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A Study ofAnatomical Variations ofCoronary Arteries inNorth Indian Population

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Abstract: *The human heart is vascularized by right and left coronary arteries. The current study was done to assess the normal patterns of coronary arteries with reference to its predominance, branching pattern, variations and anomalies.Fifty two adult North Indian cadaveric hearts from both genders fixed with 10% formalin were obtained from the Department of Anatomy, King George's Medical University, Lucknow, Uttar Pradesh, India. The exit points and various branching patterns of right and left coronary arteries were observed.Right coronary artery was originating from the anterior aortic sinus in 100%while left coronary artery took origin from left posterior aortic sinus in 96.15% and anterior aortic sinus in 3.85%.Right coronary artery gave origin to right marginal artery in 96.15% while absent in 3.85% specimen. Posterior interventricular branch coming from right coronary artery was noted in 92.31%. Accessory posterior interventricular branches were also seen in 11.54%. SA Nodal artery was noted in 34.62%, right conus artery in 57.69% and third coronary artery in 19.23%.Termination of left coronary artery was seen as bifurcation in 65.38% while trifurcation in 34.62%. Left marginal artery, a branch of circumflex artery was visualized in 15.38% specimens. Right dominance was present in 88.54%, left dominance in 7.69% andco-dominance was present in 3.85% specimens.*

Variations in branching pattern of coronary arteries as reported in present study necessitate its importance for proper diagnosis and management of coronary artery disease.

Keywords: *Right coronary artery,Left coronary artery,Aortic sinus,Dominance,Variation.*

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I. Introduction

The right and left coronary arteries issue from the ascending aorta in its anterior and left posterior sinuses. The levels of the coronary ostia are variable; they are usually at or above cuspal margins. The two arteries, as indicated by their name, form an oblique inverted crown, in which an anastomotic circle in the atrioventricular groove is connected by marginal and interventricular (descending) loops intersecting at the cardiac apex [1]. The coronary arteries supply both the atria and the ventricles; however, the atrial branches are usually small and not readily apparent in the cadaveric heart. The ventricular distribution of each coronary artery is not sharply demarcated [2].

The right coronary artery(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. Usually it gives a right conus branch (RCoA), a right marginal branch and a posterior interventricular artery (PIVA). Small branches arising from RCA are nodal (60% cases) and right atrial. Third Coronary Artery (TCA) is a direct branch from the right aortic sinus without any observable common trunk with the right coronary artery [3]. It is also called as Second right coronary artery [3], Supernumerary coronary artery, right Vieussen's artery or Adipose artery [4]. It acts as an important bridge for collateral circulation between right and left coronary system as it frequently anastomoses with either conal branch to form annulus of Vieussens [1] or anterior interventricular branch of left coronary artery [5].

Left coronary artery(LCA)has a short common stem and is generally divided into two main branches (bifurcation); the anterior interventricular branch (AIV) and the circumflex branch (Cx). In addition to these branches (14–40%), a third branch, known as the median or inter median artery, has been reported to exist [6,7]. The median artery can arise from the LCA (trifurcation or quadrifurcation) or from the proximal part of the anterior interventricular branch or circumflex artery. 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 [8]. Left marginal branch of the circumflex artery follows the left margin of the heart and supplies the left ventricle. Two or three diagonal and anterior septal branches arise from anterior interventricular branch. Left conus artery may be present and arise from left coronary, or circumflex or anterior interventricular branch. The dominance of the

coronary artery system is defined according to the coronary artery that supplies the back of interventricular septum or produces the posterior interventricular branch [9].

Coronary artery disease is one of the major causes of death in developed countries. The incidence of coronary artery disease is also increasing day by day in developing countries because of sedentary life style, hypertension, diabetes mellitus and other diseases. Therefore, a basic knowledge of coronary artery is essential for various diagnostic and interventional procedures. The present survey was therefore conducted to find out the anatomical variations in LCA and RCA with reference to its branching pattern and predominance in North Indian population.

Coronary artery anomalies (CAAs) are a diverse group of congenital disorders whose manifestations and pathophysiological mechanisms are highly variable. The subject of CAAs is undergoing profound evolutionary changes related to the definition, morphogenesis, clinical presentation, diagnostic workup, prognosis, and treatment of these anomalies [10].

