Anatomical Variations Of Coronary Arteries And Their Implications In Ischemic Events And Acute Myocardial Infarction

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***Abstract*—Introduction: The coronary arteries originate from the ascending portion of the aorta and they are responsible for the myocardium blood supply. Abnormal origins and course of coronary arteries are rare, with a prevalence of about 1%. The spectrum of coronary anomalies involves both the origin and distribution of arteries throughout the myocardium, which may be related to clinical implications for ischemic heart diseases.**

Objective: To analyze the anatomical variations of coronary arteries and their clinical implications associated with ischemia and acute myocardial infarction.

Material and Methods: This is a systematic review carried out from May to July 2022 based on articles from PubMed, Scielo, Science Direct and Virtual Health Library databases. For this study, variant cases involving origin and/or distribution of coronary arteries, as well as clinical manifestations of ischemia and acute myocardial infarction were included. The screening and selection of studies were carried out by two independent reviewers.

Results: At the end of the search, nine studies were selected, which were characterized by sample, method and results. Anatomical variations involving the right coronary arteries (45.45%) were the most prevalent findings, whereas the clinical scenario associated with acute myocardial infarction was present in 44.44% of the analyzed samples.

Conclusion: The anatomical variations of the coronary arteries represent a considerable spectrum of arterial arrangements. Thus, knowledge about these variations constitutes an essential tool for the correct interpretation of clinical presentations and prognosis in cases of myocardial ischemia and acute myocardial infarction, in addition to serving for the correct elucidation of imaging tests and facilitating the management of coronary arteries during surgical interventions.

Keywords — coronary arteries, anatomical variations, acute myocardial infarction.

I. INTRODUCTION

The coronary arteries originate from the ascending portion of the aorta and they are responsible for the myocardium blood supply. As corroborated by Veras FHAP et al [1], in the normal and universally accepted coronary anatomy, the right coronary artery (RCA) arises from the right coronary sinus and follows the anterior atrioventricular sulcus. During its course, it sends branches that irrigate the right atrium, most of the right ventricle, the diaphragmatic face of the left ventricle, the posterior third of the interventricular septum and some components of the heart electrical conduction system, such as the sinoatrial and atrioventricular nodes. The left coronary artery (LCA) arises from the ostium of the ipsilateral coronary sinus as an arterial trunk that bifurcates into the left anterior descending artery (LAD) and circumflex artery (LCX) [1], lodged, respectively, in the anterior interventricular sulcus and posterior atrioventricular sulcus. These arteries supply the left atrium, part of the left ventricle, part of the right ventricle, the anterior two-thirds of the interventricular septum and the sinoatrial node in some individuals[2].

It is known that the origins and abnormal courses of coronary arteries are rare and these anomalies have a prevalence of about 1% [3]. The spectrum of coronary anomalies involves both the origin and distribution of arteries throughout the myocardium. Regarding the arteries origin, there is a wide arterial profile with variable clinical implications. Agenesis of the right coronary sinus ostium[8, 10, 13] is a relatively frequent anomaly and induces RCA to arise from LCA branches, which may lead to a symptomatologic variation in cases of acute myocardial infarction. Similarly, the distribution of coronary arteries is another factor that may contribute to the behavior of clinical aspects in ischemic heart disease. In this case, the variation in the wide myocardial distribution of LAD may act as a confounding factor in the case of differentiating between stress-induced cardiomyopathy and acute myocardial infarction (AMI).

Therefore, this study aims to analyze the possible anatomical variations found in the coronary artery system and their relationship with clinical manifestations associated with ischemic events and AMI.

To analyze the anatomical variations of the coronary arteries and the possible clinical implications associated with ischemic events and acute myocardial infarction.

