International Journal of Anatomy and Research,
Int J Anat Res 2017, Vol 5(1):3611-17. ISSN 2321-4287
DOI: https://dx.doi.org/10.16965/ijar.2017.119

Original Research Article

ANATOMICAL VARIATION IN BRANCHING PATTERN AND DOMINANCE IN CORONARY ARTERIES: A CADAVERIC STUDY

Vandana Ravi *[1], Tejesh S [2].

[*1] Assistant Professor, Raichur Institute of Medial Sciences, Raichur, Karnataka, India.

[2] Resident, Navodaya Medical College, Raichur, Karnataka, India.

ABSTRACT

Background : The human heart is supplied by two right and left coronary arteries which arise from ascending aorta. Left coronary artery is wider in diameter and its branches supplies greater volume of myocardium & larger part of interventricular septum. Right coronary artery supplies right atrium and right ventricle. Detailed appreciation of normal origin,course,branches and myocardial distribution of these vessels is vital so that variation of normal anatomy can be more easily recognized and it is must to identify the course of coronary artery disease and perform therapeutic, radiodiagnostic and surgical procedure.

Result: Study was conducted on 30 heart specimens. Coronary arteries (CA) were dissected to know origin, location of ostia in relation to sinotubular junction (STJ) & variation in branching pattern. No variation was found in the origin, but in 10% of specimen's right coronary ostia was above the STJ and 90% of specimens it was below the STJ and in 93.3% of specimens left coronary ostia was below STJ and in 6.6% it was above STJ. The third coronary artery was found in 26.6% of specimens. Right coronary dominance was observed in 83.3%, Lt dominance in 13.3% and co-dominance in 3.3% of specimens. The mean length of trunk of LCA was found to be 14.5±4.42mm, minimum length we observed was 5mm,which is the shortest length of trunk of LCA reported so far and maximum length observed was 25mm. Bifuracation, trifurcation, tetrafurcation and pentafurcation of LCA was observed in 80%, 13.3%, 3.3%, and 3.3% of the specimen respectively.

Conclusion: An intimate knowledge of the coronary arteries the "Crown" of the heart and its variations is prerequisite for cardiac surgeons for proper diagnosis and treatment of cardiac ailments and for radiologists to refine the image interpretation.

KEY WORDS: Coronary, Sinotubular junction, Myocardial Bridge.

Address for Correspondence: Dr Vandana Ravi, Assistant Professor, Raichur Institute of Medial Sciences, Raichur, Karnataka. **E-Mail:** drvandanar@gmail.com

Access this Article online

Quick Response code

DOI: 10.16965/ijar.2017.119

Web site: International Journal of Anatomy and Research
ISSN 2321-4287
www.ijmhr.org/ijar.htm

Received: 21 Jan 2017
Peer Review: 22 Jan 2017
Revised: 12 Feb 2017
Accepted: 24 Feb 2017
Published (O): 31 Mar 2017
Published (P): 31 Mar 2017

INTRODUCTION

The coronary system of arteries consisting of two arteries is appeared to be recent evolutionary acquisition, fish and amphibians have only one coronary artery and only 60% avian species have2 coronary arteries [1].

The human heart is supplied by two coronary arteries and their branches, which issue from ascending aorta from its anterior aortic sinusand left posterior aortic sinuses. The two arteries as indicated by their name form an oblique inverted crown, with anastomotic circle in the atrioventricular sulcus connected by marginal and interventricular loops intersecting at the cardiac apex.They usually run subepicardially but those in the atrioventricular and interventricular sulci are deeply sited, occasionally

hidden by myocardium. The left coronary artery (LCA) wider in diameter than the right coronary artery (RCA), gives normally left circumflex and left anterior descending artery. LCA supplies greater volume of myocardium larger part interventricular septum and most of the left heart. RCA arises from anterior aortic sinus, it gives a conus, marginal and posterior interventricular branches and supplies right atrium, ventricle. The term dominant is used to refer the coronary artery which gives posterior interventricular branch supplies the posterior part of interventricular septum and part of posterolateral wall of left ventricle.[2] An intimate knowledge of the coronary arteries the "Crown" of the heart and its variations is prerequisite for cardiac surgeons for proper diagnosis and treatment of cardiac ailments and for radiologists to refine the image interpretation.

