ORIGINAL ARTICLE

Eur. J. Anat. 17 (4): 250-256 (2013)

A study of the distribution of the left coronary artery - clinical importance

Vaishaly K. Bharambe and Vasanti Arole

Dept. of Anatomy, Dr. D.Y. Patil Medical College, Pimpri, Pune, Maharashtra, India

SUMMARY

The object of the present work was to study the origin of the left coronary artery, its branches, and to note any variations in its distribution. Fifty human hearts were procured from dissection-room cadavers of adult age groups. The left coronary arteries were dissected meticulously; their individual branches and any variations encountered were noted.

The left coronary artery was seen originating in relation to the left posterior aortic sinus in 100% of the specimens. The incidence of bifurcation of the left coronary artery was found in 64% and trifurcation in 36%. In 26% of hearts the circumflex branch of the left coronary artery crossed the crux, in 20% the SA Nodal artery, and in 24% the AV Nodal artery was seen as a branch of the circumflex artery. 2% incidence of retroaortic course of the left circumflex artery was observed. The left coronary artery and its branches are responsible for the irrigation of most of the left ventricle and part of the right ventricle. In case of trifurcation, where the left diagonal artery takes origin directly from the left coronary artery, the size of infarct on occlusion of the left anterior descending artery would be reduced. The left circumflex artery taking origin from the right sinus of Valsalva is an anomaly which may remain clinically silent, but at times it has been known to get compressed during valve replacement surgery, if not detected preoperatively. In hearts where both SA and AV nodal arteries originated from left coronary artery (8%), occlusion of the left coronary artery could severely affect the conducting system.

Corresponding author: Vaishaly K. Bharambe. Dept of Anatomy, Dr. D.Y. Patil Medical College, Pimpri, Pune 411018, Maharashtra, India. Tel: 02025899168.

E-mail: vaishalybharambe@yahoo.co.in

Key words: Left coronary artery – Left anterior descending artery – Left circumflex artery – Left diagonal artery – SA nodal artery – AV nodal artery – Myocardial infarction

INTRODUCTION

The normal anatomy of the left coronary artery is well known. New variations in left coronary artery distribution have been detected during the course of routine dissection in the Anatomy dissection hall. These have variable clinical significance.

When coronary artery anomalies are encountered during coronary artery surgeries, even minor variations may lead to considerably increased morbidity. It thus becomes essential that the operating surgeon must have prior knowledge not only of the normal origin, course and distribution of the left coronary artery but also of its possible variations, common as well as rare.

Though many variations in the coronary arterial pattern may be clinically silent, imposing no limitations on blood flow, they require the clinician to be alert and knowledgeable. If a coronary artery anomaly is not recognized in time, it may lead to wrong diagnosis leading to incorrect treatment (Angelini, 2002).

Study of distribution of the left coronary artery and its branches and the area of myocardium irrigated by them also helps in judging the size of infarct occurring following arterial occlusive disease.

Considering the clinical significance of knowing the left coronary arterial pattern, the present study has been undertaken to shed more light on this topic. Also any variation, not yet reported in the literature, if encountered, should be noted.

Submitted: 22 October, 2012. *Accepted:* 13 June, 2013.

Abbreviations used

LC - Left coronary
LAD - Left anterior descending
LCx - Left circumflex
LD - Left diagonal
PDA - Posterior descending artery
SA - Sinuatrial
AV - Atrioventricular

MATERIAL AND METHODS

A total of 50 adult human hearts procured from dissection-room cadavers of adult age groups from the Department of Anatomy, preserved in 10% formalin, were included in this study irrespective of sex. The heart was exposed and removed from the thoracic cavity by cutting through the ribs and sternum, cutting the great vessels and finally incising the pericardium. The heart was taken out of the pericardial cavity.

The Aorta was cut open longitudinally, just on the right side of the anterior aortic sinus reaching up to a level just distal to the aortic sinuses. The ostial openings of the left coronary (LC) artery or its branches, if arising independently, were noted. The left coronary artery was traced by cleaning the epicardium and fat piecemeal. Their branches were dissected and any variations encountered were noted.

Declaration of Helsinki: Not applicable as this is a cadaveric study carried out in the Dissection Hall of the said Institute**.**

RESULTS

The LC artery was seen originating from the left posterior aortic sinus in 100% of the specimens. Depending on whether the ostia were situated below, at or above the cuspal margin of the aortic sinus, they were classified as arteries taking origin from 1) within the sinus (10%), 2) at the sinuaortic junction (66%), or 3) from the ascending aorta (24%).

