STUDY OF BRANCHING PATTERN OF LEFT CORONARY ARTERY IN 50 SPECIMENS

Dissertation submitted in partial fulfillment of the requirement for

M.S. DEGREE EXAMINATION

ANATOMY

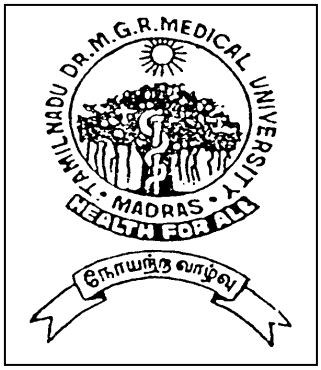
BRANCH V

INSTITUTE OF ANATOMY

MADURAI MEDICAL COLLEGE

MADURAI

MARCH 2009



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CERTIFICATE

This is to certify that the dissertation entitled "**STUDY OF BRANCHING PATTERN OF LEFT CORONARY ARTERY IN 50 SPECIMENS"** submitted by **Dr. M. Sobana,** Post Graduate in Anatomy, 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 her during the period 2006 –2008 under my direct supervision and guidance.

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ACKNOWLEDGEMENT

I sincerely thank the **DEAN**, Madurai Medical College, Madurai for permitting me to use the college and Department facilities for my study.

I profoundly thank **Dr.V.Rajaram, DLO., M.S.,** Director & Professor I/C, Institute of Anatomy, Madurai Medical College, Madurai for his constant guidance, encouragement and untiring technical help rendered throughout the period of this study.

I am grateful to **Dr.T.Hariharan M.S.,** (Rtd.,) Director, Institute of Anatomy, Madurai Medical College, Madurai for his advice and guidance in choosing the topic.

I am thankful to **Dr.K.Meiyazhagan M.D.,** Professor and HOD, Department of Forensic Medicine, Madurai Medical College, Madurai, for permitting me to collect the required specimens for my study.

I thank **Dr.T.Jeeva M.S.,** and **Dr.S.Sundari M.S.,** other faculty and non faculty members of the Institute of Anatomy, Madurai Medical College, Madurai in enabling me to continue my dissertation work with creative suggestion and constructive criticism to improve the quality of the work.

DECLARATION

I **Dr. M.Sobana,** solemnly declare that the dissertation entitled "**STUDY OF BRANCHING PATTERN OF LEFT CORONARY ARTERY IN 50 SPECIMENS"** has been prepared by me under the able guidance and supervision of my guide **Director & Prof. I/C Dr.V.RAJARAM DLO., M.S.,** Institute of Anatomy, Madurai Medical College, Madurai, in partial fulfillment of the requirement for the award of **M.S. (ANATOMY)** degree examination of The Tamilnadu Dr. M.G.R. Medical University, Chennai to be held in March 2009.

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

Place : Madurai

Date : **(Dr.M.SOBANA)**

CONTENTS

INTRODUCTION

The existence of heart was well known to ancient Greeks who gave it the name ***Kardia***.

Cardiovascular disease (CVD) is one of the leading cause of mortality worldwide. According to World Health Organization, 17.5 million people died of cardiovascular disease in 2005, developing countries contributing to 80%. In 2010, Cardiovascular disease is projected to be the leading cause of death in developing countries with coronary heart disease (CHD) predominating. Between 1990 and 2020, coronary heart disease mortality is expected to increase by 120% in women and by 137% in men in developing countries. It is estimated that the annual number of deaths caused by cardiovascular disease in developing countries will rise to 11.1 million in 2020 (Hurst, 2008). The stress on need for detailed study of coronary disease is further emphasized by the fact of early age of cardiovascular disease deaths (Park, 2007).

The branching structure of vascular system has been the subject of much discussion and debate since it was first suggested that these systems have fracial architecture (Mandelbrott, 1977). Coronary artery of human

heart and their branching characteristics have been the subject of particular attention among researchers.

