E velocity (m/s)	1.05	0.17	1.03	0.65-1.75
A velocity (m/s)	0.67	0.17	0.65	0.37-1.38
E/A ratio	1.64	0.45	1.56	0.88-3.24
ADs (mm)	16.93	4.56	17	8-32
ADd (mm)	13.92	4.30	14	6-30
Aortic strain (%)	23.13	16.03	18.75	4.54-85.71
Stiffness	3.33	1.95	2.95	0.42-12.95
Distensibility ($dyn^{-1}.cm^2.10^{-6}$)	0.010	0.008	0.008	0.002-0.061

BSA: body surface area, SBP: systolic blood pressure, DBP: diastolic blood pressure, EF: ejection fraction, LVmass: left ventricular mass, LVmass-i: ratio of left ventricular mass to body surface area, E velocity: left ventricle early filling velocity, A velocity: left ventricle late filling velocity, ADs: systolic diameter of aorta, ADd: diastolic diameter of aorta,

Table 2. Table comparing demographic, echocardiographic parameters, aortic diameters and aortic elasticity parameters according to gender

Parameters	Boy (n=103)	Girl (n=112)	p value
Age (year)	9.25 (0.04-17.83)	7.66 (0.10-17.91)	0.53[1]
BSA (m^2)	1.05 (± 0.51)	1.00 (± 0.40)	0.40[2]
BMI (kg/m^2)	16.09 (9.96-23.02)	16.32 (11.44-23.97)	0.31[2]
SBP (mmHg)	106.85 (± 16.12)	105.92 (± 12.23)	0.63[2]
DBP (mmHg)	60 (36-81)	60 (40-82)	0.64[1]
EF (%)	71 (59-87)	68 (57-88)	**0.01[1]**
LVmass (g)	51.35 (6.39-174.52)	46.96 (9.55-118.72)	0.11[1]
LVmass-i (g/m^2)	50.58 (20.63-85.57)	44.59 (28.02-90.63)	**0.009[1]**
E velocity (m/s)	1.04 (0.72-1.72)	1.01 (0.65-1.75)	0.94[1]
A velocity (m/s)	0.67 (0.37-1.38)	0.64 (0.42-1.12)	0.85[1]
E/A ratio	1.56 (0.88-2.89)	1.57 (0.88-3.24)	0.81[1]
ADs (mm)	17 (8-32)	16.40 (8-26)	0.22[1]
ADd (mm)	14 (6-30)	14 (7-24)	0.11[1]
Aortic strain (%)	18.75 (4.55-83.33)	18.75 (6.25-85.71)	0.70[1]
Stiffness	3.13 (0.53-12.95)	2.86 (0.51-10.11)	0.61[1]
Distensibility ($dyn^{-1}.cm^2.10^{-6}$)	0.007 (0.02-0.056)	0.008 (0.002-0.047)	0.62[1]

1: Mann-Whitney test, 2: student t test, BSA: body surface area, SBP: systolic blood pressure, DBP: diastolic blood pressure, EF: ejection fraction, LVmass: left ventricular mass, LVmass-i: ratio of left ventricular mass to body surface area, E velocity: left ventricle early filling velocity, A velocity: left ventricle late filling velocity, ADs: systolic diameter of aorta, ADd: diastolic diameter of aorta,

Table 3. Comparison table of aortic elasticity parameters according to age groups and gender