Two types of branching patterns of main trunk of the LC artery were observed, namely- bifurcation and trifurcation. Bifurcation of the LC artery into left anterior descending (LAD) and left circumflex (LCx) arteries was observed in 62% hearts (Fig.1,4). In 2% hearts, the LC artery divided into LAD and left diagonal (LD) artery. Here LCx artery had an ectopic origin anteriorly, directly from the anterior aortic sinus, winding posteriorly, around the aorta and pulmonary trunk to reach the posterior atrioventricular groove (Fig. 2).

In 36% of hearts trifurcation was observed (Fig. 3,4). Here the main trunk of the LC artery divided into LAD, LD and LCx arteries. The LD artery was a large artery extending down the wall of the left ventricle, running to the left of anterior interventricular groove. The LD artery later divided into 2 branches, one of which ran parallel to the LAD artery while the other branch went towards the margo obtusis (left border of the heart).

In 20% of hearts the SA nodal artery was seen as a branch of LCx artery arising in close proximity to the posterior surface of the ascending aorta, close to the upper margin of the left auricle (Fig. 5,7). This artery passed posterior to the ascending aorta, winding around the posterior surface and the right border of the right atrium to reach its anterior surface close to the entry of SVC to supply the SA node. In 8% of the hearts the AV nodal artery was found to originate just before the LCx

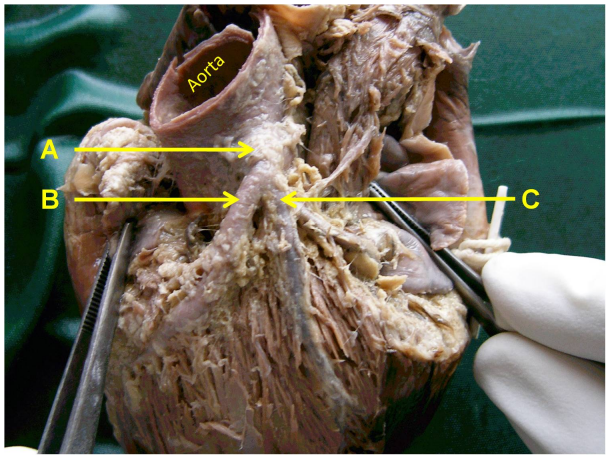

Fig. 1. Dissected heart showing bifurcation of LC artery (A) into LAD (B) and LCx (C).

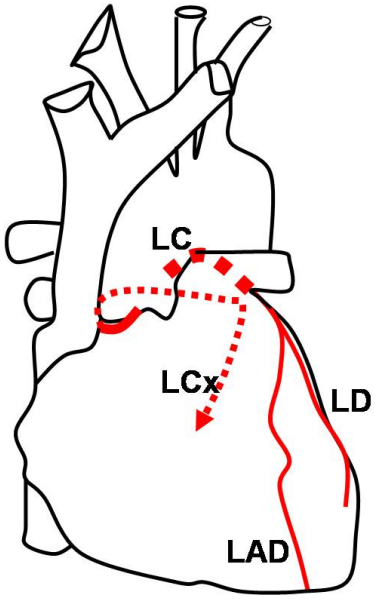

Fig. 2. Diagram showing ectopic origin of LCx artery directly from anterior aortic sinus, with a retroaortic course, to reach the posterior atrioventricular groove. The LC artery in this case can be seen bifurcating into LAD and LD arteries.

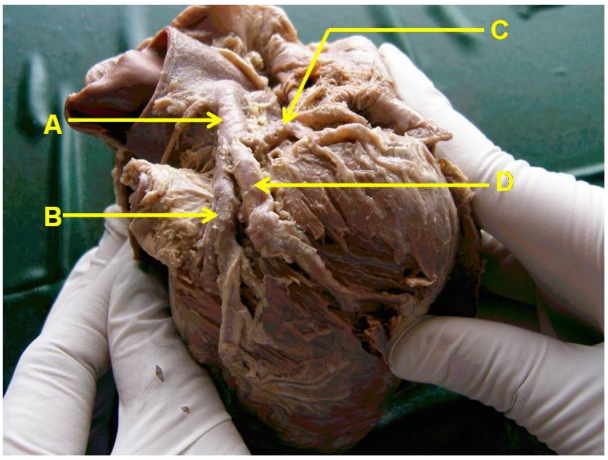

Fig. 3. Photograph of dissected heart showing trifurcation of LMCA(A) into LAD(B), LC(C) and LD(D) arteries

artery crossed the crux while in 16% hearts, it took origin just after the LCx artery crossed the crux (Fig. 6,7). In 8% of hearts, both the SA and AV nodal arteries were seen arising from the LCx branch of the LC artery with similar courses as mentioned above.

