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Original Article

Anatomy Section

Anatomical study of Right Coronary Artery and its Variations in Adult Human Cadavers: Developmental Basis and Clinical significance

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ABSTRACT

Introduction: Right coronary artery usually arises from anterior aortic sinus and its distribution is reciprocal to that of left coronary artery. Thorough knowledge of anatomical variations is essential for accurate diagnosis and treatment of coronary artery disease.

Aim: To study right coronary artery anatomy and variations and/anomalies, if present in relations to origin, termination, branching pattern, dominance and external diameter at origin.

Materials and Methods: After an ethical approval, 150 formalin fixed adult human cadaveric hearts were collected from Department of Anatomy, BVDU Medical College and Hospital, Sangli and Pune. The careful dissection was carried out to note details about right coronary artery and data was analysed using SPSS-22 computer software.

Results: Right coronary artery was originated from anterior aortic sinus in 148 hearts (98.67 %) specimens and anomalous origin in the form of vertical slit from left posterior aortic sinus in 2(1.33%) specimens. The right coronary artery gave right conus artery in 102 (68%) specimens, SA nodal artery in 120 (80%) specimens, AV nodal artery in 125 (83.33%) specimens and posterior interventricular artery was in 125 (83.33%) specimens. The right dominance was found in 125 (83.33%) specimens. Superdominant right coronary artery was found in 9 (6%) out of which 1 (0.66%) specimen had right coronary artery running below the coronary sulcus on the entire diaphragmatic surface supplying it. In two specimens, split right coronary artery was noted just near the origin while in one specimen it was bifurcated at inferior border of heart.

Conclusion: The ectopic origin of right coronary artery from left posterior aortic sinus having slit like ostium and interarterial course, superdominant right coronary artery, split right coronary artery and blood supply of both the nodes of same heart from right coronary artery are the important anatomical variations which clinicians must be aware of for successful management of coronary artery disease.

Keywords: Anomalous, Ectopic, Superdominant, SA nodal artery Ostium, Split right coronary, Sudden cardiac death

INTRODUCTION

The right coronary artery usually arises from anterior aortic sinus. The artery passes at first anteriorly and slightly to the right between the right auricle and pulmonary trunk. It then descends in right part of atrioventricular groove almost vertically; winds around the inferior border of heart and reaches the diaphragmatic surface. Here, it runs backwards and to the left in posterior part of atrioventricular groove. Terminal part of right coronary artery anastomoses with the circumflex branch of left coronary artery slightly to the left side of the crux.

The main branches of right coronary artery include right conus artery, SA nodal artery, right marginal artery, posterior interventricular artery, AV nodal artery, atrial and ventricular rami. The right conus artery is usually the first branch of coronary artery and supplies the infundibulum of the right ventricle. SA nodal artery arises as a branch from right coronary artery in around 65% individuals. When it is a branch of right coronary artery, it passes backwards between right auricle and root of ascending aorta. It then passes around the orifice of superior vena cava and finally it supplies the SA node. Right marginal artery follows the inferior border of the heart towards the apex and supplies adjoining surfaces of the right ventricle. Posterior interventricular artery arises from the right coronary artery near the crux of the heart in 70% subjects. It passes along the posterior interventricular groove and close to the apex anastomoses with the anterior interventricular branch of the left coronary artery. It gives branches to the diaphragmatic surface of right and left ventricles, septal rami which supply postero-

inferior 1/3rd of the ventricular septum and AV nodal artery. AV nodal artery is the first and largest septal ramus of the posterior interventricular artery which undergoes an inverted loop and supplies AV node. In 80% to 90% subjects AV nodal artery arises from right coronary artery. Atrial rami supply the myocardium of right atrium while right anterior and post ventricular rami supply the sternocostal and diaphragmatic surface of right ventricle respectively. Branches of right coronary artery form anastomosis with those of left coronary artery at various sites and provide collateral circulation if later is blocked [1].

Right coronary artery shows variations and/anomalies in terms of origin, course, termination, branches and distribution. Anatomical variations and/anomalies of coronary arteries greatly influence the blood supply of heart, extent of ischemia, clinical presentation and prognosis in patients of coronary artery disease [2].

