CLINICAL STUDY

Echocardiographic measurements of the aorta in normal children and young adults

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Abstract

Background: **To be able to determine aortic valve and ascending aorta pathology, especially aortic root dilatation, it is important to establish normal aortic dimensions. The aim of the study was to measure the dimensions of the aorta in normal healthy children and young adults in Slovakia.**
Patients and methods: **702 healthy subjects, from newborns to 20 years of age, were examined at our institution. The study was carried out prospectively, by a single observer, using digitized two-dimensional (2D), Doppler and M-mode echocardiography. The aorta was measured at 3 sites: 1. aortic valve annulus, 2. sinuses of Valsalva, 3. sinotubular junction. Patients were divided into 28 groups according to their body surface area (BSA) – from 0.15 to 2.0 m^2. All data were statistically evaluated (mean value, 5th and 95th percentile for all BSA groups) and regression equations were calculated for each parameter.**
Results: **All 3 measured aortic parameters correlated closely. Measures of correlation (R-squared) for aortic parameters with the square root of BSA were high: 0.89 for aortic valve annulus, 0.86 for sinuses of Valsalva and 0.86 for sinotubular junction *(Tab. 3, Fig. 7, Ref. 13)*. Full Text (Free, PDF) *www.bmj.sk***
Key words: normal aortic dimensions, echocardiography, children, young adults.

To establish normal dimensions of the aortic valve and the ascending aorta is very important in children of all age groups. To be able to distinguish normal and abnormal dimensions is necessary not only in case of managing patients with native or post-operative aortic valve disease (1), or patients with ascending aorta dilatation due to connective tissue diseases (like Marfan's syndrome) (2, 3), but also in patients with tetralogy of Fallot in the long-term follow-up after correction (4), or patients with complex congenital heart defects after surgery, where anatomically pulmonary tissue is placed in aortic position and is exposed to high/systemic pressure (like arterial switch operation for transposition of the great arteries) (5, 6, 7).

The aim of the study was to establish normal values of the aorta in Slovak population of healthy children and young adults. Compared with previously published studies (8, 9, 10, 11, 12) there was a greater number of measured subjects in all age groups from newborns to young adults.

Patients and methods

The study was carried out at the Children's Cardiac Center of the Slovak Republic in Bratislava, Slovakia. Permission for the study was obtained from all patients or their parents.

Study population

Examined were 702 healthy subjects from newborns to 20 years of age. There were 337 females (48.0 %) and 365 males (52.0 %). All subjects were without a congenital heart defect and all of them had a normal echocardiographic finding with a normal tricuspid aortic valve, and no aortic stenosis or regurgitation.

The weight of the patients varied from 1.5 to 92 kg, the height from 40 to 205 cm and the BSA from 0.15 to 2.0 m^2. For calculating BSA the Mosteller formula was used (13). The subjects were analyzed in 28 groups according to their BSA. Each group included from 18 to 43 subjects, mean 25 subjects (Fig. 1).

Echocardiographic examination

In every patient a standard transthoracic echocardiographic examination was performed. Patients were in supine or left lateral recumbent position and were not sedated.

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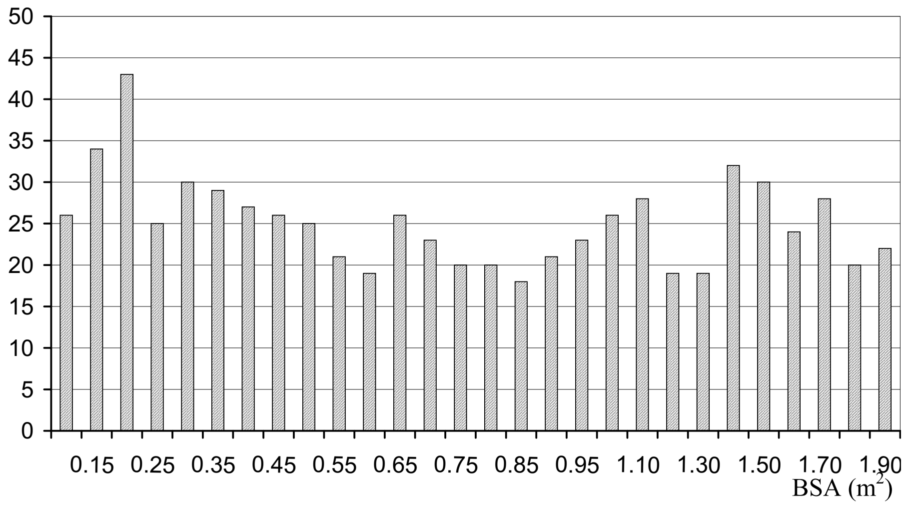

Fig. 1. Number of patients in each group according to body surface area (BSA).