MATERIALS AND METHODS

The study was carried out on 30 adult cadaveric heart specimens collected from the department of Anatomy of our Institution. Heart Specimens were obtained from the cadavers dissected for undergraduate students. The specimens were numbered 1 to 30.

Dissection method was followed

1. Gross dissection

2. Micro dissection method

Gross dissection was done with following instruments

Forceps (pointed, blunt and toothed)

Scalpel

Scissors

The coronary arteries were traced through epicardium and subepicardial adipose tissue. The observations were made with respect to its origin, level of ostium, in relation to sinotubular junction, length of trunk of LCA, normal branching pattern, variations in branching pattern, course,dominance and presence or absence of myocardial bridge. To see the location of ostia the ascending aorta was transversely sectioned approximately 1cm above the commissure aortic leaflets. The aorta was then longitudinally opened at the level of right posterior aortic sinus which enabled us to analyse the level and number of ostia with respect to sinotubular junction [4].

After dissection ostia were cleaned and then photographed using digital camera.

Micro dissection: Micro dissection was carried out by using hand lens to trace the terminal branches.

RESULTS AND DISCUSSION

It was observed that in all the 30 heart specimens 3 aortic sinuses were present and all the ostia were related to aortic sinuses. The RCA was found to be arising from the anterior aortic sinus and LCA from left posterior aortic sinus and double ostia were found in some of the specimens. ostia were observed in relation to STJ, as shown below.

Table 1: Location of Ostia of Rt & Lt coronary arteries.

Name of artery	Above STJ		Below STJ	
	No	%	No	%
Rt CA	3	10	27	90
Lt CA	2	6.6	28	93.3

Branches of RCA: Variations were found in the branches of RCA which are mentioned below.SA nodal artery usually arises from right coronary artery,but there were variations in its origin. It was originating from Rt CA in 24(80%) from Lt CA in 5(16.6%) specimens.In 1 specimen it was arising from both arteries (fig 1).

Rt conus artery arising from RCA in 22specimenss (73%) and from a separate located in anterior aortic sinus in 8 specimens (26.6%).So the presence of third coronary artery was observed in 26.6% of the specimens (fig-2). No variation was observed in the origin and course of right marginal artery.

Variation was observed in the origin of posterior interventricular artery (PIVA), in some specimens it was arising from Rt coronary artery as usual, in some specimen it was originating from Lt coronary artery and in some it was arising from both arteries.

Table 2: Coronary dominance.

Rt coronary dominance		Lt coronary dominance		Co dominance	
No	%	No	%	No	%
25	83.3	4	13.3	1	3.33

Left coronary dominance was observed in 13.3% and co-dominance in 3.3 %.(fig-3)

During the study we have observed variation in the course of RCA, immediately after its origin trunk of RCA presented 'U' shaped loop (fig-4) .

Left coronary artery: Trunk of LCA normally terminates by dividing into left anterior descending and circumflex branches; in this study we observed variations in the termination and number of branches of LCA

Table 3: Variations in the division & length of LCA.

Name of artery	Bifurcation		Trifurcation		Tetrafurcation		Pentafurcation		Length of trunk (Mean±SD)	Range
LCA	NO	%	NO	%	NO	%	NO	%	14.5±4.42mm	5-25mm
	24	80	4	13.3	1	3.3	1	3.3		

Normally the LCA bifurcates into left anterior descending artery (LAD) and left circumflex artery (Cx) but variations were also observed in the branches of bifurcation of LCA. (Tabe-4)

Table 4: variations observed in the branches of bifurcation of LCA.