II. MaterialAnd Method

Fifty two adult North Indian cadaveric hearts of both genders (aged 24–68 years) fixed with 10% formalin were obtained from the Department of Anatomy, King George's Medical University, Lucknow, Uttar Pradesh, India. The epicardium layer was detached by dissection to visualize the coronary arteries. The exit point of the left coronary artery (LCA) from theaorta, the courses and variations of the anterior inter ventricular and circumflex branches, and the existence of the median artery wasinspected. The exit points of the right coronary artery (RCA) andconus branch, the course of the marginal and posterior interventricular branches, other branchesof RCA and existence of 3rd coronary artery was observed. To determine thedominant circulation, the artery supplyingthe posterior inter-ventricular sulcus was investigated. A tag with a specific number was attached to each heart and photographs were taken.

III. Results

It was observed that RCA was originating from the anterior aortic sinus in all the hearts i.e. 52 (100%). The exit point of RCA was at the sinotubular junction in 50 (96.15%) hearts and above sinotubular (ST) junction in 2(3.85%) heart.Dominance (right or left) of heart was determined by branch of RCA or LCA that occupies the posterior part of interventricular sulcus.Right dominance was present in46 (88.54%) hearts, as the branch to this sulcus was coming from PIVA of RCA(Fig. 1a).Left dominance was reported in 4 (7.69%) hearts, as the branch to posterior part of interventricular sulcus was coming from Cx artery which is a branch of LCA (Fig. 1b). In a codominant heart, posterior part of interventricular sulcus was supplied by branches of both the RCA and Cx branch of LCA. Co-dominance was present in 2 (3.85%) heart(Fig. 1c).

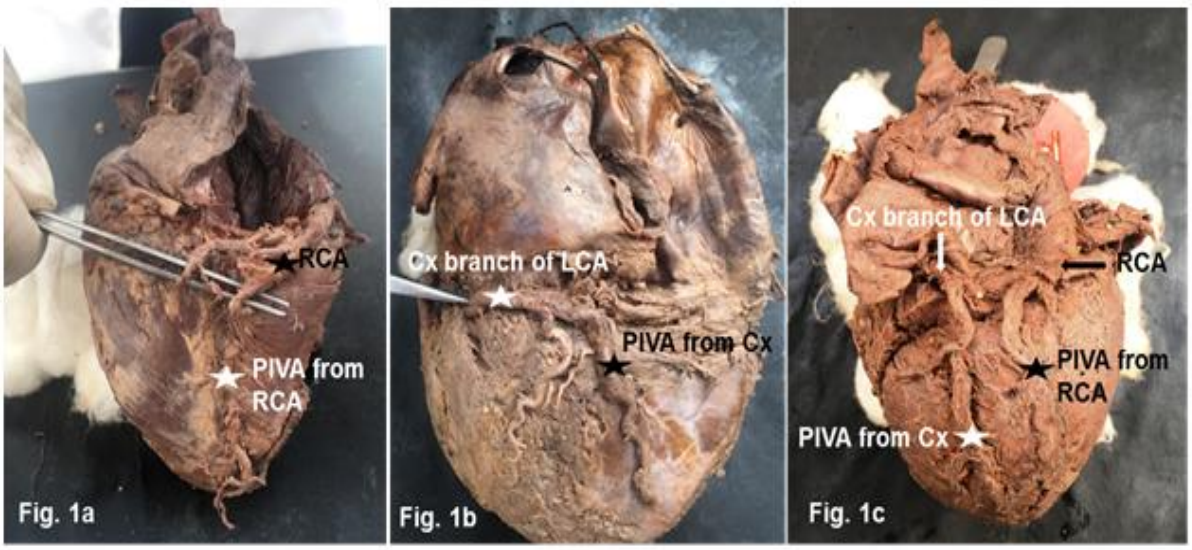


Fig. 1: Photographs showing various patterns of dominance of heart **a**. Right dominance **b.** Left dominance **c.** Co-dominance (RCA: right coronary artery, LCA: left coronary artery, PIVA: posterior interventricular artery, Cx: circumflex branch)

Regarding branches of RCA, right marginal artery was observed in 50 (96.15%) specimen while it was absent in 2 (3.85%) case in which right conus artery (RCoA) was big (Fig.2). PIVA was noted in 48(92.31%) hearts while it was absent in 4 (7.69%) cases in which left dominance was present. Parallel branches to PIVA or Accessory posterior interventricular arteries (APIVA) were also seen in 6 (11.54%) specimen(Fig. 3). Nodal artery (NA) was noted in 18(34.62%), RCoA in 30 (57.69%) (Fig. 4) and TCA in 10 (19.23%) hearts(Fig. 5).