Coronary artery anomalies are a diverse group of congenital disorders whose manifestations and pathophysiological mechanisms are highly variable (Angelini *et. al.*, 2002). The subject of coronary artery anomalies is undergoing profound evolutionary changes related to the definition, morphogenesis, clinical presentation, diagnostic workup, prognosis and treatment of these anomalies.

According to Engel (1975), 1-2% of patients studied by selective coronary arteriography, one or more major elements of the coronary arterial system originated from the sinuses of valsalva in an ectopic manner. *The majority of variations involved the left coronary artery*. The failure to recognise variations in coronary arterial origin can prolong arteriographic procedures and lead to errors in interpretation of coronary artery anatomy and pathology.

Though a number of recent techniques namely Electron Beam Computerized Tomography (EBCT), 64 slice CT Angio (2005) and intravascular ultrasound have been introduced, selective coronary arteriography remains the clinical "Gold Standard" for evaluating coronary

anatomy (Grossman, 2000). The performance of high quality coronary arteriography safely defining each and every coronary stenosis in an optimal view is an important measure of an operator's skill in cardiac catheterisation which emphasizes the importance of complete knowledge of coronary artery anatomy.

AIM OF THE STUDY

- Knowledge of the morphological characteristics of the main trunk of left coronary artery and its variations is essential for haemodynamic and surgical manipulations as well as for correctly interpreting angiographic data.
- Coronary artery anomalies occur in 0.64% to 1.3% of patients undergoing coronary angiography (Yamanaka *et. al.,* 1990).

Hence, this study of ***Branching pattern of left coronary artery*** has been undertaken to highlight the variations of branches of left coronary arterial system.

REVIEW OF LITERATURE

Study of Anatomy began atleast as early as 1600 B.C., the date of the ancient Egyptian, Edward Smith Papyrus. The ebers papyrus (1550 B.C) features a treatise on the heart. It notes that the heart is the centre of the blood supply with vessels attached for every member of the body.

In the third century B.C., in Alexander the Great's city of Alexandria, there was the first anatomical revolution. Some of the first human dissections were carried out by Greek anatomist Herophilus (Late 4^{th} century B.C.) and his younger follower Erasistratus. In his studies of the heart and blood vessels, Erasistratus came very close to working out the circulatory system of heart (Pioneers of Heart Anatomy).

Arteries contained blood and not air was discovered by Greek physician, Claudius Galen (131-200 A.D), the *Father of Experimental Physiology* who knew that the heart set the blood in motion (Lionel, 1997).

After human dissections resumed in the sixteenth century, the long held teachings of Galen were overturned by the work of Flemish anatomist Andreas Vesalius (1514-1564) who founded *modern scientific anatomy*.

The correct description of circulation of blood was provided by the English Physician, William Harvey (1578-1657). He was the first to discover that blood flows in a continuous circle from the heart to the arteries to the veins and back to the heart.

The discovery of capillaries by Italian anatomist, Marcello Malphighi (1628-1694), in 1663 provided the fractual evidence to confirm Harvey's theory of blood circulation (Pioneers of Heart Anatomy).

Since William Heberden wrote his classic account of angina in 1768 and Edward Jenner and Calab Parry were the first to suspect a coronary etiology for Angina which parry published in 1799 (Ryle and Russel, 1949).

According to Counard, Claude Bernard in 1844 was the first to insert a catheter into the heart of animals to measure temperature and pressure (Grossman, 2000).

In 1901, Osler called the anterior branch *Artery of sudden death*. In 1903, Banchi first described single coronary artery. The concept that coronary thrombosis was always fatal was finally dispelled by James Herrick in 1912.

Cardiac catheterisation in humans was inconceivable risk until Werner Frossman, a 29 yr old surgical resident in Germany, performed a self catheterisation in 1929. Morriz in Libson (1931) and Castellanos in Cuba (1937) were the first to image the interior of heart with intravenous angiograms (Grossman, 2000).

