

## Variations in the Branching Pattern of Coronary Arteries: A Cadaveric Study

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### Abstract

**Introduction:** Heart is supplied by both right and left coronary arteries. A good knowledge of coronary artery branching pattern and their abnormal branching pattern that occur during fetal development is essential for clinicians. They are associated with high incidence of morbidity and mortality due to congenital heart diseases. Failure to recognize them can lead to inadequate or prolonged procedures and may also lead to misdiagnosis and complications such as accidental ligation. **Aim:** To find out the incidence of any anomalous coronary branching pattern. **Materials & Methods:** Properly embalmed and stored 50 human heart specimens were chosen for the present study. They were manually dissected to study the course and distribution of coronary arteries. The study was carried out in dissection hall, Department of Anatomy, Rajah Muthiah Medical College and Hospital (RMMC & H), Annamalai University, Chidambaram, Tamil Nadu, India. **Results:** We found that 48 (96%) heart specimens had normal coronary branching pattern and two (4.0%) anomalous coronary branching patterns out of 50 heart specimens. They are abnormal circumflex artery from posterior aortic sinus and arteria anastomotic a. infundibularis magna, an abnormal communication between anterior interventricular artery and right coronary artery. **Conclusion:** The knowledge about the abnormal branching pattern of coronary arteries will be useful to the cardiac surgeons to improve the knowledge of defects of coronary arteries and planning of angiography, coronary by bypass grafting and other surgical interventions, radiologists for refining interpretation of imagery and anatomists for teaching both undergraduates and post graduates.

**Keywords:** Coronary Artery; Left Coronary Artery; Right Coronary Artery; Coronary Artery Anomalies; Circumflex Artery.

### Introduction

Cardiovascular diseases (CVDs), especially coronary heart disease (CHD), are the leading cause of death all over the world. An estimated 17.5 million people died from CVDs in 2012, representing 31% of all global deaths. Out of this, an estimated 7.4 million deaths were due to coronary heart disease [1]. CVDs are reached

epidemic proportion and have now become the leading cause of mortality in India. The Global Burden of Disease study estimate of age-standardized CVD death rate of 272 per 100,000 population in India is higher than the global average of 235 per 100,000 population [2]. The heart is supplied by the right and left coronary arteries namely right coronary artery (RCA) and left coronary artery (LCA). These arteries encircle the base of the ventricles like a crown [3]. The RCA supplies whole of right atrium, most of the right ventricle except a strip along the anterior interventricular groove, postero-inferior one third of ventricular septum and sinoatrial (SA) node and atrioventricular (AV) node [4]. The LCA supplies most of the left atrium and left ventricle except a strip along the posterior and inferior surfaces of the heart and also supplies antero-superior two third of the ventricular septum [4].

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Coronary artery development is a delicate, complex, and finely tuned process that includes multiple interactions among many pathways, especially in the pericardium and the developing myocardium[5]. For instance, coronary arteries are derived from endothelial buds from the truncus arteriosus on the 14th day of intra uterine life. The coronary arteries once established, mature rapidly and the larger branches comes near the surface of the heart, whereas smaller branches ramify into rich capillary beds terminating into the developing muscle fibers. Some of the small arteries make connections with the endothelium based spaces that persist among the trabecula after flattening of the early mesh work. The minute intramural vessels potentially connect to the ventricular cavities from epicardial coronary arteries. In the thick walled neonatal heart right and left ventricular branches from the extra mural coronary arteries enter the myocardium. It is very important to identify the causes of anomalous coronary development, as the coronary arteries may present with many anomalies that occur during fetal development. There are different patterns of anomalous coronary arteries, with variable risk of myocardial ischaemia, malignant arrhythmias, and sudden cardiac death.