Some of the variations and/anomalies are asymptomatic and some are associated with morbidity and mortality. The symptoms may be atypical chest pain, shortness of breath, arrhythmia, development of heart failure or acute myocardial infarction or sudden cardiac death. [3]. Kaku B et al., reported symptoms of syncope, aortic regurgitation, conduction disturbances like complete AV block and complete right bundle branch block [4]. Presence of such variations and/anomalies may confuse interpretation of the images and may create a difficulty during procedures, such as angiography, angioplasty, and coronary artery bypass grafting [5]. The awareness of which increases the success rate of coronary procedures. Hence, present study has been undertaken to note origin, branches, termination, dominance pattern and external diameter of right coronary artery

MATERIALS AND METHODS

After an ethical approval (Letter No- BVDUMC/IEC/85A), the observational and analytical study was carried out from February 2009 to October 2010. Formalin fixed 150 adult human cadaveric hearts without any gross anomalies or trauma, obtained from Bharati Vidyapeeth (Deemed to be University) Medical College Sangli and Pune were used for study. Epicardium and fat was removed in piecemeal. A 'T' shaped incision was taken on ascending aorta consisting of a horizontal incision 1 cm above the aortic sinus and vertical incision at the level of right posterior aortic sinus (non coronary sinus) to study the details of ostia. Location of ostium of right coronary artery was noted and height of ostium (mm) from base of cusp was measured with the help of divider and scale. Then right coronary artery was dissected carefully from its origin to the termination to observe its course, extent and branches. The hearts showing origin right dominance were documented when the right coronary artery gave posterior interventricular artery. Diameter of right coronary artery at its origin was measured with digital vernier caliper. The data was analysed with SPSS-22 computer software and most representative specimens were photographed. In the present study the same specimens of heart have been used as in a published study by the same authors [6].

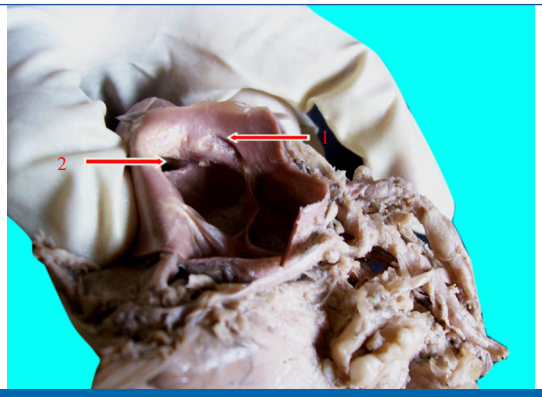
RESULTS

In present study, ostium of right coronary artery was observed in anterior aortic sinus in 148 hearts (98.67%). The ostium of right coronary artery was located at sinuotubular junction in maximum cases [Table/Fig-1].

Location of ostia	No. of Cases	Percentage	Height of ostium from base of cusp (mm)
Sinus	15	10	6 - 8
Sinotubular	101	67.33	8 - 12
Tubular	34	22.67	12 -19

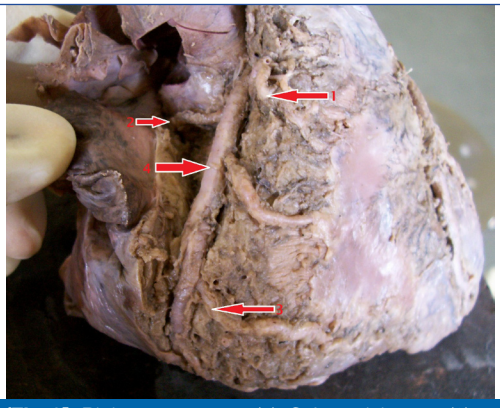
[Table/Fig-1]: Showing location of ostium of right coronary artery and its height (mm) from the base of cusp.

In two cases (1.33%), the aberrant origin of right coronary artery was noted. Anomalous artery was originated from the left posterior aortic sinus instead of anterior aortic sinus. Ostium of these anomalous right coronary arteries were in the form of vertical slit and located just above and ahead of the normal left coronary ostium [Table/Fig-2]. The origin of left coronary artery in these cases was normal from left posterior aortic sinus with circular ostium located near the sinotubular junction. Anomalous right coronary followed the interarterial course between pulmonary trunk and ascending aorta before reaching anterior part of atrio-ventricular groove.

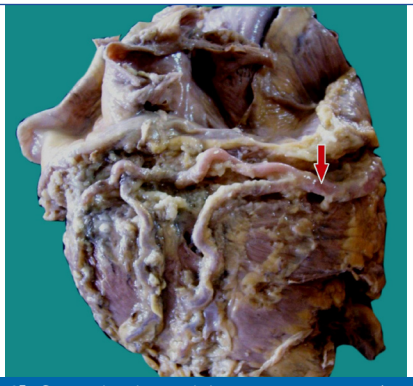


[Table/Fig-2]: Left posterior aortic sinus showing aberrant origin of right coronary artery with slit like ostium (1) just above the sinotubular junction and normal ostium of left coronary artery (2) at sinotubular junction.

