Original article

Variations in the anatomy of the coronary arteries

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Abstract

Introduction: Even though anatomic variations in the cardiac circulation are quite common, there is little information concerning the Brazilian population. This study intends to describe the most common variations found during the autopsies for the AMA Study. **Material and methods:** fifty human cadavers had their hearts were dissected and analyzed. **Results:** variations occurred in 64% of all cases and were more common in the posterior circulation (40.6%); arterial hypoplasia was present in 14% of the circumflex arteries, 12% of the marginal arteries; duplication of the posterior interventricular artery occurred in 2%; muscular bridges occurred in 4%; anomalous origin of arteries occurred in 14% in total; right dominant pattern was present in 88%, left dominant in 8%, and undetermined in 4%. **Conclusion:** Brazilian population variations are in accordance with the literature; anatomic variations of the heart arteries are common; and there seems to be no difference among different populations.

Keywords: coronary arteries, heart, arterial malformation.

1 Introduction

Variations in the anatomy of the circulatory system are common; the same arteries in different people are not necessarily equal. In order to differentiate the common anatomy of the heart arteries from the anomalies that can be found, some characteristics have been proposed (Chart 1) (TRIVELLATO, ANGELINI and LEACHMAN, 1980).

Anomalies or variations of arterial anatomy can have an impact in the blood supply of the affected organ, the clinical presentation and prognosis of its diseases, and even the development and distribution of atherosclerosis (TRIVELLATO, ANGELINI and LEACHMAN, 1980; KIKUCHI, YAMAMOTO and NAKAMURA, 1973; MATTI, 1973; ROUTSONIS, STAMBOULIS and CHRISTODOULAKI, 1973; MERKKOLA, TULLA, RONKAINEN et al, 2006).

Knowing the variations in the anatomy of the heart vessels enhances the quality of treatment, especially when an angioplasty or a bypass is considered. Thus, considering there is few data on anatomic variation in the heart vessels of the Brazilian population (LIMA JÚNIOR, CABRAL and DE PRATES, 1993), this study will contribute to our current knowledge in anatomical variations between different populations.

2 Methods and casuistic

This study was approved by the Ethics in Research Committee from Centro de Ciências Médicas de Sorocaba, in June, 2010, as a part of the AMA Study.

In order to be included for analysis, the cadavers' legal guardians had to agree on signing the written consent for participating in the study, the cadaver had to be 40 years old or more, and all cardiac arteries had to be available for evaluation.

The arteries were dissected from their end to their origin, avoiding damaging both the heart and the vessel itself; initially the inferior wall, then the anterior wall, finally the aorta for the left coronary, then the marginal artery and the aorta for the right coronary. Arterial branches that perforated the cardiac muscle were not evaluated. The heart muscle itself was not dissected, nor was any type of resin inserted in the arteries, so that their endothelium was not damaged (NORDON and RODRIGUES JÚNIOR, 2012).

The cardiac pattern of dominance was defined as the artery that supplied the posterior interventricular groove on macroscopic analysis, and could be either right, if it were the posterior descending artery (PDA) or the right marginal artery, or left, if it were the anterior descending artery (ADA) or the circumflex (PENTHER, BARRA and BLANC, 1976).

3 Results

Fifty cadavers were obtained for this analysis. The most common cause of death was respiratory failure (36%), followed by heart failure (22%), what included infarction (4%), dilated cardiopathy (16%), and *cor pulmonale* (2%). In 20%, cause of death could not be defined.

Eighteen hearts (36%) had no alterations in their arteries; 20 (40%) had one alteration, 10 (20%) had two and only two (4%) had three or more. Variations occurred in the inferior circulation in 13 (40.6%), in the anterior in 12 (37.5%) and in both in 7 (21.9%). The main anatomic variations found are represented in Table 1.

The most common variation found in this sample was a hypoplastic Cx or important collateral vasculature (14%), followed by a hypoplastic marginal artery (12%) and important collateral vasculature to PDA (10%). Arterial duplication occurred in the PDA in one case (2%). It was

considered as duplication, rather than the developing of collateral vessels, as both ran in the interventricular groove and each was originated from a different coronary artery.

PDA originated from the LCA was present in three cases (6%), and Cx originated from the RCA in 4 (8%). In one case (2%), the origin from both Cx and PDA could not be determined; this patient had Chagas' disease, the anatomy of the heart was completely altered, and the arterial histology was very similar to that of veins.

