

Analysis of the influence of heart size and gender on coronary circulation type

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Currently, there are many types of classification of coronary circulation. The first type was introduced in 1904 by Banchi. Hettler provides very detailed criteria for the type classification based on the course of the anterior and posterior interventricular branches. Hettler defined the following types: left coronary artery dominance, right coronary artery dominance, and co-dominant. The objective of this study was to analyse coronary circulation types in the studied material and their correlation with heart size and gender. The study was carried out on 102 human hearts (59 male and 43 female). True casts of coronary vessels were obtained using epoxide resins. The prepared specimens were measured for heart dimensions and evaluated for coronary circulation type. The majority of the specimens were classified as the co-dominant type, followed by the right coronary artery dominant type. The left-dominant coronary artery type represented the lowest number of heart specimens. No statistically significant correlation between the type of coronary circulation and heart size or gender was found. The coronary circulation type is not correlated with heart size or with gender. This confirms that it is a hereditary trait. (Folia Morphol 2010; 69, 1: 35–41)

Key words: coronary circulation type, left coronary artery, right coronary artery

INTRODUCTION

Many anatomists have attempted to classify coronary circulation for the large variety of coronary branches, their variable course, and range of anatomical areas supplied with blood. The first classification was introduced by Banchi [4] in 1904. He observed the dominance of the right coronary artery in 17%, the left coronary artery in 10%, and the co-dominant type in 73% of examined hearts. Adachi [1] introduced five coronary circulation types. In type I, normal, or co-dominant, the heart is supplied by both coronary arteries in a balanced manner and is observed in 60% of the population. This type is characteristic for primates and is defined as classical in humans. Type II is characterised by the domi-

nance of the right coronary artery. This results from the excessive development of the posterior part of the right coronary artery, with the simultaneous involution of the circumflex branch. Consequently, the posterior wall of the left ventricle is supplied mainly by the right coronary artery. This type is observed in 20–24% of the general population, and is typical for even-toed ungulates. Additionally, Adachi [1] described a mixed type between I and II and evaluated its frequency in the population as 10–12%. Type III is characterised by the dominance of the left coronary artery and is observed in 10–14% of the general population.

Schlesinger [24] claimed that if the right coronary artery runs beyond the crux cordis and projects

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its branches to the posterior wall of the left ventricle, there is always dominance of the right coronary artery. He classified as mixed type only those cases when each ventricle is supplied with blood from the relevant artery, i.e. right from the right and left from the left. The dominance of the left coronary artery was appropriate only for those cases when the circumflex branch ran over the crux cordis, forming the posterior interventricular branch and supplying the entire posterior part of the ventricular septum. Following such criteria Schlesinger observed right coronary artery dominance in 48% of the examined cases, left coronary artery dominance in 18% of cases, and mixed type in 34% of cases. According to Schaede [in 10], the normal type of coronary circulation is observed when posterior interventricular branches originate only from the right coronary artery, and when branches of the posterior wall in the left ventricle do not reach near the posterior interventricular septum. The left-dominant type applies, according to Schaede, to those cases when the left posterior ventricular branches reach the posterior septum, or beyond it, and project branches to the septum. However, according to Schaede [quoted in 10], dominance of the right coronary artery is observed when posterior septum interventricular branches created by the right coronary artery reach beyond the septum and supply the posterior wall of the left ventricle.

In 1964 Paulin [22] observed arteries *in vivo* in coronarography and reported that the best criterion for the evaluation of coronary artery dominance is their size. He measured the artery diameter and found that in 66% of cases the left artery had the largest diameter, in 8% of cases the right artery diameter was larger than the left, and in 26% cases both coronary arteries had the same diameter.

Very detailed classification criteria are provided by Hettler [10]. In the normal type of circulation by Hettler [10] the posterior interventricular branch originates from the right coronary artery, diverges in the posterior interventricular groove, and runs inside it up to at least 3/4 or 4/5 of its length. The anterior interventricular branch penetrates to the diaphragmatic heart side, enters inferiorly to the posterior interventricular groove, and occupies the remaining part of the groove. The circumflex branch in this circulation type runs beyond the heart margin, enters the posterior atrioventricular groove, and terminates projecting branches without reaching the crux cordis. Thus, the dominance of the left coronary artery occurs when the

circumflex branch runs to the posterior atrioventricular groove with a large arch, forming the posterior interventricular branch and branches to the posterior part of the septum. In this type, the inferior part of the groove can be occupied by the terminal part of the anterior interventricular branch, reaching even to the middle of its height. The right-dominant type concerns cases in which the posterior interventricular branch originates from the right coronary artery and runs in the posterior interventricular groove reaching even to the apex of the heart. In this type, the anterior interventricular branch does not penetrate to the diaphragmatic surface to the posterior interventricular groove. Based on such a classification, Hettler identified the normal type of coronary circulation in 79% of examined cases, 4% right-dominant, and 17% left-dominant coronary circulation. Brandenburg [in 20] presented different data regarding the frequency of individual coronary circulation types, reporting dominance of the right coronary artery in 70% of cases, left-dominant type in 10% of cases, and co-dominant type in 20% of cases.

