STUDY OF BRANCHING PATTERN OF RIGHT CORONARY ARTERY IN 50 SPECIMENS

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CERTIFICATE

This is to certify that the dissertation entitled "**STUDY OF BRANCHING PATTERN OF RIGHT CORONARY ARTERY IN 50 SPECIMENS"** submitted by **Dr. K.PARTHIBAN** to the Faculty of Anatomy, The Tamilnadu Dr. M.G.R. Medical university, Chennai in partial fulfillment of the requirement for the award of M.S. Degree in Anatomy is a bonafide work carried out by him during the period June 2005 – Nov 2007 under my direct supervision and guidance.

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DECLARATION

I **Dr. K.Parthiban,** solemnly declare that the dissertation entitled "**STUDY OF BRANCHING PATTERN OF RIGHT CORONARY ARTERY IN 50 SPECIMENS"** has been prepared by me under the able guidance and supervision of my guide **Prof.Dr.V.RAJARAM M.S.,** Institute of Anatomy, Madurai Medical College, Madurai, in partial fulfilment of the regulation for the award of **M.S. (ANATOMY)** degree examination of The Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in March 2008.

This work has not formed the basis for the award of any other degree or diploma to me previously from any other university.

Place : Madurai
Date :

CONTENTS

INTRODUCTION

Coronary artery disease is the commonest cause of heart diseases and the most important cause of death all over the world. According to Parks (2005) it is the cause of 25-30 percent of deaths in most industrialised countries. Coronary artery occlusion may either result in myocardial infarction or lead onto ischemia and angina pectoris. The recent advances in direct coronary artery surgery, the newly invented techniques in bypass surgery and the modern methods of revascularisation require a complete knowledge of the coronary circulation.

The introduction of selective coronary arteriography by Sones (1959) 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 non invasive 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-director row CT findings and intelligent plan of coronary surgery.

The heart is supplied by the right and left coronary arteries which encircle the base of the ventricles like a crown. Variation with relation to origin, course and termination are most frequently reported in the right coronary artery. According to angiographic study in western population done by Topez et.al (1992), the right coronary artery was the most common anomalous artery. It has been proved that the anomalous coronary arteries are associated with high incidence of congenital heart diseases. Hence the right coronary artery is selected for the present study.

Angiographic recognition of anomalous coronary arteries prior to cardiac surgery is important. Failure to recognise them can cause inadequate or prolonged procedures and may lead to misdiagnosis and complications such as accidental ligation [Donaldson (1982)]. An inadvertent incision of the anomalous artery or failure to perfuse the anomalous vessel during cardiopulmonary bypass [Longenecker et.al.,(1961)] may result in acute myocardial infarction [Mahowald et.al.,(1986)]. Obstruction of the ostium [Lillehei et.al.,(1964)] of an anomalous artery and compression along its course by a valvular prosthesis also have been reported [Roberts (1969)].

The stress on need for detailed study of the coronary arteries is further emphasized by the fact that a high incidence of the coronary anomalies has been observed in young victims of sudden death as compared to adults (4-15 percent versus 1 percent respectively) (Engel HJ et.al.,1975)

With increasing utilization of coronary arteriography in the diagnosis of ischemic heart disease and with the advent of ECG-gated multi-detector row CT, unexpected origin and course of coronary arteries are encountered more frequently. This study of origin and variation of right coronary artery is done with an expectation that it will hopefully contribute to better and complete interpretation angiographic studies, prevent unwanted surgeries due to misdiagnosis and better utilisation of anomalous vessels in bypass surgeries.

AIM OF THE STUDY

Coronary artery disease, in developing world as compared to the developed world, occurs a decade earlier. In India, it has been the most frequent single cause of death in men under the age of 65. In U.S sudden death is more common in young adults with coronary arterial anomalies (Liberthson RR 1979).

The increasing use of diagnostic and therapeutic interventional procedures in bypass surgeries and myocardial revascularization, outlines the necessity for a sound basic knowledge in anatomy of coronary circulation.

With this aim, an attempt has been made to study the right coronary artery in detail i.e. its origin, course, branching patterns, termination and the presence of anomalous artery.

REVIEW OF LITERATURE

The coronary arteries derive their nomenclature from the latin word, ‘La corona’, which means a ‘Royal crown ‘. The two arteries, as indicated by their name, form an oblique inverted crown, with an anastomotic circle in the atrio-ventricular sulcus connected by marginal and interventricular loops intersecting at the cardiac apex.

The coronary arteries have some special features that distinguish them from other medium sized arteries both in normal health and in disease.

(a) They are probably the only normal arteries arising from the ascending aorta.

(b) They are among the smallest in calibre of the vessels that originate from the heart.

(c) They have a peak flow during diastole than systole.

(d) Since collateral blood flow is poorly developed in the normal human heart, these vessels behave like end arteries.

The fundamental traits in the anatomy of the coronary arteries as they are perceived today were known as early as sixteenth century by Fallopius (1562) and subsequently by Riolanus (1649) and Vieussens (1796). The understanding of the relationship of coronary artery disease to anginapectoris and myocardial ischemia was established by Jenner (1799). This initiated extensive study of coronary arteries and their variations by very many scientists.

Various methods are made available for delineating the anatomy of coronary arteries, like the manual dissection method, injection of dyes, radio opaque contrast materials etc.,

Krause (1865) first described the coronary arterio-venous fistula. Hyrtl (1873) demonstrated the injection corrosion technique by using metal alloys with a low melting point. This method was an ideal technique for the study of vasculature in great detail because the vascular tree was inspected from an unlimited number of directions. Hyrtl (1873) found in his study the extensive distribution of one coronary artery over the whole heart while the other coronary artery was attretic. The other materials that can be used for injection include Gelatin mass, Starch mass, Wax, Plaster of Paris, Glue, Gum Arabic, Nylon, Latex and others. The most

satisfactory material presently used, is Plastic, eg. Vinylite dissolved in Acetone.

Brooks (1886) observed the origin of right coronary artery from the pulmonary trunk. Banchi (1904) Italian anatomist presented a detailed description of the anatomy of coronary artery. Koch (1909) reported the origin of sinuatrial artery directly from a bronchial artery.

Haas (1911) first described the blood supply of atrioventricular node. Evans (1933) observed that extreme ectopia with a coronary artery arising from the branch of the aorta or internal mammary artery was rare and predominantly associated with other cardiovascular anomalies. Antopol and Kugel (1933) first described the origin of circumflex coronary artery from the right sinus of valsalva or from right coronary artery.

Krumbhear and Erlich (1938) studied about the varieties of single coronary artery in man occurring in isolated cardiac anomalies. Schlesinger et.al. (1949). had appreciated a third coronary artery. Smith (1950) classified isolated single coronary artery pattern.

Andre cournard (1941) performed the first heart catheterization in a human patient. Hacken sellner (1955) noticed the “High take off” of coronary arteries in apparently normal hearts. Alexander and Griffith (1956) found 54 cases of coronary anomalies in 18,950 autopsies (0.3%). Sones (1959) introduced selective coronary arteriography to assess the nature and location of the occlusion in coronary artery. James (1961) studied the coronary vasculature by preparing casts using plastics. Reemtsma et.al (1961) pointed out that the atrioventricular nodal artery may be injured in the closure of ostium primum defect. Schulze (1961) suggested that the coronary anomalies are deviations from normal anatomy and their interpretation could be based on their mechanism of origin.

According to paulin(1964) by coronary angiographic studies significant cranial displacement was found on the right side more frequently than on left side. Amplatz et.al. (1967) proved that there was more amount of technical difficulties for selective catheterization because of the cranial displacement of the coronary ostium. VIodaver (1972) reported that both coronary ostia were situated above the sinotubular junction in 6 percent of unselected adult hearts. VIodaver et.al, (1972)

found right coronary artery arose from the posterior aortic sinus – an extreme rare anomaly. Spring and Thomson (1973) also reported “High take off” coronary artery. Sharbaugh (1974) reported the incidence of single coronary artery.

Engel (1975) studied the incidence of origin of the right coronary artery from the left sinus of Valsalva. Chaitman et.al, (1976) again reported the incidence of origin of the right coronary artery from the left sinus of Valsalva. Thompson et.al, (1976) reported the aberrant origin of right coronary artery in two patients with typical angina pectoris. Lipton et.al, (1979) classified the isolated single coronary artery pattern. Bermudez et.al, (1979) studied anomalous origin of right coronary artery from pulmonary artery at autopsy.

Hobbs (1982) reported 1.55% of coronary anomalies in 38,703 coronary arteriographies, of these 87% were anomalies of origin and distribution and 13% were coronary artery fistulas. Out of this 0.13% was ectopic origin of right coronary artery from the left sinus of Valsava, 0.18% were high right coronary artery take off. Roberts (1982) reported necropsy findings in which the right coronary artery arose from the left aortic sinus and the ostium of right coronary artery was slit like.

Kyriakidis et.al.,(1983) found that the sinoatrial nodal artery arose from the right coronary artery in 59 %, from the circumflex in 38% and from both arteries in 3%. Liberthson (1983) reported sudden death in an infant with aberrant origin of the right coronary artery from left sinus of Valsalva.

Ferguson (1985) reported a case of a 30 year old female patient with a single coronary artery. In this patient the right coronary artery had an anomalous origin from the left circumflex coronary artery. There was no left anterior descending coronary artery. William (1986) reported a case in which the right coronary artery was from the non coronary sinus. He proved that this anomaly was always associated with definitive cardiomegaly.

Miyazaki and Kato (1986) comparatively investigated stereoscopically, human fetal hearts and adult hearts and inferred that the incidence of third coronary artery was higher in adults than foetuses. Partridge (1986) observed that right coronary artery took origin from the middle third of the ascending aorta together with leftward displacement. Nath et.al, (1987) described two cases in which the right coronary artery originated from the mid portion of the left anterior descending artery.

Gupta et.al., (1987) presented a rare case of a patient with supernumerary right coronary arteries in whom the two vessels arose from the right coronary sinus from two separate ostia adjacent to each other.

Bezerra et.al, (1989) described a rare case of myocardial bridge over the trunk of the right coronary artery in an adult male. Mc.Manus et.al, (1990) found that in a child the right coronary artery arose from the left sinus of Valsalva. Thakur et.al., (1990) described a rare anomaly in which the right coronary artery originated two centimeters above the left posterior sinus of Valsalva in association with an aortic valve having two leaflets. Aoyagi et.al, (1991) described a case with anomalous origin of the right coronary artery from the ascending aorta above the left sinus of Valsalva. This patient also had bicuspid aortic valve. Fernandes et.al, (1992) found that coronary artery anomalies, some of which are clinically insignificant can be associated with other congenital heart defects, myocardial ischemia and reduced life expectancy.

Itho et.al, (1993) presented a rare case in which the coronary angiogram demonstrated an anomalous origin of the right coronary artery from the non coronary sinus of Valsalva. Choi YH,Park JH,Hwang HK (1994) angiographically studied normal variations of coronary arteries.

Okuyama et.al, (1995) found the anomalous origin of the right coronary artery from the left ventricle in an adult. Antonellis et.al., (1996) found single coronary artery from the right sinus of Valsalva, associated with absence of left anterior descending and an ostium secondum type of atrial septal defect. Gaudino et.al., (1997) demonstrated that an unrevealed high origin of the right coronary artery from the left coronary sinus led to major complications during routine atrial septal defect closure. Hughes (1997) studied about the anomalous origin of the right coronary artery from the left anterior descending coronary artery.

Berna et.al, (1998) found an anomalous origin of the sinus node artery from the left main trunk. It is considered a potential cause of iatrogenic hypokinetic arrythmia. Rahmatullah et.al, (1998) described a rare coronary artery anomaly in which the right sinus of Valsalva had separate origins for all three major coronary arteries. Goswami (1998) in Cross sectional and Doppler echocardiographic study of the right coronary artery, reported it to arise from posterior aortic sinus. Eiden et.al, (1998) found that the anomalous right coronary artery arose from the pulmonary artery in Taussig – Bing anomaly.

Ogino et.al, (1999) found that the high origin of the right coronary artery was associated with congenital heart disease. Maluf et.al, (1999) studied about the anomalous origin of the right coronary artery from the pulmonary artery. VanLangenhove et.al, (1999) found that the intralobar pulmonary sequestration was supplied by the right coronary artery. Ivan stankovic (2004) studied morphometric characteristics of the conal coronary artery in 23 hearts from cadavers of adult individuals and found that eight out of 23 hearts (34.8%) had the aortic origin of the conal artery.

The importance of anatomical knowledge is greatly increased because of constant introduction of newer and modified techniques in the diagnosis and management of coronary artery disease rendering ongoing research necessary and inevitable.

MATERIALS AND METHODS

From early days, manual dissection of the coronary vessels from their origin in the aortic root to their apparent distal termination – where they attenuate to such a degree that they cannot be followed further by visual inspection.

Injection of dyes into the coronary arteries before dissection is an adjunctive method that greatly facilitates the procedure and improves its accuracy. Replacing the dyes with radio-opaque fluids permits post-mortem angiography which facilitates careful study of the vessels without disturbing their anatomic integrity. Hildebrand (1900) introduced such a technique to study systemic circulation and Fryett (1905) later extended it, to study the coronary circulation. The most selective technique for the study of vasculature in detail was described by Hyrtl (1873). It involves filling the vasculature with a mass that hardens, to corrode the organ leaving a cast of vaculature (Injection Corrosion Technique). Nussbaum (1912) used metal alloys and later James (1961) used plastics to prepare casts.

Of the various methods available for studying the anatomy of coronary arteries, the method followed for the present study is the Manual Dissection method.

MATERIALS

The 50 specimens for this present study were obtained from the Forensic medicine department. The specimens were collected without any age, sex, socio-economic status, religion, and pathological bias.

