

# Coronary artery variations and median artery in Turkish cadaver hearts

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## ABSTRACT

**Introduction:** This study examined the routes and variations of the left coronary artery (LCA), the right coronary artery (RCA), and their branches, as well as the frequency of a median artery in cadaver hearts.

**Methods:** The hearts of 50 adult Turkish cadavers from various centres were dissected.

**Results:** The LCAs branched out of the aortic sinus and had an average diameter of 4.44 +/- 1.79 mm. They gave rise to two branches (bifurcation) in 46 percent, three branches (trifurcation) in 44 percent and four branches (quadrifurcation) in ten percent of the hearts. The median artery was identified in 27 hearts, with a mean diameter of 2.00 mm (standard deviation 0.67). The RCAs branched out from the right aortic sinus and had an average diameter of 3.32 +/- 0.79 mm. The conus branch, classically known as a branch of the RCA, branched out from the RCA in 32 percent of the hearts and from the right aortic sinus in 68 percent. Right dominance was observed in 42 percent, left dominance in 14 percent, and equal dominance in 44 percent of the hearts. Myocardial bridges were found on the LCA branches in 22 of the 27 hearts in which the median artery existed.

**Conclusion:** There is a close relationship between the existence of the median artery and myocardial bridges. This suggests that the median artery might be important in myocardial bridges, which exist in embryos but do not result in any clinical symptoms for many years in a large number of people.

**Keywords:** left coronary artery, median artery, myocardial bridge, right coronary artery

*Singapore Med J 2010; 51(10): 775-780*

## INTRODUCTION

The heart is supplied by two coronary arteries (left and right) and their branches, which are located between

the epicardium and myocardium; these vessels arise from the bulbus aorta as two branches of the ascending aorta.<sup>(1-3)</sup> The left coronary artery (LCA) is wider in diameter than the right coronary artery (RCA). It lies between the pulmonary trunk and the left auricle, and supplies a greater volume of the myocardium, a larger part of the interventricular septum and most of the left heart. It is generally divided into two main branches, the anterior interventricular branch and the circumflex branch.<sup>(3,4)</sup> In addition to these branches (14%–40%), a third branch, known as the median or intermedian artery, has been reported to exist.<sup>(5,6)</sup> The median artery can arise from the LCA (trifurcation or quadrifurcation) or from the proximal part of the anterior interventricular branch or circumflex artery.<sup>(6,7)</sup> It goes obliquely around the sternocostal surface of the left ventricle and is spread around the middle area between the base and the apex of the heart.<sup>(7)</sup> The RCA begins at the right aortic sinus and goes along the coronary sulcus. It supplies the right atrium, right ventricle, atrioventricular septum and a part of the left ventricle. Along its course, it produces a conus branch, a right marginal branch and a posterior interventricular branch.<sup>(1,2)</sup>

The dominance of the coronary artery system is defined according to the coronary artery that supplies the back of the interventricular septum or produces the posterior interventricular branch.<sup>(3)</sup> In humans, it has been reported that the posterior interventricular branch branches off from the RCA in 75% of cases (right dominance) and from the LCA in 10% of cases (left dominance), and goes around the back of the anterior interventricular branch, creating an anastomosis with the posterior interventricular branch in 15% of cases (equal dominance).<sup>(1)</sup> This study aimed to examine the variations in LCA and RCA branches, the existence and frequency of the median artery, and the relationship between this artery and myocardial bridges.

## METHODS

The hearts of 50 adult Turkish cadavers from both genders (aged 25–70 years) that were fixed with 10% formaldehyde were collected from various centres and used for the study, which was conducted at the Department of Anatomy, Meram Medical Faculty,