Levin et al. [17] described the range of supplied areas depending on the coronary circulation type as follows: in right-dominant type the right coronary artery supplies only the posterior diaphragmatic part of the interventricular septum and the diaphragmatic surface of the left ventricle; in the left-dominant type both above-mentioned areas are supplied by the left coronary artery; and in the co-dominant type the posterior diaphragmatic surface of the interventricular septum is supplied by the right coronary artery, but the diaphragmatic surface of the left ventricle is supplied by the left coronary artery.

The objective of this study was to evaluate the coronary circulation types in the studied material, and the correlation between coronary circulation type and heart size and gender.

MATERIAL AND METHODS

The study was carried out on 102 human hearts from White citizens of West-Pomeranian Region — Caucasian population, 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 hearts were collected within 24 hours of death and then the preparing process on the fresh hearts was started.

Table 1. Distribution of coronary circulation type in examined hearts by sex (in %)

Sex	Parameter	Type			Total
		M	L	R	
Male	Number	40	9	10	59
	Percentage	67.80%	15.25%	16.95%	100%
Female	Number	28	3	12	43
	Percentage	65.11%	6.98%	27.91%	100%
Total	Number	68	12	22	102
	Percentage	66.67%	11.76%	21.57%	100.00%

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

The coronary vessels of the examined hearts and the ascending aorta were filled with epoxide resin Polimal 100, Polimal 150, and Duracryl resin. Duracryl, owing to its consistency, allowed the filling of even very small branches of coronary vessels. The resin was mixed with an appropriate pigment: red for arteries and blue for veins. Colour pigment was added in order to identify arteries and veins.

The epoxide resin was dissolved in a solvent-acetone with added hardening agent and pigment [3]. When the resin attained the consistency of honey, it was injected via the aorta into coronary vessels under a constant pressure of 120 mm Hg.

Afterwards, under the same pressure, the heart chambers were filled: left ventricle and left atrium via the aorta (after ligation of pulmonary veins), and right atrium and right ventricle via the superior vena cava (after closure of outflow via inferior vena cava and 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 the large vessels in order to avoid any contact with hard surfaces which might have resulted in deformation. After solidification of the resin, 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.

The following measurements of the heart were performed on the fresh heart:

- heart depth — the largest sagittal dimension of the heart;
- heart length — the largest longitudinal dimension of the heart from the apex of the heart to the plane adjacent to the base of the heart;
- heart width — the largest diagonal dimension of the heart.

Heart measurements were performed using a breadth calliper, with an accuracy of 1 mm. Types of coronary circulation were evaluated based on the classification established by Hettler, after break down of the soft tissues [10].

Afterwards, the heart volume index was calculated as the ratio of heart length, depth, and width. The correlation between the type of coronary circulation and heart size and gender was evaluated. The obtained data were analysed with statistical methods. For each measured parameter's mean value, the median, minimum, and maximum values were calculated. Preliminary statistical analysis was performed 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

Results from heart measurements are presented in Table 1.

The mean value of the heart volume index for the total number of examined specimens was $841835.2 \pm 246919.2 \text{ mm}^3$.

The mean heart volume by gender group was lower in the group of female hearts than in the male hearts and amounted to $810034.0 \pm 251575.1 \text{ mm}^3$ and $865012.3 \pm 242988.4 \text{ mm}^3$, respectively. No statistically significant correlation between the heart volume ratio and gender was found. The mean value of the heart volume index in the co-dominant type of coronary circulation was $804934.3 \pm 260888.9 \text{ mm}^3$, in the left-dominant type it was $810164.6 \pm 208164.4 \text{ mm}^3$, and in the right-dominant type, which was the largest, it was $973167.2 \pm 174152.4 \text{ mm}^3$. The observed differences were not statistically significant.