The hearts were removed during autopsy by following method: A transverse cut was made through the manubrium of sternum immediately inferior to its junction with the first costal cartilage. An incision was made through the parietal pleura in the first intercostal space extending up to mid- axillary line. From this line, the second and subsequent ribs were divided inferiorly up to the level of xiphisternal joint. The inferior part of the sternum with costal cartilage and anterior parts of ribs were elevated. The parietal pleura extending from back of sternum on to the mediastinum on both sides was divided. The anterior part of sternum was lifted up and hinged on the superior part of the abdominal wall after dividing the sternopericardial ligaments. The fibrous pericardium was separated from

the adjoining structures. 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 veins and artery.

The collected specimens were preserved in 10% formalin solution and numbered serially from 1 to 50. The specimens were dissected using a pair of scissors, forceps and scalpel.

The standard text book of Anatomy (Grays 1999) describe the course of right coronary artery as follows.

COURSE: The right coronary artery arises from the anterior (‘right coronary’) aortic sinus. It passes at first anteriorly and slightly to the right between the right auricle and pulmonary trunk to reach the coronary sulcus. It descends in this sulcus almost vertically to the right acute cardiac border, curving around it into the posterior part of the sulcus, where it approaches the crux of the heart. The artery reaches crux and ends a little to the left of it (60%) , often by anastomosing with the circumflex branch of the left coronary artery. In 10% it ends near the right cardiac border. In 10%, it ends between right cardiac border and the crux. In 20% it reaches the left border replacing part of the circumflex artery.

The right coronary artery is divided into first segment (between its origin and right margin of the heart) and second segment (between the right border and crux).

BRANCHES

(i) Branches from the first segment

a.Right conus artery

b. Atrial and right anterior ventricular rami

c.Sino Atrial nodal artery

d.Right marginal artery

Right conus artery – It is usually the first branch of right coronary artery. It ramifies anteriorly on the lowest part of the pulmonary conus and upper part of the right ventricle, to anastomose with its fellow of the opposite side to form ***'annulus of vieussens'*** around the pulmonary trunk. Sometimes the right conus artery arises separately from the anterior aortic sinus in 36% of individuals, called as ***'third coronary'*** artery.

Atrial and right anterior ventricular rami – Anterior and lateral groups of atrial rami arise at right angles from the first segment of right

coronary artery. They supply the myocardium of right atrium. Right anterior ventricular rami, usually two or three arise at right angles from the right coronary artery and supply sternocostal wall of the right ventricle.

Sino atrial nodal artery – It belongs to atrial rami. It arises in 65% of individuals from the first segment of the right coronary artery and in 35% of individuals from the circumflex branch of left coronary artery. This nodal artery usually passes back in the groove between the right auricular appendage and aorta. Whatever its origin, the artery usually branches around the superior venacava's base, commonly as an arterial loop from which small rami supply the right atrium.

Right marginal artery – It belongs to ventricular rami. It follows the inferior border of the heart towards the apex and supplies adjoining surfaces of right ventricle.

(ii)Branches from the second segment

a. Right posterior ventricular rami
b. Posterior interventricular artery
c. Atrio ventricular nodal artery

d. Right posterior atrial rami

Right posterior ventricular rami – usually two or three, arise from the second segment of the right coronary artery, supply the diaphragmatic surface of the right ventricle.

Posterior interventricular artery – As the right coronary artery approaches the crux, it usually gives one to three posterior interventricular branches, but only one in the posterior interventricular sulcus. It is usually single (70%), and flanked either to the right or left or bilaterally by parallel branches. It is replaced in 10% of individuals by a left coronary branch. On the basis of posterior interventricular branch from right or left coronary artery, the ***'right coronary dominance'*** or ***'left coronary dominance'*** is expressed.

Atrio ventricular nodal artery – it is commonly from the inverted loop said to characterize the Right coronary artery at the crux, where its posterior interventricular artery arises. It is usually from the dominant coronary artery.

Right posterior atrial rami – Supply posterior surface of both right and left atria.

In the present study, the right coronary artery was identified in the coronary sulcus and posterior interventricular sulcus by removing the serous pericardium and fat. Dissection of the right coronary artery was done to study the following.

1. Location of Ostium

2. Level of Ostium with relation to sino tubular junction

3. Course of the right coronary artery

4. Branches of right coronary artery in first segment

5. Frequency of occurrence of third coronary artery

6. Branches in second segment

7. Point of termination of right coronary artery

8. Point of termination of posterior interventricular artery in posterior interventricular sulcus

9. Dominant circulation

10. Anomalous right coronary artery

1.Location of Ostium

Usually the ostium for the right coronary artery is located in the anterior aortic sinus (right coronary sinus). A search was made to study the position of ostium in any other sinuses of Valsalva

2. Level of ostium with relation to sinotubular junction

Usually the ostium is located below the sinotubular junction. Sometimes it may be at the ostium or above the ostium. These variations were looked for.

3. Course of the right coronary artery

The right coronary artery is found in the anterior and posterior part of the coronary sulcus. Any variations in its course was searched for. The course of the right coronary artery is divided into the two segments.

First segment – Between its origin and right border of the heart.

Second segment – Between the right border and crux.

4. Branches of right coronary artery in first segment

Three named major branches normally arise from the first segment of the right coronary artery. They are,

a.Right conus artery

b.Sinoatrial nodal artery

c.Right marginal artery.

The distance between the commencement of these three arteries from right coronary artery and from the ostium was measured. Any variations in these arteries were observed.

5.Frequency of occurrence of third coronary artery

The right conus artery arising separately from the anterior aortic sinus is the third coronary artery. A search was made to find out the third coronary artery.

6. Branches in second segment

Two named major branches normally arise from the second segment of the right coronary artery. They are,

a. Artioventricular nodal artery

b. Posterior interventricular artery

The A.V. nodal artery arises commonly from the inverted loop said to characterize the right coronary artery at crux where the posterior interventricular artery arises. A search was made to find out the origin of the A.V. nodal artery.

The posterior interventricular artery usually arises from right coronary artery and sometimes may arises from left circumflex coronary artery. The search is made to find the source of the posterior interventricular artery. Parallel branches to posterior interventricular artery were also searched for.

7. Point of termination of right coronary artery

The right coronary artery terminates at the level of right cardiac border or between right border and crux or at crux or beyond crux or reaching the left border. These variations were looked for.

8. Point of termination of posterior interventricular artery in posterior interventricular sulcus

The posterior interventricular artery may terminate in the proximal one-third or middle one-third or distal one-third. A search was made to find out the point of termination of posterior interventricular artery

9. Dominant circulation

The artery that gives rise to the posterior interventricular branch determines the ***Dominant Circulation.*** A search was made to find out the right or left dominance.

10. Anomalous right coronary artery

The presence of anomalous right coronary artery was looked for.

Statistical analysis:

Statistical scrutinizing of various data was made employing methods appropriate to the design of experiments and in line with the objective of investigation. The data collected were subjected to statistical analysis.

OBSERVATIONS

Right Coronary Artery

1. Location Of Ostium (Diag. 1)

The right coronary ostium for 49 hearts was present in the anterior aortic sinus and one ostium was present in the left posterior aortic sinus (Specimen No.4) (fig.no. 1)

Location of Ostium

Name of the sinus	Frequency
Anterior aortic sinus	49
Left posterior aortic sinus	1
Total	50

2. Level of ostium with relation to Sino tubular junction (diag. 2)

In 45 hearts the right coronary ostium was situated below the sinotubular junction (fig.no. 2), in 5 hearts (Sp.no.8, 14, 20, 30, 39) ostium was found at sinotubular junction (fig.no.3)

Level of ostium with relation to Sino tubular JUNCTION

Position	Frequency
Below	45
At	5
Above	0
Total	50

3. Course of the right coronary artery

The course of the right coronary artery was observed to be normal in all the hearts dissected except in two (sp.no 6 and 31). In specimen no 6 right coronary artery, one cm from its origin deviated from the coronary sulcus and ran in the sternocostal surface, cut the inferior border, reached the anterior part of the diaphragmatic surface. In specimen no 31(fig.no.4)

right coronary artery initially ran in the coronary sulcus, then deviated from the sulcus, ran in the sternocostal surface to end at the inferior border.

4. Branches of right coronary artery in first segment

a. Right conus artery (fig.no. 5)

The right conus artery was present in all the specimens. The distance between the ostium of right coronary artery and the origin of right conus artery varied between a maximum of 22mm and minimum of 2mm with a mean of 8.62mm and Standard Deviation of 3.82.

In 5 specimens right conus artery arose from the anterior aortic sinus from a separate ostium as the third coronary artery.

In all the specimens right conus artery was the first branch except in three specimens (sp.no.10, 40 and 46) where the Sino atrial nodal artery was the first branch.

b. Sino atrial nodal artery (fig.no. 6)

Occurrence	Frequency
Present	38
Absent	12
Total	50

The sino atrial nodal artery was present in 38 and absent in12 specimens. The distance between the ostium of right coronary artery and the origin of sino atrial nodal artery varied between a maximum distance of 32mm and a minimum of 7mm with a mean of 16.39mm and Standard Deviation of 5.89

The sino atrial nodal artery arose from the left circumflex artery in 12 specimens where it was absent from right coronary artery.

c. Right marginal artery (fig.no. 7)

The right marginal artery was present in all 50 specimens. The range observed in the distance between ostium of right coronary artery and origin of right marginal artery was found to be 20mm to 62mm with a mean of 40.04mm and Standard Deviation of 8.49

In specimen no 33 (fig.no.8) right marginal artery initially coursed along the inferior border and cut the inferior border, ran across the anterior part of the diaphragmatic surface to reach the middle of the posterior interventricular groove which was occupied by posterior interventricular branch. This posterior interventricular branch was flanked by parallel branches on either side.

5. Frequency of occurrence of third coronary artery

Occurrence	Frequency
Present	5
Absent	45
Total	50

The right conus artery arising separately from the anterior aortic sinus as the third coronary artery. (fig.no.9) The third coronary artery was present in 5 specimens studied (sp.no.2, 16, 22, 23 and 25).

6. Branches in second segment

a. Atrioventricular nodal artery

The A.V. nodal artery arises commonly from the inverted loop said to characterize the right coronary artery at the crux where the posterior interventricular artery arises. It was a branch of right coronary artery in 41 and from left coronary artery in 9 specimens. The source of the atrioventricular nodal artery is tabulated below.

Atrioventricular nodal artery

Source of AV nodal artery	Frequency
From the right	41
From the left	9
Total	50

b. Posterior interventricular artery

Origin of posterior inter ventricular artery	Frequency
From the right	41
From the left	9
Total	50

The posterior interventricular artery was found to arise from right coronary artery in 41 specimens and from the left in 9 specimens. Parallel branches to posterior interventricular artery were noted in 8 specimens (sp.no.2,9,12,21,28,33,45and50) studied.(fig.no.10, 10a,10b,10c& 10d)

In specimen no.2 one parallel branch was present on the right side of the posterior intervetricular artery. In specimen no.9 and 33 posterior interventricular artery was flanked by parallel branches on either side. In specimen no.12 two parallel branches on the right side and one parallel on the left side of the posterior interventricular artery were present. In specimen no. 21 one parallel branch was present on the left side of the posterior interventricular artery. In specimen no.28 (fig.no.10) four

parallel branches on the right side and one parallel branch and left side of the posterior interventricular artery were present. In specimen no.45 one parallel branch was present on the left side of the posterior interventricular artery. In specimen no.50 one parallel branch on the right side and three parallel branches on the left side were present.

In specimen no.9 posterior interventricular artery was divided into two branches in the proximal part of the interventricular groove (fig.no.11). In specimen no.20 (fig.no.12) the posterior interventricular artery initially ran in the proximal part of the posterior interventricular sulcus, then crossed the sulcus, ran across the posterior part of the diaphragmatic surface and divided into two branches which ran towards the posterior surface of the apex.

c.Right posterior ventricular rami

In specimen no 16, a large ventricular branch arose from the right coronary artery, between the right border and crux, which ran across the anterior part of the diaphragmatic surface to meet the posterior interventricular sulcus at its distal part. In specimen no 34, (fig. no.13) a large ventricular branch arose from the right coronary artery, between the

crux and left border, which ran across the posterior part of the diaphragmatic surface and terminated at the posterior surface of the apex.

7. Point of termination of right coronary artery (diag. 3)

Point of termination	Frequency
Between crux and left margin	31
At right margin	7
Reaching left border	6
At crux	4
Between right margin and crux	2
Total	50

In majority of the specimens, the right coronary artery terminated between crux and left border (fig.no.14). In 7 specimens it terminated at the right margin (fig.no.15). In 2 specimens it terminated between the right margin and crux (fig.no.16). In 4 specimens it terminated at crux (fig.no.17) In 6 specimens it reached up to the left border (fig.no.18).

8. Point of termination of posterior interventricular artery in posterior interventricular sulcus (diag. 4)

Point of termination in posterior interventricular sulcus	Frequency
Distal one-third	24
Middle one-third	16
Proximal one- third	10
Total	50

In 24 specimens posterior interventricular artery terminated in the distal one-third of the posterior interventricular sulcus (fig.no.19). In 16 specimens posterior interventricular artery terminated in the middle one-third of the posterior interventricular sulcus (fig.no.20). In 10 specimens posterior interventricular artery terminated in the proximal one-third of the posterior interventricular sulcus (fig.no.21).

9. Dominant circulation

The artery that gives rise to the posterior inter ventricular branch determine the ***dominant circulation.***

Dominant circulation (diag. 5)

Dominant artery	Frequency
Right	41
Left	9
Total	50

In 41 specimens the posterior interventricular artery arose from the right coronary artery indicating right dominance and in 9 specimens from the left circumflex coronary artery indicating left dominance.

10. Anomalous right coronary artery

The right coronary artery arose from the left posterior aortic sinus, below the sinotubular junction in specimen no 4, was considered as an anomalous right coronary artery.

DISCUSSION

1. Location of ostium

The topography of the ascending aorta and the aortic bulb and the size and position of the coronary artery orifices is necessary for the successful performance of a coronary arteriogram.