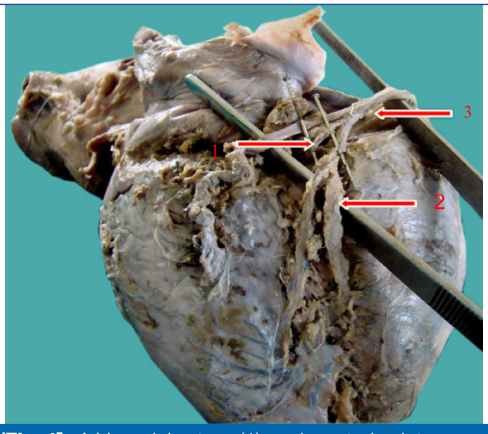
The right coronary artery gave right conus artery in 102 (68%) specimens, SA nodal artery in 120 (80%) specimens [Table/Fig-3]. AV nodal artery was a branch of right coronary artery in 125 (83.33%) specimens and posterior interventricular artery was in 125 (83.33%) specimens [Table/Fig-4]. Right dominance



[Table/Fig-3]: Right conus artery (1), S.A. nodal artery (2) and right marginal artery arising (3) from right coronary artery (4).



[Table/Fig-6]: Superdominant right coronary artery (arrow) running along entire length of posterior part of atrioventricular groove and terminating at left border of heart.



[Table/Fig-4]: A.V. nodal artery (1) and posterior interverentricular artery (2) arising from right coronary artery (3) hence presenting right dominance.

[Table/Fig-7]: Superdominant right coronary artery[arrow] running over diaphragmatic surface below the posterior part of atrioventricular groove [coronary sulcus] and reaching up to left border of heart.

was found in total 125 (83.33%) specimens. Both nodes of a heart were supplied by right coronary artery in 64% cases.

The extent of right coronary is given in [Table/ Fig-5].

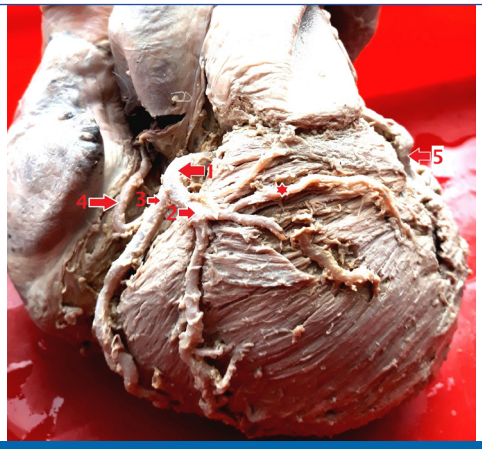
In nine (6%) specimens, superdominant right coronary artery was found, out of which eight (5.33%) specimens had artery running along entire length of posterior part of atrioventricular groove [Table/Fig-6] and in one (0.66%) specimen right coronary artery was running below the coronary sulcus on the entire diaphragmatic surface supplying it [Table/Fig-7].

Extent of RCA	No. of hearts	Percentage (%)
RCA ending at the inferior border of heart	12	8
RCA ending between inferior border and crux	13	8.67
RCA continued till the crux	15	10
RCA continued 1-3 cm beyond the crux	101	67.33
Superdominant RCA which continued up to left border of heart	9	6

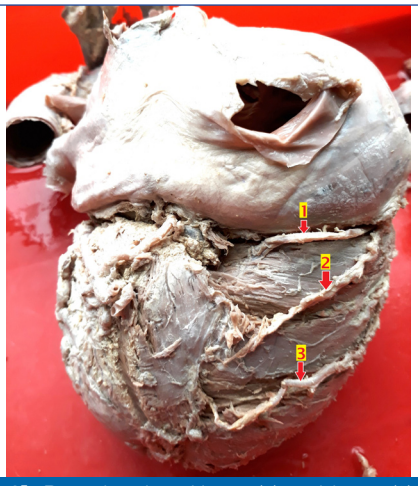
[Table/Fig-5]: Showing the extent of right coronary artery.
RCA: Right Coronary Artery