Schlesinger (1938) used a radiopaque injection mass to study the distribution of the vessels and stated that judged by the method he employed, the coronary artery in normal human hearts, are functionally end ones without anastamoses. The term dominant coronary artery was introduced by Schlesinger (1940) who used it to indicate the areas of heart supplied by each artery.

Prinzmetal (1947) by using a finer injection medium of radioactive red cells and microscopic glass beads showed that within the heart, the artery and arterioles anastamose with each other and also anastamose directly with veins.

Both coronary arteries have also been reported arising by a single stem (White and Edwards, 1948).

According to Smith (1950), an example of a single coronary artery was reported by Thebesius in 1716. Essenberg (1950) showed a case with three separate arteries arising from the left posterior aortic sinus, one representing the anterior interventricular artery, another a twig to the aorta and pulmonary artery and the third the left marginal and presumably the circumflex branch of left coronary artery.(Hollinshead, 1961)

The high susceptibility of single coronary artery to atherosclerosis due to absence of intercoronary collaterals was shown by Alexander and Griffith (1956). Angiogram became the essence of cardiovascular imaging for several decades after mid twentieth century, vital to diagnosis and management of coronary disease during 1960's and continue to play a central role.

Polacek and Zechmeister (1968) tried to contribute to the selection of an ideal experimental model by giving a classification of the coronary vascular pattern in different species.

According to Ogden (1970), although anomalies of coronary artery are relatively rare causes of cardiac pathology, atypical position or branching may be found in upto about 2% of human beings. Ogden (1970) showed the origin of the left coronary artery from the anterior aortic sinus. Individuals

with this anomaly are at risk from sudden death. According to Ogden and Goodyer (1973), single coronary artery incidence in general population is 0.01-0.04%.

Liberthson *et. al.*, (1974) also showed the origin of left coronary artery from anterior aortic sinus. Engel (1975) showed that one of the vessel was very tiny so that essentially a single coronary artery was present.

In man, as in all mammals, birds and reptiles, the arterial supply to the heart is achieved by two arteries which are the only branches of the ascending aorta. In each case these artery branch in such a manner that occupy the atrioventricular and interventricular sulci in the shape of a "Crown". Hence, they are called the "Coronary Artery" (Allwork, 1976).

Morettin (1976) reported complete duplication of a coronary artery or one of its branches in approximately 1% of his cases. A very rare variant is the origin of left circumflex artery, branch of left coronary artery from pulmonary artery (Ott, Cooley, 1978).

Single coronary artery is rare in normal hearts but occurs with some frequency in congenitally malformed hearts. Lipton (1979) described a classification for single coronary artery.

In most individuals with left dominance, the right coronary artery is usually small and often fails to reach the acute right margin of the heart (Raphael, Hawtin, Allwork, 1980) so that an acute proximal occlusion could have disastrous consequence.

According to Spindola – Franco (1983) and colleagues, the incidence of dual anterior interventricular artery in otherwise normal heart is about 1% and found frequently with congenital malformations of heart.

Although the major branches of coronary artery are subepicardial, they are frequently contained in places by strands of myocardium which are mostly small and of no significance. Boucek and Judkine (1984), observed myocardial bridges occur in upto 60% of normal hearts. They occur most often over the anterior interventricular artery of left coronary artery and its diagonal branch (Sally Allwork, 2008).

Ferguson (1985) reported a case with single coronary artery, According to Berth (1986) anomalous origin of the left coronary artery from the right sinus of valsalva (RSOV) with its course between the aorta and pulmonary trunk is rare, causing sudden exercise related cardiac death in young.

The overall incidence of atherosclerotic disease in coronary artery was 68% in those who had undergone angiography (Charles *et.al.,* 1988). Electron Beam Computerised Tomography (EBCT) introduced in 1990 has become a popular way to detect early coronary disease. Patients with anomalies with left coronary artery from right Sinus of valsalva (RSOV) are prone for myocardial infarction and sudden death was studied by Taylor *et. al.,* (1992) by Transesophageal two dimensional Echocardiogram .