The right coronary ostium is situated in the centre of right sinus of Valsalva close to free edge of the aortic cusp [Angelini(1989)] or at sinotubular junction as suggested by Waller (1998). This ostial location allows maximal coronary filling during ventricular diastole.

In the present study, right coronary ostium for 49 hearts was present in the anterior aortic sinus (right aortic sinus) and one ostium was present in the left posterior aortic sinus.

Donaldson et.al., (1982) reported the origin of right coronary artery from left the posterior aortic sinus. It is an uncommon anomaly, and its incidence is 0.07 – 0.19% angiographically and 0.004% at autopsy (Engel HJ et.al., 1975). Although this minor congenital anomaly was considered of no clinical significance, current studies indicate that myocardial

infraction, angina pectoris, syncope and sudden death can be attributed to this aberrant condition. (Frescura et.al., 1998). Liberthson and colleagues (1983) reported sudden death in a 9 month old infant with aberrant origin of the right coronary artery from left sinus of Valsalva. Roberts (1982) analysed 10 autopsy patients with origin of right coronary artery from left sinus of Valsalva and found that 3 patients with clinical problems; one with recurrent ventricular tachycardia, one with typical angina pectoris and one with sudden death.

A rare anomaly of a right coronary artery arising from posterior (non coronary) sinus has also been reported (William, 1986). In the present study no such ostium was found.

2. Level of ostium with relation to sino tubular junction

The level of ostium is significant in patients who are subjected to coronary arteriographic studies. Difficulty in manipulating the catheter tips will be considerably higher in patients with the ostium above the level of sino tubular junction.

The cranial displacement of the ostium, a few centimeters or more, higher up arising from ascending aorta was reported by Mc Alpine (1975).

Greater cranial displacement of the ostium is suggested by Paulin (1997) to occur in Marfan's syndrome. According to Amplatz et.al., (1967) the cranial displacement usually creates more technical difficulties for selective catheterization, since it often requires more extensive catheter manipulations. This ostial dislocation is called "Higher take off" coronary artery demonstrated by Spring and Thompson (1973). High take off position of coronary ostium also has been postulated as a cause of sudden death.

In our present study the right coronary ostium was below the sino rubular junction in 45 hearts and at sino tubular junction in 5 hearts. The right coronary ostium above the sino tubular junction was not found in any of the specimens studied.

Extreme ectopia of coronary artery arising from a branch of the aorta or from internal mammary artery is rare and occurs in patients with other cardiovascular anomalies (Evans 1933, Alexander and Griffith, 1956). Single coronary artery is a rare congenital anomaly diagnosed at autopsy. Single coronary artery arising from the right coronary sinus seems to be more commonly associated with athero sclerosis than a network with two coronary arteries (Benslimane et.al., 1988). Ectopic

origin of one of the coronary arteries from the non coronary sinus is reported and commonly associated with transposition of large vessels (Vladover et.al., 1972). However in our study, none of these variations were found.

3. Course of the right coronary artery

The right coronary artery was found in the coronary sulcus as well as in the posterior interventricular sulcus. Variations in the course of right coronary artery have rarely been reported. Dual origin from the right sinus of Valsalva has been reported. In about 10% of the hearts, it bifurcates within a few millimeters of the aortic ostium, forming two diverging trunks of equal size (Kirklin and Barratt – Boyes,1993).

In the present study two specimens showed variation in the course of right coronary artery (sp.no. 6 and 31). In both these is specimens the right coronary artery initially found in the coronary sulcus, after a short course in the sulcus, deviated from the sulcus, ran in the sternocostal surface. In specimen no 6, it cut the inferior border and terminated at the anterior part of the diaphragmatic surface and in specimen no 31, it terminated at the inferior border.

Vladover et.al., (1972) described aplasia of right coronary artery in which the place of right coronary artery is taken over by the left coronary artery. Atresia or hypoplasia of the right coronary artery as a rare cause of ischemic heart diasease in infancy and childhood was reported by Blackman et.al., (1981). There was no such variation in the present study.

4. Branches of right coronary artery in first segment

a. Right conus artery

The first and highest branch of the first segment of the right coronary artery is the conus artery. It joins with the left conus artery of left anterior descending artery infront of out flow tract of the right ventricle at about the level of pulmonary valve. This vascular anastamotic ring is called as circle of vieussens (1796) (fig.no.22). The primary importance of this ring is to serve as a source of collateral circulation in patients with left anterior descending artery occlusion [Bittl and Levin (1997)].

In the present study, right conus artery originated as a branch of right coronary artery in 45 hearts, from a separate ostium in 5 hearts.

Sometimes the conus artery arises from the right coronary artery as a second branch and the first branch is the sinoatrial nodal artery. This finding was present in three specimens of present study.

b. Sino atrial nodal artery

Kyriakidis et.al., (1983) documented sino atrial nodal artery as the second branch arising from the first segment of the right coronary artery. It has been found by Kyriakidis et.al. (1983) that this vessel arises from the right coronary artery in 59%, from the left circumflex in 38% and from both arteries with a dual blood supply in 3 %. It arises from proximal portion of the right coronary artery in more in more than half a human hearts [James (1977)]. It courses posteriorly and superiorly over the anterior wall of the right atrium beneath the right atrial appendage to the base of superior vena cava [Kirklin and Barratt – Boyes (1993)].

In the specimen demonstrated by Keith and Flack (1907) the connection between the two coronary arteries was so large as to continue on origin for the sinuatrial nodal artery from each. Koch (1909) had found the sino atrial nodal artery totally derived from bromchial artery. Choi YH (1994) found that sino atrial nodal artery originated from left circumflex

artery in 54.4% of cases, from right coronary artery in 43.7% of cases and from both coronary arteries in 1.9% of cases in his angiographic study of Korean population.

In the present study, the incidence of sino atrial nodal artery arising from the right coronary artery was 76%.

c. Right marginal artery

As the right coronary artery runs along the anterior aspect of atrioventricular sulcus, sends one or more branches to the anterior wall of the right vemtricle. The largest branch, which is greater in calibre and long enough to reach the apex in most hearts, is the right marginal artery [Baroldi and Scomazzoni (1967)]. In those hearts where the posterior interventricular artery is a branch of the left circumflex, the right marginal artery may be the main terminal branch of the right coronary artery. This marginal artery may serve as sources of collateral circulation in patients with left anterior descending artery occlusion [Bittl and Levin (1997)].

In the present study, the right marginal artery was present in all the specimens. The shortest distance of origin of the right marginal artery from the ostium was 20 mm and the longest distance was 62 mm with a

mean of 40.04 mm. Study of the distance between the coronary ostium and the origin of the major branches from its proximal portion of the coronary artery indicates a wide variation with relation to the site of origin of the branches.

In the present study, slight variation in the course of right marginal artery was found in one specimen (sp.no.33). In this specimen (fig.no.) right marginal artery initially coursed along the inferior border and cut the inferior border, ran across the anterior part of the diaphragmatic surface to reach the middle of the posterior interventricular groove which was occupied by posterior interventricular branch. This posterior interventricular branch was flanked by parallel branches on either side.

5. Frequency of occurrence of third coronary artery

The conus artery arising separately from the anterior aortic sinus is called as third coronary artery [Reed and Stafford (1985)]. The presence of third coronary artery was studied angiographically by Levin et.al., (1981). Banchi (1904) observed the separate orifice of a small conus artery from right coronary sinus in 33% of cases and he named this occurrence as arteria accessoria. Schlesinger et.al., (1949) reported 51%

incidence of third coronary artery. Choi YH (1994) reported 52.4% incidence of third coronary artery in his angiographic study of Korean population. Ivan Stankovic (2004), in his morphometric study of the conal coronary artery, reported 34.8% of third coronary artery.

In our study, third coronary artery was present in 10% of the specimens studied.

The conus artery originating from separate ostium, requires the use of special catheters, since they are not opacified during routine angiography.

6. Branches in second segment

a. Atrio ventricular nodal artery

At or near the crux, the right coronary artery takes a characteristic deep ‘U’ turn as it changes its direction from the posterior part of coronary sulcus to the posterior interventricular sulcus. At the apex of ‘U’ turn, the right coronary artery gives the atrioventricular nodal artery.

According to James (1961) the atrioventricular nodal artery is a branch of the right coronary artery in about 90%. It communicates with

the great auricular anastomatic artery of Kugel (1928). The first description of the blood supply of the atrioventricular node was by Haas (1911). James (1961) pointed out that the origin of atrioventricular nodal artery is consistently at the site of typical ‘U’ turn of the right or left coronary artery beneath the posterior interventricular vein (middle cardiac vein). Reemtsma et.al, (1961) reported that the atrioventricular nodal artery may be injured in the closure of ostium primum defect. Choi YH (1994), reported the origin of atrioventricular nodal artery from the right coronary artery in 93.4% cases, from the left circumflex artery in 5.8% cases and from both arteries in 0.8% cases in his angiographic study of coronary arteries in Korean population.

In the present study the atrioventricular nodal artery arose from right coronary artery in 82%, from the left coronary artery in 18%.

b. Posterior interventricular artery

James (1961) described that the posterior interventricular artery is a terminal branch of the right coronary artery in 90% of 106 specimens. According to Gray (1999), posterior interventricular artery is a branch from right coronary artery in 90% and from left circumflex branch in 10%

In the present study, the posterior interventricular artery arose from the right coronary artery in 82% and from left circumflex artery in 18%.

According to Gray (1999), posterior interventricular artery is generally single in about 70%, and flanked either to the right or left or bilaterally by parallel branches from the right coronary artery. If these flanking vessels exist, branches of the posterior interventricular artery are small and sparse. In the present study, parallel branches were present in 16% of the specimens.

Reul (1984) reported the presence of two posterior interventricular arteries derived one from the right coronary artery and other from the left coronary artery. Similar vessels are not found in the present study. But in one specimen posterior interventricular artery was divided into two branches in the proximal part of the interventricular groove.

Slight variation in the course of the posterior interventricular artery was noted in one specimen, in which the posterior interventricular artery initially ran in the proximal part of the posterior interventricular sulcus, then crossed the sulcus, ran across the posterior part of the diaphragmatic

surface and divided into two branches which ran towards the posterior surface of the apex.

7. Point of termination of right coronary artery

According to Gray (1999), the right coronary artery terminates at the right margin in 10%, between right margin and crux in 10%, a little beyond crux in 60%, and reaches the left border in 20%. According to James (1961), the right coronary artery terminated at the right margin in 2%, between right margin and crux in 7%, at crux in 9%, between crux and left border in 64%, and reached the left border in 18%.

In the present study, the right coronary artery terminated at the right margin in 14%, between right margin and crux in 4%, at crux in 8%, between crux and left border in 62% and reached the left border in 12%.

8. Point of termination of posterior interventricular artery in posterior interventricular sulcus

James (1961) described that the posterior interventricular artery is a terminal branch of the right coronary artery in 90% of 106 specimens. In 88% of them posterior interventricular artery extends halfway or more down the posterior interventricular sulcus.

In the present study, the posterior interventricular artery terminated in the distal one-third of the posterior interventricular sulcus in 48%, in the middle one-third of the posterior interventricular sulcus in 32%, in the proximal one-third of the posterior interventricular sulcus in 20%.

9. Dominant circulation

Variability in the origin of the posterior descending artery is expressed by the term ***"dominance".*** The dominant vessel is one that supplies the posterior diaphragmatic portion of the interventricular septum and the diaphragmatic surface through posterior interventricular artery. The term right or left "coronary preponderance" or "dominance" is used to show which coronary irrigates the hearts diaphragmatic surface (Schlesinger, 1940). This term is frequently used but is potentially misleading: it could be taken to mean that the dominant coronary is the one that irrigates the greater part of the myocardium, but in fact it is always the left coronary artery that does so. The term refers to the supply of the hearts diaphragmatic surface, which may be the right or left coronary.

As suggested by Bittl and Levin (1997), the right coronary artery is dominant in about 85% of humans. A left dominant circulation occurs in 10 – 15% of hearts [Kirklin and Barratt-Boyes (1993)]. Choi YH (1994), found right dominance in 88.4%, left dominance in 4.3% and balanced dominance in 7.2% in his angiographic study in Korean population. Cavalcanti et.al. (1995), found right dominance in 88.18% and left dominance in 11.82%.

In present study, the right coronary artery was the dominant in 82% and left coronary artery was the dominant in 18%.

This distinction as to whether the right or left coronary artery supplies the posterior interventricular artery is important in evaluating patients with coronary artery disease and in the planning of coronary artery bypass grafting [Kirklin and Barratt-Boyes (1993)].

10.Anomalous right coronary artery

The term “anomaly” is used for variations that occur in less 1% of the general population (Angelini et.al. 1999). Any anatomic feature that does not fulfill the criteria for coronary artery normality is automatically an anomaly [Ogden (1970)].

The coronary artery anomalies are concerned with coronary artery origin, distribution and termination. Some of these to be considered clinically insignificant can be associated with other congenital heart defects, myocardial ischemia and reduced life expectancy. Congenital anomalies of either of coronary arteries occur in 1 to 2% of the population [Engel (1975), Hursts the heart (2001)]. Such anomalies increase the risk of coronary artery trauma during surgical procedures and are frequently incidental findings, in which the anatomy is altered but physiology is normal, i.e. Coronary blood flow is normal. However certain anomalies are associated with myocardial ischemia or infarction, heart failure and sudden death.

Right coronary artery anomalies may be either in relation to origin – high aortic origin, from left posterior aortic sinus of Valsalva, from pulmonary artery, common origin with left coronary artery atresia, hypoplasia, aneurysms or coronary atriovenous fistula. Ogden (1970) considered high origin of right coronary artery to be more than 1 cm. above the sinotubular junction as a minor coronary anomaly. Such a high origin is not observed in the present study.