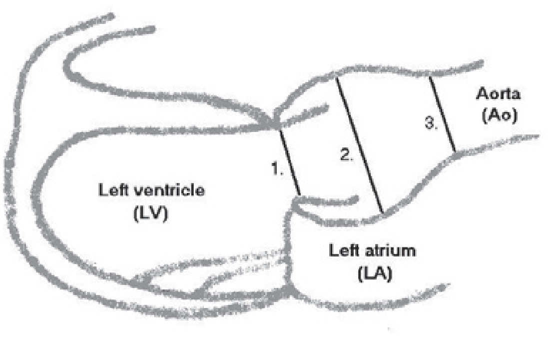

Fig. 2. Measurement sites: 1. Aortic valve annulus, 2. Sinuses of Valsalva, 3. Sinotubular junction.

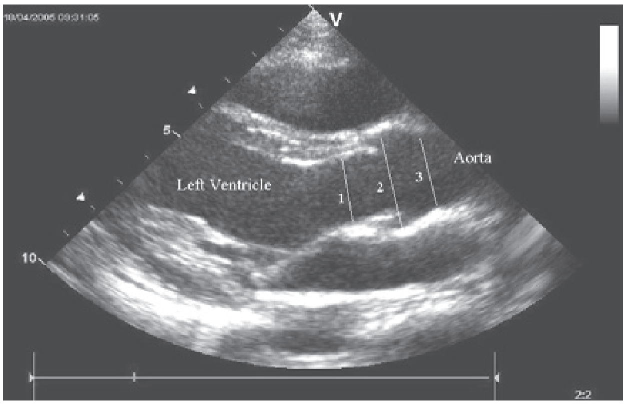

Fig. 3. Echocardiographic measurement sites: 1. Aortic valve annulus, 2. Sinuses of Valsalva, 3. Sinotubular junction, parasternal long axis.

For the examination General Electric GE Vivid 7 or Vivid 4 ultrasound systems were used. According to patients' size adequate (3 MHz, 5 MHz or 10 MHz) multi-frequency transducers were used. Standard subcostal, apical, parasternal and suprasternal views were used. 2DE, Doppler and M-mode examinations were performed. The studies were digitized and saved in computer GE Echopack raw-data analyzing system.

Echocardiographic analysis

The measurements were obtained either live during the echocardiographic examination or from the saved raw-data using GE Echopack analyzing system. The data were analyzed by a single observer.

In every patient the measurements of the aorta at 3 sites were carried out: 1. the aortic valve annulus, 2. the sinuses of Valsalva, 3. the sinotubular junction (Fig. 2). The measurements were obtained in systole from the parasternal long axis view (Fig. 3). For every aortic parameter the mean value of 3 measurements was used.

Statistical analysis

Computer programs Microsoft Excel and JMP 5.1 were used for statistical analysis. All 3 aortic dimensions were plotted against patient's BSA and median for every patient group was calculated. 5th and 95th percentile of measured values for every group were derived as ±2 standard deviations (SD) above and below the regression line of aortic dimensions. For nonparametric analysis Wilcoxon test was used. Regression equations were calculated for every aortic parameter. The quality of regression models was evaluated via R-squared.

Tab. 1. Aortic dimensions – median, 5th and 95th percentile in 28 groups according to body surface area (BSA).