It is recommended that angiographic recognition of anomalous coronary arteries is very essential before undertaking any cardiac surgery. Failure to recognize them can lead to inadequate or prolonged procedures and may also lead to misdiagnosis and complications such as accidental ligation [6]. An inadvertent incision of the anomalous artery or failure to perfuse the anomalous vessel during cardiopulmonary bypass may result in acute myocardial infarction (AMI) [7,8]. Therefore, our aim is to find out the incidence of any anomalous coronary branching pattern in our study population of 50 heart specimens.

## Materials and Methods

The study of coronary arteries regarding its course and distribution was carried out in dissection hall, Department of Anatomy, Rajah Muthaiah Medial College and Hospital (RMMC & H), Annamalai University, Chidambaram, Tamil Nadu, India, with 50 heart specimens in the age group of 20–65 years from August 2010 to July 2013. The vital organ, heart is located in the thoracic cavity. A transverse incision was made through the manubrium sternum to expose underneath parts. Another incision was made through the parietal

pleura in the first intercostal space extending from the lateral sternal border up to the left mid-axillary line. From the ends of the line the second and subsequent ribs were divided inferiorly up to the level of xiphisternal joint.

The lower part of the sternum and the costal cartilage and anterior parts of the ribs were elevated. The parietal pleura extending from back of sternum up to the mediastinum on both sides were divided. The upper part of the sternum was lifted up by dividing the sternopericardial ligaments. The fibrous pericardium was separated from the adjoining structure by dividing the fibrous pericardium. The heart was exposed and delivered out of middle mediastinum by cutting branches of Arch of Aorta, superior and inferior vena cava, pulmonary artery and veins. After the removal of heart specimens from the thoracic cavity, they were preserved in 10% formalin solution for one week. After adequate fixation, the manual dissection was carried out on the hearts.

The visceral pericardium from the sternocostal of the heart was removed. The anterior interventricular branch of the LCA and the great cardiac vein were exposed by scraping the fat from the anterior interventricular sulcus. The branches of the artery to both ventricles and to the interventricular septum which lies deep to it were noted. The artery inferiorly was traced to the diaphragmatic surface and superiorly to the left of the pulmonary trunk. The fat from the coronary sulcus was carefully removed and avoided to prevent any damage to the small anterior cardiac vein crossing from the right ventricle to enter the right atrium directly. The right coronary artery was found in the depth of the sulcus. The course of the artery was traced superiorly to its origin from the right aortic sinus (a swelling at the root of the ascending aorta deep to the right auricle) and inferiorly till it turned on to the posterior surface of the heart. The branches to the right ventricle and atrium were noted. For statistical analysis, the data are expressed as percentage.

## Results

We selected 50 heart specimens and we approached with manual dissection method. We found that 48 (96%) heart specimens had normal coronary branching pattern out of 50 heart specimens. Interestingly, we found two (4.0%) anomalous coronary branching patterns with two of the heart specimens. Figure 1, 2, 3 and 4 show

normal coronary branching patterns while figure 5 and 6 show the abnormal coronary branching pattern. Out of the two abnormal coronary branching patterns, one is abnormal circumflex artery from posterior aortic sinus which we have reported here while the other one is arteria anastomotica in fundibularis magna, an abnormal communication between anterior interventricular artery and right coronary artery which was earlier published by us [9].

The RCA arose from the anterior aortic sinus, the artery passed at first anteriorly and slightly to the right between the right auricle and pulmonary trunk. Reaching the atrioventricular (coronary) sulcus, it descended in almost vertically to the right cardiac border, curving around it into the posterior part of the sulcus, where it approached its junction with both interatrial and interventricular grooves, a region appropriately termed the crux of the heart. Branches of the RCA supplied both right atrium and ventricle and, variably, parts of the left chambers and atrioventricular septum. The first branch was the conus artery and it ramified anteriorly on the lowest part of the pulmonary conus and upper part of right ventricle.