Origin of right coronary artery from left posterior aortic sinus of Valsalva, an uncommon anomaly was recognized in 0.02% of coronary arteriogram by Donaldson et.al, (1982), 0.04% by Engel et.al, (1975), 0.17% by Kimbiris et.al (1978) and 0.16% by Chaitman et.al, (1976). Such an anomalous artery is found in the present study in 2% of the hearts. Aberrant origin of right coronary artery was considered to be a benign condition but Thomson et.al, (1976) reported two patients with typical angina pectoris. According to Hursts the heart (2001), 12 patients with this anomaly, 3 died suddenly and 2 had angina or syncope. At necropsy, transmural ventricular scars were seen in 2. Sudden death in a 9 month old infant reported by Liberthson (1983) with this anomaly. Of 10 autopsy patients with this anomaly, Roberts and colleagues (1982) reported 3 patients with the clinical problems; 1 with recurrent ventricular tachycardia, 1 with typical angina pectoris and 1 with sudden death.

Hypoplasia of proximal portion of right coronary artery was observed by Liberthson (1979), Cheitlin (1974) and Benge (1980) reported young adult males who had hypoplasia of right coronary artery along with inferior myocardial infarctions. Slit like ostium of right coronary artery from left aortic sinus, limits coronary blood flow during

exercise [Roberts (1982)]. This study does not reveal any hypoplastic right coronary artery or ostial narrowing.

Anomalous branches of right coronary artery like left circumflex artery [Antopol and kugel (1933), Donaldson et.al, (1982)] and anterior descending interventricular artery [Donaldson et.al, (1982), Engel (1975)] although reported, is not seen in the present study.

Origin of both coronary arteries from a single ostium is not observed in the present study. But this was observed by Sharbaugh (1974) in 0.04% and Lipton (1979) in 0.2%.

The anomalous origin of right coronary artery from the pulmonary artery was reported by Bermudez (1979) and Fontanna and Edwards (1962). Coronary atrio – venous fistula was reported by Vogelbach et.al, (1979). William (1986) found an extremely rare anomaly in which the right coronary artery arose from the posterior (non – coronary) aortic sinus. This study does not reveal any of these anomaly.

CONCLUSION

The present work was carried out to study the branching pattern of right coronary artery in 50 specimens.

The right coronary artery was found to arise from the anterior aortic sinus in all the specimens except one, in which the right coronary artery was found to arise from left posterior aortic sinus.

The right coronary ostium was below the sino rubular junction in 90% of the specimens and at sino tubular junction in 10%. The right coronary ostium above the sino tubular junction was not found in any of the specimens studied.

A slight variation in the course of the right coronary artery was noticed in 2 specimens.

The average distances of the three branches of first segment of right coronary artery from the ostium were found to be 8.62mm,16.39mm and 40.04mm respectively. These measurements will probably be of use in planning bypass grafting.

The incidence of sino atrial nodal artery arising from the right coronary artery was 76%.

Third coronary artery was present in 10% of the specimens studied.

The atrioventricular nodal artery arose from right coronary artery in 82%, from the left coronary artery in 18%.

The posterior interventricular artery arose from the right coronary artery in 82% and from left circumflex artery in 18%. Parallel branches were present in 16% of the specimens.

The right coronary artery terminated between crux and left border in 62%, at the right margin in 14%, reached the left border in 12%, at crux in 8%, and between right margin and crux in 4%,.

The posterior interventricular artery terminated in the distal one-third of the posterior interventricular sulcus in 48%, in the middle one-third of the posterior interventricular sulcus in 32%,in the proximal one-third of the posterior interventricular sulcus in 20%.

The right coronary artery was the dominant in 82% and left coronary artery was the dominant in 18%.

The presence of anomalous artery-right coronary artery arising from the left posterior aortic sinus was found in only one out of fifty specimens studied.

An in depth knowledge of the anatomy of the coronary arteries, ‘crown’ of the heart, is a self evident prerequisite for a complete under standing of the coronary artery disease or for more intelligent planning of surgery. The present study on the right coronary artery, its origin, course, branching patterns, termination and the presence of anomalous arteries was to be of some use to the specialists during cardiac catheterizations and to effectively plan bypass surgeries using normal or anomalous coronary arteries. This study would be of use to interventional radiologists and cardiologists for their invasive or non invasive procedures.

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THE 50 SPECIMENS OF THE PRESENT STUDY

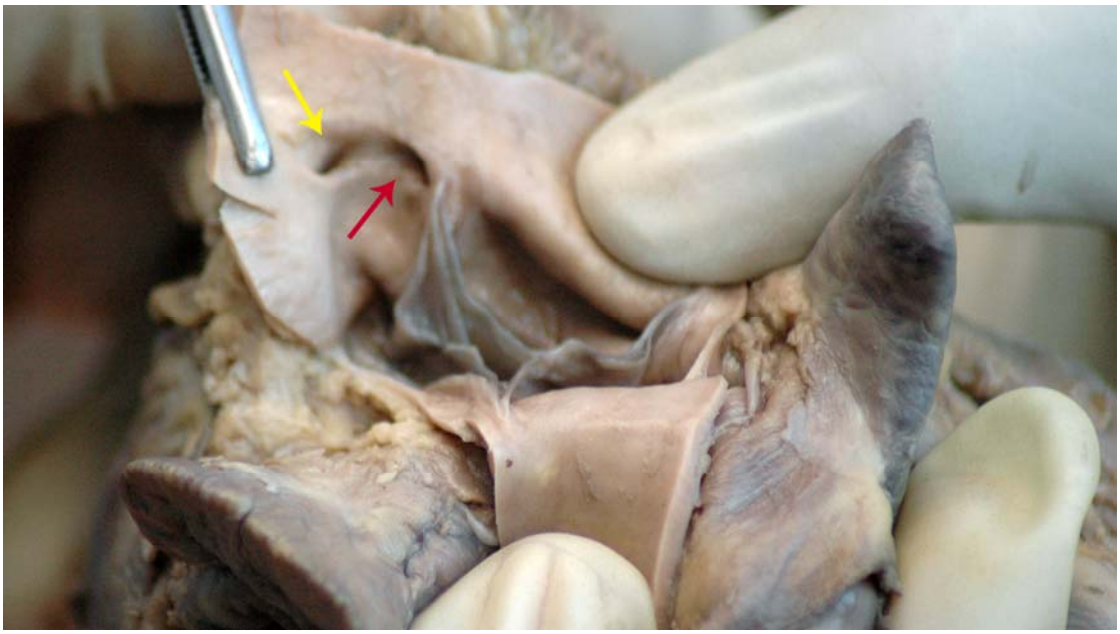
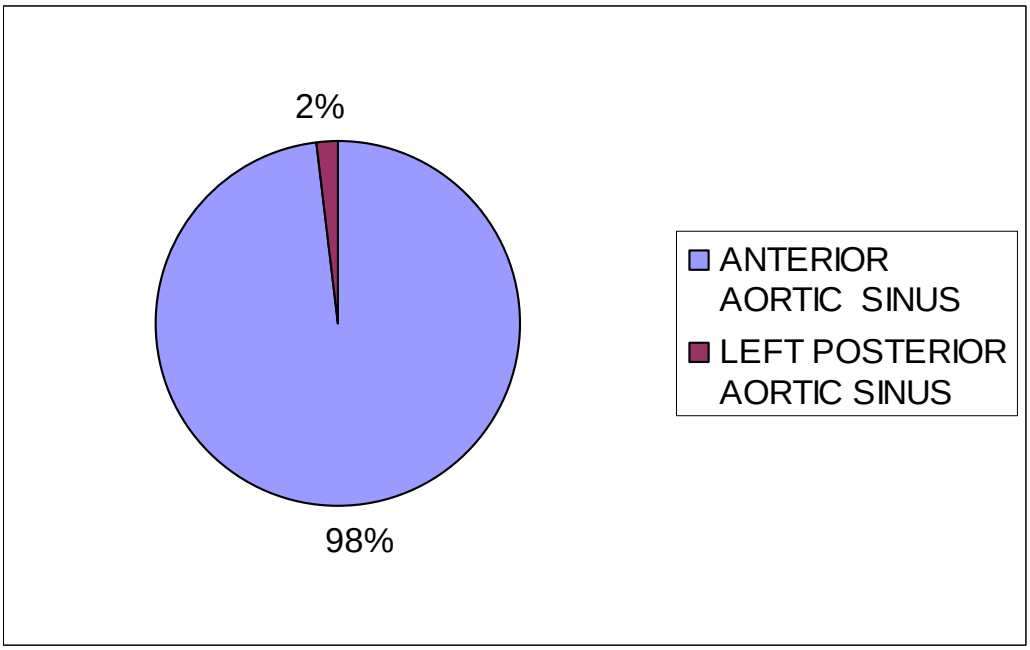


Fig.no 1- Right Coronary Ostium at the Left Posterior Aortic Sinus
→Right Coronary Ostium →Left Coronary Ostium

DIAGRAM 1. LOCATION OF OSTIUM



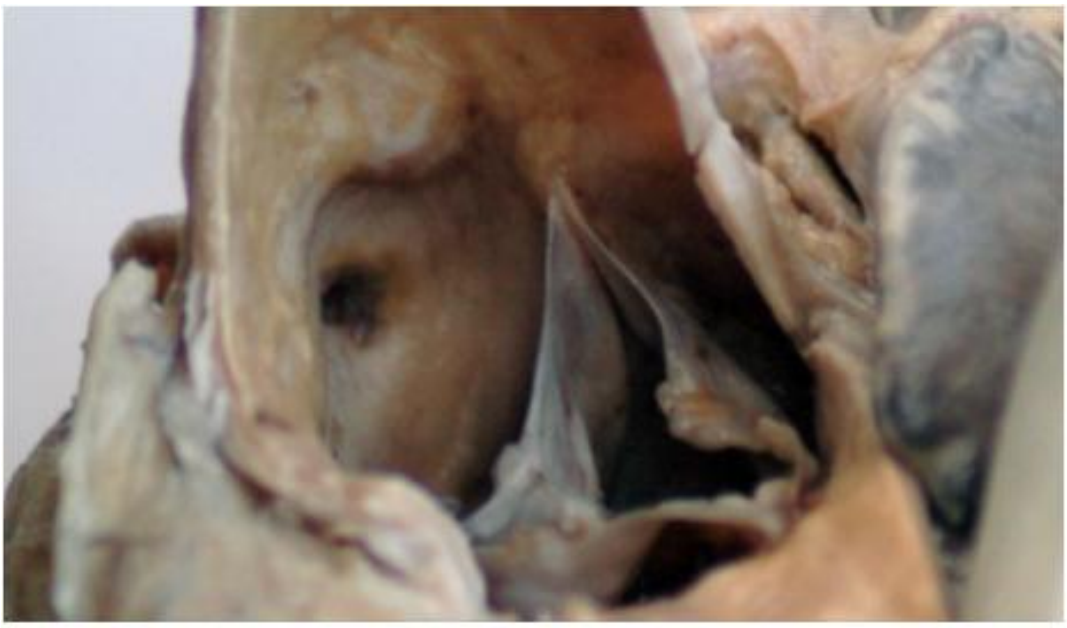


Fig no. 2- Right Coronary Ostium – Below STJ

Fig no- 3 Right Coronary Ostium – AT STJ

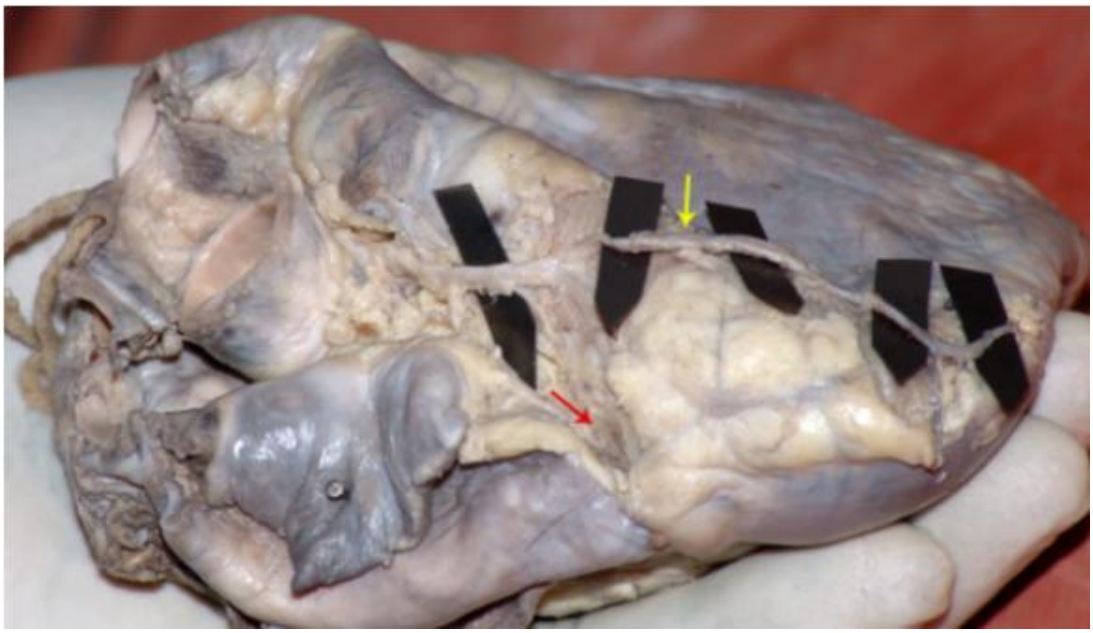


Fig.no 4- Variation in the Course of RCA
→ RCA →Right Coronary Sulcus

Fig no. 5 –First Segment of RCA
→ . Right Conus Artery

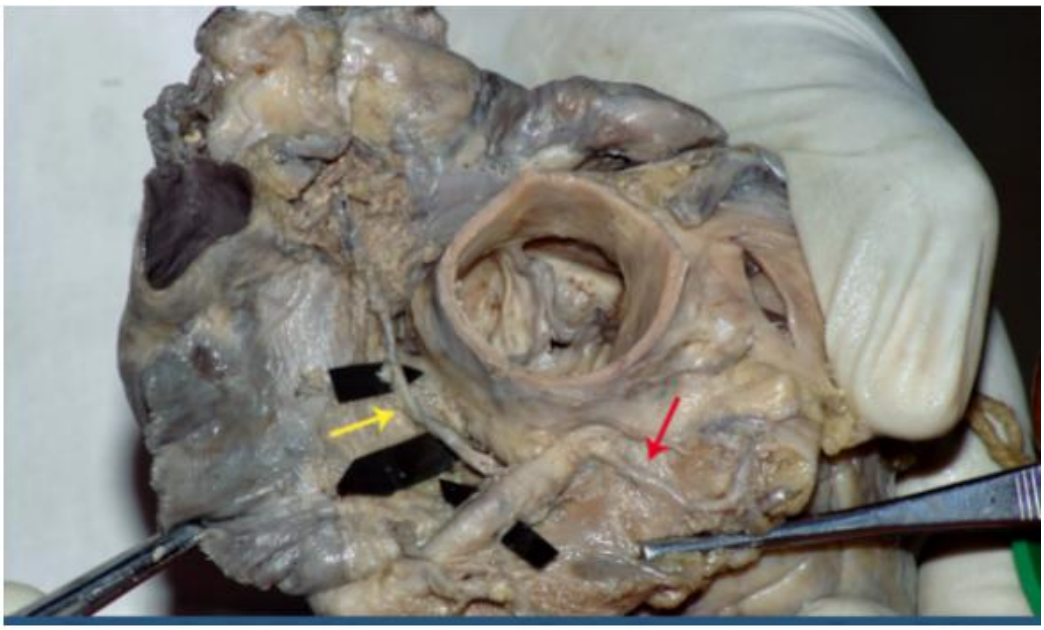


Fig.no 6 –SA Nodal Artery And Right Conus Artery From RCA
→ SA Nodal Artery → Right Conus Artery