BSA (m2)	No. of pts.	1. Aortic valve annulus (mm)			2. Sinuses of Valvalva (mm)			3. Sinutubular junction (mm)		
		Median	5th Percentile	95th Percentile	Median	5th Percentile	95th Percentile	Median	5th Percentile	95th Percentile
0.15	26	6.0	4.0	8.2	7.5	4.9	10.2	6.0	3.6	8.2
0.20	34	6.8	4.9	8.8	8.7	5.6	11.3	6.8	4.4	9.4
0.25	43	7.8	5.7	9.7	9.7	6.8	12.5	8.0	5.6	10.4
0.30	25	8.5	6.1	10.6	10.8	7.9	13.7	9.0	6.4	11.5
0.35	30	9.2	6.9	11.2	11.7	8.7	14.8	9.7	7.2	12.3
0.40	29	9.7	7.4	12.0	12.5	9.4	15.8	10.6	7.7	13.3
0.45	27	10.3	8.1	12.6	13.3	10.3	16.4	11.1	8.7	13.9
0.50	26	10.9	8.4	13.0	13.9	10.9	16.9	11.8	9.1	14.5
0.55	25	11.4	9.0	13.7	14.7	11.5	18.2	12.5	9.6	15.5
0.60	21	11.8	9.4	14.3	15.5	12.0	19.0	13.0	10.0	15.9
0.65	19	12.2	9.8	14.8	16.0	12.5	19.6	13.5	10.5	16.8
0.70	26	12.8	10.3	15.4	16.5	13.0	20.3	14.2	11.3	17.2
0.75	23	13.1	10.6	15.9	17.0	13.6	21.0	14.5	11.6	17.8
0.80	20	13.6	11.0	16.1	17.8	14.0	21.6	15.2	12.0	18.4
0.85	20	14.0	11.0	16.8	18.5	14.5	22.3	15.7	12.3	19.0
0.90	18	14.3	11.6	17.2	18,85	15.0	23.1	16.0	12.8	19.6
0.95	21	14.8	12.0	17.5	19.4	15.0	23.7	16.5	13.0	20.0
1.0	23	15.2	12.4	18.1	19.6	15.9	24.0	16.9	13.5	20.5
1.1	26	15.7	13.1	18.8	20.6	16.7	25.0	17.8	14.4	21.4
1.2	28	16.6	13.8	19.5	21.7	17.7	25.8	18.5	15.0	22.3
1.3	18	17.2	14.4	20.4	22.7	18.0	26.8	19.0	15.4	23.1
1.4	18	17.8	15.0	21.1	23.3	18.8	28.1	19.9	16.0	23.8
1.5	32	18.7	15.5	22.0	24.5	19.4	29.1	20.7	16.5	25.0
1.6	30	19.2	15.9	22.4	25.0	20.0	30.3	21.0	17.2	25.4
1.7	24	19.9	16.5	23.4	26.4	20.6	30.8	22.0	17.6	26.3
1.8	28	20.5	16.9	23.8	26.8	21.3	32.3	22.6	18.1	27.0
1.9	20	21.0	17.5	24.4	27.5	21.4	33.0	23.1	18.5	28.0
2.0	22	21.5	17.9	25.2	28.3	22.6	34.0	23.7	18.8	28.6

Tab. 2. Relationship of measured aortic dimensions to BSA.

Aortic dimensions	Equations	R-squared	P value
1. Aortic valve annulus	$6.46 + 8.76\ BSA - 2.23\ (BSA-0.89)^2$	0.89	(P<0.0001)
2. Sinuses of Valsalva	$8.28 + 11.49\ BSA - 2.92\ (BSA-0.89)^2$	0.86	(P<0.0001)
3. Sinotubular junction	7.02 + 9.87 BSA - 3.12 (BSA-0.89)2	0.86	(P<0.0001)

Results

In Table 1 all measured aortic parameters analyzed in 28 groups accordimg to patients' BSA are listed. Median value, 5th and 95th percentile of every BSA group are shown.

Figure 4 shows the estimated dimensions of aortic valve annulus, Figure 5 the sinuses of Valsalva and Figure 6 the sinotubular junction, all plotted against BSA. All 3 aortic parameters correlated closely with the square root of BSA. All measures of correlation (R-squared) were high and statistically significant: 0.89 ($p<0.0001$) for 1. aortic valve annulus, 0.86 ($p<0.0001$) for 2. sinuses of Valsalva and 0.86 ($p<0.0001$) for 3. sinotubular junction. Table 2 shows the regression equations calculated for all 3 aortic parameters.