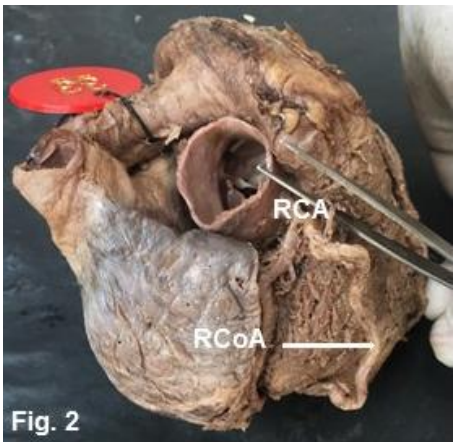
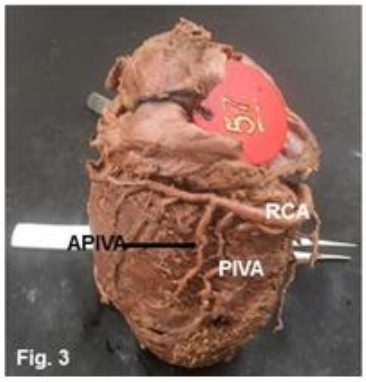
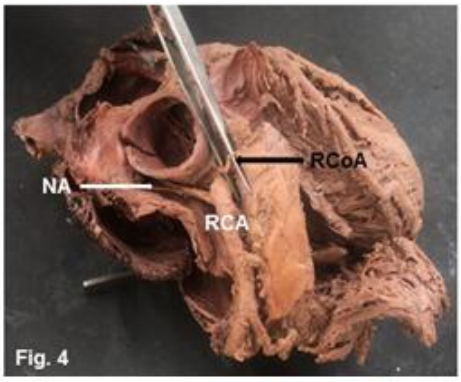


Fig. 2: Photograph showing absence of right marginal artery and big right conus artery (RCoA)
RCA: right coronary artery





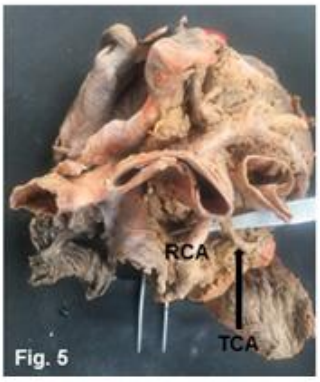
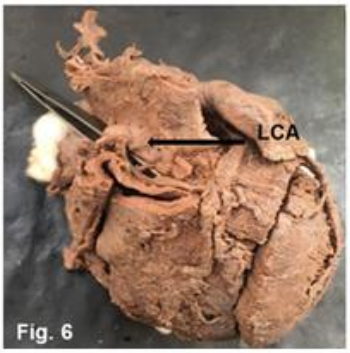
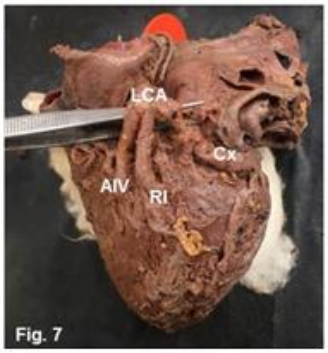


Fig. 3: Photograph showing accessory posterior interventricular arteries (APIVA)
RCA: right coronary artery, PIVA: posterior interventricular artery
Fig. 4: Photograph showing nodal artery (NA) and right conus artery (RCoA) coming from right coronary artery (RCA)
Fig. 5: Photograph showing third coronary artery (TCA) arising from right aortic sinus
RCA: right coronary artery

On examination, the LCA was seen to be originating from left posterior aortic sinus in 50 (96.15%) hearts and anterior aortic sinus in 2 (3.85%) heart (Fig. 6). The exit point of LCA was at the sinotubular junction in 44 (84.62%) hearts, just below ST junction in 6 (11.54%) and above ST junction in 2 (3.85%) heart. Bifurcation of LCA into anterior interventricular and circumflex branches was noted in 34 (65.38%) hearts. Ramus intermedius (RI) or median artery was noticed in 18 (34.62%) specimen (trifurcation) that coursed on the front wall of the left ventricle (Fig. 7). Left marginal artery (LMA), a branch of circumflex artery was detected in 8 (15.38%) specimens while left conus artery (LCoA) was seen in 2 (3.85%) case which was coming from anterior interventricular artery (Fig. 8). Posterior interventricular branch going into posterior part of interventricular sulcus was originating from circumflex artery in 4 (7.69%) specimen which determine the left dominance in these 4 (7.69%) hearts.