Parameters	Groups	Sex	Mean	SD	Min-max.	5th	95th	p-value

Age (year)	**<1y**	**M (n=16)**	0.23	0.22	0.04-0.96	0.04	0.57	0.22[1]
		F (n=11)	0.30	0.19	0.03-0.69	0.03	0.66	
	1-5y	**M (n=18)**	2.87	1.20	1.00-4.50	1.00	4.34	0.86[2]
		F (n=15)	2.94	1.28	1.08-4.66	1.08	4.61	
	5-9y	**M (n=16)**	7.15	1.20	5.00-8.83	5.00	8.71	0.61[2]
		F (n=43)	7.30	1.13	5.00-8.91	5.21	8.83	
	9-13y	**M (n=19)**	10.57	1.28	9.00-12.91	9.00	12.75	0.25[2]
		F (n=22)	11.03	1.18	9.08-12.91	9.10	12.90	
	13-18y	**M (n=34)**	15.64	1.54	13.00-17.83	13.12	17.70	0.95[1]
		F (n=21)	15.42	1.82	13.08-17.91	13.08	17.76	
Aortic strain (%)	**<1y**	**M (n=16)**	14.16	6.33	5.88-28.57	5.88	26.07	0.27[1]
		F (n=11)	16.05	6.84	6.67-30.00	6.66	29.00	
	1-5y	**M (n=18)**	27.24	19.41	9.09-83.33	9.09	72.61	0.92[1]
		F (n=15)	22.81	9.71	8.33-42.86	8.33	37.14	
	5-9y	**M (n=16)**	27.76	13.08	14.29-70.00	14.28	46.00	0.99[1]
		F (n=43)	30.44	20.15	6.25-85.71	6.82	84.52	
	9-13y	**M (n=19)**	20.77	10.60	5.56-45.45	5.55	41.66	0.12[1]
		F (n=22)	15.84	4.90	10.53-31.25	10.55	30.86	
	13-18y	**M (n=34)**	19.24	10.72	4.55-58.33	6.13	41.05	0.61[1]
		F (n=21)	21.15	18.42	8.33-82.22	8.33	49.76	
Stiffness	**<1y**	**M (n=16)**	4.10	2.16	1.53-10.81	1.53	7.46	0.78[1]
		F (n=11)	4.00	1.69	1.64-7.60	1.64	7.21	
	1-5y	**M (n=18)**	2.41	1.34	0.53-6.30	0.53	4.01	0.40[1]
		F (n=15)	2.99	1.77	1.36-7.05	1.36	6.51	
	5-9y	**M (n=16)**	2.61	1.09	0.67-5.38	0.67	4.28	0.48[1]
		F (n=43)	2.72	2.10	0.51-10.11	0.61	8.12	
	9-13y	**M (n=19)**	4.01	2.58	1.58-12.95	1.58	6.16	0.71[2]
		F (n=22)	3.77	1.05	1.52-5.48	1.57	5.47	
	13-18y	**M (n=34)**	3.86	2.12	1.15-10.88	1.37	9.99	0.59[1]
		F (n=21)	4.01	2.06	0.62-9.18	0.62	6.75	
Distensibility ($dyn^{-1}.cm^{2}.10^{-6}$)	**<1y**	**M (n=16)**	0.009	0.004	0.003-0.020	0.003	0.017	0.71[1]
		F (n=11)	0.008	0.003	0.004-0.017	0.003	0.016	
	1-5y	**M (n=18)**	0.015	0.012	0.004-0.052	0.003	0.030	0.40[1]
		F (n=15)	0.011	0.005	0.004-0.020	0.004	0.020	
	5-9y	**M (n=16)**	0.011	0.005	0.005-0.029	0.004	0.021	0.55[1]
		F (n=43)	0.014	0.010	0.002-0.050	0.002	0.039	
	9-13y	**M (n=19)**	0.008	0.004	0.002-0.015	0.002	0.014	0.78[1]
		F (n=22)	0.006	0.002	0.004-0.015	0.004	0.015	
	13-18y	**M (n=34)**	0.007	0.003	0.002-0.018	0.002	0.015	0.57[1]
		F (n=21)	0.008	0.008	0.002-0.041	0.002	0.019	

1: Mann-Whitney test, 2: Student t test, F: female, M: male, y: year, SD: standart deviastion

Table 4. Table showing the correlation relationship of aortic stiffness parameters with various parameters