Fig.no 7- The Right Coronary Artery with its Right Marginal Branch

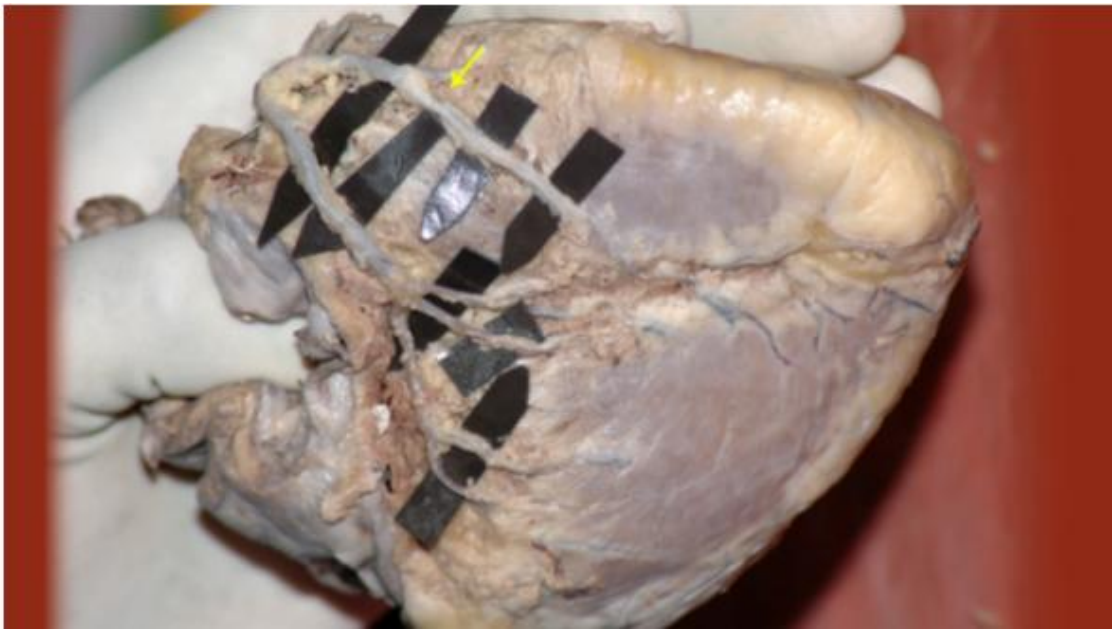


Fig.no.8 – Rt Marginal Artery Running Across the Diaphragmatic Surface

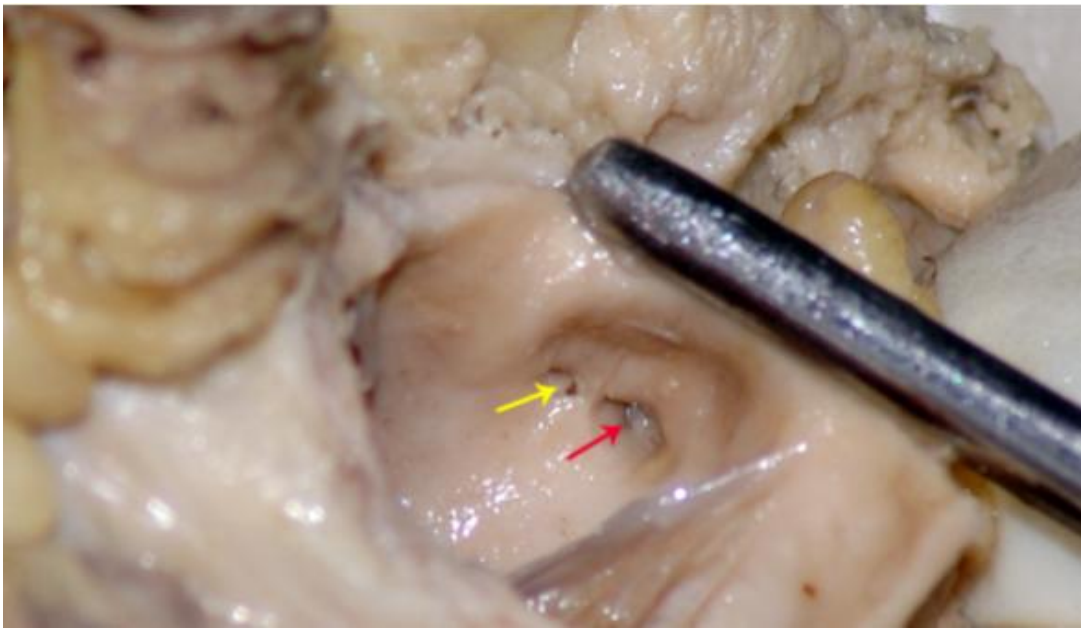


Fig.no. 9 →Ostium For Third Coronary Artery
→ Ostium For Right Coronary Artery

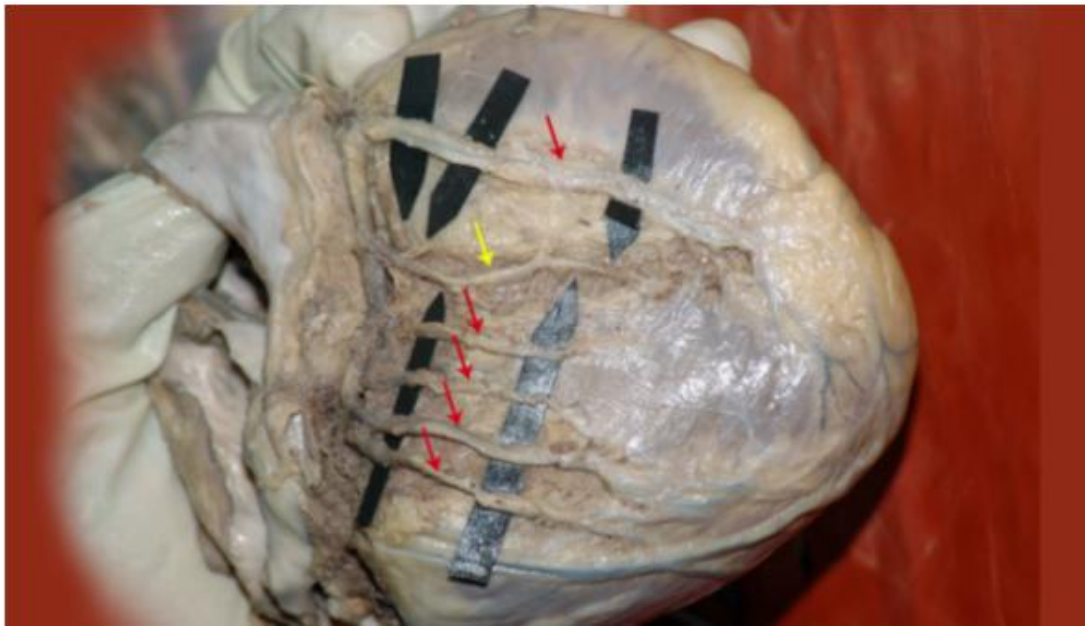


Fig.no 10- Parallel Branches to PIVA
→ - PIVA, →- Parallel Branches

Fig no -11 PIVA Dividing into Two Branches

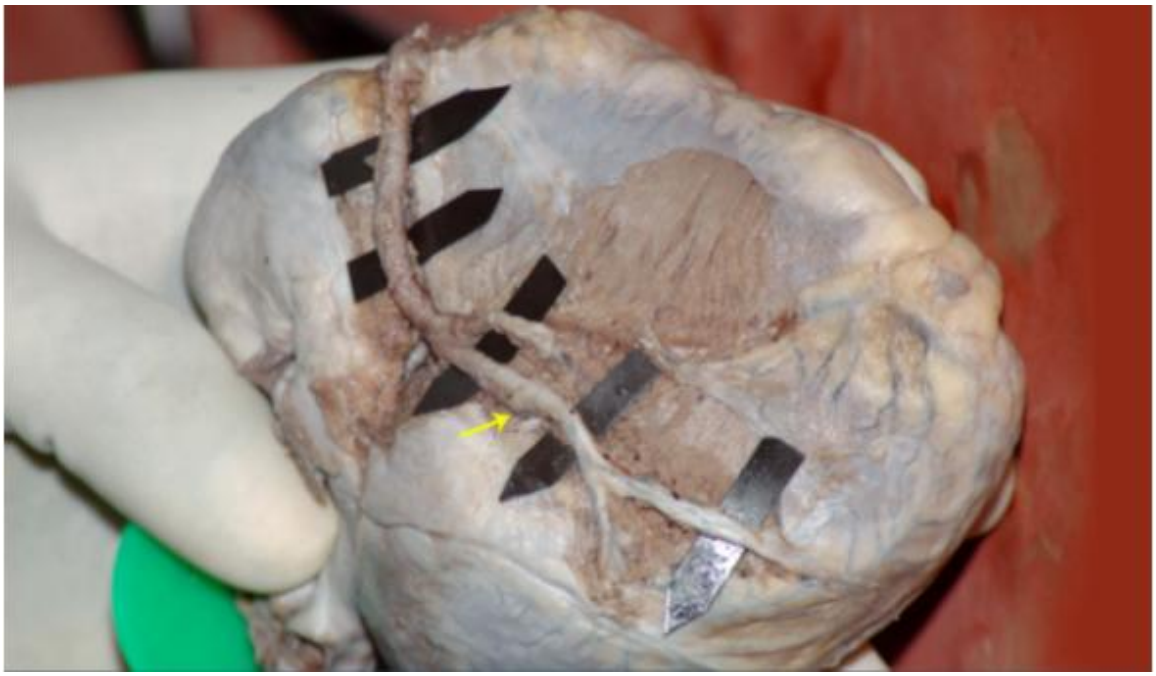


Fig. no. 12 – PIVA Crossing the PIVS and Running Across the Diaphragmatic Surface

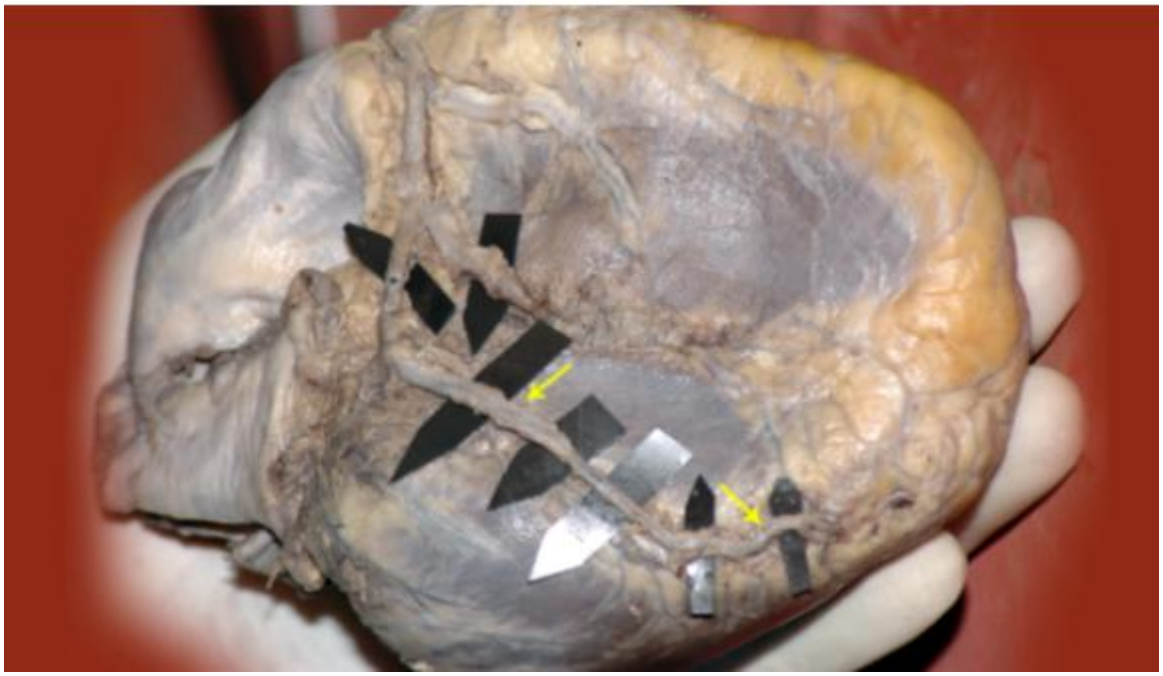


Fig. no. 13- Ventricular Branch of RCA Running Across the Diaphragmatic Surface Towards Apex