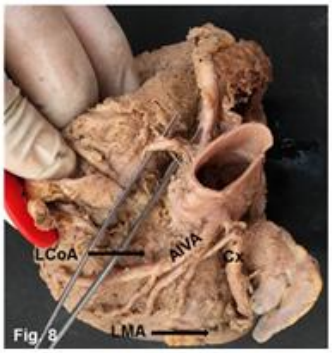


Fig. 6: Photograph showing origin of left coronary artery (LCA) from anterior aortic sinus
Fig. 7: Photograph showing trifurcation of left coronary artery (LCA) into anterior interventricular branch (AIV), circumflex branch (Cx) and ramus intermedius (RI)
Fig. 8: Photograph showing left marginal artery (LMA) coming from circumflex (Cx) and left conus artery (LCoA) from anterior interventricular artery (AIVA)

IV. Discussion

Variations in the branching patterns and distribution of the coronary arteries are common. In the most common right dominant pattern, present in approximately67% of people, the RCA and LCA share about equally in the blood supply of the heart. In approximately 15% of hearts, the LCA is dominant in that the posterior IV branch is a branch of the circumflex artery. There is codominance in approximately 18% of people, in which branches of both the right and left coronary arteries reach the crux of the heart and give rise to branches that course in or near the posterior IV groove. A few people have only one coronary artery. In other people, the circumflex branch arises from the right aortic sinus. Approximately 4% of people have an accessory coronary artery [2].

According to Snell [11], variations in the blood supply to the heart do occur, and the most common variations affect the blood supply to the diaphragmatic surface of both ventricles. Here the origin, size, and distribution of the posterior interventricular artery are variable. In right dominance, the posterior interventricular artery is a large branch of the right coronary artery. Right dominance is present in most individuals (90%). In left dominance, the posterior interventricular artery is a branch of the circumflex branch of the left coronary artery (10%). Nearly similar findings were observed in our study i.e. right dominance in 92.31% and left dominance in 7.69% cases.Schlesinger [12] reported right dominance in 48% of hearts, left dominance in 18% and a balance in 34%. The dominance of right coronary artery was present in 69.09%, of left coronary artery in 11.82% and 19.09% of the hearts had balanced distribution [13]. Nonetheless, other authors have reported much higher percentages for right dominance i.e. between 60% and 80% [14,15]. The present study also reported a higher percentage of right dominance (88.54%) which runs parallel with these studies.

It has been reported that the posterior interventricular branch originates from the circumflex branch of LCA at a rate of 7.5%–20% [16,17]. Our study also establishes similar findings with these studies i.e. 7.69%. Parallel branches to PIVA (accessory PIVA) were noted in 6% of the specimens by Kalpana [15].While it was noted in 11.54% of specimens in the present study.

The location, level and size of the ostium is very important in the successful performance of a coronary angiogram [10].Kalpana [15] noted that the right coronary ostium was present in all the specimens in the right anterior aortic sinus and it was below sinotubular junction (STJ) in 90% specimens. Similarly in our study, RCA was originating from the anterior aortic sinus in 100% hearts but the ostium was at the sinotubular junction in 96.15% hearts.LCA was arising from left posterior aortic sinus in 96.15% while from anterior aortic sinus in 3.85% hearts and the level of ostium was found to be maximum (84.62%) at STJ level. This finding is contradictory to Kalpana [15] who observed 100% LCA originating from left posterior aortic sinus of which 80% were noted below STJ. Difficulty in manipulating the catheter tips will be considerably higher in patients with the ostium above the level of STJ [18].

SA nodal artery usually (51-58%) comes from RCA [15,19,20]but we observed it coming from RCA in only 34.62% cases. The right conus artery and the right marginal artery were present in 100% specimens in a previous study in South Indians[15] but we observed the right conus artery in 57.69% and right marginal artery in 96.15% cases. The results of our study done in North Indian population are comparable with that of Kalpana [15]which was carried out in South Indians (Table 1).

The right coronary artery arises from a single orifice in the right aortic sinus. The most frequent variation is the presence of an accessory orifice for the conal artery, which is even given a name of its own: the third coronary artery [21].Its prevalence varies between 33% and 51% [21-23]. The orifice of the conal artery is usually in front of the coronary orifice or at the same level. The diameter varies between 0.5 and 1.5 mm.Its

frequency of occurrence varies (7.6%–51%), and some ethnic differences have been observed to exist [6,16].The conus artery may provide collateral blood flow to the heart when the left anterior descending artery is occluded [24].