Parameters		**r value**	**p value**	**Parameters**		**r value**	**p value**
AS	**ADs**	-0.04	0.55[1]	**Stiffness**	**ADs**	0.12	0.07[1]
	ADd	-0.31	0.000[1]		**ADd**	0.38	0.000[1]
	Stiffness	-0.91	0.000[1]		**AS**	-0.91	0.000[1]
	Distensibility	0.88	0.000[1]		**Distensibility**	-0.97	0.000[1]
	Age	-0.07	0.36[1]		**Age**	0.15	0.02[1]
	BSA	-0.07	0.32[1]		**BSA**	0.17	0.01[1]
	BMI	0.02	0.73[2]		**BMI**	0.03	0.65[2]
	SBP	-0.04	0.51[1]		**SBP**	0.21	0.002[1]
	DBP	-0.12	0.07[1]		**DBP**	-0.006	0.93[1]
	LVmass	-0.02	0.72[1]		**LVmass**	0.12	0.07[1]
	EF	0.07	0.04[1]		**EF**	-0.10	0.13[1]
	E/A ratio	0.19	0.005[1]		**E/A ratio**	-0.15	0.02[1]

Parameters		**r value**	**p value**
Distensibility	**ADs**	-0.27	0.000[1]
	ADd	-0.51	0.000[1]
	AS	0.88	0.000[1]
	Stiffness	-0.97	0.000[1]

Age	-0.30	0.000^{1}
BSA	-0.32	0.000^{1}
BMI	-0.19	0.007^{2}
SBP	-0.40	0.000^{1}
DBP	-0.17	0.01^{1}
LVmass	-0.27	0.000^{1}
EF	0.21	0.002^{1}
E/A ratio	0.13	0.05^{1}

1: spearman's test, AS: aortic strain, ADs: systolic diameter of aorta, ADd: diastolic diameter of aorta, BSA: body surface area, SBP: systolic blood pressure, DBP: diastolic blood pressure, LV: left ventricle, EF: ejection fraction, E: left ventricle early filling velocity, A: left ventricle late filling velocity

4. Discussion

The most basic result of our study is that aortic elasticity parameters differ according to age and sex in healthy children without obesity, without a family history of cardiovascular or other chronic diseases, and with normal ventricular function. Aortic elasticity decreases during puberty. This shows that hormonal status and puberty affect aortic elasticity.

The vascular system exhibits different structural and functional characteristics. Large elastic arteries provide constant blood flow in diastole and store blood during systole (1). Aortic stiffness has a strong predictive value independent of the risk of cardiovascular diseases. A relationship exists between central aortic stiffness and arterial stiffness (17). The embryonal development of the ascending aorta, isthmus aorta, and descending aorta are different (31). Although their histological structures are similar, the negative correlation of distensibility and stiffness with blood pressure in our study supports this. Maintaining blood pressure may have a positive effect on preserving aortic elasticity (32). The ventricular function plays an important role in ensuring the continuity of this function. Aortic elasticity is closely associated to left ventricular function (33, 34). In our study, left ventricular systolic and diastolic function parameters were studied for this purpose. The correlation between ventricular function and aortic elasticity parameters in our study supports this finding.

Many imaging methods are used to evaluate aortic stiffness (4, 18-21, 30). They have advantages and disadvantages. Pulse wave velocity (PWV) is the gold standard for evaluating aortic stiffness (19). PWV can be measured by sonographic methods, magnetic resonance imaging (MRI) or computed tomography (CT), echocardiography, or invasively. Studies have shown that invasive and noninvasive measurements have similar values (35).

The normal ranges of aortic elasticity parameters measured from the ascending aorta in healthy children have been little studied in the literature (22). In the current study, aortic distensibility and stiffness parameters were measured using aortic diameters and a special software program, considering the fields produced by the device and blood pressure values (22). A large-scale study including children and adults evaluated aortic elasticity by measuring PWV using a sonographic method (36). Although PWV measurement is considered the gold standard for the evaluation of aortic elasticity, it has some disadvantages (19). First, a special device is required for the measurements using this method. In the evaluations, the distance between peripheral arteries was calculated by measurement. However, owing to the angle of the arteries, the distance between their projections on the skin may not reflect the actual measurement. Another disadvantage is that the process is time-consuming (37, 38).