Figure 7 shows the correlation of the median values of all 3 parameters when indexed to BSA. The greatest were the values in the smallest children, with growth the indexed value to BSA progressively decreased and this trend was similar for all 3 aortic parameters. Calculated were also the ratios of the sinuses of Valsalva to the aortic valve annulus (sinuses/annulus) and the sinotubular junction to the aortic valve annulus (junction/annulus). The mean ratio sinuses/annulus was 1.3 (1.24–1.33) and the mean ratio junction/annulus was 1.09 (1.03–1.13). There was no correlation with BSA – the sinuses of Valsalva to aortic valve annulus ratio as well as the sinotubular junction to aortic valve annulus ratio remained constant regardless of patients BSA.

Aortic dimensions were significantly greater in males than females ($p<0.0005$ for 1.aortic valve annulus, $p<0.0001$ for 2. sinuses of Valsalva and $p=0.0005$ for 3. sinotubular junction) when patients of all groups were compared. Though, there was no significant difference between male and female aortic dimensions when each BSA group was tested separately, neither when they were divided only into 7 BSA groups (0.15–0.3, 0.35–0.5, 0.55–0.7, 0.75–1.0, 1.1–1.5, 1.6–2.0 m^2).

Discussion and conclusion

The aortic dimensions at the level of aortic valve annulus, sinuses of Valsalva and sinotubular junction were measured by 2D echocardiography in 702 healthy Slovak children and young adults.

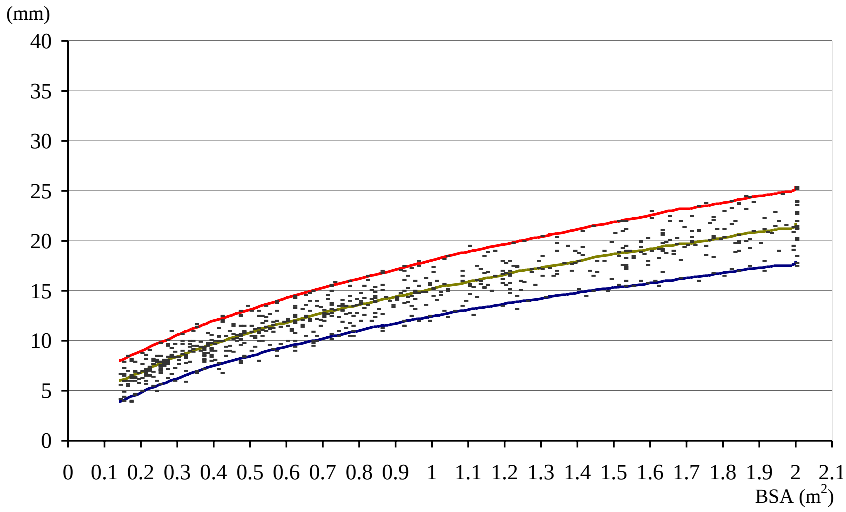

Fig. 4. Aortic valve annulus plotted against body surface area (BSA).

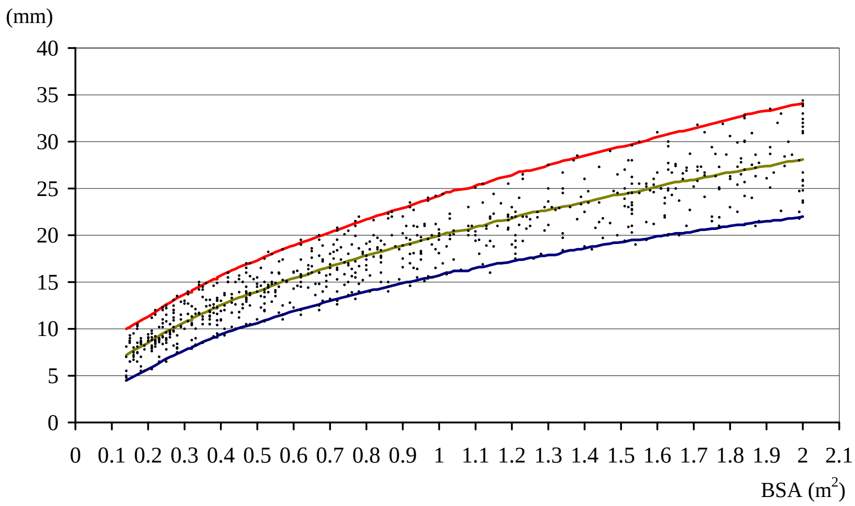

Fig. 5. Sinuses of Valsalva plotted against body surface area (BSA).