Pattern of dominance was: right in 88% of the cases, left in 8%, and undetermined in 4%. Undetermined were both the case with Chagas' disease, and the case of duplicated PDA. Excluding the undetermined patterns, right was present in 91.5%, and left in 8.5%

Chart 2 compares the criteria from Trivellato, Angelini and Leachman (1980) and the findings from our study.

According to Trivellato's proposal of normality, six of our cases were abnormal: in four cases (8%) the Cx originated from the right coronary artery, and in two (4%), there was muscular bridging.

Table 1. Main anatomic variations in the arteries analyzed.

Artery	Variation	N	%
LCA	Hypoplastic	4	8
	3 to 4 additional diagonal arteries	2	4
RCA	Hypoplastic	1	2
ADA	Important collateral vasculature	2	4
PDA	Important collateral vasculature	5	10
	Hypoplastic	1	2
	Originated from the left coronary	3	6
	Undetermined origin	1	2
	Diagonal origin from the right coronary	1	2
	Duplicated	1	2
Cx	Undetermined origin	1	2
	Important collateral vasculature	7	14
	Hypoplastic	7	14
	Originated from the right coronary	4	8
	On the anterior wall	2	4
Right marginal	Hypoplastic	6	12
	Important collateral vasculature	1	2
Pattern of dominance	Right	44	88
	Left	4	8
	Undetermined	2	4

4 Discussion

The coronary artery system is considered to be right dominant in most of the cases (76% to 86.6%), left dominant in 8% to 9.2%, and co-dominant in 4.2% to 15% (KOSAR, ERGUN, OZTÜRK, et al, 2009; VIRAGH and CHALLICE, 1981). Other autopsy studies (FAZLIOGULLARI, KARABULUT, UNVER DOGAN et al., 2010; SCHLESLINGER, 1976; BLUMGART, SCHLESINGER and DAVIS, 1940) identified a right dominance in 40-48%, co-dominance in 34-44%, and left dominance in 14-20%, what is rather different from the radiological findings (Table 2). This is probably due to the technique: the anatomical evaluation through dissection is not always the same as the radiological evaluation or the determination of dominance through perfusion (VASKO, GUTELIUS and SABISTON JUNIOR, 1961); angiography generates a better analysis of the heart's blood supply and is less prone to mistake, as even the vessels that penetrate the cardiac muscle can be evaluated, as opposed to the macroscopic dissection, that may neglect microscopic anastomosis between the left and right circulation.

The most commonly used technique for the dissection and anatomical analysis of arteries is by injecting resins into the vessels and corroding the organ (VASKO, GUTELIUS and SABISTON JUNIOR, 1961; TOMPSETT, 1959). As considered above, the original aim of this study was to evaluate atherosclerosis, therefore resins could not be injected.

Nevertheless, our findings are similar to another study performed in Brazil (the first of its kind in our country) (LIMA JÚNIOR, CABRAL and DE PRATES, 1993); in this study, right dominance was found in 70%, left in 16%, and co-dominance in 12%. In spite of the technique being similar to other anatomical studies, and the definition for dominance being the same from Schleslinger (1940), as opposed to ours, (PENTHER, BARRA and BLANC, 1976) their findings are neither much different from ours, nor from the radiological findings, (CADEMARTIRI, LA GRUTTA, MALAGÒ et al., 2008; ABDELLAH, ELSAYED and HASSAN, 2009; KOSAR, ERGUN, OZTÜRK et al., 2009; FANFANI, 1953) or other anatomical studies (PENTHER, BARRA and BLANC, 1976; JAMES, 1965).

The pattern of dominance is the most important anatomical variation, concerning the functional impact of ischemia. If the pattern is left, a great amount of myocardium depends solely on one artery for its nurturing (SCHLESLINGER, 1976).

Muscular bridges of the coronaries were present in only two cases (4%), which is quite uncommon; it is generally

Chart 1. Minimal criteria for normal coronary arteries (adapted from TRIVELLATO, ANGELINI and LEACHMAN, 1980).

1. The aorta arises dually from the right and left coronary cusps.
2. The right coronary artery (RCA) follows the atrioventricular groove.
3. The left coronary artery (LCA) lies behind the pulmonary artery and has a main trunk of variable length that divides into two branches: the left anterior descending artery (here named anterior interventricular artery, ADA) and the circumflex (Cx) coronary arteries. The ADA follows the interventricular groove and forms septal perforator branches, and the Cx follows the left atrioventricular groove.
4. The posterior descending branch (here named posterior interventricular artery, PDA) originates from either the right or left coronary artery, follows the posterior interventricular groove, and divides into septal perforator branches.
5. The major coronary branches flow epicardially (extramurally).
6. The coronary arteries terminate at the capillary (myocardial) level.

present in 10% to 37%. (CADEMARTIRI, LA GRUTTA, MALAGÒ et al., 2008; KOSAR, ERGUN, OZTÜRK et al., 2009) Such difference may be related the small sample. An autopsy study (FANFANI, 1953) found muscular bridging in 81.4% of the median arteries (which is an extra artery between the Cx and the ADA); however, it did not analyze muscular bridging in the coronaries, as most studies.