In 12% of hearts the posterior descending (posterior interventricular) artery (PDA) was a branch of the LC artery. In 16%of hearts the LCx branch of the LC artery crossed the crux.

DISCUSSION

LC artery disease represents a significant independent predictor of mortality in patients with ischemic heart disease (Suzuki et al., 2010). A postmortem angiographic study showed that 63.8% of the heart is irrigated by LC artery (Kalbefleisch and Hort, 1977). It irrigates not only most of the left ventricle but also part of the right ventricle (Reig and Petit, 2001). Thus occlusion of the main trunk of the LC artery would result in ischemia of a large portion of the myocardium.

40-50 % of myocardial infarctions occur due to occlusion of the LAD artery, while 15-20% occur due to occlusion of the LCx artery (Moore et al., 2010). Both LAD and LCx take origin from the LC artery. Thus (40-50% + 15-20%) 55-70% of myocardial infarctions can be said to occur due to occlusion of the LC artery branches. The size of the infarct in case of occlusion of an artery would depend upon the area of myocardium being perfused by it.

Thus, knowledge of distribution of the LC artery and its branches is essential for correctly assessing the size of an infarct in myocardial infarction, haemodynamic and surgical manipulation thereafter, as well as for correct interpretation of angiographic data.

The LC artery normally takes origin from the left posterior aortic sinus (Standring, 2008). This was observed in 100% of hearts in the present study. The LCx artery and the LAD arteries may on occasion arise from the right sinus of Valsalva (Yang and Ma, 2010). Anomalous origin of the LC artery from the anterior aortic sinus has also been described (Ishizawa et al., 2006; Vencelj et al., 2010). However, no such anomalous origin of LC artery was observed in the present study. The finding of the origin of the LCx artery from the anterior aortic sinus (right sinus of Valsalva) with the LC taking origin from left posterior aortic sinus (2% hearts) is discussed later in this article.

The coronary arteries arising within the aortic sinuses or at the sinuaortic junction allow maxi-

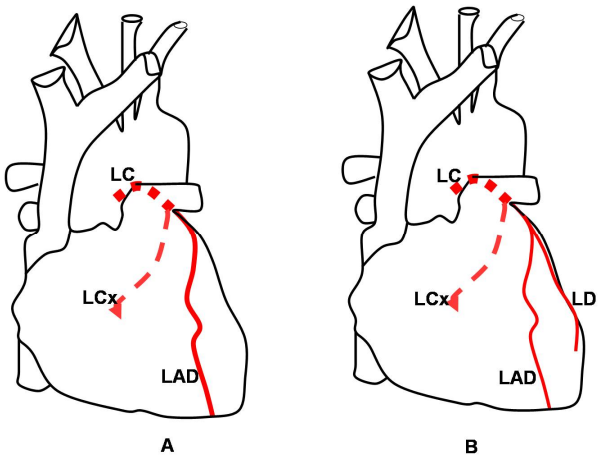

Fig. 4. Diagrams showing bifurcation **(A)** and trifurcation **(B)** of LC artery into LAD and LCx in case of bifurcation and LAD, LD and LCx in case of trifurcation respectively.

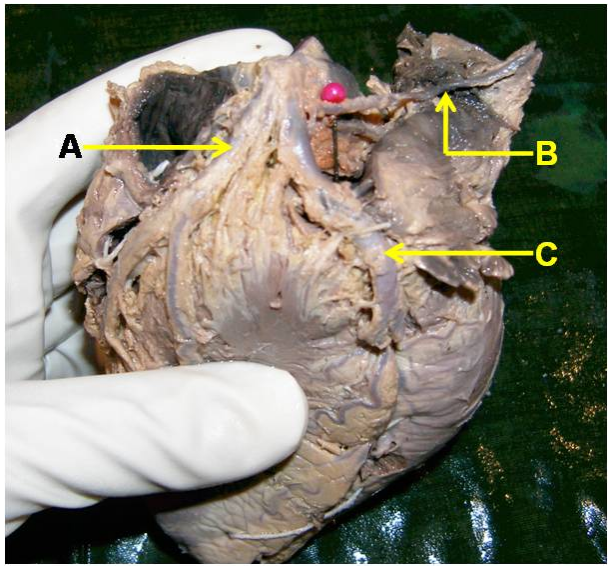

Fig. 5. Dissected heart showing SA Nodal artery (B) taking origin from LCx (C) artery. Also seen is the LAD (A) artery.