Fineschi *et. al.,* (1998) showed that all three major coronary arteries arose separately from right sinus with separate ostia.

Harikrishnan *et. al.,* (2001) concluded that the most common anomaly was separate origin of anterior interventricular artery and left circumflex artery (35.3%). The next most common anomalies were the origin of left circumflex artery from the right sinus (20%). Incidence of primary congenital coronary anomalies varies from 0.95%-2% in the adult population undergoing coronary angiography. Many of the anomalies are silent and discovered as incidental findings during coronary arteriography.

Coronary artery fistulas are rare congenital anomalies with incidence of 0.002% (Maleszka *et. al.,* 2005). The new 64 slice computerized

tomography angio (2005) provides detailed anatomy of coronary artery and its wall motion.

The term “anomaly” is used for variations that occur in less than 1% of the general population (Angelini *et. al.,* 2007).

“Median artery” is the artery deriving from the main trunk in addition to two terminal branches originating from the left coronary artery and ramus lateralis (ramus diagonalis) as branches originating from arteria interventricularis anterior *(Cenk Kilic et. al., 2007).*

Recent studies show that the coronary artery disease is the leading cause of death not only in men but also in women and an important cause of disability though the risk is underestimated accounting for one third of all deaths in women (Sarita Gulati, 2008).

MATERIAL AND METHODS

Material

Fifty specimens taken up for this present study of ***Branching pattern of left coronary artery*** was obtained from the cadavers of Institute of Anatomy and Department of Forensic Medicine with age, sex, socio economic status etc no par.

In the dissection hall, the heart specimens were obtained by the following method described below with the help of following materials.

1. Forceps (Non-toothed)
2. Scalpel
3. Scissors
4. Cotton
5. 0.4mm Thread
6. Measuring Scale
7. Knife and bone cutter
8. Gloves and Apron
9. 10% formalin

Method (as in Romanes' Cunningham's manual of practical anatomy)

A transverse cut was made through the manubrium of the sternum immediately inferior to its junction with the first costal cartilage. The cut was more superficial taking care not going deeper. The parietal pleura was cut through in the first intercostal space (ICS) on both sides. This cut extended as far back as possible. The next cut was made inferiorly through the second and subsequent ribs and intercostal spaces from the posterior end of the pleural incision to the level of the xiphisternal joint. A cut was made through the internal thoracic vessels in the first intercostal space. The inferior part of the sternum was gently elevated with the costal cartilages and anterior parts of the ribs. A cut through the parietal pleura was made where it leaves the sternum. The anterior part of the sternum is lifted away and hinged on the superior part of the abdominal wall. The cut through the parietal pleura was extended along its line of reflection from the sternum on to the mediastinum to the level of the lower border of the heart.

After defining the heart with its pericardium, a vertical cut was made through each side of the pericardium immediately anterior to the line of the phrenic nerve. The lower ends of these two incisions were joined by a transverse cut approximately one cm above the diaphragm. The flap of the pericardium was turned upwards and the pericardial cavity examined. The

attachment of the flap of the pericardium to the superior venacava, aorta and pulmonary trunk was determined and a cut through these attachments were made separating the heart which was taken out of the cadaver. This same procedure was also followed in autopsy by the personnel of forensic department for collection of heart specimens.

The specimens thus obtained from both these departments were preserved in 10% formalin solution before undertaking the study.