II. MATERIAL AND METHODS

This study is a systematic review. The electronic search was carried out from May to July 2022. To carry out this study, the following databases were consulted: PubMed (National Library of Medicine), Scielo, Science Direct and the Virtual Health Library (BVS). Articles were selected without time restriction, in English, Spanish and Portuguese. For prospecting the studies, the descriptors were used in combination using Boolean operators (AND). For the search in the databases, the following combination was considered: "anatomical variation" AND "coronary artery" AND "myocardial infarction".

Duplicates were checked. The inclusion criteria were original articles involving the anatomical variations of coronary arteries in humans. Review articles and studies with animal models were excluded. From the identified studies, those that met the inclusion criteria were selected, considering titles and abstracts.

The selection of studies was performed by double-blinded pairs, as recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)4 protocol recommendations for literature reviews. Then, the interobserver agreement index was calculated.

Statistical analysis

The database search was performed by two independent reviewers. The analysis of interobserver agreement was performed using the Kappa test, using the Bioestat V 5.0 software, according to the method by Landis and Koch5. The value found was K=0.8694 (almost perfect agreement).

III. RESULTS

Figure 1 presents the summary of the electronic search, as well as the reasons for the inclusion/exclusion of the analyzed studies. Initially, 12,230 articles were identified. A total of 1,746 were excluded after applying the study type filters to exclude reviews. Then 10,472 studies were considered not relevant, 1 study excluded because of wrong population (animals), 1 exclusion for unavailable access and 1 duplicate. Therefore, 9 studies remained, which were submitted to careful analysis of the abstracts to verify the inclusion and exclusion criteria. All nine articles adequately met the inclusion criteria and were selected for full-text analysis.

In the selected studies, the nine individuals had acute myocardial infarction (AMI) or sought medical care with complaints of angina and there is one case of death. Clinical findings are grouped in Table 2 and organized by study. Table 3 shows the absolute and relative frequencies of reported clinical manifestations. In addition, in these cases, the following types of anatomical variations of the coronary arteries were found.

Figure 1 Search and selection of studies for the systematic review according to PRISMA4 recommendations.