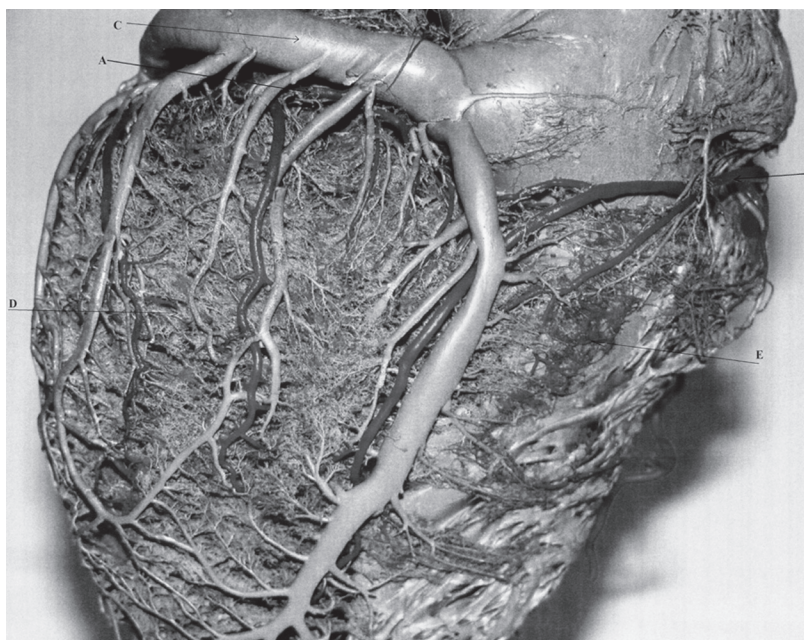


Figure 1. Posterior aspect of the heart. The co-dominant coronary circulation type; A — circumflex branch of left coronary artery; B — right coronary artery; C — coronary sinus; D — left ventricle; E — right ventricle.

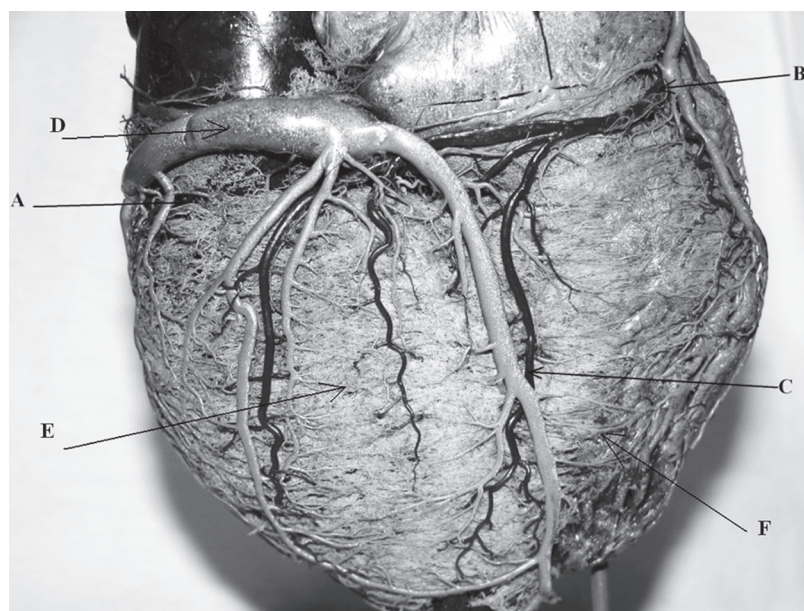


Figure 2. Posterior aspect of the heart. The right-dominant type of coronary circulation; A — circumflex branch of left coronary artery; B — right coronary artery; C — posterior interventricular branch of right coronary artery; D — coronary sinus; E — left ventricle; F — right ventricle.

Of the 102 examined hearts, 68 (66.66%) had the co-dominant coronary circulation type (Fig. 1), 22 (21.56%) the right-dominant type (Fig. 2), and 12 (11.76%) — the left-dominant type (Fig. 3). The

distribution of coronary circulation type by gender is presented in Table 2.