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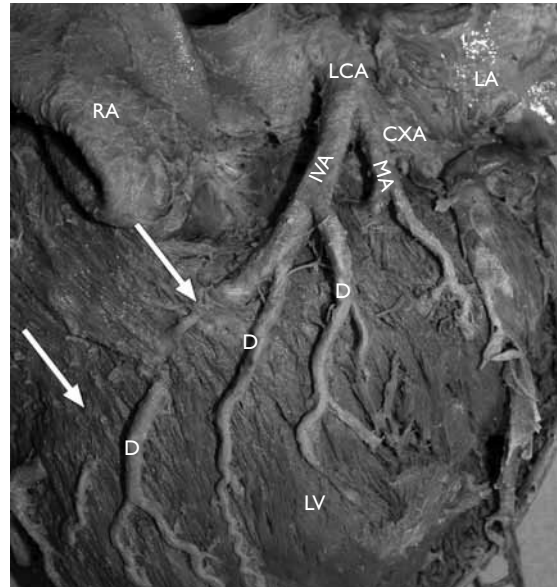
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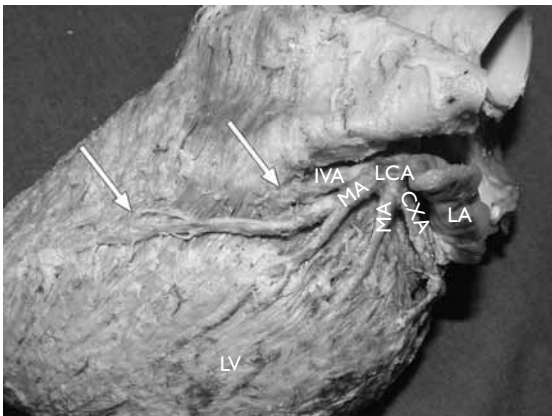
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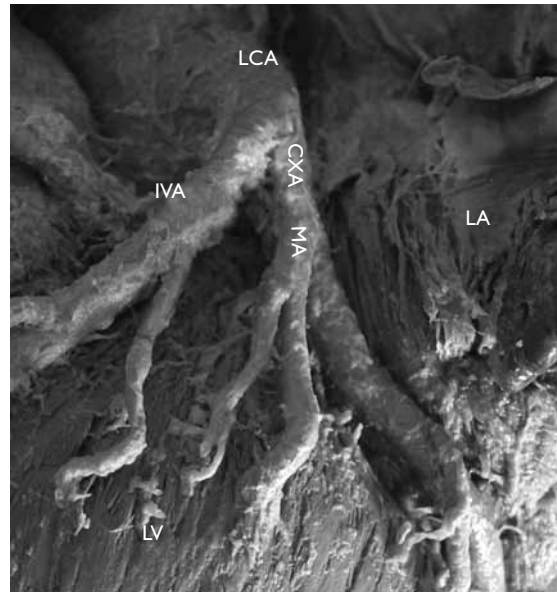
**Fig. 1** Photograph shows two branches arising as the anterior interventricular branch (IVA) and the circumflex branch (CXA) (bifurcation) of the left coronary artery (LCA).  
LA: left auricle; LV: left ventricle



**Fig. 2** Photograph shows three branches arising as the anterior interventricular branch (IVA), the circumflex branch (CXA) and the median artery (MA), which course on the front wall of the left ventricle (trifurcation) from the left coronary artery (LCA). The presence of a myocardial bridge (arrows) over the anterior interventricular branch can also be observed.  
LA: left auricle; LV: left ventricle; RA: right auricle; D: diagonal artery



**Fig. 3** Photograph shows four branches arising as the anterior interventricular branch (IVA), the circumflex branch (CXA), and two median arteries (MA) (quadrifurcation) of the left coronary artery (LCA). The presence of a myocardial bridge is observed (arrows).  
LA: left auricle; LV: left ventricle



**Fig. 4** Photograph shows the median artery (MA) arising from the circumflex branch (CXA).  
LA: left auricle; LV: left ventricle; IVA: anterior interventricular branch; LCA: left coronary artery

Selçuk University, Konya, Turkey. The procedures followed were compatible with the ethical standards of the faculty's committee responsible for human experimentation, which were based on the Helsinki Declaration. The epicardium layer was removed by microdissection, and the coronary arteries were observed. The exit point of the LCA from the aorta, the courses and variations of the anterior interventricular branch and circumflex branch, and the existence of the median artery were investigated. The exit points of the RCA and conus branch, the courses of the posterior interventricular branch and the variations of the RCA branches were determined. The external diameters at the starting points of these branches were measured

using 0.01 mm sensitive digital calipers. To determine the dominant circulation, the artery that supplies the posterior interventricular sulcus was investigated. All dissections were performed under a dissection microscope (magnification  $\times 4$ ) and photographed.