During the study, the visceral pericardium was stripped off the left coronary artery issuing from the ascending aorta from its left posterior aortic sinus (LPAS) identified and its course traced as per Gray's Text Book of Anatomy (2005) who describes as follows:

It's initial stem, between the ostium in the left posterior aortic sinus and its first branches varies in length from a few millimeters to a few centimeters. It lies between the pulmonary trunk and the left auricular appendage emerging into the atrioventricular sulcus, in which it turns left; this part is loosely embedded in the subepicardial fat. Reaching the coronary sulcus the left coronary artery divides into two or three main rami. The two main rami are

a. Anterior interventricular artery

b. Circumflex artery

A) Anterior Interventricular Artery (AIVA)

This branch being commonly described as its continuation descends obliquely forwards and left in the interventricular sulcus, sometimes deeply embeded or crossed by bridges of myocardial tissue and by the Great cardiac vein. It reaches apex almost always, terminating there in one third of specimens. But more often turning around the apex into the posterior interventricular sulcus (PIVS) in which it traverses a third to half of its length, to meet the terminal twigs of corresponding right coronary ramus. The anterior interventricular artery produces right and left anterior ventricular, anterior septal and variable, corresponding posterior rami.

The major branches of anterior interventricular artery are

i) Diagonal Artery

ii) Left Conus Artery

i) Diagonal Artery

From two to nine large left anterior ventricular arteries, one is often large and may arise separately from the left coronary trunk (which then ends by trifurcation).

ii) Left Conus Artery

Small left conus artery frequently leaves the anterior interventricular artery near its commencement anastamosing on the conus with that of right coronary artery (RCA).

B) Circumflex Artery

The circumflex artery curves left in the atrioventricular sulcus continuing round the left cardiac border into the posterior part of the sulcus and ending left of the crux in most hearts. The major branches are

i) Left marginal artery

ii) Posterior interventricular artery (occasionally)

i) Left marginal artery

In 90%, a large ventricular branch, the left marginal artery arises perpendicularly from it to ramify over the rounded obtuse margin.

ii) Posterior interventricular artery (PIVA)

Rarely, posterior interventricular artery (PIVA) is seen as a continuation of circumflex artery. Such a left posterior interventricular artery is frequently double or triple.

Atrial rami from the circumflex artery supply the left atrium.

Search was also made for the inconstant branches namely

a) The artery to the sinoatrial (SA) node which is a branch in 35% usually from anterior circumflex segment.
b) The artery to the atrioventricular (AV) node, the terminal ramus in 20% arises near the crux and then the circumflex usually supplies a posterior interventricular ramus.
c) Kugel's anastamotic artery, usually from its anterior part traversing the interatrial septum to establish anastamosis with right coronary artery.

After having a complete anatomical knowledge about left coronary artery (LCA) its origin, course, branches and termination, this study of ***Branching pattern of left coronary artery*** has been undertaken under the following headings.

1. Location of ostium
2. Level of ostium with relation to sinotubular junction (STJ)
3. Length of main trunk
4. Division of main trunk of left coronary artery
5. Median artery
6. Anterior interventricular artery (AIVA)
7. Branches of anterior interventricular artery

    a. Left conus artery
    b. Diagonal artery
    c. Atrial rami
    d. Ventricular rami
8. Myocardial bridges over anterior interventricular artery
9. Termination of anterior interventricular artery
10. Left Circumflex Artery
11. Branches of left circumflex artery (LCX)
    a. Sinoatrial nodal artery
    b. Left marginal artery
    c. Posterior interventricular artery
    d. Atrioventricular nodal artery
12. Termination of left circumflex artery
13. Coronary dominance
14. Anomalous left coronary artery

OBSERVATIONS

This current study of ***branching pattern of left coronary artery*** (LCA) in fifty specimens reveals the following results :-

I. Location of ostium

The ostium of left coronary artery in the study was seen in left posterior aortic sinus in all fifty specimens.

Table – 1 : Location of ostium

Name of Sinus	Frequency	Percentage
Left Posterior aortic sinus	50	100%
Others	Nil	-

II. Level of Ostium with relation to Sinotubular junction (STJ)

In this study, ostium of left coronary artery was at the level of sinotubular junction in five specimens (Figure No 1) and below sinotubular junction in forty five (Fig No. 2).