In two (1.33%) specimens, split right coronary artery giving anterior branch and posterior branch was noted. In one (0.66%) specimen of split right coronary artery, anterior branch of right coronary artery was larger in diameter and was seen running on free wall of right ventricle (sternocostal surface), winded around the inferior border and ran on the diaphragmatic surface and terminated at posterior interventricular groove giving septal branch. The anterior branch of split right coronary artery supplied anterior and inferior surface of right ventricle including infundibulum and it also gave a long branch which ran on anterior free wall of right ventricle and terminated at anterior interventricular groove by giving a septal branch and anastomosing with left anterior descending branch of left coronary artery [Table/Fig-8,9]. The posterior branch was running in right part of atrioventricular groove and bifurcated at inferior border into upper and lower division. Upper division ran in atrioventricular groove and terminated by supplying AV node and lower division ran on diaphragmatic surface and terminated at posterior interventricular groove giving a septal branch. This

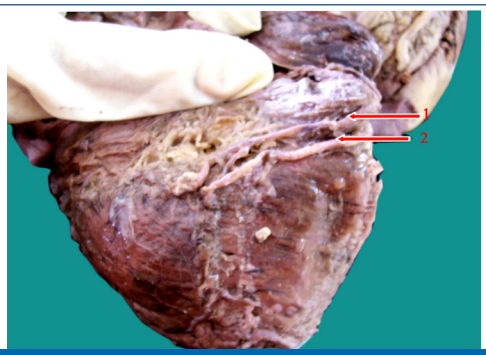
branch supplied right atrium, right ventricle, SA node and AV node and interventricular septum [Table/Fig-8,9].



[Table/Fig-8]: Anterior view: Split right coronary (1) giving anterior branch (2) and posterior (3). Posterior branch is giving S. A. nodal artery (3) while anterior branch is giving a long branch (*) which is anastomosing with left anterior descending artery (5) and terminating by giving septal branch at anterior interventricular groove.



[Table/Fig-9]: Posterior view: Upper (1) and lower (2) division of posterior branch and continuation of anterior division (3) of split right coronary artery.



[Table/Fig-10]: Bifurcation of right coronary artery at inferior border. Branch closer to the crux (1) gave AV nodal artery and other (2) crossed posterior interventricular groove and gave smaller branch in the groove.

In one specimen, right coronary artery bifurcated at inferior border of heart. Branch closer to the crux gave AV nodal artery and other crossed posterior interventricular groove and gave smaller branch in the groove [Table/Fig-10].

In three (2%) specimens, instead of typical posterior interventricular artery running in posterior interventricular groove, it was observed that right coronary or its terminal branches crossing the posterior interventricular groove supplied the territory of posterior interventricular artery [Table/Fig-7,9,10].

In the present study, the mean external diameter of right coronary artery at origin was 3.75±1.0095 mm.

DISCUSSION

Development of coronary arteries is a complex and very precisely coordinated process. The basis of coronary artery variations can be better understood by knowledge of its development. The coronary arteries were considered for a long time as outgrowths of the aortic root which progressively grow to vascularize the heart. In 1989, Bogers AJJC et al., in their study showed that the major coronary arteries could be seen even before the presence of coronary arterial orifices, which led to the new concept of ingrowth instead of outgrowth of the coronary arterial vasculature [7]. Epicardium plays an important role in the development of coronary arteries. Some of the epicardial cells undergo epithelial-to-mesenchymal transition induced by underlying myocardium [8]. Lluri G et al., in their review described that in humans, at about the 25th embryonic day, the vessel-like structures are observed in the space between epicardium and the myocardium. These structures fuse to form vascular plexus. This diffused elaborate vascular network extends toward the truncus arteriosus. The channels from this peritruncal network ultimately contact and penetrate the aortic root and lead to abrupt exposure to the systemic pressure and high flow. These changes result in the maturation of these vessels, including the migration of smooth-muscle cells and the proper arrangement of these cells and further growth of some vessels and regression of others through apoptosis. Variations in this delicate controlled process may lead to the congenital coronary artery anomalies [9]. Hood LC et al., in his study reported that cardiac neural crest cells may have a secondarily inductive effect in the growth of peritruncal vessels into the aorta as well as normal orderly development of coronary artery Vascular Smooth Muscle Cells (VSMC). When cardiac neural crest cells were surgically ablated in chicken embryos, coronary artery anomalies like ectopic sites of origin, abnormal vessel pattern and asymmetric development of the tunica media were observed [10].