It is unclear whether the parameters used to evaluate aortic elasticity are superior. Aortic strain is the change in the aortic diameter during systole and diastole. Aortic distensibility is the change in aortic diameter corresponding to the change in pulse pressure. Aortic stiffness is the change in blood pressure corresponding to the change in aortic diameter. Distensibility and stiffness were inversely proportional (30). In our study, although there was a significant correlation between aortic strain, left ventricular function parameters, and diastolic aortic diameter, no correlation was found between blood pressure, age, and left ventricular mass. There was a significant correlation between aortic distensibility and aortic diameter, blood pressure, age, BSA, BMI, left ventricular mass, and left ventricular function parameters. Aortic stiffness significantly correlated with diastolic aortic diameter, systolic blood pressure, age, and left ventricular diastolic function parameters. It is unclear which parameter is used to evaluate the elasticity of the aorta. However, this distinction was not the subject of the present study. Studies have shown a close relationship between aortic elasticity and heart function, blood pressure, and aortic diameters (39). In our study, the correlation between aortic elasticity parameters, such as aortic distensibility, left ventricular function, aortic diameter, and blood pressure, and the strong correlation of distensibility with aortic stiffness brings to the fore the use of distensibility in clinical practice. A previous study reported that aortic distensibility was the best parameter among aortic elasticity parameters for showing atherosclerosis (34). To address this issue, it is necessary to change the study design and design in which the parameters can be used.

The aorta's elastic function decreases with age. Although the histological structures of the ascending, isthmus, and descending aorta were similar, they developed embryonically from different formations. With advancing age, the medium layer increased. The most significant increase occurs in the ascending aorta, and the elasticity of the ascending aorta decreases (31). In our study, in line with the literature, aortic elasticity decreased with aging (22, 40).

One of the striking results of our study is that aortic strain and distensibility are higher in girls and stiffness is higher in boys after the age of 9. This shows that the elasticity properties of the aorta change during puberty. This finding supports the hypothesis that hormones affect aortic elasticity. Therefore, it is necessary to conduct a more detailed study of this subject.

In conclusion, the normal ranges of the aortic elasticity parameters were evaluated according to age and sex. Age, heart function, blood pressure, and aortic diameter affect the aortic elasticity. Aortic elasticity decreases with age. The elasticity of the aorta changes during puberty.

Limitations of our study: The main limitation of our study was that it was a single-center retrospective study. Another limitation of our study is that intraobserver and interobserver reliability studies were not conducted. The blood pressure value measured from the peripheral arm was used to calculate the stiffness and distensibility, which are aortic elasticity parameters. Peripheral blood pressure may not reflect aortic pressure. The blood triglyceride and cholesterol levels were not assessed in our patients. Another limitation of our study was that the effects of the atherogenic properties of the lipids were not evaluated.