mum coronary filling during ventricular diastole (Alexander et al., 2005). The present findings of 10% of LC arteries taking origin from within the sinus and 66% from the sinuaortic junction can be taken to indicate that 76% of individuals as per present study show maximum diastolic filling of LC arteries.

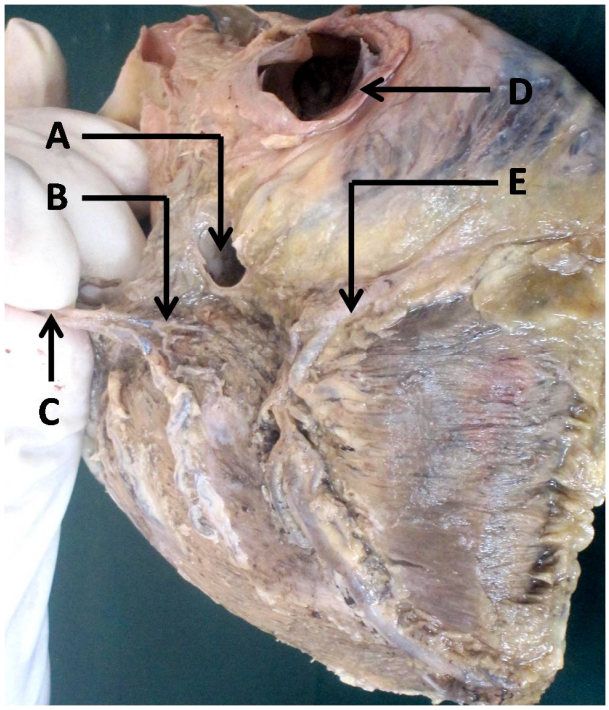

Fig. 6. Dissected heart (diaphragmatic surface) showing AV Nodal (B) artery seen passing towards the region housing the AV node. Also seen is the LCx (C) artery and right coronary artery (D). The opening of coronary sinus (A) and Inferior vena cava (D) into the right atrium can also be visualized.

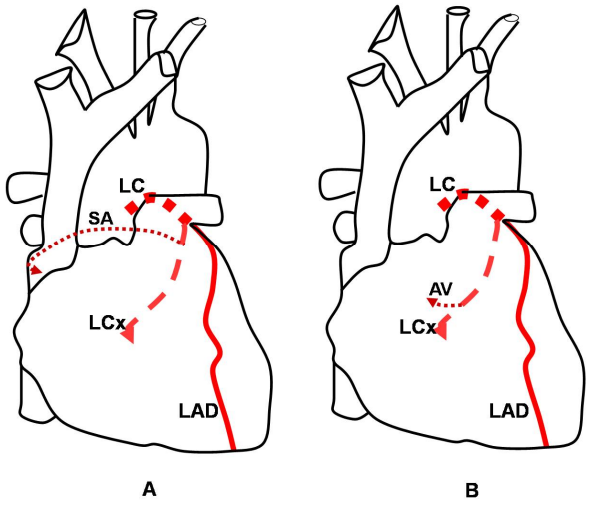

Fig. 7. Diagrams A and B showing the course of SA and AV nodal branches of LCx branch of LC artery, respectively.

The LC artery has been described in texts (Standring, 2008) as dividing into two or three main rami. When it divides into LAD and LCx arteries, it is said to be bifurcating. One large ventricular ramus of LAD is called LD artery. When it arises directly from the LC artery along with origins of LAD and LCx arteries, it is called median artery, and the LC artery is said to be ending in a trifurcation (Reig and Petit, 2004). Two morphological types of median arteries have been described (Reig and Petit, 2004), the 1st having a course similar to the LD artery and the 2nd having a course similar to the left marginal branch of the LCx artery passing towards the margo obtusis. All the median arteries in the present study were found to have a course similar to the LD artery, i.e., 1st type of median artery. When the LC artery divides into LAD, LCx and two LD arteries (referred to as first and second diagonal arteries) it is said to be in tetrafurcation (Ballesteros and Ramirez, 2008). This variation was not observed in the present study.