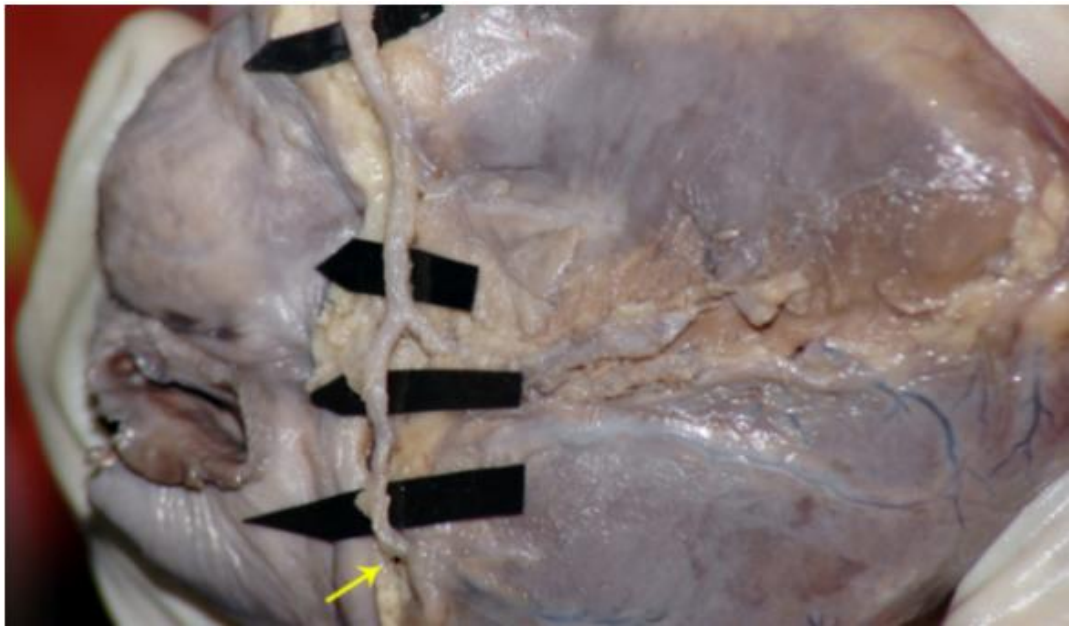


Fig. no 14 – Termination of RCA Between Crux and Left Margin

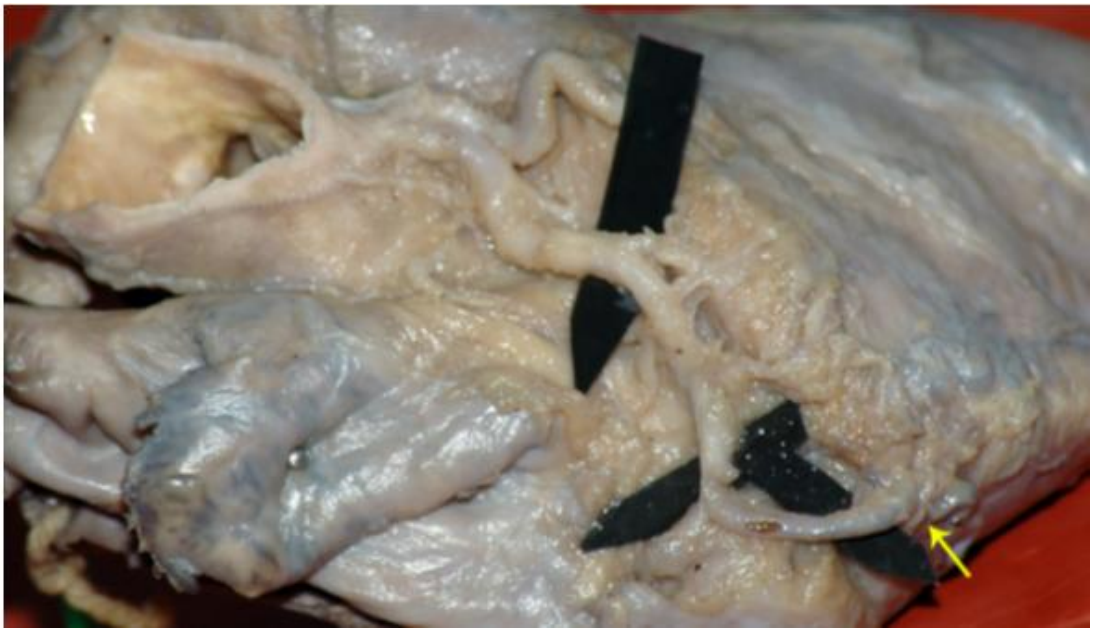


Fig.no 15 – Termination of RCA at the Right Margin

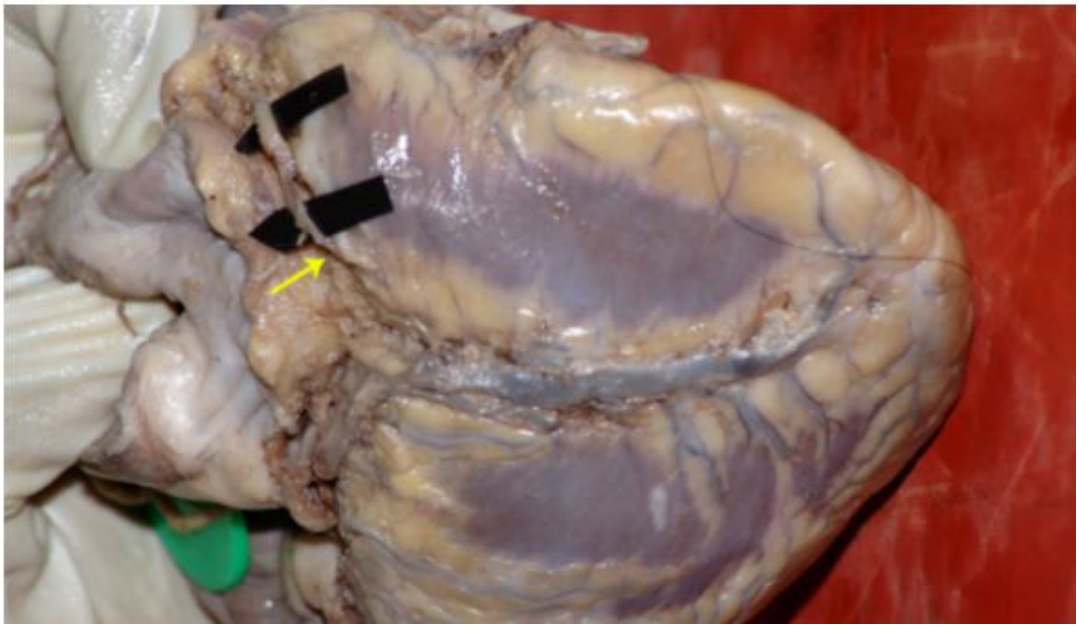


Fig.no 16 – Termination of RCA Between Right Margin & Crux

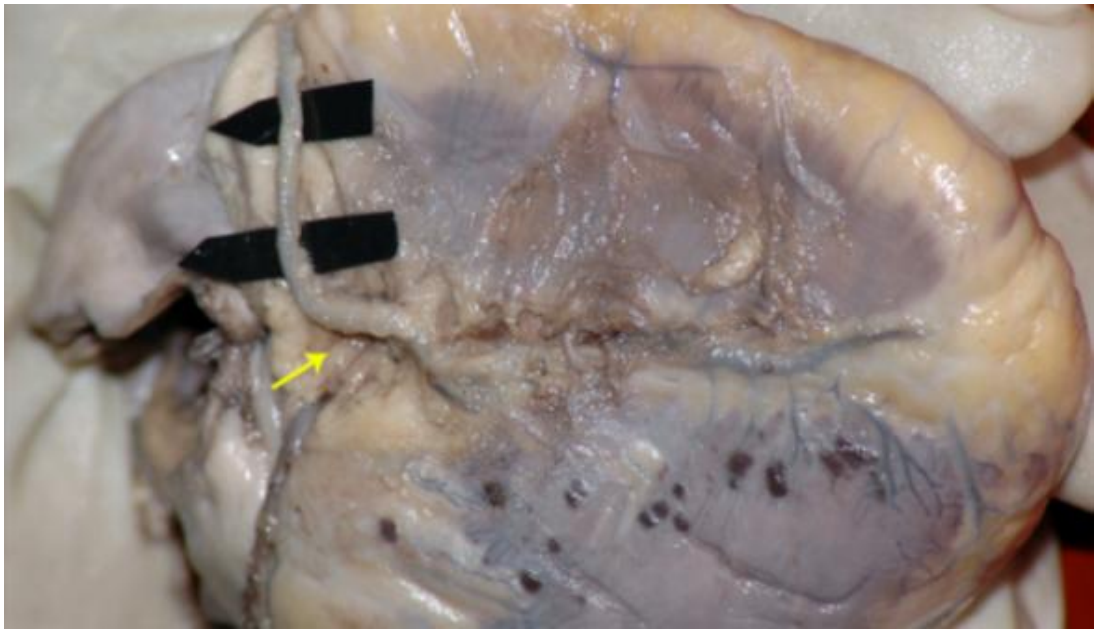


Fig.no 17 – Termination of RCA at Crux

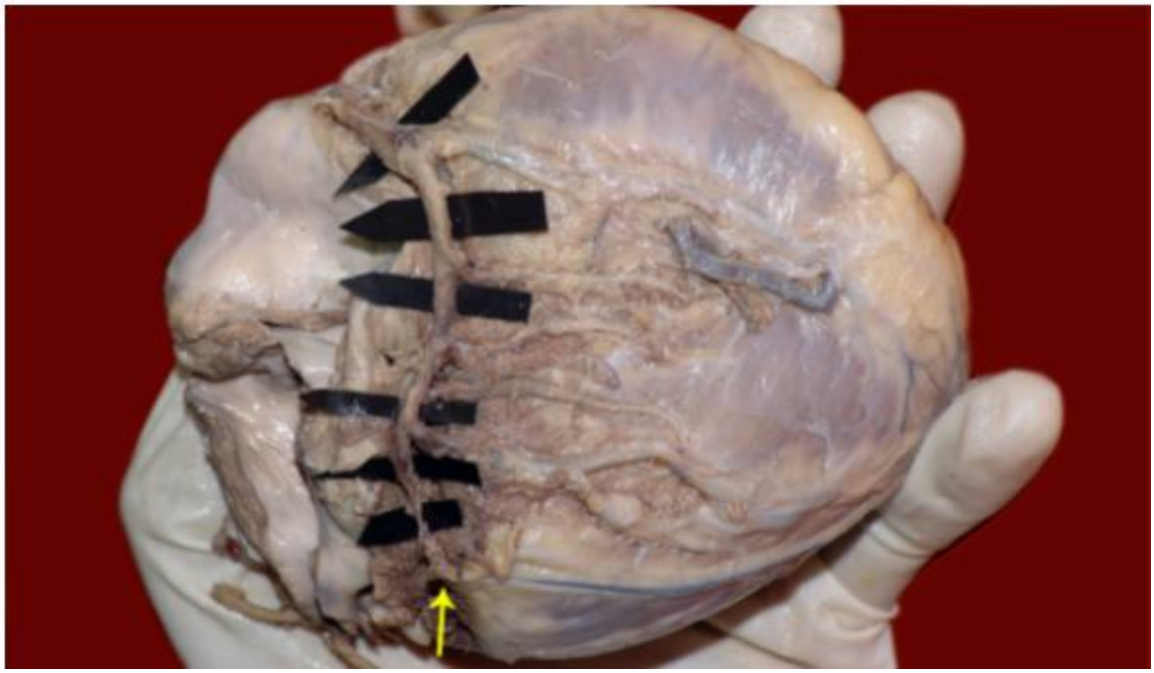


Fig.no 18 – RCA Reaching the Left Margin

DIAGRAM 3- POINT OF TERMINATION OF RIGHT CORONARY ARTERY

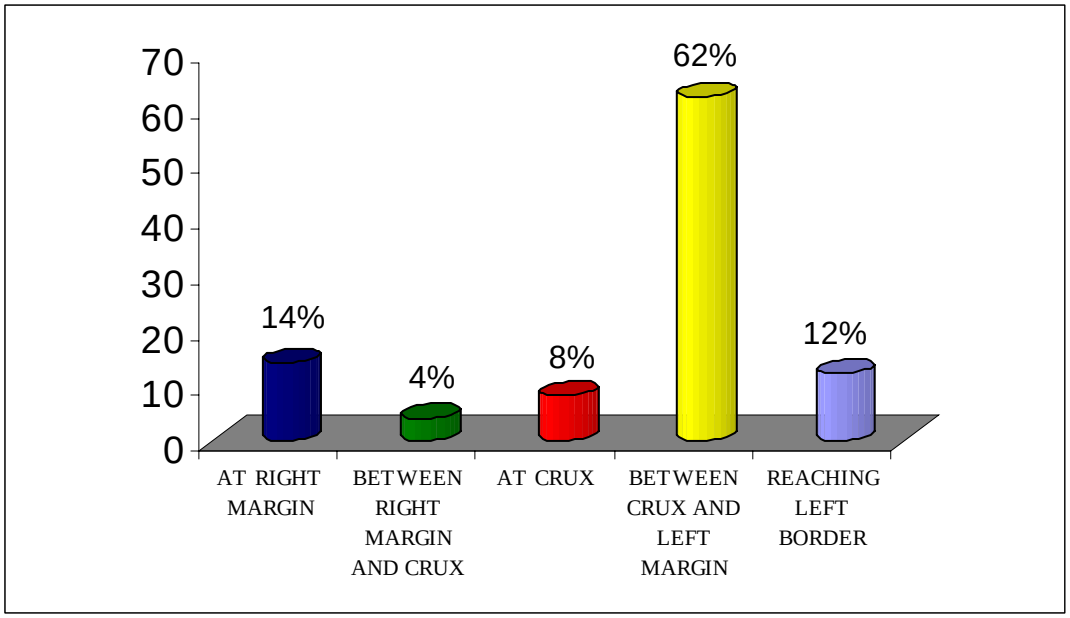
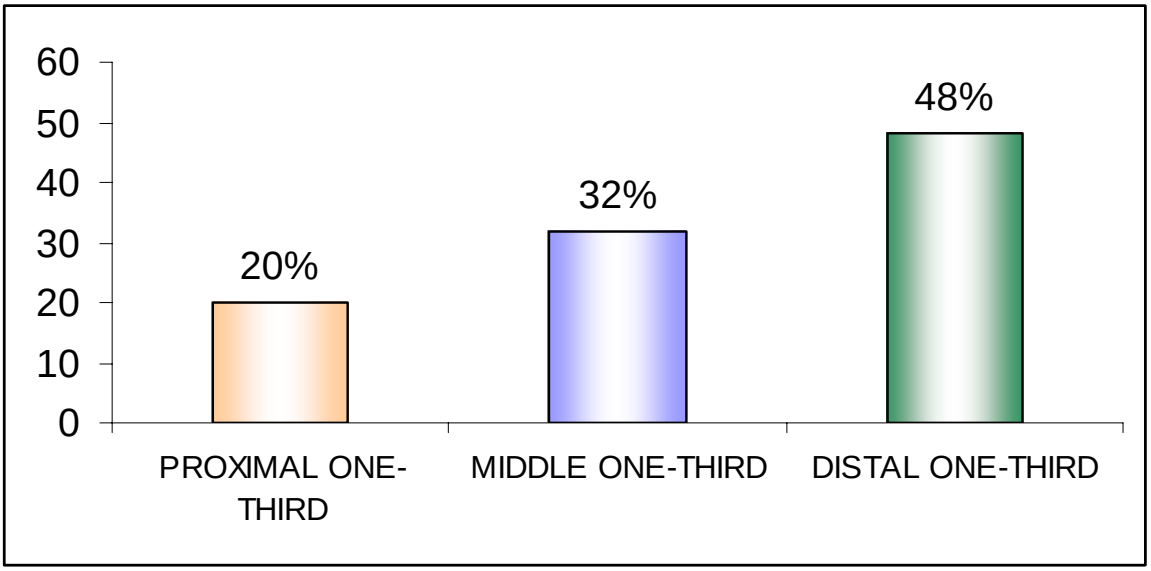


DIAGRAM 4- POINT OF TERMINATION OF POSTERIOR INTERVENTRICULAR ARTERY IN POSTERIOR INTERVENTRICULAR SULCUS.



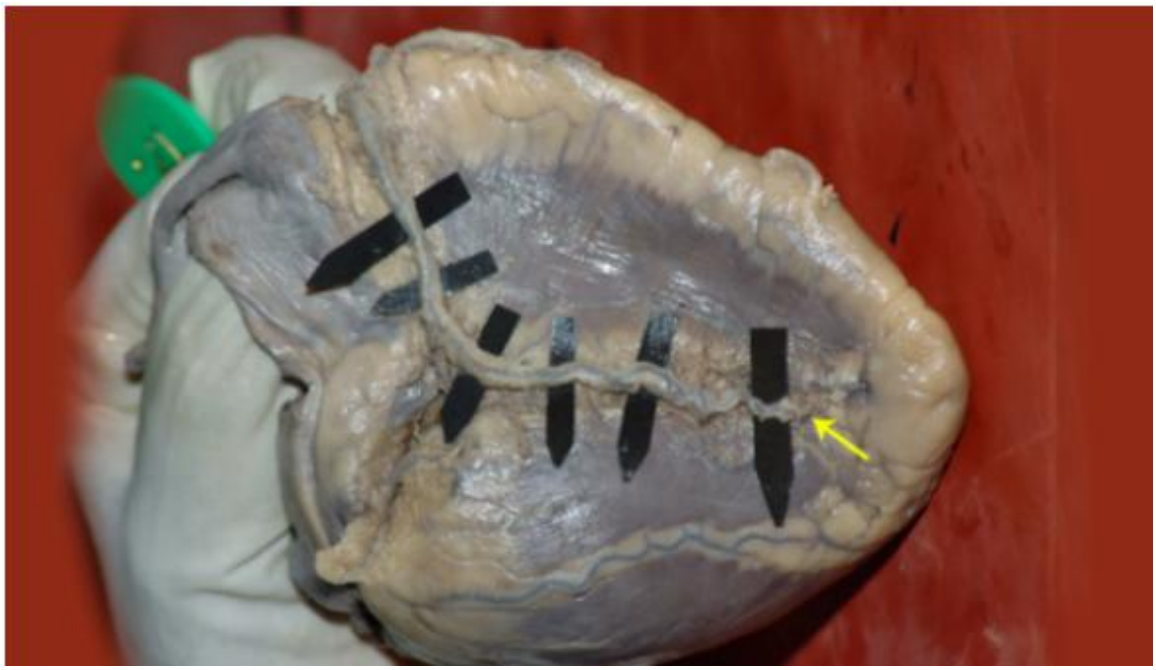


Fig.no 19 – Termination of PIVA in Distal one-third of PIVS

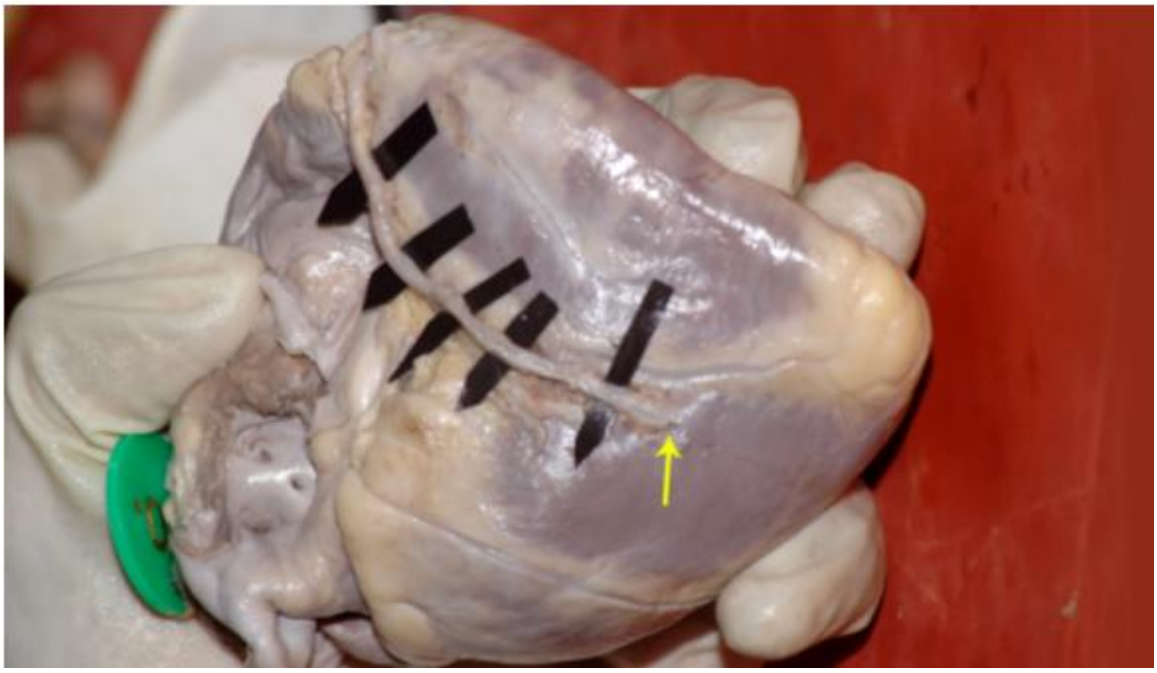


Fig.no 20 – Termination of PIVA in Middle one- third of PIVS

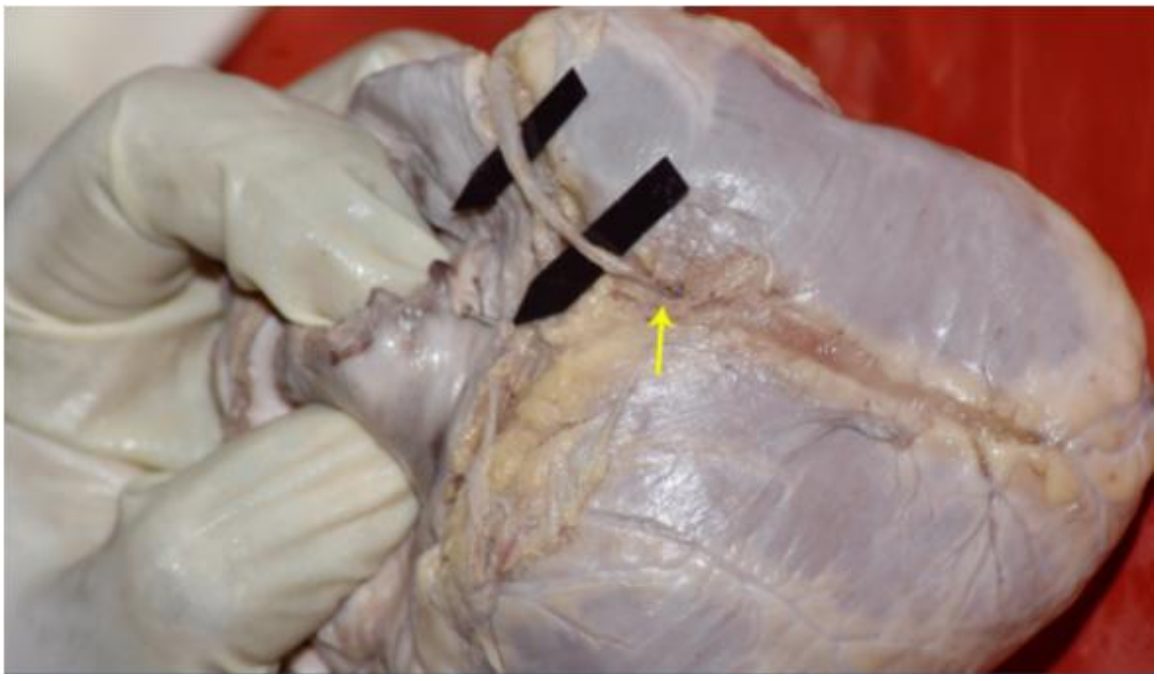