Table – 2 : Level of Ostium with relation to Sinotubular junction

Position of ostium	Frequency	Percentage
Above	Nil	-
At	5	10%
Below	45	90%
Total	**50**	**100%**

III. Length of Main Trunk

In this present study, trunk of seven specimens were very short ranging ≤ 5mm, twenty six specimens ranged between 6-10mm, fifteen specimens ranged between 11-15 mm and two specimens ranged between 16-20mm. The mean length was about 9.32mm.

The minimum length was 5mm.

The maximum length was 19mm.

Table 3: Length of Main Trunk

Length of Main Trunk (mm)	**Frequency**	**Percentage**
≤ 5mm	7	14%
6-10mm	26	52%
11-15mm	15	30%
16-20mm	2	4%
Total	**50**	**100%**

IV. Division of Main Trunk of left coronary artery

In this current study, left coronary artery was seen bifurcating into its two main branches in thirty one specimens (Figure 3), trifurcation in sixteen specimens (Figure 4) and quadrification in three specimens (Figure 5).

Among the sixteen trifurcating specimens, in five specimens the diagonal artery which was not seen arising from the anterior interventricular artery was seen at the junction between its two branches and in eleven specimens, diagonal artery was seen arising from anterior interventricular artery and an additional branch was seen at the junction called the "Median Artery".

Table – 4 : Division of Main Trunk of left coronary artery

Number of Branches	Frequency	Percentage
Bifurcation	31	62%
Trifurcation	16	32%
Quadrification	3	6%

V. Median Artery

In this present study, eleven trifurcating specimens showed a branch at the junction of its two main branches along with the diagonal artery arising separately from anterior interventricular artery (Figure 6).

Table - 5 : Median Artery

Median Artery	Frequency	Percentage
Present	11	22%
Absent	39	78%
Total	**50**	**100%**

VI. Anterior Interventricular Artery (AIVA)

This major branch of left coronary artery was seen in all fifty specimens coursing in the anterior interventricular sulcus. This branch is also called the left anterior descending artery (LAD)

VII. Branches of anterior interventricular artery

Left conus artery was present in all fifty specimens (Figure 7).

Diagonal artery was seen in all fifty specimens. It was seen as trifurcation in five specimens (sp.13, 20, 30, 41, 42) (Figure 8), parallel branch to diagonal artery was seen in specimens 31 and 37 (Figure 9) .

Atrial rami and anterior ventricular rami were seen in all fifty specimens.

Table - 6 : Branches of anterior interventricular artery

Name of Branches	Frequency	Percentage
Left conus artery	50	100%
Diagonal artery	50	100%
Atrial Rami	50	100%
Ventricular Rami	50	100%

VIII. Myocardial bridges over anterior interventricular artery

In this present study, myocardial bridges was seen over anterior interventricular artery in fifteen specimens (Figure 9).

Table – 7 : Myocardial bridges over anterior interventricular artery

Occurrence	Frequency	Percentage
Present	15	30%
Absent	35	70%

IX. Termination of anterior interventricular artery

In this study, anterior interventricular artery terminated at various levels. In two specimens, it terminated before apex in the sternocostal surface (Figure 10) , in eighteen specimens it terminated over the apex, in twenty eight specimens it terminated crossing the apex and going to the diaphragmatic surface (Figure 11) and in two specimens it terminated at the junction of posterior two third and anterior one third of posterior interventricular sulcus.

Table – 8 : Termination of anterior interventricular artery

Level of Termination of anterior interventricular artery	Frequency	Percentage
Before Apex	2	4%
Apex	18	36%
Beyond Apex	28	56%
Junction of posterior 2/3 and Anterior 1/3 of posterior interventricular sulcus	2	4%
Total	**50**	**100%**

X. Left Circumflex Artery (LCX)

The next major branch of left coronary artery namely the left circumflex artery was seen in all fifty specimens.

Table – 9 : Left Circumflex Artery

Occurrence	Frequency	Percentage
Present	50	100%
Absent	Nil	-

XI. Branches of left circumflex artery

a) Sinoatrial Nodal Artery

This artery which is usually a branch from right coronary artery was seen arising as first branch of left circumflex artery in twelve specimens (Figure No 12).