REFERENCES

1. Gkaliagkousi E, Douma SJH. The pathogenesis of arterial stiffness and its prognostic value in essential hypertension and cardiovascular diseases. 2009;13(2):70.
2. Prakash A, Adlakha H, Rabideau N, Hass CJ, Morris SA, Geva T, et al. Segmental aortic stiffness in children and young adults with connective tissue disorders: relationships with age, aortic size, rate of dilation, and surgical root replacement. 2015;132(7):595-602.
3. Roman MJ, Devereux RB, Schwartz JE, Lockshin MD, Paget SA, Davis A, et al. Arterial stiffness in chronic inflammatory diseases. 2005;46(1):194-9.
4. Weismann CG, Lombardi KC, Grell BS, Northrup V, Sugeng L. Aortic stiffness and left ventricular diastolic function in children with well-functioning bicuspid aortic valves. 2016;17(2):225-30.
5. S Stakos DA, Schuster DP, Sparks EA, Wooley CF, Osei K, Boudoulas H. Cardiovascular effects of type 1 diabetes mellitus in children. 2005;56(3):311-7.
6. Vogt M, Kühn A, Baumgartner D, Baumgartner C, Busch R, Kostolny M, et al. Impaired elastic properties of the ascending aorta in newborns before and early after successful coarctation repair: proof of a systemic vascular disease of the prestenotic arteries? 2005;111(24):3269-73.
7. Oyamada J, Toyono M, Shimada S, Aoki-Okazaki M, Takahashi T. Altered central aortic elastic properties in Kawasaki disease are related to changes in left ventricular geometry and coronary artery aneurysm formation. 2012;25(6):690-6.
8. Wójtowicz J, Łempicka A, Łuczyński W, Szczepański W, Zomerfeld A, Semeran K, et al. Central aortic pressure, arterial stiffness and echocardiographic parameters of children with overweight/obesity and arterial hypertension. 2017;26(9).
9. Schack-Nielsen L, Mølgaard C, Larsen D, Martyn C, Michaelsen KF. Arterial stiffness in 10-year-old children: current and early determinants. 2005;94(6):1004-11.
10. Covic A, Mardare N, Gusbeth-Tatomir P, Brumaru O, Gavrilovici C, Munteanu M, et al. Increased arterial stiffness in children on haemodialysis. 2006;21(3):729-35.
11. Ulger Z, Aydinok Y, Gurses D, Levent E, Ozyurek AR. Stiffness of the abdominal aorta in β-thalassemia major patients related with body iron load. 2006;28(10):647-52.
12. Redheuil A, Yu W-C, Wu CO, Mousseaux E, De Cesare A, Yan R, et al. Reduced ascending aortic strain and distensibility: earliest manifestations of vascular aging in humans. 2010;55(2):319-26.
13. Marti CN, Gheorghiade M, Kalogeropoulos AP, Georgiopoulou VV, Quyyumi AA, Butler