Fig.no 21 – Termination of PIVA in Proximal one- third of PIVS

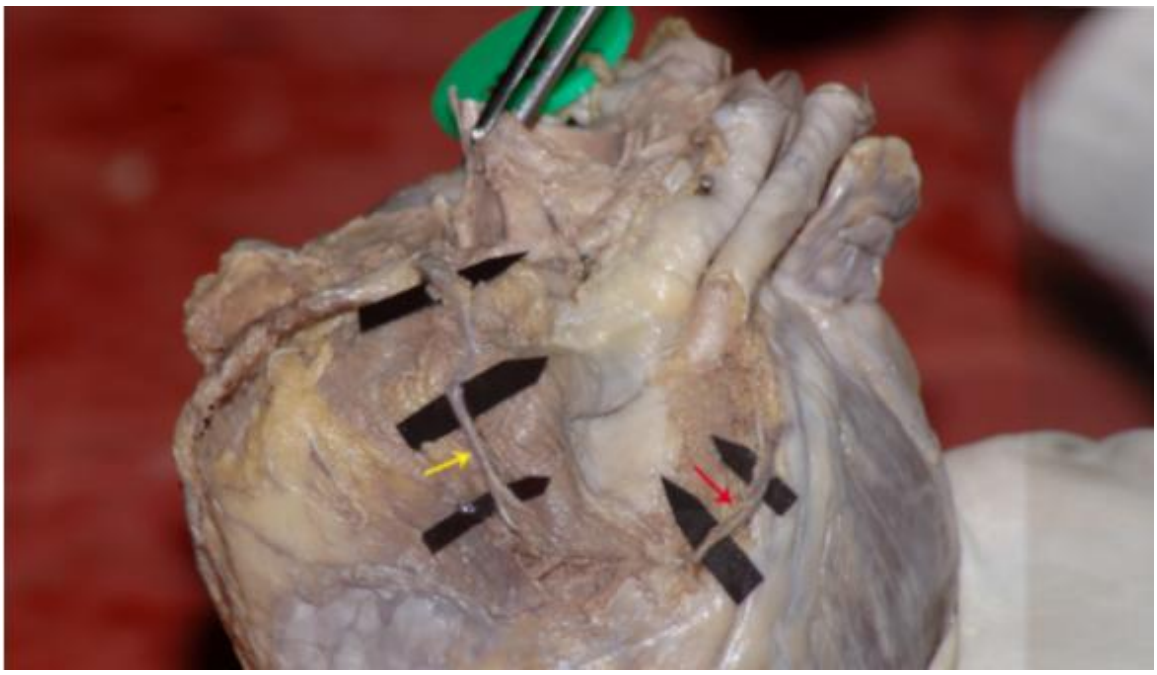


Fig.no 22 – The Circle of Vieussens

→ Right Conus Artery → Left Conus Artery

PARALLEL BRANCHES TO POSTERIOR INTERVENTRICULAR ARTERY

Fig 10a

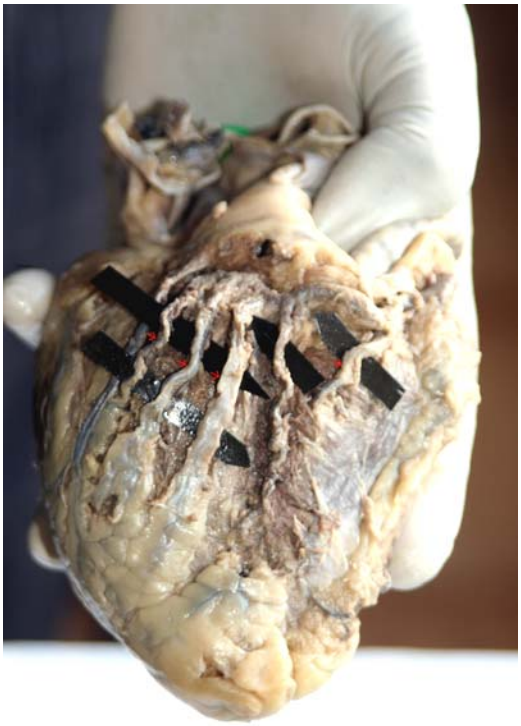


Fig 10b

Fig 10c

Fig 10d

MASTER CHART ABBREVIATIONS

AAS	-	Anterior aortic sinus
V	-	Variation
BFS	-	Branches in First segment
DFO	-	Distance from ostium
RCOA	-	Right conus artery
SANA	-	Sino atrial nodal artery
RMA	-	Right marginal artery
TCA	-	Third coronary artery
BSS	-	Branches in second segment
AVNA	-	Atrio ventricular nodal artery
PIVA	-	Posterior interventricular artery
PB	-	Parallel branches
RCA	-	Right coronary artery
RM	-	At right margin
BRMC	-	Between right margin and crux
AC	-	At crux
BCLB	-	Between crux and left border
RLB	-	Reaching left border
PIVS	-	Posterior interventricular sulcus
ARCA	-	Anomalous right coronary artery