The Cx originated from the RCA in 8%; Cx is originated from the right coronary sinus in 0.1% of cases, (KOSAR, ERGUN, OZTÜRK et al., 2009) and is absent in 0.1% to 0.7%, (ABDELLAH, ELSAYED and HASSAN, 2009; KOSAR, ERGUN, OZTÜRK et al., 2009) but there is no mention in the literature as to how frequently it is originated from the RCA. The PDA originated from the LCA in 6% of cases; another autopsy study (FAZLIOGULLARI, KARABULUT, UNVER DOGAN et al., 2010) found it in 4% of cases, and also absence of PDA in 10%, what was not identified in this study.

As for other arterial absences and anomalous origins, the left trunk is not found in 4.1% of cases, (CADEMARTIRI, LA GRUTTA, MALAGÒ et al., 2008) the left coronary, in 0.4% to 6% of cases, (CADEMARTIRI, LA GRUTTA, MALAGÒ et al., 2008; ABDELLAH, ELSAYED and HASSAN, 2009; KOSAR, ERGUN, OZTÜRK et al., 2009) the RCA is originated from the left coronary sinus in 0.5%, and the LCA is originated from the right coronary sinus in 0.2% (KOSAR, ERGUN, OZTÜRK et al., 2009). There is no mention in the literature as to the absence of RCA. None of these absences or anomalous origins was found in this study.

Arterial duplication occurred in 2% of cases; there is no mention to it in the literature, as the arteries are most commonly not considered as duplicated, rather as having collateral vasculature. In this case, however, the PDA was definitely duplicated.

Comparing this study with other studies from different populations, there is no reason to believe that there is any difference between races in the distribution of anatomic variations in the arteries of the heart.

Chart 2. Trivellato's criteria for normal and abnormal arteries, and the percentage of such variations found in this study (in parenthesis).

Normal	Abnormal
1. Dual aortic origin (100%)	1. Single coronary artery (right or left) (0%) Anomalous origin of right and/or left coronary artery from pulmonary artery (0%)
2. RCA in right atrioventricular groove (100%)	2. Origin of part of right coronary artery from left ostium (0%)
3. LCA in left atrioventricular groove + anterior interventricular groove (100%)	3. Anomalous origin of ADA or Cx from right coronary artery (8%)
4. PDA from right coronary artery or Cx (94%)	4. PDA from ADA (0%)
5. Major vessels course epicardially (100%)	5. Muscular bridges (intramural major coronary branches) (4%)
6. Arteries terminate in myocardial capillary bed (100%)	6. Coronary fistula connects with right atrium, right ventricle, pulmonary artery, pulmonary vein, left atrium, left ventricle or mediastinum (0%)

Table 2. Coronary dominance pattern according to different authors and method of analysis.

Author	Right	Left	Co-dominance
	Radiological analysis		
Cademartiri, La Grutta, Malagò et al. (2008)	86.6	9.2	4.2
Abdellah, Elsayed and Hassan (2009)	77	8	15
Kosar, Ergun, Oztürk et al. (2009)	76	9.1	14.8
Fanfani (1953)	77	16	7
Vasko, Gutelius and Sabiston Junior (1961)	48	16	36
Campbell (1929)	14	72	14
May (1960)	55	36	9
Zoll (1951)	50	44	16
	Anatomical analysis		
Falci Júnior (1993)	72	16	12
Penther, Barra and Blanc (1976)	90	10	Within the 90%
Fazliogullari, Karabulut, Unver Dogan et al. (2010)	42	14	44
Schleslinger (1976)	48	18	34
Blumgart, Schlesinger and Davis (1940)	40	20	40
James (1965)	90	10	Within the 10%
Our findings	91.5	8.5	-

5 Conclusion

Anatomic variations of the heart vessels are common; right is the most common anatomical dominance pattern in the heart. There seems to be no difference between the findings from this study and others from different populations.

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Received April 23, 2012
Accepted September 15, 2012