Table 1 depicts the incidence of bifurcation, trifurcation and tetrafurcation of LC artery as observed in the present study in comparison with the findings of various authors.

It is observed from the table above that incidence of bifurcation and trifurcation of the LC artery is almost the same after being studied by different authors with a small difference in incidence observed when method of study changes from dissection to angiography.

In bifurcation of the LC artery, a large portion of myocardium is irrigated singly by the LAD artery. An occlusion of the LAD artery would then result in a large sized infarct. In trifurcation the same portion of myocardium is irrigated separately by the LAD and the LD arteries. An occlusion of either of the arteries would therefore result in a smaller sized infarct, as the other artery would continue to irrigate the rest of the myocardium.

Angiographic examination of the LC artery is often limited to lesions in the LAD and LCx arteries (Levin, 1983). In case of trifurcation a median artery of large caliber may give rise to arteries supplying sternocostal surface of the left ventricle, some anterior septal arteries and arteries supplying the anterior papillary muscle of the left ventricle (Reig, 2003). Thus the median artery, if present, also needs to be carefully looked for angiographically, as occlusion of a median artery of large caliber may result in a large infarct.

Thus, as a result of trifurcation:

1. existence of a separate LD artery (median artery) may decrease the size of infarct following occlusion of the LAD artery, which otherwise would have been very large.

2**.** the occlusion of the LD artery itself could be missed on angiography if only LAD and LCx are looked for, and yet the patient may have a significantly large sized infarct.

In a study carried out in 1949, it was suggested that variations of coronary arteries might be responsible for the lower incidence of angina pectoris and myocardial infarction in the Bantu population. The role of LD artery referred to as an "extra branch of LC artery" was proposed as an important source of collateral circulation here (Brink, 1949). This was followed by an angiographic study of the coronary arterial pattern carried out on European and Bantu populations in 1960. The incidence of trifurcation of the LC artery was found to be 38% and 74% respectively (Pepler and Meyer, 1960). Here the LD artery was referred to as "the third primary division of left coronary artery". The findings of the latter study confirmed that the higher incidence of LD branch coming directly from the LC artery may act as an important source of collateral circulation explaining the rarity of angina pectoris and myocardial infarctions in the Bantu population (Pepler and Meyer, 1960). An in-depth study of coronary arterial circulation in the Bantu population was carried out subsequently in 1982 by dissection method. 89.5% incidence of trifurcation of the LC artery was observed, again confirming the high incidence of trifurcation of the LC artery in the Bantu population. However here the authors have stated their belief that the differences in incidence of trifurcation of LC artery probably is more an individual than a racial variation (Grande et al., 1982).

The third terminal branch of LC artery (median artery) observed in trifurcation has also been described as "ramus diagonalis". Despite contrary opinion expressed in the abovementioned study in 1982, authors today clearly state that "ramus diagonalis" presents an important pattern of collateral circulation having special meaning in coronary insufficiency (Lujinovic et al., 2005). The "ramus diagonalis" has been observed in 36% of hearts in the present study.

The region formed by intersection of the LAD artery and the LCx artery with the great cardiac vein is called as Brocq and Mouchet's triangle. This region will be traversed by the LD artery in case of trifurcation.This triangle is commonly used when performing intravascular ultrasound of coronary arteries to help in identifying pericardium, myocardium and vessels in the neighborhood. The location of the triangle is also important in procedures like percutaneous mitral annuloplasty (Andrade et al., 2010).

Bifurcation of LAD artery has been described (Reig, 2003). However no such bifurcation of LAD artery was observed in the present study.

The human heart has 2 coronary arteries, namely right and left (Standring, 2008). In the present study in 2% cases right sinus of Valsalva is seen giving origin to both the right coronary artery and the LCx artery by separate ostia, while the left sinus of Valsalva gave origin to LC which bifurcated into LAD and LD arteries. Since the three major arteries of the heart are seen originating by separate ostia from the aortic sinuses, can this LCx artery be referred to as 3rd coronary artery? And can such a heart be said to be irrigated by 3 coronary arteries?

Traditionally the right conus artery arising separately from the anterior aortic sinus (Right sinus of Valsalva) is called as "third coronary artery" (Reig, 2003). We propose that where the LCx artery is seen originating from the aortic sinus directly, it be referred to as "3rd coronary artery".