LAD&Cx		LAD & Diagonal		LAD &Common trunk	
NO	%	NO	%	NO	%
15	50	5	16.6	4	13.3

In all trifurcation LCA was dividing into one LAD, one diagonal and one circumflex branch. In tetrafurcation it was dividing into one LAD, two diagonal and circumflex arteries. In pentafurcation LAD, three diagonal and one circumflex branch. (Fig-5). Variation in the origin of Circumflex branch was also found, it was arising from LCA in 23 specimens (76.6%) & from diagonal artery in7 specimens (23.3%).

Myocardial bridge was observed during the study on posterior interventricular artery (PIVA) in 6 specimens (20%) and left anterior descending artery in 7 specimens (23.3%) respectively.

Fig. 1: Showing SA nodal artery from both RCA and LCA.

Fig. 2: Showing 3rd Coronary Artery.

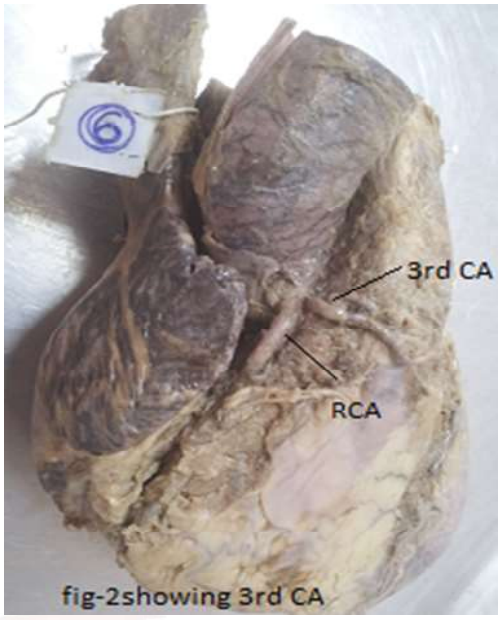


Fig. 3: Showing tri. Tetra and penta furcations.

Fig. 4: Showing loop of trunk of RCA

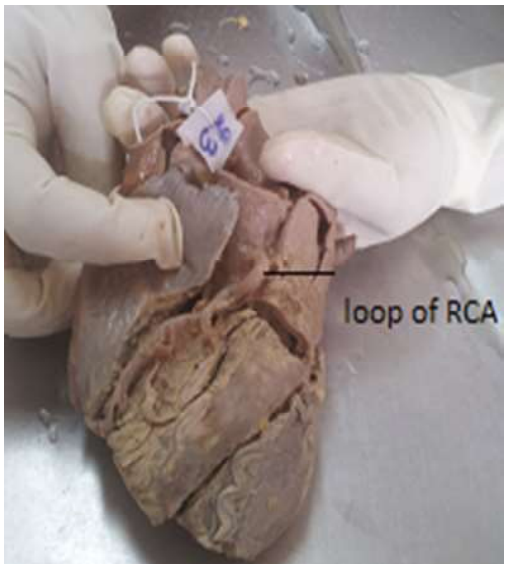
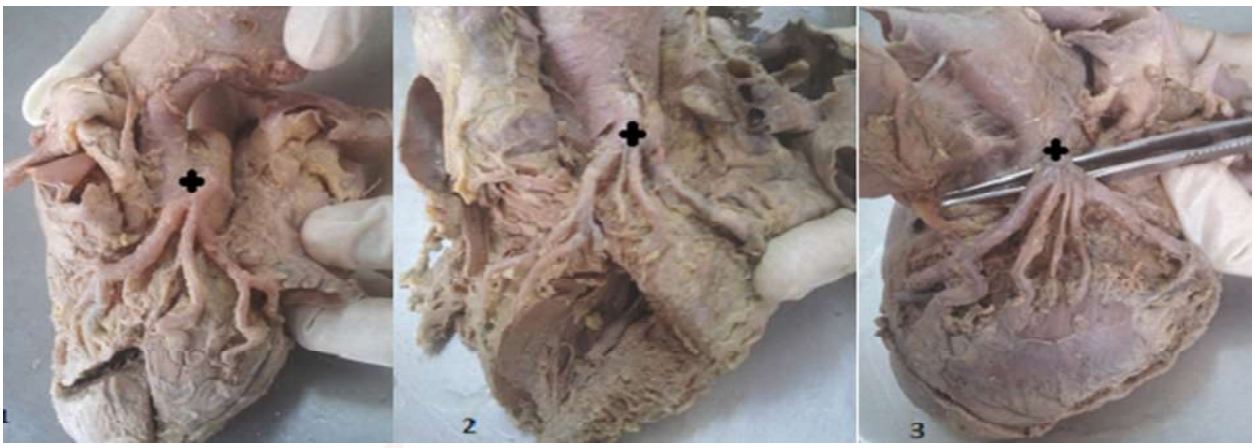


