

Analysis of the correlation between aortic diameter, heart size, and type of coronary circulation

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The objective of this study was to analyse the correlation between aortic diameter, heart size, and type of coronary circulation. The study was carried out on 102 human hearts (59 male and 43 female). Casts of the vascular system of each heart were prepared using epoxide resins. The hearts were measured for their size and aorta diameter, and classified to a coronary circulation type. The examination of materials indicated no significant correlation between aortic diameter and sex or coronary circulation type. However, a statistically significant correlation between aortic diameter and heart volume index was found. (Folia Morphol 2010; 69, 1: 30–34)

Key words: aortic ostium, coronary circulation type, heart volume index

INTRODUCTION

The increase in heart weight during postnatal development is not proportionate to a child's other individual traits [24, 26]. The largest heart mass increases occur during the first year of life and during puberty [20]. A *Tabulae Biologicae* monograph published in 1941 under the editorship of Krogman [in 20] provides a summary of data collected up to 1933 on linear dimensions of the heart, its weight, and surface of aortic and vein ostia in postnatal human development. Measurement results vary by age and sex and emphasize the differentiation by sex observed in the postnatal period. Wolański [in 20] studied children's hearts from infancy and found that the weight of the heart in infants was about 20.0 g, increasing to 38.0 g in the first year of life, 51.5 g in the second year of life, and attaining a weight characteristic for adults at approximately 18–20 years of life. The weight of the heart in adult humans varies and ranges between 300 and 400 g [17]. Considerable differences are observed in heart weight between male and female individuals in the same

age groups, with the male's heart weight being greater by about 10–20 g. In addition, measurement results for heart length and width are greater in male than in female individuals [9, 13, 20]. Sexual dimorphism reflected in the size of the human heart is observed early in the foetal period [20]. During ontogenesis the shape of the heart also changes from round in the foetal period to an oblong in adult individuals [20]. Wolański [in 20] studied the correlation between the width and length of the heart and found it to be 1.3 in newborns and only 1.08 in children aged 11. Other authors do not provide data on the correlation between sex and heart size and weight [20]. However, it is known that the proportion between heart weight and body mass is certainly greater in the foetus than in children (in newborns 0.73–0.77%) or adults (0.57–0.58%). The weight and size of the heart may change in adults over their lifespan depending on various factors [25]. Most frequently, it results from pathological hypertrophy of the cardiac muscle, but heart weight may also increase after intense physical activity. Zandri-

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no [30] described the hearts of athletes, whose weight was greater than the control group, and the weight increase was correlated with the development of the left coronary artery trunk and the anterior interventricular branch. This raises an interesting question: whether hearts of greater dimensions also have greater aortic diameter, and whether this diameter is correlated with the coronary circulation type. The objective of this study was to find an answer to these questions.

MATERIAL AND METHODS

The study was carried out on 102 human hearts, of which 59 were male and 43 female, dissected from patients aged between 12 and 70, deceased for non-cardiac causes. Only hearts without apparent morphological lesions within the heart muscle and coronary vessels were qualified for the study. The study material was derived from the collection of the Department and Institute of Normal Anatomy of the Pomeranian Medical University.

The coronary vessels of the examined hearts and the ascending aorta were filled with epoxide resin Polimal 100, Polimal 150, and Duracryl resin, which have a low coefficient of shrinking (6%). Duracryl, owing to its consistency, allowed the filling of even very small branches of the coronary vessels. The resin was mixed with appropriate pigments: red for arteries and blue for veins. The epoxide resin was dissolved in a solvent, with added hardening agent and pigment [3]. When the resin attained the consistency of honey it was injected via the aorta into the coronary vessels under a constant pressure of 120 mm Hg.

Afterwards, under the same pressure, the heart chambers were filled: the left ventricle and left atrium via the aorta (after ligation of the pulmonary veins), and the right atrium and right ventricle via the superior vena cava (after closure of outflow via the inferior vena cava and the pulmonary trunk). The prepared specimens were immersed in glycerol for 24 hours, which allowed the preservation of the natural shape of the heart and coronary vessels. For the time of preservation, the hearts were suspended by large vessels in order to avoid any contact with hard surfaces which might have resulted in deformation. After the resin's solidification, the hearts were immersed in 40% hydrochloric acid to break down soft tissues. Consequently, true casts of the hearts and all coronary vessels were obtained (Figs. 1, 2).

The following measurements were performed: heart depth (SGL) — the largest sagittal dimension

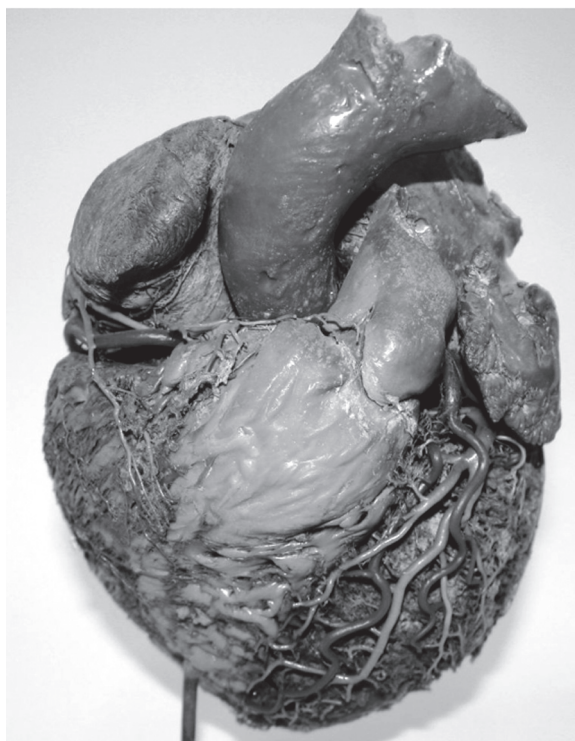


Figure 1. Specimen of the heart — anterior view.