Anterior atrial and ventricular rami diverged from the first segment of the right coronary, extending from its origin to the right margin of the heart. The right anterior ventricular rami, ramified towards the cardiac apex. As the RCA approached the crux, it gave off posterior interventricular rami but only one in the interventricular sulcus; this was described as the posterior interventricular artery. The atrial rami of the RCA were described as

anterior, lateral (right or marginal) and posterior groups.

LCA arose from the left posterior aortic sinus. In its course, it was found between the pulmonary trunk and the left auricle emerging to reach the atrioventricular sulcus, in which it turned to the left. It reached the coronary sulcus and divided into 3 main branches of which the anterior interventricular (descending) ramus is commonly described as the continuation of LCA. It reached the apex of the heart and turned in to the post (inferior) interventricular sulcus to meet the branches of RCA. This artery had anteriorseptal and anteriorventricular rami, anterior diagonal branch and conus branch.

LCA was found larger than RCA in all cases and was found supplying a major part of myocardium and most of the interventricular septum. During its course, it was found between the pulmonary trunk and the left auricle to reach the atrioventricular sulcus and turned to the left. It was traced to the apex of the heart and was found turning in to the post interventricular sulcus to meet the branches of RCA. The left anterior ventricular artery was found arose from LCA and by trifurcation to give off left diagonal artery. Circumflex artery was found running in the atrioventricular sulcus and curved around to end a little to the left of the posterior of the crux. The left marginal artery was found arising perpendicularly from the circumflex artery and anterior ventricular branches were found arising parallel to the diagonal artery. Atrial rami were also found arising from the circumflex artery (Fig 1, 2, 3 & 4).