The data is reported as mean  $\pm$  standard deviation. The relationship between myocardial bridges and the median artery was evaluated using the chi-square test.



**Fig. 5** Photograph shows the conus branch (Co) originating from the right coronary artery (RCA).  
RV: right ventricle



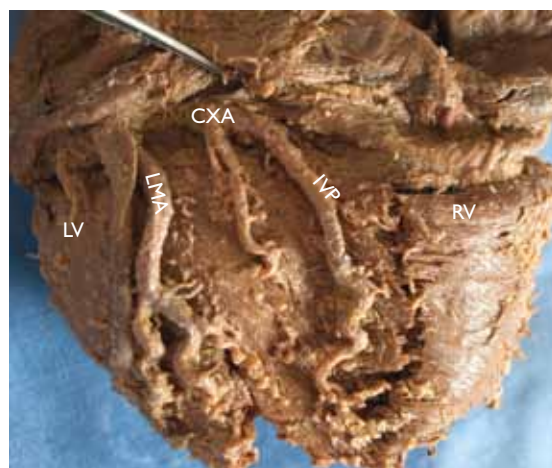
**Fig. 6** Photograph shows the conus branch (Co) branching out from the right aortic sinus.  
RCA: right coronary artery; RV: right ventricle

Statistical analysis was performed using the Statistical Package for the Social Sciences version 16.0.0 for Windows (SPSS Inc, Chicago, IL, USA).

## RESULTS

On examination of the main branches and variations of the LCA, we noted that the LCA branched out of the aortic sinus in all the hearts and had an average diameter of  $4.44 \pm 1.79$  mm. In 23 (46%) hearts, the LCA was separated into the anterior interventricular branch and the circumflex branch (bifurcation) (Fig. 1). In 22 (44%) hearts, in addition to the anterior interventricular branch and the circumflex branch, there was a median artery that coursed on the front wall of the left ventricle (trifurcation) (Fig. 2). In five (10%) hearts, branching occurred as in trifurcation but with two median arteries emerging from the LCA (quadrifurcation) (Fig. 3).

In all the hearts, the anterior interventricular branch was observed to arise from the LCA under the left auricle and coursed along the anterior interventricular sulcus toward the apex cordis, and the average diameter was  $3.13 \pm 0.64$  mm. The anterior interventricular branch coursed on the front surface in 28 (56%) hearts and passed to the posterior surface in 22 (44%) hearts. In 17 (34%) cases, the anterior interventricular branches that passed to the posterior surface caused anastomosis, with the posterior interventricular branch in the posterior interventricular sulcus. In all the hearts, the circumflex branches arose from the LCA and coursed around the left



**Fig. 7** Photograph shows the posterior interventricular branch (IVP) arising from the left circumflex branch (CXA).  
LV: left ventricle; RV: right ventricle; LMA: left marginal artery

side of the heart along the coronary sulcus, and had an average diameter of  $2.89 \pm 1.08$  mm.

The median artery was identified in 27 out of the 50 hearts (54%) and had a mean diameter of  $2.00 \pm 0.67$  mm. All the median arteries coursed so that they could supply the anterior and anterolateral sides of the left ventricle. This branch arose from the LCA in 26 hearts (Figs. 2 & 3), and from the circumflex branch in one heart (Fig. 4). In 19 out of the 27 hearts, only one median artery (Fig. 2) was observed, while in five hearts, two median arteries (Fig. 3) were noted, and in three hearts, the median artery first branched out as one branch and

**Table I. A comparison of the frequency of left coronary artery branching types among various studies.**

Study	No. of participants	Method	Percentage of participants		
			Bifurcation	Trifurcation	Quadrifurcation
Surucu et al <sup>(6)</sup>	40	Dissection	47.5	47.5	2.5
Kalbfleisch et al <sup>(10)</sup>	400	Angiography	41	53	6
Leguerrier et al <sup>(11)</sup>	80	Dissection	65–70	20–30	5–10
Kalbfleisch et al <sup>(12)</sup>	141	Angiography	51.1	44.4	4.3
Lo et al <sup>(13)</sup>	200	Dissection	69.35	36.6	-
Present study	50	Dissection	46	44	10