Fig. 5: Showing tri, tetra and penta furcation



DISCUSSION

The origins of coronary arteries show great variability about 90% of anomalies were anomalies of origin. [4] Occasional cases of documenting the anomalous origins of coronary arteries from pulmonary artery and from the right position (non-coronary sinus) [5-7].

In the present study we did not observe any anomalous origin of coronary artery. In all the specimens right coronary artery was arising from the anterior aortic sinus and left coronary artery was arising from left posterior aortic sinus. Knowledge of location, position and ostia with respect to sinotubular junction is important for performing successful coronary angiography. Coronary ostia can be located below, at or above the sinotubular junction. Ostia located just above the aortic sinus were considered variants of normal origin. It is difficult to insert the catheter tips in patients with the ostium above the level of sinotubular junction and during open aortic surgeries. It is very difficult to cannulate the vessels which arise from the anomalous ostia [8].

The level of ostium was studied in this work in relation to sinotubular junction. Similar study was done by Johannes Piegger et al(2001), Muralimanju et al(2006), Markou et al(2007), Louis I

Bezold(2010), Subhash et al(2010) [3].

Muralimanju et al (2006) reported that the right coronary artery was below the sinotubular junction in 16% and was above sinotubular in 2% of cases. Subhash et al reported the location is 89%.In 2011Bhimalli Shilpa et al reported that the right coronary arising from anterior aortic sinus below the sino-tubular in 84% of specimens.In a study by Kalpana R A the author observed that the right coronary ostium was present below sinotubular junction in 90%, at STJ in 9% and above STJ in 1% of cases [9-12].

In the present the right coronary ostia was below the sinotubular junction in 90% and above sinotubular junction was 10%. The left coronary ostium was situated below the sinotubular junction is 93.3% and above sinotubular junction was in 6.6% of specimens.Our observations were nearer to the observations reported by KalpanaRA and Bhimalli shilpa.

Generally there is only one orifice in the anterior aortic sinus from which the right coronary artery originates; however more than one orifice is sometimes observed. It has been observed that right conus branch originate from this accessory orifice; in this case, the conus branch is called the 3rd coronary artery. Its frequency of occurrence varies (7.6%-51%) and some ethnic differences have been observed to exist.. Recently Cademartiri et al reported in two 64-slice computed tomography coronary angiography studies examining the origin of right conus branch that this artery arises from a location proximal to the right coronary artery and aortic ostium and aorta.[13] Bhimalli Shilpa et al reported that the conus artery arose in 36% of cases from a separated ostium(3rd coronary artery) in the anterior aortic sinus of Valsalva. In another study by Kalpana RA the author observed the presence of 3rd coronary artery in 24%of specimens out of 100 dissected heart specimens. Pinar kosar et al in 2009 observed

presence of 3rd coronary artery in 22% of specimens. UdayaSankri et al reported the presence of 3rd coronary artery in 23.3% of his specimens [3, 11, 12, 14].