Pearson's correlation matrices were used to analyse the correlation between the coronary circula-

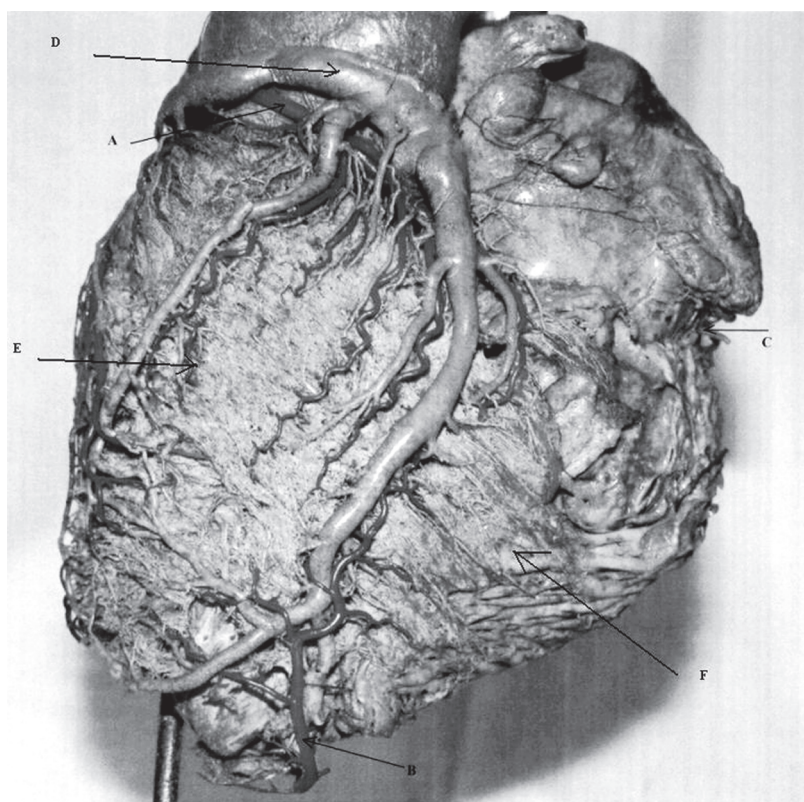


Figure 3. Posterior aspect of the heart. The left-dominant type of coronary circulation; A — circumflex branch of left coronary artery; B — anterior interventricular branch of left coronary artery in the posterior interventricular groove; C — right coronary artery; D — coronary sinus; E — left ventricle; F — right ventricle.

Table 2. Results from heart measurement by sex

Parameter	Mean [mm]			Minimum [mm]			Maximum [mm]			SD		
	T	F	M	T	F	M	T	F	M	T	F	M
Heart length	98.8	97.9	99.4	73	73	82	114	114	112	8.9	9.5	8.4
Heart width	96.4	94.9	97.5	65	65	80	125	119	125	10.9	11.3	10.6
Heart depth	85.9	84.5	87.0	49	49	51	112	105	112	13.5	13.4	13.5
Heart circumference	270.7	265.3	274.7	176	176	180	343	336	343	49.8	50.3	49.5

T — total; F — female; M — male; SD — standard deviation

tion type and gender. No statistically significant correlation between the coronary circulation type and gender was found (Fig. 4).

In the co-dominant type of circulation the average age of examined hearts was 44.1 ± 20.4 years, in the left-dominant type the average age was 49.8 ± 15.2 , and the oldest hearts were found in the group with the right-dominant type of circulation, with an average age of 55.7 ± 13 years. No statistically significant correlation between the type of coronary circulation and heart size described by the heart volume index (SVOL) was found.

DISCUSSION

The literature published on coronary vessels frequently refers to coronary circulation types [1, 6, 8–10, 13, 15, 16, 19, 21, 25, 28, 30]. However, there is a disagreement in the studies carried out by various authors regarding the distribution of the three major types of coronary circulation in the general population. This results from various classification criteria describing the types adopted by individual researchers [1, 4, 8, 10, 13, 22, 32]. This study, which is based on classification criteria by Hettler [10], demonstrated the prevalence of the co-dominant coro-

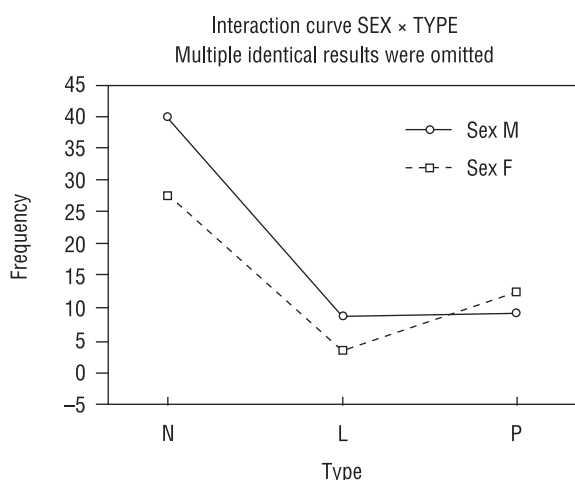


Figure 4. Correlation between coronary circulation type and sex; M — mixed (co-dominant) type of coronary circulation; L — left-dominant, dominance of the left coronary artery; R — right-dominant, dominance of the right coronary artery; M — male; F — female.