**Table II. A comparison of the frequency of coronary circulation types among various studies.**

Study	No. of participants	Method	Percentage of participants		
			Left	Equal	Right
Ortale et al <sup>(15)</sup>	40	Dissection	12.5	25	62.5
Schlesinger et al <sup>(16)</sup>	225	Dissection	18	34	48
Kronzon et al <sup>(17)</sup>	104	Angiography	10	3	87
Hadziselimovic et al <sup>(18)</sup>	200	Angiography	13	24	63
Velican et al <sup>(19)</sup>	566	Angiography	15	27	58
Kurjia et al <sup>(20)</sup>	119	Dissection	14	40	46
Loukas et al <sup>(21)</sup>	200	Dissection	24	33	55
Present study	50	Dissection	14	44	42

then divided into two (Fig. 4).

The main branches and the variations of the RCA were also examined. In all the hearts, the RCA branched out from the right aortic sinus and was located in the atrioventricular sulcus. The average diameter of the RCA was  $3.32 \pm 0.79$  mm. In 16 (32%) hearts, the conus branch, which is classically known as a branch of the RCA, branched out from the RCA (Fig. 5). In 34 (68%) hearts, the conus branch branched out from the right aortic sinus (Fig. 6). The average diameter of this artery was  $1.76 \pm 0.50$  mm.

The posterior interventricular branch arose from the RCA in 43 (86%) hearts and from the left circumflex branch in two (4%) hearts (Fig. 7). The posterior interventricular branch was not found in five (10%) hearts. In these cases, the lower part of the posterior interventricular sulcus was supplied by the anterior interventricular branch after turning to the back of the heart. In three cases, the upper part of the posterior interventricular sulcus was supplied by small branches originating from the posterior left and right ventricular branches of the circumflex branch and the RCA; in one case, it was supplied by the circumflex branch and in another case, by small branches of the RCA. The average diameter of the posterior interventricular branch was  $1.95 \pm 0.68$  mm. No variation was found in the other

branches of the RCA.

The coronary dominance of all hearts in this study was as follows: right dominance was found in 21(42%) hearts, left dominance, in seven (14%) hearts, and equal dominance, in 22 (44%) hearts. The relationship between myocardial bridges and the median artery was explored. A myocardial bridge was present over the anterior interventricular branch in 21 (77.7%) hearts, and over the circumflex branch in one out of 27 (3.7%) hearts that were found to have a median artery (Figs. 2 & 3). There was a myocardial bridge over the anterior interventricular branch in 12 out of 23 (52.2%) hearts. The coronary arteries were normal in 11 out of 23 (47.8%) hearts that did not have a median artery.

## DISCUSSION

Clinicians and anatomists have been examining coronary artery variations for a long time. In particular, from the 1960s when the use of selective coronary angiography began, the number of investigations on this topic has increased. However, there is still no consensus on the normality or abnormality of coronary arteries. While it is generally accepted that the human heart has two main coronary arteries (right and left), some claim that the condition of possessing three or four coronary arteries is normal.<sup>(7)</sup> In general, coronary artery variations

are regarded as either major or minor, important or unimportant. Minor anomalies are not clinically evident and are usually accepted as normal changes. Major anomalies that are accepted as variations are reported in less than 1% of the general population.<sup>(7,8)</sup>

In angiographic and cadaver studies carried out among different ethnic groups, Garg et al reported that the most frequent coronary artery variations were observed in the RCA (62%) and the left circumflex branch (27%),<sup>(8)</sup> while Topaz et al observed 48.71% of variations in the RCA and 35.89% in the left circumflex branch.<sup>(9)</sup> In our study, as in previous studies, it was determined that the most frequent variation (64%) was the conus branch of the RCA, which originates from the aortic sinus. Researchers have reported different results regarding the LCA branching frequency (Table I). While the rates of bifurcation and trifurcation in our study were very similar to each other and to the rates found by Surucu et al, the quadrification rate was similar to the results reported by Leguerrier et al.<sup>(6,11)</sup> The similarity between the bifurcation and trifurcation rates suggests that the normal division of the LCA into two branches should be reconsidered.