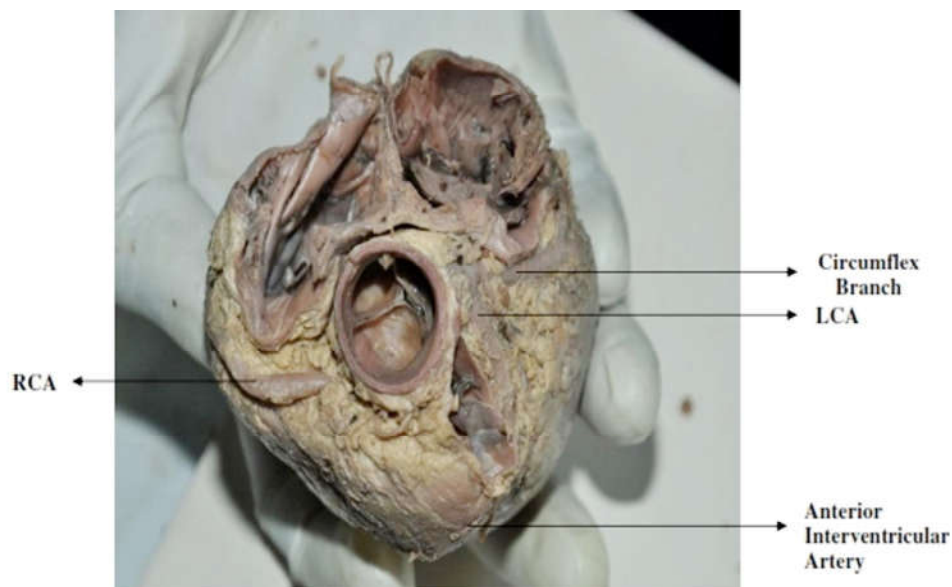


Fig. 1: Showing superior view of coronary arteries commencement

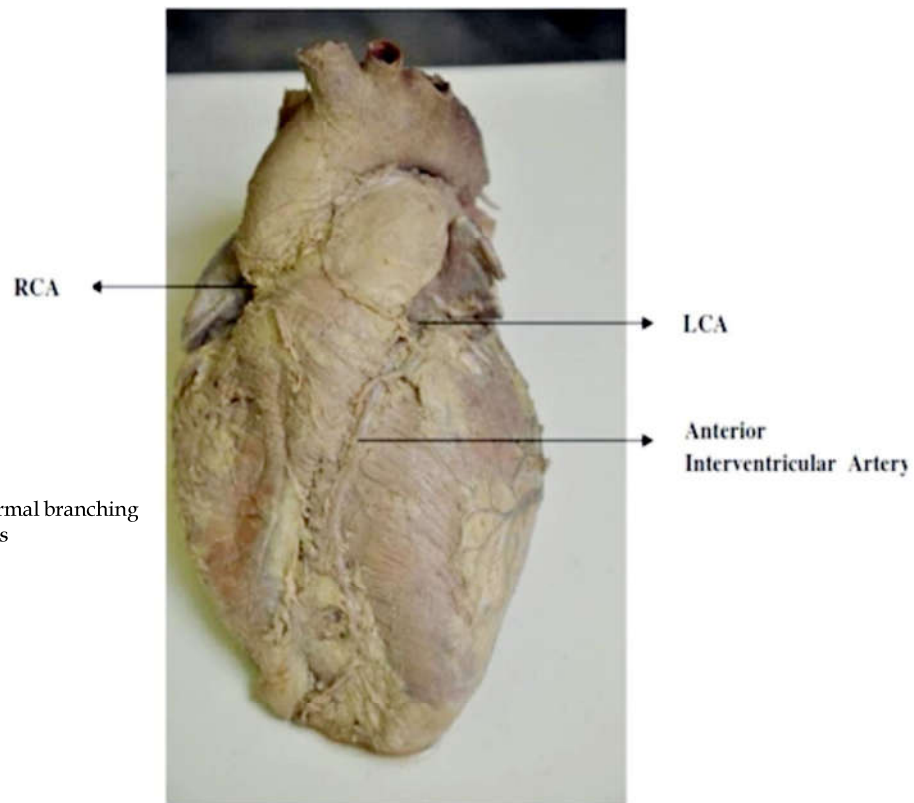


Fig. 2: Showing normal branching of coronary arteries

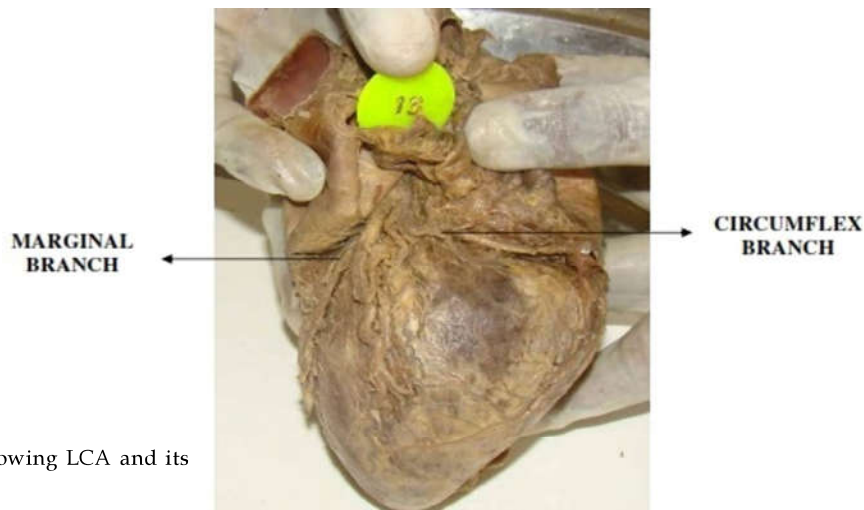


Fig. 3: Showing LCA and its branches

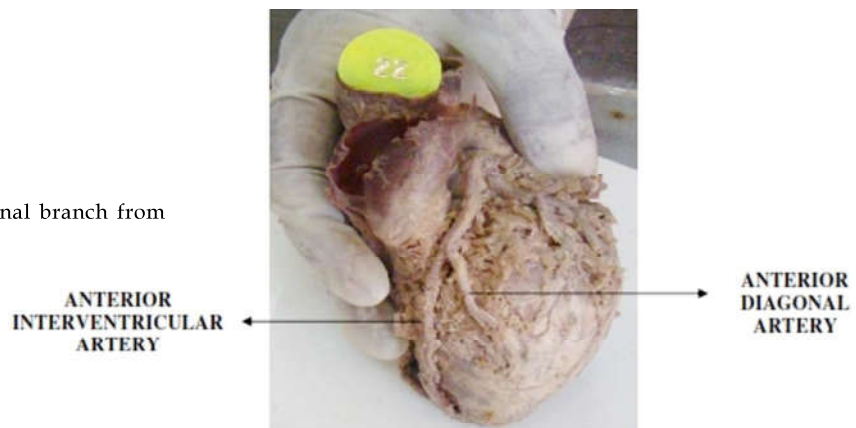


Fig. 4: Showing anterior diagonal branch from anterior interventricular artery

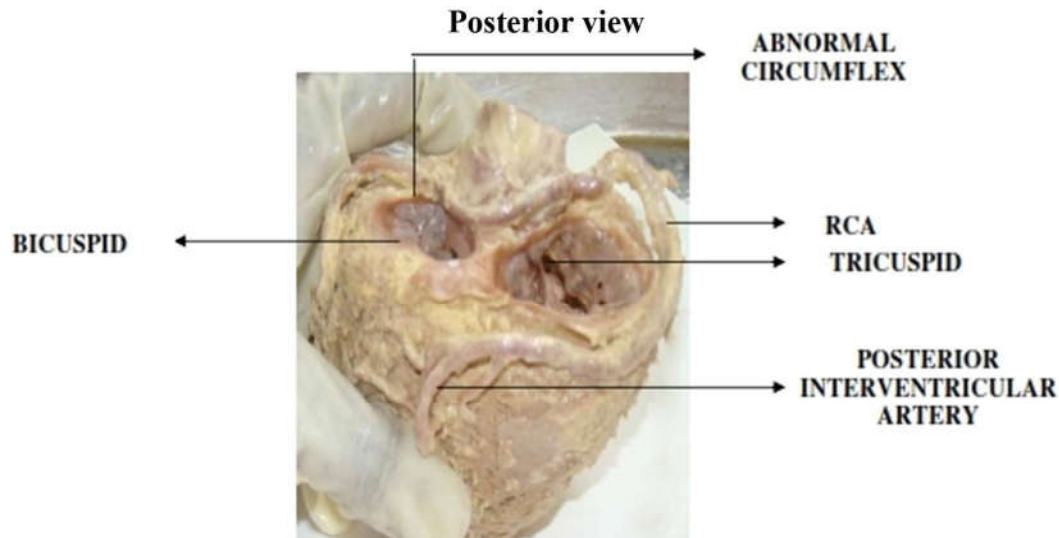


Fig. 5: Showing abnormal circumflex from right posterior aortic sinus both atrium is removed

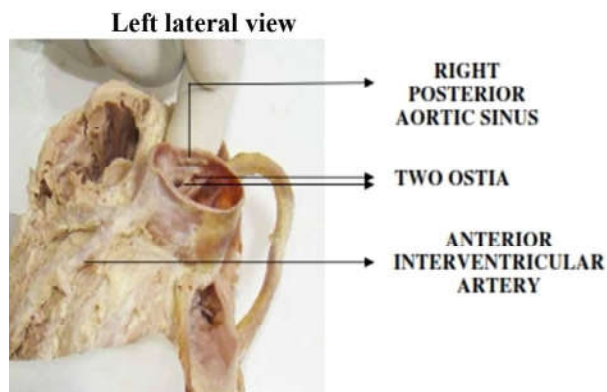


Fig. 6: Showing two ostia are observed in right posterior aortic sinus one for RCA other for abnormal circumflex

As far as the abnormal branching pattern of coronary artery was concerned, we observed an abnormal circumflex artery, found arising from the right posterior aortic sinus by a separate ostium. Then it wound round the posterior aspect of ascending aorta and reached to the left side of it and then ran in the left atrioventricular sulcus, towards the left border of the heart. AV nodal branch arose from it, one centimeter from its commencement and after reaching the left border, it was found giving off left marginal, left atrial and ventricular branches.