DIAGRAM 2 - FREQUENCY OF LEVEL OF OSTIUM WITH RELATION TO SINO TUBULAR JUNCTION

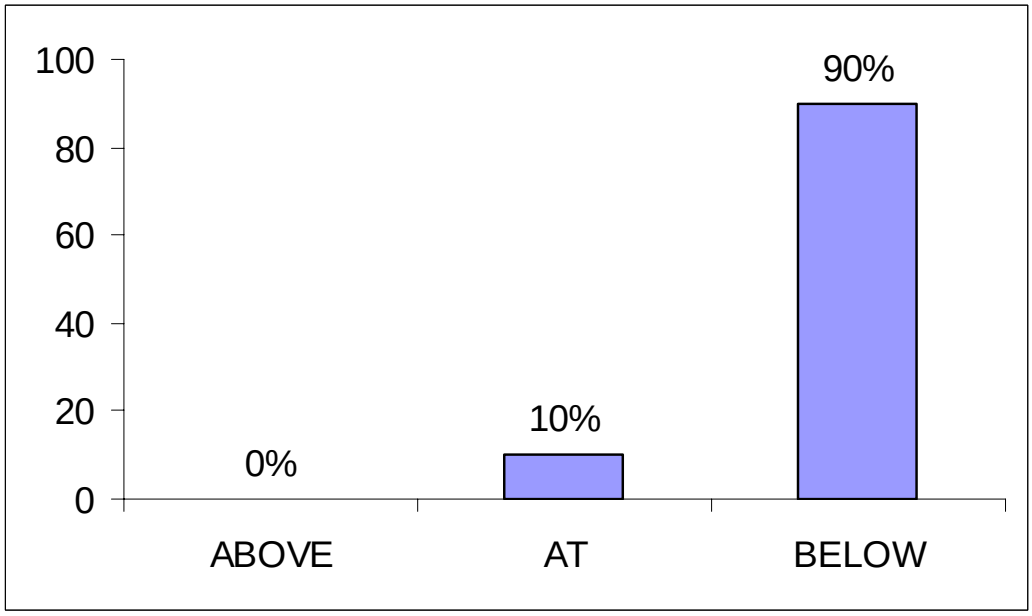
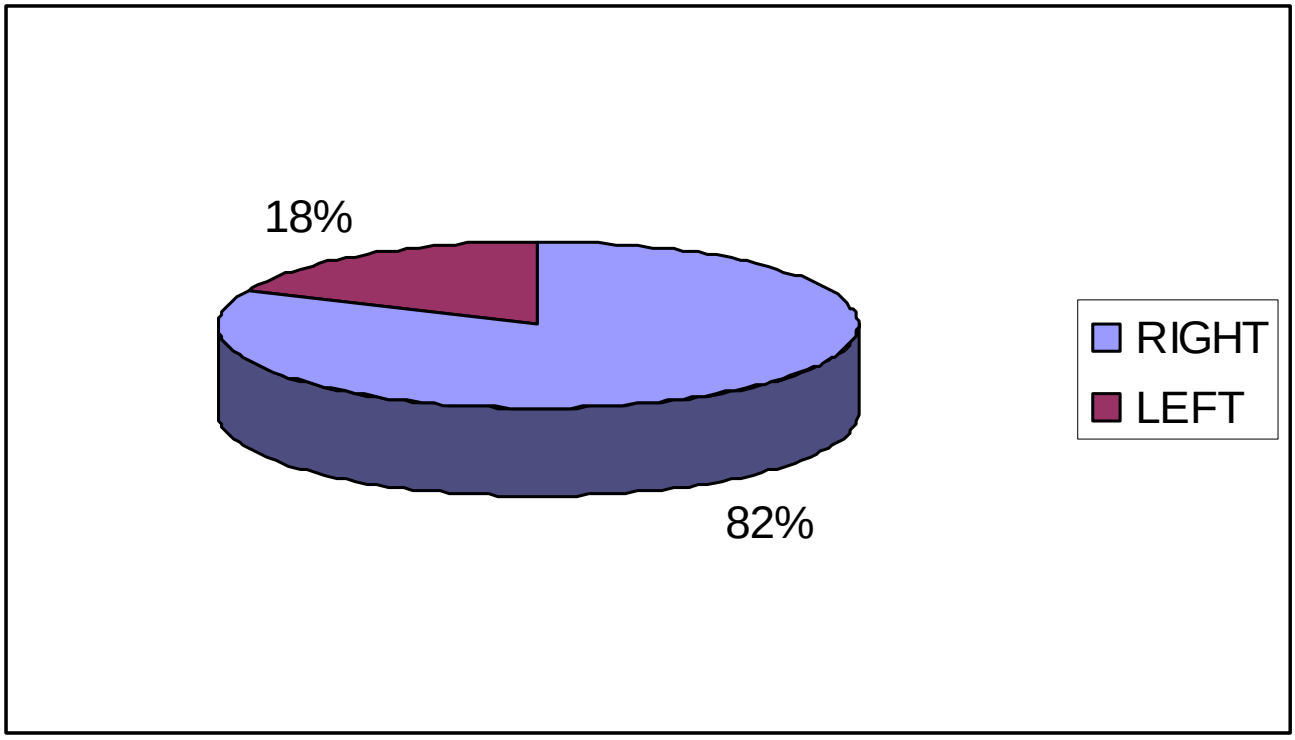


DIAGRAM 5- DOMINANT CIRCULATION



MASTER CHART- RIGHT CORONARY ARTERY

S.NO	LOCATION OF OSTIUM	LEVEL OF OSTIUM IN RELATION TO STJ	COURSE	BFS DFO IN mm			TCA	BSS		TERMINATION OF RCA					TERMINATION OF PIVA IN PIVS	DOMINANCE	ARCA
				RCOA	SANA	RMA		AVNA	PIVA/PB	RM	BRMC	AC	BCLM	RLM			
1	AAS	Below	N	2	-	52	-	-	-		+				P	L	-
2	AAS	Below	N	-	15	50	+	+	+/+				+		D	R	-
3	AAS	Below	N	12	16	51	-	+	+/-			+			M	R	-
4	LPAS	Below	N	6	20	62	-	+	+/-				+		M	R	+
5	AAS	Below	N	12	27	49	-	+	+/-				+		D	R	-
6	AAS	Below	V	12	15	22	-	-	-	+					D	L	-
7	AAS	Below	N	6	18	48	-	-	-		+				P	L	-
8	AAS	AT	N	12	26	28	-	+	+/-				+		M	R	-
9	AAS	Below	N	5	12	39	-	+	+/+				+		D	R	-
10	AAS	Below	N	8	7	42	-	+	+/-				+		D	R	-
11	AAS	Below	N	7	-	32	-	-	-	+					D	L	-
12	AAS	Below	N	13	21	42	-	+	+/+					+	D	R	-
13	AAS	Below	N	12	15	42	-	+	+/-				+		M	R	-
14	AAS	AT	N	12	18	31	-	+	+/-				+		D	R	-
15	AAS	Below	N	6	18	36	-	+	+/-			+			M	R	-
16	AAS	Below	N	-	12	42	+	+	+/-				+		M	R	-
17	AAS	Below	N	18	-	48	-	+	+/-				+		D	R	-
18	AAS	Below	N	3	8	34	-	+	+/-				+		M	R	-
19	AAS	Below	N	12	16	34	-	+	+/-				+		P	R	-
20	AAS	AT	N	17	22	42	-	+	+/-				+		P	R	-
21	AAS	Below	N	22	24	46	-	+	+/+				+		M	R	-
22	AAS	Below	N	-	12	20	+	+	+/-				+		P	R	-
23	AAS	Below	N	-	22	38	+	+	+/-				+		M	R	-
24	AAS	Below	N	6	14	38	-	+	+/-				+		D	R	-
25	AAS	Below	N	-	12	42	+	+	+/-				+		D	R	-
26	AAS	Below	N	6	13	42	-	-	-	+					D	L	-
27	AAS	Below	N	4	14	33	-	+	+/-				+		M	R	-
28	AAS	Below	N	6	32	36	-	+	+/+					+	M	R	-
29	AAS	Below	N	3	-	32	-	+	+/-	+			+		D	R	-
30	AAS	AT	N	6	-	52	-	-	-	+					P	L	-
31	AAS	Below	V	8	19	20	-	-	-						M	L	-
32	AAS	Below	N	8	18	38	-	+	+/-					+	D	R	-
33	AAS	Below	N	6	13	52	-	+	+/+				+		P	R	-
34	AAS	Below	N	3	14	48	-	+	+/-					+	M	R	-

35	AAS	Below	N	4	24	46	-	+	+/-				+		D	R	-
36	AAS	Below	N	6	17	34	-	+	+/-				+		M	R	-
37	AAS	Below	N	6	-	36	-	+	+/-				+		M	R	-
38	AAS	Below	N	5	-	36	-	+	+/-			+			D	R	-
39	AAS	AT	N	13	15	46	-	-	-	+					D	L	-
40	AAS	Below	N	15	12	47	-	+	+/-				+		M	R	-
41	AAS	Below	N	6	-	42	-	-	-	+					D	L	-
42	AAS	Below	N	6	-	47	-	+	+/-				+		D	R	-
43	AAS	Below	N	12	13	38	-	+	+/-				+	+	D	R	-
44	AAS	Below	N	5	13	28	-	+	+/-						D	R	-
45	AAS	Below	N	6	-	36	-	+	+/+				+		D	R	-
46	AAS	Below	N	8	7	33	-	+	+/-				+		D	R	-
47	AAS	Below	N	18	22	32	-	+	+/-				+		P	R	-
48	AAS	Below	N	6	-	52	-	+	+/-			+			P	R	-
49	AAS	Below	N	6	-	34	-	+	+/-				+		P	R	-
50	AAS	Below	N	13	13	52	-	+	+/+					+	D	R	-

S.NO	LOCATION OF OSTIUM	LEVELOR OSTIVM IN RELATION TO STJ	COURSE	BFSDFOINMM			TCA	BSS		TERMINATION OF RCA					TERMINATION OF PIVA IN PIVS	DOMINANUE	ARCA
				RCOA	BANA	RMA		ANNA	PIVA/PB	RM	RMC	AC	BC	RLB			
26	AAS	Below	N	6	13	42	-	-	-	+					D	L	-
27	AAS	Below	N	4	14	33	-	+	+/-				+		M	R	-
28	AAS	Below	N	6	32	36	-	+	+/+					+	M	R	-
29	AAS	Below	N	3	---	32	-	+	+/-				+		D	R	-
30	AAS	AT	N	6	---	52	-	-	-	+					P	L	-
31	AAS	Below	V	8	19	20	-	-	-	+					M	L	-
32	AAS	Below	N	8	18	38	-	+	+/-					+	D	R	-
33	AAS	Below	N	6	13	52	-	+	+/+				+		P	R	-
34	AAS	Below	N	3	14	48	-	+	+/-					+	M	R	-
35	AAS	Below	N	4	24	46	-	+	+/-				+		D	R	-
36	AAS	Below	N	6	17	34	-	+	+/-				+		M	R	-
37	AAS	Below	N	6	---	36	-	+	+/-				+		M	R	-
38	AAS	Below	N	5	---	36	-	+	+/-			+			D	R	-
39	AAS	AT	N	13	15	46	-	-	-	+					D	L	-
40	AAS	Below	N	15	12	47	-	+	+/-				+		M	R	-
41	AAS	Below	N	6	---	42	-	-	-	+					D	L	-
42	AAS	Below	N	6	---	47	-	+	+/-				+		D	R	-
43	AAS	Below	N	12	13	38	-	+	+/-				+		D	R	-
44	AAS	Below	N	5	13	28	-	+	+/-					+	D	R	-
45	AAS	Below	N	6	---	36	-	+	+/+				+		D	R	-
46	AAS	Below	N	8	7	3	-	+	+/-				+		D	R	-
47	AAS	Below	N	18	22	32	-	+	+/-				+		P	R	-
48	AAS	Below	N	6	---	52	-	+	+/-			+			P	R	-
49	AAS	Below	N	6	---	34	-	+	+/-				+		P	R	-
50	AAS	Below	N	13	13	52	-	+	+/+					+	D	R	-