While Vilallonga reported that the external diameter of the median artery was thinner than the anterior interventricular branch and thicker than the circumflex branch, Surucu et al reported that it was thinner than both.<sup>(5,6)</sup> Our study was similar to Surucu et al's, in that the average median artery thickness ( $2.00 \pm 0.67$  mm) was lower than that of the anterior interventricular branch ( $3.13 \pm 0.64$  mm) and the circumflex branch ( $2.89 \pm 1.08$  mm).<sup>(6)</sup> The course of the anterior interventricular branch, generally found on the front surface of the heart along the posterior interventricular sulcus and surrounded by the apex of the heart, is called Mouchet's posterior recurrent interventricular artery,<sup>(5)</sup> and has been observed at a frequency of 28.18%–50%.<sup>(14,15)</sup> This course at the anterior interventricular branch was observed in 44% of the hearts in our study. As Mouchet's artery contributes to the feeding of the posterior interventricular sulcus, it changes the dominant circulation of the coronary arteries in favour of co-dominance. The existence of this artery is important for the collateral circulation that is required to supply the sulcus in the event of posterior interventricular branch stenosis.

Ortale et al examined dominant circulation in 40 cadaver hearts, and accepted the posterior interventricular branch arising from the RCA and its branches supplying at least the middle medial part of the left ventricular posterior face as right dominance (62.5%). In addition, they accepted the branching of the posterior interventricular branch from the circumflex branch or supplying the sulcus with the anterior interventricular branch by moving posterior to the heart as left dominance (12.5%), and the nourishment

of the sulcus by both coronary arteries as co-dominance (25%). Moreover, they determined subtypes according to the blood supply on the left ventricle posterior surface and posterior interventricular sulcus.<sup>(15)</sup> In previous studies, right dominance was found to have the highest frequency rate of occurrence, and left dominance and co-dominance had lower reported frequencies (Table II). In contrast, in our study, the rates of right- and co-dominance were similar and high (42% and 44%, respectively), while left dominance was found at the lowest rate (14%). It has been reported that the posterior interventricular branch originates from the circumflex branch at a rate of 7.5%–20%.<sup>(1,3,5,15)</sup> Our study established that the posterior interventricular branch originates from the circumflex branch at a lower rate (4%).

Generally, there is only one orifice in the aortic sinus from which the RCA originates; however, more than one orifice is sometimes observed. It has been reported that the conus branch originates from this accessory orifice; in this case, the conus branch is called the third coronary artery. Its frequency of occurrence varies (7.6%–51%), and some ethnic differences have been observed to exist.<sup>(5,16,20)</sup> Recently, Cademartiri et al reported in two 64-slice computed tomography coronary angiography studies examining the origin of the conus branch, that this artery originates from a location proximal to the RCA (64.1% and 59%) or the aortic ostium and aorta (33.9% and 39%, respectively).<sup>(22,23)</sup> Our study, in contrast, found the branching of the conus branch from the aortic ostium and aorta in 68% of cases, and its branching from the RCA in 32% of cases. Kurjia et al noted that establishing the location and origin of the conus artery in relation to the right ventricular outflow tract radiologically prior to surgery is essential for the treatment of tetralogy of fallot.<sup>(20)</sup>

Loukas et al examined the connection between muscle bridges and coronary artery dominance, and observed left dominance in 66.6%, right dominance in 24.6% and co-dominance in 8.7% of hearts that had myocardial bridges. They also reported a close connection between myocardial bridges and dominance.<sup>(21)</sup> In our study, 22 of the 27 hearts (81.5%) were found to have a median artery and the existence of myocardial bridges in branches of the LCA (anterior interventricular and circumflex branch). Our results suggest that there is a statistically significant relationship between the presence of the median artery and myocardial bridges ( $p = 0.003$ ). This close relationship has not been reported in previous studies. It is not known why there are no signs or symptoms before the third decade of life, as myocardial bridges are present at birth.<sup>(24)</sup> We believe that symptoms do not appear until the later years because the median artery found in the hearts with myocardial bridges

compensates for the bridges by providing additional blood flow. In conclusion, knowledge of individual and racial variations in coronary arteries is essential for the diagnosis and treatment of coronary artery patients.

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