Table – 10 : Sinoatrial Nodal Artery

Occurrence	Frequency	Percentage
Present	12	24%
Absent	38	76%

b) Left Marginal Artery

This branch which was seen in all fifty specimens had parallel branches in ten specimens (Fig -13,14) and seen as termination of left circumflex artery in ten specimens (Fig - 15).

Table – 11: Left Marginal Artery

Occurrence	Frequency	Percentage
Parallel branch to LMA	10	20%
Termination of LCX as Left marginal	10	20%

LMA – Left Marginal artery
LCX – Left Circumflex artery

c) Posterior interventricular artery (PIVA)

This branch which determines coronary dominance was seen arising from left circumflex artery in five specimens (Sp. 20, 28, 38, 39, 45). (Figure - 16) and in one specimen (Sp.No.20) it had a parallel branch (Figure - 17).

Table – 12: Posterior interventricular artery

Occurrence of PIVA	Frequency	Percentage
Present	5	10%
Absent	45	90%

d) Atrioventricular Nodal Artery

In this study, atrioventricular nodal artery was seen arising as a septal branch of posterior interventricular artery in the Posterior interventricular sulcus since, in five specimens left circumflex artery continued down as posterior interventricular artery (Sp 20, 28, 38, 39, 45).

Table – 13: Atrioventricular Nodal artery

Occurrence	Frequency	Percentage
Present	5	10%
Absent	45	90%

XII. Termination of left circumflex artery

In this study, left circumflex artery terminated at the obtuse border in thirteen specimens, between obtuse border and crux in thirty one specimens, at the level of crux in one specimen (Figure – 18). Five specimens showed the left circumflex artery crossing the crux and running towards the acute or inferior border. Left circumflex artery terminated as left marginal artery in nearly ten specimens.

Table – 14: Termination of left circumflex artery

Termination of LCX	Frequency	Percentage
Obtuse Border	13	26%
Obtuse / Crux	31	62%
Crux	1	2%
Crux / Acute	5	10%
Total	**50**	**100%**

LCX - Left circumflex artery

XIII. Coronary Dominance

In this present study, posterior interventricular artery was seen arising from left circumflex artery showing left coronary dominance in five specimens (Sp.20, 28, 38, 39, 45) and the rest of the specimens showed right dominance.

Table – 15: Coronary Dominance

Dominance	Frequency	Percentage
Right	45	90%
Left	5	10%

XIV. Anomalous Left Coronary Artery

In this present study, no anomalous origin of left coronary artery was found in any specimen.

DISCUSSION

I. Location of Ostium

Aortic sinus is one of the anatomic dilatations of the ascending aorta which occurs just above the aortic valve. The ostium of left coronary artery is seen commonly in left posterior aortic sinus. The left coronary opening may be double, leading into major initial branches, usually the circumflex and anterior interventricular; one may lead into a stem common to one such branch and a diagonal ventricular ramus (Gray's Text Book of Anatomy, 2005).

Duplication of the ostia within the left aortic sinus is occasionally the consequence of a very short or even absent left main trunk and separated origin of the branches. This phenomenon is also designated as 'early' division of the left coronary artery. It occurs in 1-8% of otherwise normal hearts (Baroldi and scomazzoni , 1965, Vlodaver *et.al.,* 1976 : Angelini 1989)

In this study, the ostium of left coronary artery was seen in left posterior aortic sinus in all fifty specimens.

In the left aortic sinus there are reports of the coexistence of an independent origin for anterior interventricular artery and circumflex artery or duplication of either (Waller, 1983).

The situation of coronary orifices in the aortic sinus varies both cross sectionally and in frontal plane. Left coronary artery may originate in the mid third of sinus (87%), from posterior one third (10%) and anterior one third (3%) (Reigvilallonga, 2003).

According to Angelini *et.al.,* (2007) 0.15% incidence of anomalous origination of the left coronary artery from the right aortic sinus was reported.