nary circulation type (66.7%), followed by the right-dominant type (21.5%), and the left-dominant type (11.8%). Similar results were obtained by Adachi [1], von Ludinghausen [29] and Vieweg et al. [27]. These results also confirm the pronounced prevalence of co-dominant coronary circulation in humans, which was also reported by Banchi [4], Grosse and Piquand [quoted in 20], and Hettler [10]. Differences in comparison to the results obtained by Hettler [10] refer to the frequency of occurrence of the right- and left-dominant coronary circulation types. Entirely different results were obtained by Di Dio and Wakiefield [9], who applied anatomical criteria established by Schlesinger [24], and who observed the dominance of the right coronary artery in 73.5% of examined cases, the dominance of the left coronary artery in 19.4% of cases, and the co-dominant type in 7.1% of cases. Vasko et al. [26], who analysed the type of coronary circulation by perfusion technique, found the left-dominant type in 69%, the right-dominant type in 19%, and the co-dominant type in 12% of cases. In studies by Kronzon et al. [14] the right-dominant type was observed in 87% of examined cases, the left-dominant type in 10% of cases, and the co-dominant type in 3% of examined cases. In 1940 Schlesinger [24] suggested the differentiation of two types depending on the divergence point of the posterior interventricular branch. This included the right-dominant type, in which the branch diverges from the right coronary artery, and the left-dominant type, in which the branch diverges from the circumflex branch. Based on this classification it has

been evaluated that from 77% to 90% of the general population has the right-dominant circulation type [5, 11, 12, 17, 24]. Correspondingly, in this study, in 88% of the examined hearts the posterior interventricular branch diverged from the right coronary artery (this referred to 67% of hearts with the co-dominant type of circulation and 21% of the right-dominant type). Adams and Treasure [2] reported that 90% of the general population had hearts with dominance of the right coronary artery. Research made by Cademartiri et al. [8] showed right dominance in 86.6%, left in 9.2%, and balanced type in 4.2% of cases. The arteries were observed in 64-slice computed tomography coronary angiography. Welker et al. [30] stated right side dominance in conventional X-ray coronary angiography; additionally, they observed that coronary artery anomalies are rare in the general population, being more commonly seen in patients with congenital heart disease. The majority of researches did not study differences between genders. We analyzed female and male data separately and we noted that co-dominant type of circulation is dominant in both genders. Differences between left-dominant and right-dominant types are not significant.

Non-balanced coronary circulation types, i.e. with dominance of the right or left coronary artery, may be an individual trait or even be related to the human developmental period. According to Nowak [20], the left-dominant type is prevalent in the prenatal period. In the presented research, the observed group did not allow for division into age groups because it was too small. We observed the average age to be about 44 years in the co-dominant type of circulation and 49 years in the left-dominant type. We noted the presence of the right-dominant type in the oldest hearts, average age about 55 years. The differences were not significant. The previous studies did not concentrate on the correlation between heart size and type of circulation, so we cannot compare our observation that the correlation between the type of coronary circulation and heart size is not statistically significant.

Whitten [31] reported the prevalence of the left-dominant circulation type observed in infants, while Hettler [10] suggested that in an individual the primary type of coronary circulation may transform as a consequence of lesions in coronary vessels and the development of collateral circulation, thus creating the secondary circulation type. Hettler [10] observed 67% of secondary circulation types with dominance of the right coronary artery, 10% left-dominant, and

in 23% of cases the vessels underwent transformations disabling their classification to any of the three major types. There are also other authors who describe the hyper-developed right coronary artery as a consequence of considerable stenosis or even atresia of the left coronary artery trunk [7, 23, 25]. Differences in the distribution of circulation types expressed in percent by various authors may result from the fact that the examined material was not verified appropriately and may have been evaluated as «normal» hearts together with those after vascular transformation. This study was carried out exclusively on hearts without lesions. Findings from the study indicate that in human hearts without lesions the co-dominant coronary circulation type is prevalent.

CONCLUSIONS

Literature data infrequently refer to the correlation between the circulation type and heart size or gender. This study demonstrated that the coronary circulation type is not correlated with heart size or with gender. This conclusion supports the theory by Marek [18] suggesting that the type of coronary circulation is a hereditary trait.

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