The anomalous origin of the right coronary artery from left posterior aortic sinus is a rare congenital cardiac malformation. The incidence of such anomaly reported in present study (1.33% specimen) is higher than that reported by Kaku B et

al., (0.31%), Xu H et al., (0.41%), Namgung J et al., (0.463%) in their angiographic studies [4,11,12]. This may be due to the large sample size of their study.

The interarterial course of this anomalous right coronary artery may create a risk of sudden cardiac death since the anomalous artery can get compressed between the pulmonary trunk and aorta, particularly during or immediately after exercise. The mechanism of ischemia or infarction is also related to the shape of coronary ostium of the anomalous vessel. Normally, the coronary ostia are round to oval in shape, but in this anomaly the coronary artery has an acute angle take off that makes the ostium slit like in shape. With increase in cardiac output, the aorta dilates with stretching of aortic wall, so that this slit like ostium may become severely narrowed [13]. In present case, anomalous right coronary artery had slit like orifice and interarterial course which are anatomical risk factors.

In a study done by Kos¸ar P et al., the SA nodal artery originated from the right coronary artery as its second branch in 79% which is slightly lower than present study. They also found origin of SA nodal artery directly from the right sinus of Valsalva with a separate ostium in 0.4% cases [14] while Anjali S et al., reported a case of SA nodal artery arising from right marginal artery instead of main trunk of right coronary artery. No such variation was found in present study [15].

In present study, both the nodes of same heart were supplied by right coronary artery in 64% specimens of heart. So sinus arrhythmias may develop in patients of acute myocardial infarction involving right coronary artery [16]. Deeprasertkul P et al., has reported sinus arrest following right coronary artery stent implantation [17].

Superdominant right coronary is another clinically important anatomical entity where the artery runs in almost entire length of atrioventricular groove and supplies left ventricle and part of left atrium which is usually supplied by circumflex branch of left coronary artery. Majid Y et al., reported a case of absent left circumflex coronary artery with superdominant right coronary artery. Coronary artery disease involving such artery may be associated with chest pain due to ischemia of inferior and septal wall of left atrium especially during physical exertion [18]. However, in present study circumflex branch was present in all the specimens of hearts with superdominant right coronary artery.

Sawaya FJ et al., reported a case of split right coronary artery and its distribution similar to that of our study. His group reported a case of occlusion of the anterior bifurcation of a split RCA which resulted in an infarct that involved anterior and inferior right ventricular free wall as well as inferoseptal left ventricular wall in 64-year-old man. [19]. Villa AD and his group reported split Right Coronary Artery (RCA) as the most common type of coronary anomaly (1.23%) in their review. This incidence is similar to present study (1.33%) [20].

The mean external diameter of right coronary artery recorded in present study (3.75±1.0095 mm) at its origin is less than external diameter of proximal segment of right coronary artery reported by El Sayed S et al., (5.1±0.7 mm) and slightly more than that reported by Ballesteros LE et al., (3.42±0.66 mm) [21,22].

The diameters of coronary arteries are inversely associated with the severity of coronary artery disease [23]. Dilatation of the epicardial coronary arteries of 1.5 to 2 times that of a normal adjacent segment is called coronary ectasia and dilatation more than two times the normal adjacent segment is called coronary aneurysm [24]. The term ectasia refers to diffuse dilation of a coronary artery whilst focal dilation is called as coronary aneurysm. Coronary artery ectasia may coexist with aneurysms of other arterial beds, particularly abdominal aorta, even with venous varicosities [25]. The proximal and middle segments of the RCA are the most common sites for Coronary artery ectasia. Coronary artery ectasia can be associated with different complications such as thrombus formation, vasospasm, and spontaneous dissection [26]. Measurement of external diameter provides a reference data to compare the diameter of normal coronary artery with that of pathological conditions such as ectasia or aneurysm [23].

LIMITATION

As in present study some heart specimens already available in the departmental collection were used, we could not record a data age wise and sex wise. So, it was not possible to categorize and compare the variations, anomalies and diameter of the right coronary artery based on age and sex.

CONCLUSION

Some of the rare variations like aberrant origin of right coronary artery from left posterior aortic sinus having slit like ostium and interarterial course, superdominant right coronary artery and split right coronary artery were found during present study. Thorough knowledge of these variations is essential for radiologists, interventional cardiologists and cardiothoracic surgeons to enhance the success rate of diagnostic and therapeutic cardiac procedures.

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