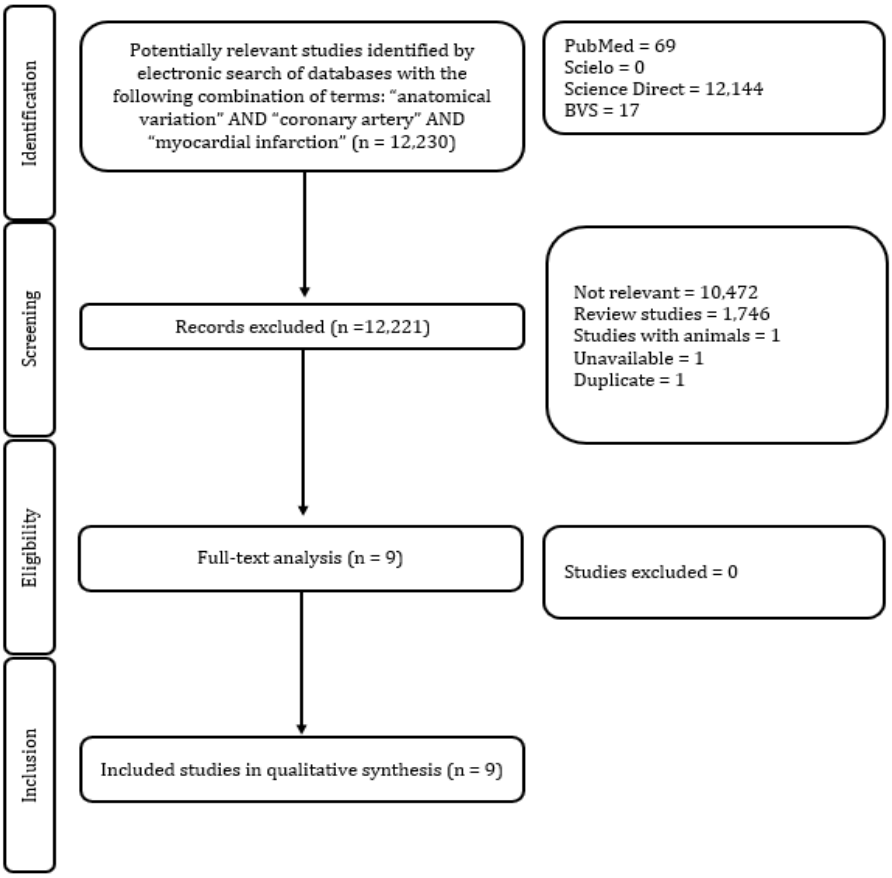

Table 1 Analysis of the studies that presented the anatomical variations of the coronary arteries.

Author and publication year	Sample	Method	Results
Dursun Dursunoglu et al.[6] (2007)	Single	Coronary angiography	Occluded RCA and anomalous origin of the circumflex artery from the right coronary sinus.
Sung Kyun Shin et al.[7] (2010)	Single	Coronary angiography	LAD was widely distributed throughout the myocardium along the apex and mid posterior surface of the LV.
A.Y. Andreou et al.[8] (2012)	Single	Coronary angiography	Single LCA isolated with two RCAs, one RCA originating from LAD and the other RCA arising as a terminal extension of the LCX. The origin of the sinus node artery from an aberrant RCA connected to the LAD. There was no ostium in the right coronary sinus and no aberrant RCA had significant occlusion.
Rosa Maria Martinez et al.[9] (2014)	Single	Autopsy and postmortem imaging	RCA and LCA arising from the right ostium of the sinus of Valsalva. LCA coursed between the aortic root and the pulmonary trunk, with a short proximal intramural segment. The cause of death was heart failure because of pneumothorax tension.
Erkan Yildirim et al.[10] (2016)	Single	Coronary angiography	RCA originating from the left coronary sinus ostium and presenting a “malignant course”. Ischemia was not observed.
Lt Col Akhilesh Rao et al.[11] (2016)	Single	Angiography	Common origin of RCA, LCX and LAD in the ostium of the right coronary sinus. LAD exhibited a “malignant” interarterial course, traversing the ascending aorta and pulmonary trunk to reach the anterior interventricular sulcus.
Pankaj Jariwala et al.[12] (2018)	Single	Coronary angiography	Dominant LAD, which continued as PDA in the posterior interventricular sulcus. RCA was small and non-dominant, and it did not show communication with the PDA.
Keyur Vora et al.[13] (2021)	Single	Coronary angiotomography	Coronary ostium of the left coronary leaflet with absence of RCA origin in the right leaflet or in the non-coronary leaflet. RCA had its origin in the LAD middle segment, in addition to an aberrant and tortuous course.
Mohammadreza Zarisfi et al.[14] (2022)	Single	Coronary angiotomography	RCA divided into two branches of almost equal size that ran relatively in parallel, one in the right atrioventricular sulcus and the other slightly anterior to it. Both RCAs terminated in posterior descending arteries and separate posterolateral branches.

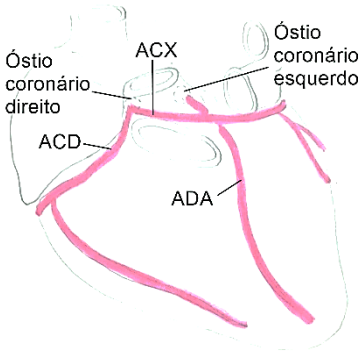

Figure 2.A Origin of the left circumflex artery (LCX) from the right coronary sinus.

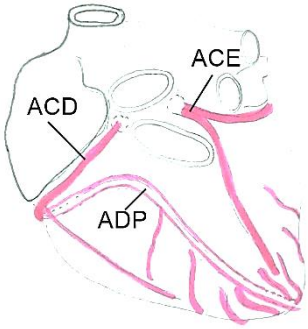

Figure 2B Great apicoposterior distributior of the right coronary artery (RCA).