Figure 2. Specimen of the aorta — superior view.

of the heart, heart length (SDL) — the largest longitudinal dimension from the apex of the heart to the plane adjacent to the base of the heart, and heart width (SSZ) — the largest diagonal dimension of the heart. The diameter of the aorta was measured at the level above the divergence point of the left coronary artery (Fig. 3).

Heart measurements were performed using a breadth calliper, with an accuracy of 1 mm. Types

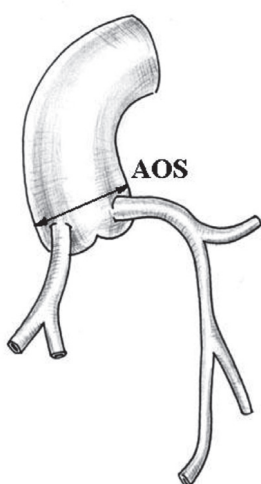


Figure 3. Scheme of aorta diameter measurement (AOS).

of coronary circulation were evaluated based on the classification established by Hettler [11].

Afterwards, the heart volume index was calculated as the ratio of heart length, depth, and width. The correlation between heart size and the type of coronary circulation was analysed using Pearson's correlation matrices. Further analyses involved Kruskal-Wallis's non-parametric ANOVA and U Mann-Whitney's tests. Statistical significance was observed at $p < 0.05$.

RESULTS

The aortic diameter was larger in male hearts, on average, by 0.5 mm, in comparison with female hearts. This difference was not statistically significant (Table 1).

The aortic diameter was comparable in groups with different coronary circulation types (Table 2). Differences in aortic diameter between the studied groups were not statistically significant. The examination of materials indicated no significant correlation between aortic diameter and sex or coronary circulation type. Analysis demonstrated a statistically significant correlation between aortic diameter and heart volume index ($p \leq 0.016$). In smaller hearts ($HVOL \leq \text{median}$) the aortic diameter was larger and amounted, on average, to 27 ± 2.2 mm, while in larger hearts ($HVOL > \text{median}$) it was lower and amounted, on average, to 26 ± 3.5 mm.

DISCUSSION

There is an extensive amount of medical publications on coronary vessels. In the available literature the correlation between coronary vessels and other factors is most frequently analysed with reference to heart weight [6, 7, 30]. Currently, owing to the development of imaging techniques offering a 3D heart image, the analysis is based on heart volume parameters. Therefore, in this study the heart volume index was used as an indicator of its size. The heart volume index was previously used in studies on foetal hearts by Nowak and Boziłow [21]. They demonstrated the high significance of this factor for the evaluation of heart size increase. This study confirmed the difference in heart size depending on sex, and confirmed that male hearts are larger than female ones. However, the differences were not statistically significant. Similar conclusions were presented by Nowak [20], who reported that initially in the foetal period "the arithmetical values of heart dimensions are higher in female individuals, but in the last trimes-

Table 1. Results from measurement of aortic diameter by sex

Parameter	Mean [mm]			Minimum [mm]			Maximum [mm]			Standard deviation		
	T	F	M	T	F	M	T	F	M	T	F	M
Aortic diameter	26.3	25.9	26.5	17	17	19	35	35	32	3.0	3.3	2.8

T — total; M — male hearts, F — female hearts

Table 2. Results from measurement of aortic diameter by coronary circulation type

Parameter	Mean [mm]			Minimum [mm]			Maximum [mm]			Standard deviation		
	M	L	R	M	L	R	M	L	R	M	L	R
Aortic diameter	26.5	25.3	26.1	19	17	20	35	29	32	3.0	3.7	2.7

M — mixed (co-dominant) type of coronary circulation, L — left-dominant, dominance of the left coronary artery, R — right-dominant, dominance of the right coronary artery

ter differences tend towards higher values in male hearts". Similarly, Chrobot [6] and Chrobot et al. [7] reported that sexual dimorphism in heart size is poorly pronounced and is not statistically significant in the majority of cases.

The literature provides many classification methods regarding coronary circulation type [2, 5, 8–11, 14–16, 19, 22, 27, 29]. Most frequently, there are three types: with dominance of the right artery, with dominance of the left artery, and the co-dominant circulation type [1, 10, 16]. Most classification methods are based on the course of the main vascular trunks and their branches. Vasko [28] analysed types of coronary circulation using the perfusion technique. However, this type of classification is very rarely used. This study applied the classification criteria established by Hettler [11], which are clear, easy to interpret, and are based on the course of interventricular branches and the analysis of the range of areas supplied by them. The findings from this study indicate that the co-dominant coronary circulation type was prevalent. Similar results were obtained by Adachi [2], Banchi [4], Paulin [23], and Hettler [11].

There are very few publications on the size of the aorta and its correlation with coronary vessels. The measurement of the aortic ostium itself is difficult, owing to its fluctuation over the cardiac cycle [1, 12]. The aortic opening is the widest, and image quality is best 50–100 ms after the R peak using multidetector computed tomography [1]. Chrobot [6], who studied the development of large vessels during the foetal period, observed a larger aortic diameter in the female foetus. Marek [18], in his study on the cause of sudden death, reported that lower aortic diameter was one of the features frequently detected in a group of suddenly deceased individuals without atherosclerotic lesions within coronary vessels [18]. Based on the carried out study, no correlation between aortic diameter and type of coronary circulation or sex was observed. However, a statistically significant correlation between aortic diameter and heart volume index was found. The aortic diameter was larger in small size hearts and vice versa.

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