In this present study the presence of 3rd coronary artery was observed is 26.6% of specimens. This report go in hand with observations made by Kalpana R A (2003) 24%, Pinar kosar et al (2009) 22% and Udayasankri(2011) 23.3% and differences with Bhimalli Shilpa et al (2011) 36% and it could be due to geographic variations [3,11,12,14]. Kurjia et al noted that establishing the location and origin of the right conus artery in relation to the right ventricular outflow tract radiological prior to surgery is essential for the treatment and tetralogy of Fallot [15]. SA nodal artery is the branch of right coronary artery. Many authors have reported variations in the origin of SA nodal artery. Uemura et al observed the origin of SA nodal artery from right coronary artery in more than 60%and left coronary artery in less than 44%of cases. [16] Lakshimi Ramanathan et al reported the origin of SA nodal artery was mainly from right coronary artery in 53.3% and left coronary artery is 42.66% and only in 4.33% cases was arising from both coronary arteries. [17]Bhimalli Shilpa et al reported the origin of SA nodal artery from right coronary artery in 66.66% and from left coronary artery in 28% of the specimens [11].

In the present study the origin of SA nodal artery from right coronary artery was observed in 60% of specimens which is similar to results reported by Uemura in 1999(60%). [16] In 16% of specimens it was arising from left coronary artery which was much less frequent than report observed by Uemuraet al (1999) 44%, Lakshmi Ramanathanet al (2011) 42.66% and Bhimalli Shilpa (2011) 25% [11, 17].

Ortale et al (2004) examined the dominant circulation in 40% cadaver hearts reported 62.5% of right dominance, 12.5% left dominance and co-dominance 25% of specimens,Kurjia et al in (1986) reported 46% of right dominance, 14% of left dominance and 40% of co-dominance in their studies in 119 cadaver heart specimens. Loukas et al in 2006 reported 55% right dominance, 24% left dominance and 33% of co-dominance in their studies. [15, 18, 19] Fazligullari et al reported right dominance is 42%, left dominance is 14% and co-dominance is 44% in their study. Bhimalli shilpa et al reported right dominance is 66%, left dominance is 23.33% and has not reported about the co-dominance [11, 13].

Table 5: Dominant pattern observed by various authors.

Authors	Rt dominance	Lt dominance	Co dominance
Kurjia et al	46%	14%	40%
Ortale et al	62%	12.50%	25%
Loukas et al	55%	24%	33%
Fazligullari et al	42%	14%	44%
Bhimalli et al	66%	23.30%	-
Calcavanti et al	88.18%	11.80%	-
Kalpana et al	89%	11%	-
Present et al	83%	13.30%	3.30%

The present study shows the right dominance in 83% specimen and left dominance is 13.3% of specimens. Which are near to the observations made by Calcavanti et al and KalpanaRA. [12, 20] In some specimens we observed more than one PIVA. We also observed co-dominance in 3.3% of specimens which was very less when compared to the studies done by Kurjia et al, Loukas et al, Ortale et al and Fazligullari et al. [13, 15, 18, 19].

The length of the trunk of left coronary artery in general varies from 2 – 12mm but it may be upto 30mm. [21 Green G E et al studied the length of left main coronary artery in 50 consecutive autopsy specimen in which 48% of cases, the length of left coronary artery was 10mm or less and in remaining 52% of cases, the length was up to 25mm. The short left main coronary artery explain some failures of adequate coronary perfusion. During aortic valve surgery, myocardial perfusion depends on the placement of one or more cannulas in the coronary arteries. In this regard, the length of left main coronary artery prior to its bifurcation is particularly important [22].

P Dharmender reported the mean length of left coronary artery was found to be 9.2± 0.31mm [23]. Ballesteros LE et al reported average length of trunk of left coronary artery was 6.48± 2.57mm. Fox et al have reported the shortest length to date 5.5mm [24].