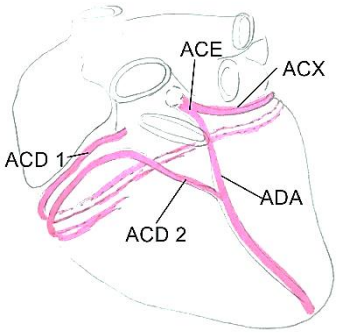

Figure 2C Single coronary artery with two right coronary arteries (RCAs).

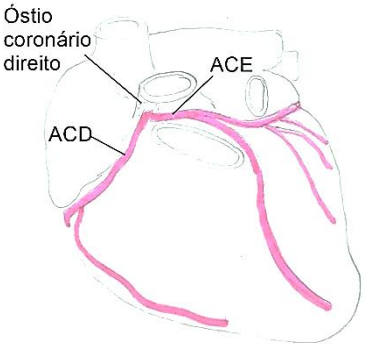

Figure 2D Left coronary artery (LCA) arising from the right coronary sinus along with the RCA.

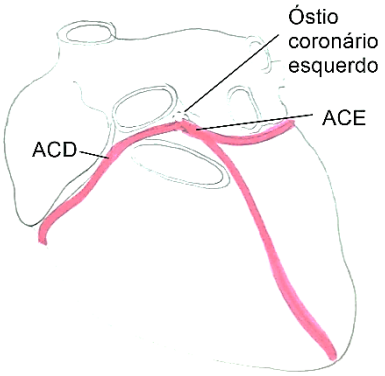

Figure 2E RCA arising from the left coronary sinus.

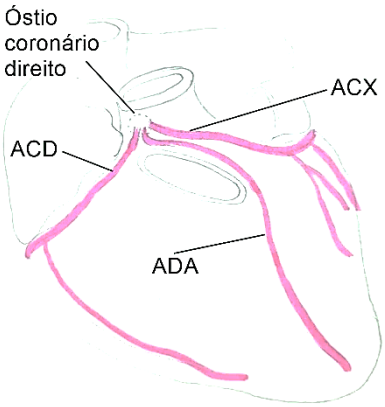

Figure 2F Common origin of the RCA, LCX, and left anterior descending artery (LAD) in the right coronary sinus.

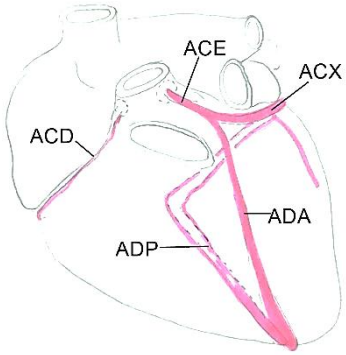

Figure 2G LAD and posterior descending artery (PDA) continuation and small and non-dominant RCA.

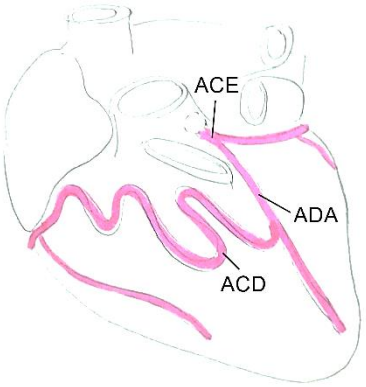

Figure 2H RCA origin from the LAD middle segment.

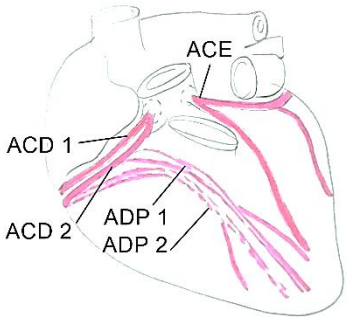

Figure 2I Double RCA.