J. Endothelial dysfunction, arterial stiffness, and heart failure. 2012;60(16):1455-69.
14. Della Corte V, Tuttolomondo A, Pecoraro R, Di Raimondo D, Vassallo V, Pinto A. Inflammation, endothelial dysfunction and arterial stiffness as therapeutic targets in cardiovascular medicine. 2016;22(30):4658-68.
15. Cecelja M, Chowienczyk P. Role of arterial stiffness in cardiovascular disease. 2012;1(4):1-10.
16. Laurent S, Boutouyrie P, Asmar R, Gautier I, Laloux B, Guize L, et al. Aortic stiffness is an independent predictor of all-cause and cardiovascular mortality in hypertensive patients. 2001;37(5):1236-41.
17. Agabiti-Rosei E, Mancia G, O'Rourke MF, Roman MJ, Safar ME, Smulyan H, et al. Central blood pressure measurements and antihypertensive therapy: a consensus document. 2007;50(1):154-60.
18. Boonyasirinant T, Rajiah P, Flamm SD. Abnormal aortic stiffness in patients with bicuspid aortic valve: phenotypic variation determined by magnetic resonance imaging. 2019;35(1):133-41.
19. Covic A, Siriopol D. Pulse wave velocity ratio: the new "gold standard" for measuring arterial stiffness. Am Heart Assoc; 2015. p. 289-90.
20. Ganten M, Boese JM, Leitermann D, Semmler WJ. Quantification of aortic elasticity: development and experimental validation of a method using computed tomography. 2005;15:2506-12.
21. Oren A, Vos LE, Uiterwaal CS, Grobbee DE, Bots ML. Aortic stiffness and carotid intima-media thickness: two independent markers of subclinical vascular damage in young adults? 2003;33(11):949-54.
22. Hauser M, Kühn A, Petzuch K, Wolf P, Vogt M. Elastic Properties of the Ascending Aorta in Healthy Children and Adolescents–Age-Related Reference Values for Aortic Wall Stiffness and Distensibility Obtained on M-mode Echocardiography–. 2013;77(12):3007-14.
23. Vanderschuren MM, Uiterwaal CS, van der Ent CK, Eising JB. Feasibility and characteristics of arterial stiffness measurement in preschool children. 2017;24(17):1895-902.
24. Reusz GS, Cseprekal O, Temmar M, Kis E, Cherif AB, Thaleb A, et al. Reference values of pulse wave velocity in healthy children and teenagers. 2010;56(2):217-24.
25. Thurn D, Doyon A, Sözeri B, Bayazit AK, Canpolat N, Duzova A, et al. Aortic pulse wave velocity in healthy children and adolescents: reference values for the vicorder device and modifying factors. 2015;28(12):1480-8.
26. El Edelbi RA, Lindemalm S, Nydert P, Eksborg SJIJoP, Medicine A. Estimation of body surface area in neonates, infants, and children using body weight alone. 2021;8(4):221-8.
27. Must A, Anderson SE. Body mass index in children and adolescents: considerations for population-based applications. 2006;30(4):590-4.
28. Lopez L, Saurers DL, Barker PC, Cohen MS, Colan SD, Dwyer J, et al. Guidelines for performing a comprehensive pediatric transthoracic echocardiogram: recommendations from the American Society of Echocardiography. 2024;37(2):119-70.
29. Devereux RB, Reichek N. Echocardiographic determination of left ventricular mass in man. Anatomic validation of the method. 1977;55(4):613-8.
30. Stefanadis C, Stratos C, Boudoulas H, Kourouklis C, Toutouzas P. Distensibility of the ascending aorta: comparison of invasive and non-invasive techniques in healthy men and in men with coronary artery disease. 1990;11(11):990-6.
31. van Meurs-van Woezik H, Klein HW, Markus-Silvis L, Krediet P. Comparison of the growth of the tunica media of the ascending aorta, aortic isthmus and descending aorta in infants and children. 1983;136(Pt 2):273.
32. Boutouyrie P, Chowienczyk P, Humphrey JD, Mitchell GF. Arterial stiffness and cardiovascular risk in hypertension. 2021;128(7):864-86.
33. Kaess BM, Rong J, Larson MG, Hamburg NM, Vita JA, Cheng S, et al. Relations of central hemodynamics and aortic stiffness with left ventricular structure and function: the Framingham Heart Study. 2016;5(3):e002693.
34. Eren M, Gorgulu S, Uslu N, Celik S, Dagdeviren B, Tezel T. Relation between aortic stiffness and left ventricular diastolic function in patients with hypertension, diabetes, or both. 2004;90(1):37-43.
35. Styczynski G, Rdzanek A, Pietrasik A, Kochman J, Huczek Z, Sobieraj P, et al. Echocardiographic assessment of aortic pulse-wave velocity: validation against invasive pressure measurements. 2016;29(11):1109-16.
36. Avolio AP, Chen SG, Wang RP, Zhang CL, Li MF, O'Rourke MF. Effects of aging on changing arterial compliance and left ventricular load in a northern Chinese urban community. 1983;68(1):50-8.
37. Allen J. Photoplethysmography and its application in clinical physiological measurement. 2007;28(3):R1.
38. Tillin T, Chambers J, Malik I, Coady E, Byrd S, Mayet J, et al. Measurement of pulse wave velocity: site matters. 2007;25(2):383-9.
39. I Isnard RN, Pannier BM, Laurent S, London GM, Diebold B, Safar ME. Pulsatile diameter and elastic modulus of the aortic arch in essential hypertension: a noninvasive study. 1989;13(2):399-405.
40. O'rourke MF, Hashimoto J. Mechanical factors in arterial aging: a clinical perspective. 2007;50(1):1-13.