The coronary artery variations which have a prevalence of more than 1% in the general popu-

Table 1. Incidence of bifurcation, trifurcation and tetrafurcation of the left coronary artery.

	Method used	Bifurcation into LAD and LCx arteries	Bifurcation into LAD and LD arteries	Trifurcation	Tetrafurcation
Present study (2012)	**Dissection**	**62%**	**2%**	**36%**	**0%**
Ballesteros and Ramirez, 2008	Injecting with synthetic resins	52%		42.2%	5.8%
Lujinovic et al. 2005	Dissection	65%		35%	
Lujinovic et al. 2005	Angiography	71%		29%	
Reig and Petit, 2004	Dissection	62%		38%	
Cavalcanti et al. 1995	Dissection	60%		38.18%	
Pepler (in European population) 1960	Angiography	62%		38%	
Pepler and Meyer (in Bantu population) 1960	Angiography	26%		74%	

lation are referred to as “normal variants”, while those with less than 1% prevalence, are considered as coronary “anomalies” (Angelini et al., 1999). Patients with coronary artery anomalies are often asymptomatic, but some symptoms associated with coronary anomalies include angina pectoris, syncope, ventricular tachycardia, cardiac arrest and myocardial infarction (Rigatelli and Rigatelli, 2003). Thus most coronary artery anomalies only occasionally cause critically severe clinical events, and are otherwise compatible with a normal life. Coronary artery anomalies have been classified into 4 classes to facilitate their clinical management and follow-up (Rigatelli and Rigatelli, 2003). They are thus classified into 4 classes namely benign, relevant, severe and critical based on their clinical relevance (Rigatelli and Rigatelli, 2003).

Ectopic origins of both the LAD and the LCx arteries from separate ostia in the right sinus of Valsalva have been described, the anomaly being revealed on angiography (Yang and Ma, 2010). The patient did not need any specific therapy for the anomaly and only required regular follow-up. According to the above mentioned classification, this anomaly falls under Class I, i.e., benign.

Similarly, origin of LCx artery from the right sinus of Valsalva as seen in the present study is a coronary artery anomaly belonging to Class I, which is the class of benign coronary artery anomalies. It is usually clinically silent, but may be associated with various degrees of atherosclerotic disease. Once detected, this coronary artery anomaly needs the clinician to follow up the case regularly. A retroaortic circumflex artery is prone to accidental compression during surgery for valve replacement. It may also be damaged by sutures placed in the mitral annulus during the valve replacement or annuloplasty (Taylor et al., 1989). The operating surgeon should watch out for anomalous retroaortic position of circumflex artery during such surgeries (Rigatelli and Rigatelli, 2003).

In the present study, in 20% of hearts the SA nodal artery, and in 24% of hearts the AV nodal artery, were branches of LCx branch of left coronary artery. The incidence of SA nodal artery taking origin from LCx branch of LC artery has been found to range between 20% to 45% by different authors (Kalpana, 2003; Bezerra et al., 2008; Pejkovic et al., 2008). In the present study, in case of occlusion of LC artery, in 20% of the hearts the SA node would be affected. Thus, in comparison with findings by other authors, fewer hearts may show ischemia of SA nodal tissue in case of occlusion of the LC artery in the present study. In 8% of the hearts studied, the LC artery supplied both SA and AV nodes. When both the nodal tissues are irrigated by the same coronary artery, in case of occlusion of that artery the effect of the ischemia on the conducting system could be severe enough to result in cardiac arrest.

The term ‘dominant’ is used to refer to that coronary artery which gives origin to the “posterior interventricular artery” (Standring, 2008). In the present study, the posterior interventricular artery was a branch of the LC artery in 12% hearts. Thus, left coronary dominance using the parameter of “coronary artery giving origin to posterior interventricular artery” can be said to be of 12%.

The concept of coronary artery predominance is also based on which artery crosses the crux of heart, which is the point where the coronary sulcus, atrioventricular and interventricular sulci meet (Ahmed et al., 1972). In the present study LCx branch of LC artery crossed the crux in 16% hearts. Thus LC dominance using the parameter of “coronary artery crossing the crux” is found to be 16%.

ACKNOWLEDGEMENTS

Institution responsible for research support and/or financial support: Dr.D.Y.Patil Medical College, Pimpri, Pune, Maharashtra, India. 411018. This work was carried out in the Dissection Hall of the said Medical College. No separate financial support was obtained. Conflict of Interest: none declared.

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