These variant forms were grouped according to the affected artery. Thus, variations involving RCA include its large apicoposterior distribution, double arteries and abnormal origin, which does not occur in the right coronary sinus. The variation related to LCA concerns its origin from the right coronary system. Regarding LCX, its abnormal origin was also reported, starting from the right coronary sinus and an atypical course. Finally, LAD-related variations include its origin in the right coronary system and continuous course with PDA. Through this grouping, Table 4 shows the types of variations found involving the coronary artery system, as well as the absolute and relative frequencies related to the analyzed studies. It is important to point out that some patients had more than one anatomical variation. Therefore, the absolute total of variant forms observed in the 9 patients of the included articles was 11.

Table 2 Types of variations found in the analyzed studies and respective clinical presentations.

Author and publication year	Reported variation	Clinical condition
Dursun Dursunoglu et al.[6] (2007)	LCX	Precordial pain with exertion for five months. Inferior wall AMI with proximal RCA occlusion.
Sung Kyun Shin et al.[7] (2010)	LAD	Precordial pain for more than 30 minutes. Acute coronary syndrome misdiagnosed as stress-induced cardiomyopathy (Takotsubo syndrome). Patient with ST elevation AMI had echocardiographic findings typical of stress-induced cardiomyopathy because of anatomical variation.
A.Y. Andreou et al.[8] (2012)	RCA	Acute coronary syndrome (AMI without ST elevation). Total occlusion in the LCX middle segment.
Rosa Maria Martinez et al.[9] (2014)	LCA	Acute bronchitis, which evolved with a hypertensive crisis. Soft tissue emphysema was noted and pneumothorax was suspected. During placement of chest drainage, he developed bradycardia and ended up dying of cardiac arrest. A direct relationship between the anomalous origin of the LCA and the cause of death could not be established.
Erkan Yildirim et al.[10] (2016)	RCA	Assessment of atypical precordial pain and palpitations. There was no significant atherosclerotic disease in the coronary artery system and no ischemia was detected.
Lt Col Akhilesh Rao et al.[11] (2016)	LCX and LAD	Assessment of typical precordial pain with onset during exertion. There were no signs of atherosclerosis in the coronary artery system.
Pankaj Jariwala et al.[12] (2018)	RCA and LAD	The patient had anterior wall AMI, underwent LAD primary angioplasty, which continued as PDA in the posterior interventricular sulcus. Coronary angiography revealed 99% stenosis in the proximal segment of LAD.
Keyur Vora et al.[13] (2021)	RCA	Patient with precordial pain, without signs of stenosis or calcifications in any coronary artery segment.
Mohammadreza Zarisfi et al.[14] (2022)	RCA	Patient with intermittent, effortless, sharp pain in the left chest. There were no signs of atherosclerosis involving the coronary artery system.

Table 3 Absolute and relative frequencies of clinical manifestations reported in the analyzed studies.

Clinical condition	Absolut frequency	Relative frequency
Myocardial infarction	4	44.44%
Precordial pain without signs of arterial occlusion	4	44.44%
Death	1	11.11%
Total	9	100%

Table 4 Absolute and relative frequencies of anatomical variations involving the RCA, LCA, LCX and LAD in the included studies.

Site of variation	Absolut frequency	Relative frequency
RCA	5	45.45%
LCA	1	9.09%
LCX	2	18.18%
LAD	3	27.27%
Total	11	100%

IV. DISCUSSION

This review aimed to investigate and relate the anatomical variations of coronary arteries with the occurrence of acute myocardial infarction and ischemic events. In the included studies, the observation of the different arterial arrangements was performed using coronary angiography/angiotomography, after seeking medical attention due to the complaint of precordial pain, or autopsy with postmortem imaging.