The RCA in this specimen was found arising from the same right posterior aortic sinus, from where the abnormal circumflex artery originated. It ran in the atrioventricular sulcus to the right border. It was found giving off the right marginal branch and then approached the posterior aspect of right atrioventricular sulcus. Here it was found giving off atrial and ventricular branches and posterior

interventricular branch. Then it was found crossing the crux of the heart, where it gave left atrial and ventricular branches (Fig. 5&6).

### Discussion

Various patterns of coronary arteries are essential for the clinicians and surgeons. The coronary circulation was studied by many anatomists by manual dissection method and other special methods like injecting contrast dye into the vessels then analysed the X ray picture taken after the dye injection. They found out the normal and abnormal patterns of coronary arteries. And they also correlated the above views with developmental anomalies of the heart. Most of them reported that RCA arose from the anterior aortic sinus of the ascending aorta and passes forward and to the right between the pulmonary trunk and right auricle along the right part of the atrioventricular sulcus and LCA was found arising in majority of cases from left posterior aortic sinus and in some cases from the pulmonary trunk or from pulmonary artery and found that LCA arising from the anterior sinus instead of left posterior aortic sinus. In some cases they found that LCA arising from anterior aortic sinus along with RCA. Our findings are in confirming with most of the previous studies [10,11]

Coronary artery anomalies (CAAs) are a group of congenital disorders. They are defined as variants of the normal coronary artery [12]. The incidence of coronary artery anomalies is approximately 1% among patients undergoing cardiac catheterization [13]. The anomalous coronary



arteries are associated with high incidence of congenital heart diseases and some anatomic presentations of coronary anomalies are considered to be high-risk groups. However, most of the coronary anomalies are asymptomatic and benign but may cause myocardial ischaemia and sudden death. Some of them are fatal if they are associated with other heart diseases [14,15,16]. Majority of people (90%) possesses right coronary dominance, where the posterior interventricular artery is large and arises from RCA. Minority of population (10%) has left coronary dominance, where the posterior interventricular artery is a branch of left coronary artery [17,18]. These peoples are likely to be affected by coronary artery diseases because the entire left ventricle and the interventricular septum are under the nutritional control of LCA. Any obstruction in the LCA may produce output failure of systemic circulation. The technique of selective coronary arteriography provides accurate visualization of the artery and its pathology. The recent development of electrocardiographically (ECG)-gated multi-detector row computed tomography (Cardiac CT) allows accurate and noninvasive depiction of coronary artery pathology. A sound knowledge of normal anatomy of the coronary arteries and their variations is therefore absolutely necessary for interpretation of angiography, ECG-gated multi-detector row CT findings and good plan of coronary artery surgery.

The most common coronary branching pattern is the anomalous left circumflex artery and this anomaly arises from a separate ostium within the right sinus, or a very unusual as a proximal branch of the RCA [19,20]. The circumflex artery from the right coronary sinus is among the most common variations and usually is not associated with major complications. However, during surgical interventions, these anomalous coronaries can result in significant complications. Especially, aortic valve operations and valve sparing aortic root remodeling or replacement procedures can be complicated by obstructions of the ectopic coronary ostium or the proximal course near the annulus [21].

## Conclusion

Like most other organs, the heart also presents with many variation regarding coronary artery branching pattern. In the present study, we observed normal branching pattern of both right and left coronary arteries, except in two hearts. The present study showed an important and rare occurrence of an anomalous circumflex artery from

posterior aortic sinus. As the left coronary artery is one of the main arteries supplying the heart, a sound knowledge of the variations in its branching pattern is indispensable for the diagnosis and treatment of patients with coronary artery disease.

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