Our study showed the average length of trunk left coronary artery was 14.5±4.42mm shortest length we have observed was 5mm which is

even shorter than the shortest length till date reported by the author Fox et al, maximum length observed was 2.5mm in our specimen. Short

trunk of left coronary artery could be at risk during aortic valve replacement surgeries. The catheter may be inserted into one of the terminal branches, thereby producing an ischemic area, which can lead to arrhythmia, myocardial ischemia or both. Short trunk also been considered as a risk factor in developing coronary atherosclerosis [24].

The termination of left main coronary artery varies from 2 or more branches and accordingly named as bifurcation, trifurcation, tetrafurcation and pentafurcation. Previous studies have reported wide variations in branching of trunk of left coronary artery and have found greater prevalence of bifurcated expression. Table 6 shows report of various authors in termination of trunk of left coronary artery.

Table 6: Termination of trunk of LCA.

Authors	Bifurcation	Trifurcation	Tetrafurcation	Pentafurcation
Baptista et al	54.70%	38.70%	6.70%	-
Calcavanti et al	60%	38.18%	-	-
Kalpana RAet al	47%	40%	11%	1%
Bhimalli et al	56.66%	33.30%	8.30%	1%
LE Ballesteros	70%	36%	5.80%	-
P Dharmendra	58.06%	35.48%	6.45%	-
Present study	80%	13.30%	3.30%	3.30%

In the present study we observed higher frequency of bifurcation (80%) compared to the previous reports (Table-6) and trifurcation was much less frequent than the previous reports mentioned in the Table-6. Normally left coronary artery bifurcates into LAD and circumflex branches, but in our study we have come across, variation in the branches of bifurcated trunk of left coronary artery (table-6), where trunk of left coronary artery was dividing into LAD and circumflex 50% of specimens, LAD and diagonal in 12.5% and LAD and common trunk or stem in 16.6 of specimens. Such observations of LAD and common stem from trunk of LCA have not been reported so far. During our study we also observed variations in the origin of circumflex branch, in 23.3% of specimens it was arising from diagonal branch. Such variation has not been reported so far in the literature. Rajani singh et al, Ballesteros LE et al (2008), Fazligullari et al (2010), David M Fiss (2007), the study.[42,22,3]

In present study also we have observed the presence of myocardial bridges over LAD and PIVA in 25% and 29.16% of specimens respectively.

CONCLUSION

Rate of coronary artery related disease in increasing by leaps and bounds in recent times. The anatomy of coronary arteries has recently been re-emphasized in association with the use of coronary arteriography. The high degree of variability of the coronary arteries and their branches must be carefully observed and studied from anatomical, pathophysiological, diagnostic and therapeutic viewpoints. The advances made in coronary artery bypass surgery and newer methods of myocardial revascularisation demands a complete knowledge of normal and variable anatomy of coronary artery, therefore the present study was undertaken. Variations of coronary arteries mentioned in the present study along with new variant of myocardial bridge makes this study of paramount importance in management of heart disease for cardiac surgeons and variant anatomy for anatomists.

ABBREVIATIONS

Cx- Circumflex
CA- Coronary Artery
LAD- Left Anterior Descending
Lt – Left
LCA- Left Coronary Artery
Mm- Millimeter
PIVA- Posterior Interventricular Artery
RCA- Right Coronary Artery
Rt- Right
STJ- Sinotubular Junction
SA na- Sino Atrial Nodal Artery

Conflicts of Interests: None

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How to cite this article:

Vandana Ravi, Tejesh S. ANATOMICAL VARIATION IN BRANCHING PATTERN AND DOMINANCE IN CORONARY ARTERIES: A CADAVERIC STUDY. Int J Anat Res 2017;5(1):3611-3617. **DOI:** 10.16965/ijar.2017.119