It was observed in 45.45% (Table 4) of the analyzed studies that RCA anatomical variation is the most prevalent one. Of these, 60% had absence of the ostium of the right coronary sinus, detected by coronary angiography, with RCA arising from other arterial points of the heart, such as double RCA originating from LCA branches, one originating directly from LAD and the other as a continuation of the LCX (Andreou et al [8]), in addition to the appearance of the RCA in the left coronary sinus together with LCA (Erkan Yildirim et al[10]) and origin in the LAD middle segment, reported by Keyur Vora et al. [9] The remaining 40% of RCA variations consisted of a decrease in size and non-dominance (Pankaj Jariwala et al [12]), in addition to the RCA trunk bifurcating into two parallel coronary arteries, each originating PDA and posterolateral branches (Mohammadreza Zarisfi et al. [14]).

The anatomical variation involving LCA, which appeared in the right coronary sinus, was present in only one of the analyzed studies, with a relative frequency of 9.09% (Table 4). This variation has been related to sudden death and myocardial ischemia, which emphasizes the importance of medical follow-up even in the case of asymptomatic patients, as highlighted by Cihan Altin et al [17]. However, in the case report described by Rosa Maria Martinez et al. [9], the patient lived for 75 years with such anomaly, which was only identified at autopsy with postmortem imaging tests, and no direct evidence was found between this variation and the cause of death from cardiac arrest.

LCA and LAD anomalies are more clinically relevant than those involving the LCX (Cihan Altin et al[17]). In the present review, the origin of the LCX from the right coronary sinus was reported in two cases Dursunoglu et al. [6] and Lt Col Akhilesh Rao et al. [11]), with a relative frequency of 18.18% (Table 4).

Regarding LAD, variation was observed in 27.27% (Table 4) of the included studies with different anatomical profiles. Lt Col Akhilesh Rao et al. [11] reported, through an angiographic study, the origin of LAD from the right coronary sinus along with the LCX and RCA, in addition to highlighting a malignant course of LAD, which moved between the ascending aorta and the pulmonary trunk until reaching the anterior interventricular sulcus. Among related studies, dominant and continuous LAD with PDA as a single artery was also observed (Pankaj Jariwala et al. [12]) and widely distributed LAD, especially apicoposterior in the left ventricle (Sung Kyun Shin et al. [17]).

In their prospective study, Cihan Altin et al. [17] mention that the most common clinical presentations of the 78 patients with anomalies in the coronary arteries were atypical chest pain, in 61.5% of cases, typical angina, in 25.6%, acute coronary syndrome in 9% and syncope in 3.9% of patients. In this study, four patients (44.44% - Table 3) manifested chest pain, but the imaging exams did not show evidence of ischemia or coronary artery occlusion, nor any relationship between the respective anatomical variation and the patient's clinical condition.

Furthermore, four patients (44, 44% - Table 3) had AMI, and in two of these cases there was no occlusion of the anatomically variant arteries (Dursun Dursunoglu et al [6] and Andreou et al. [8]). In the case reported by Sung Kyun Shin et al. [7], because of LAD anatomical variation with great distribution along the myocardium, there was an initial erroneous diagnosis of stress-induced cardiomyopathy (Takotsubo syndrome) instead of AMI. In this report, the LAD variant was occluded and related to the patient's clinical condition. In addition, there was a relationship between the variant form and the patient's clinical condition in the report by Pankaj Jariwala et al. [12], considering that occlusion was present in continuous LAD with PDA.

Regarding the only case of death (11.11% - Table 3), although the origin of the left coronary artery in the right coronary sinus is associated with sudden death and myocardial ischemia (Cihan Altin et al. [17]), Rosa Maria Martinez et al. [9] concludes that there is not enough significant evidence that this variation was related to the reported death.

V. CONCLUSION

The anatomical variations of the coronary arteries, despite having a prevalence of 1%3, represent a considerable spectrum of arterial arrangements. Thus, knowledge about these variations constitutes an essential tool for the correct interpretation of clinical presentations and prognosis in cases of myocardial ischemia and acute myocardial infarction, besides serving for the correct elucidation of imaging tests and adequate management of coronary arteries during surgical interventions.

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