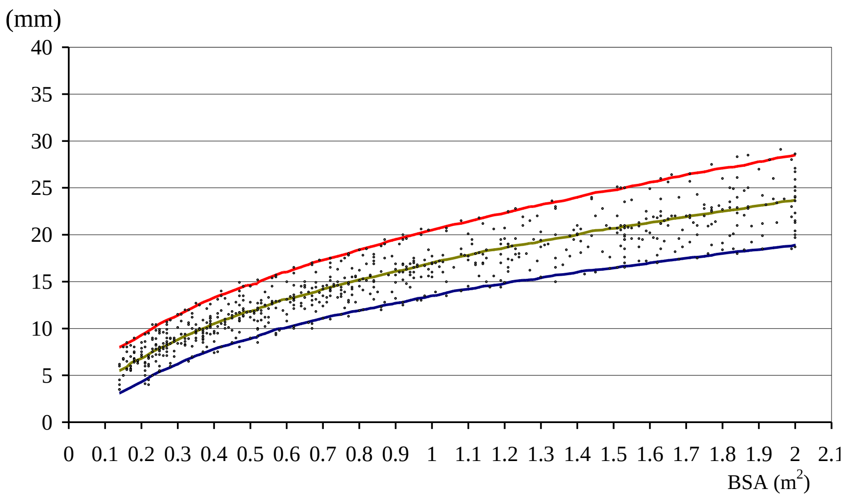

Fig. 6. Sinotubular junction plotted against body surface area (BSA).

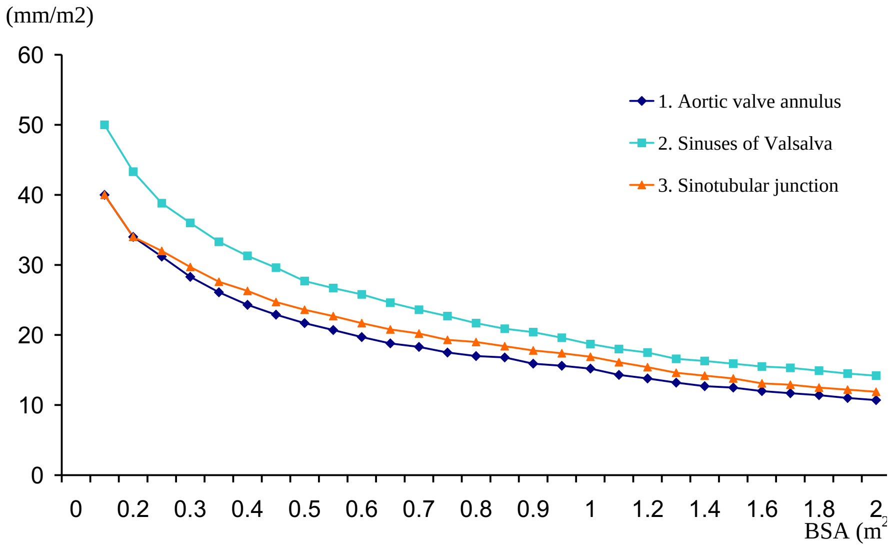

Fig. 7. Indexed aortic diameters plotted against BSA.

All 3 measured aortic dimensions correlated closely with the square root of the body surface area of the patients. The ratios – sinuses of Valsalva to aortic valve annulus and sinotubular junction to aortic valve annulus ratio were 1.3 and 1.09, regardless of patients' BSA.

To establish precise normal values of the aortic dimensions is very important in the whole wide range of children population from newborns to young adults. Not only in older age, but also during childhood may be the dilatation of the proximal part of the aorta a serious problem. A close follow-up of patients with connective tissue diseases is necessary, as well as patients with congenital heart defects after surgery, who are predisposed to dilatation of the proximal part of aorta.

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