The prevalence of third coronary artery has wide geographical differences. Occurrence of third coronary artery in different populations is as follows, Japanese – 36.8% [25], Kenyans – 35% [3], Bulgarians – 34.8% [4], Indians – 24% [15], English population – 15.8% [26], Iraqis – 8% [6] and Germans – 7.1% [27]. Report of these studies supports the hypothesis of Garg et al. [8]that coronary artery variations may have genetic basis. The incidence of third coronary artery in present study is 19.23% which is in consensus with the study previously done by Kalpana in South Indian population i.e. 24% [15].

The termination of left main coronary artery varies from 2 or more branches and accordingly named as bifurcation, trifurcation, tetrafurcation and pentafurcation. Banchi [22] described the termination of left main coronary artery varying between two to three branches with the most common pattern of the bifurcation being 64%. This is very close to the observationsof our study i.e. 65.38% hearts. Trifurcation was noted in 34.62% cases of present study which runs parallel with findings of Cavalcanti et al. [13]who observed trifurcation in 38.18% of heart specimens. He observed bifurcation in 60%, and in 1.82% anterior interventricular and circumflex branches were arising directly from aorta. Baptista et al. [28] observed that the left main coronary artery bifurcated in 54.7%, trifurcated in 38.7% and quadrifurcated in 6.7% of cases in Caucasians.Different results have been reported regarding the frequency of branching pattern of LCA (Table 2). Considering this, the normal division of LCA into two branches should be reassessed.Left conus artery was seen in 3.85% case which was coming from LCA in present study.

Table 1: Comparison of various parameters of coronary arteries with previous study

Parameters	**Kalpana (2003)**	**Present Study (2017)**
Population studied	South Indian	North Indian
Rt. Coronary Ostium (In Anterior aortic sinus)	100%	100%
Level of Rt. Coronary Ostium-		
Below STJ	90%	0%
At STJ	9%	96.15%
Above STJ	1%	3.85%
SA Nodal artery from RCA	56%	34.62%
Rt. Conus artery	100%	57.69%
Rt. Marginal artery	100%	96.15%
Third Coronary artery	24%	19.23%
Post. Interventricular artery-		
From RCA	89%	92.31%
From LCA	11%	7.69%
Accessory Post. Interventricular artery	6%	11.54%
Lt. Coronary Ostium-		
Lt. Posterior aortic sinus	100%	96.15%
Anterior aortic sinus	-	3.85%
Level of Lt. Coronary Ostium-		
Below STJ	80%	11.54%
At STJ	20%	84.62%
Above STJ	-	3.85%
Bifurcation of LCA	47%	65.38%
Trifurcation of LCA	40%	34.62%
Quadrifurcation of LCA	11%	-
Pentafurcation of LCA	1%	-
Lt. Conus artery	-	3.85%
Coronary dominance-		
Right	89%	88.54%
Left	11%	7.69%
Co-dominance	0%	3.85%

Table 2: Comparison of branching pattern of left coronary artery with previous studies

Branches	**Baptista [28] (1991)**	**Cavalcanti [13] (1995)**	**Kalpana [15] (2003)**	**Present Study (2017)**
One Branch	-	-	1%	-
Bifurcation	54.7%	60%	47%	65.38%
Trifurcation	38.7%	38.18%	40%	34.62%
Quadrifurcation	6.7%	-	11%	-
Pentafurcation	-	-	1%	-

Coronary arteries are essentially functional end arteries. A sudden block of one of the large branches of either coronary artery will usually lead to necrosis of the cardiac muscle (myocardial infarction) in that vascular area, and often the patient dies. Because coronary bypass surgery, coronary angioplasty, and coronary artery

stenting are now commonly accepted methods of treating coronary artery disease, it is incumbent on the student to be prepared to interpret still- and motion-picture angiograms that have been carried out before treatment. For this reason, a working knowledge of the origin, course, and distribution of the coronary arteries should be memorized [11].

V. Conclusion

As the arterial supply to the myocardium is very critical for the normal functioning of the heart, the variations which exist in its branches are gaining importance, more so, because of the angiographic procedures and the numerous bypass surgeries which are being done. Although numerous data on the variations of the coronary arteries have been reported, further exploration in this field would still enrich the knowledge on them and it is also essential in view of their great clinical significance.

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Conflict of interest: None to declare.

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