II. Level of Ostium with Sinotubular junction

Position of coronary orifices is described in terms of their relation to the sinotubular junction. A high left coronary orifice is usually associated with a long left coronary artery and is therefore at a greater risk of injury during surgery (Neufeld and Schneeweiss, 1983). Most haemodynamics agree that high or low coronary orifices represent an added difficulty in coronary angiography (Paulin 1983; Greenberg 1989).

The most frequent position of the coronary orifice is at the level of sinotubular junction or below it (56%) followed by a high left orifice and a low right orifice or at sinotubular junction (30%) (Vlodaver *et. al.,* 1976).

In this present study, ostium of left coronary artery was at the level of sinotubular junction in 10% specimens and below sinotubular junction in 90% specimens. None of the ostium was seen above sinotubular junction level.

III. Length of Main Trunk

In 92-95.5% of autopsy cases examined by Angelini (1989) the left coronary artery had a single initial stem or trunk of variable length (2-40mm, mean 13.5mm).

In this study seven specimens were ≤5mm, twenty six specimens ranged between 6-10mm and fifteen specimens ranged between 11-15mm and two specimens ranged between 16-20mm. The maximum length was found to be 19mm.

The mean length was 9.32 mm.

Anatomically, the length of main trunk has been found to range between 1-26mm before bifurcation. Short common trunk presents the same potential risk as the absence of the common trunk (McAlpine, 1975).

When the common trunk is above 15mm, it is considered long which is seen in 11.5%-18% (Petit and Reig, 1993). It is considered 'short' when it is less than or equal to 5mm (Vlodaver *et.al.,* 1976) which is frequently between 7-12% (Petit and Reig, 1993).

In patients with the short main left coronary artery, the atherosclerotic lesions in the anterior descending and circumflex branch appear earlier , progress faster at higher level of severity and lead more frequently to myocardial infarction , than in cases with the long left coronary trunk (Gazetopoulos *et.al.,* 1976)

Going with the above study, 4% specimens in this study were considered 'long' with their main trunk exceeding above 15mm, 14% specimens were considered 'short' with the length of main trunk less than or equal to five millimeters.

IV. Division of Main trunk of left coronary artery

According to Davidson's Text Book (2006), the single main stem of left coronary artery within 2.5cm of its origin divides into left anterior descending and left circumflex artery.

The division of the common trunk into anterior interventricular, circumflex and median or intermediate artery is a variation found in between 25-40% of cases and number of studies had been undertaken by different authors regarding branching of left coronary artery with varying percentages which are shown below.

Table – 16: Division of main trunk of left coronary artery

No. of Branches	Baptista (1991)	Cavalcanti (1995)	Reig and Petit (2003)	Lujinovic (2005)	Present study (2009)
Bifurcation	54.7%	60%	62%	65%	62%
Trifurcation	38.3%	38.18%	38%	35%	32%
Quadrification	6.7%				6%

V. Median artery

According to James 1961, Median artery is one which

1) Originates in the vertex of the angle formed by the main terminal arteries of the left coronary artery or in the first millimeters.
2) Possesses a substantial caliber

3) Has an area of distribution extending half-way down the free wall of left ventricle.

Levin (1983) states that angiographic examination of left coronary artery should not be focused on the two main branches alone, since the involvement of median artery may, depending on is distribution be as dangerous as the involvement of the two arteries (Roberts *et. al.* 1986)

According to Helen Genevier (2004), in 30-37% of patients the left main coronary artery terminates in a bifurcation in which case it also gives rise to the ramus intermedius artery that is directed laterally.

'Median Artery' is the artery deriving from the main trunk in addition to two terminal branches originating from the left coronary artery and 'ramus lateralis' (ramus diagonalis) as branches originating from arteria interventricularis anterior. The most frequent type of division of the main trunk of left coronary artery was bifurcation and arteria mediana was detected in seven hearts (Cenk kilic *et.al.,* 2007).

In this study, median artery was found in 22% specimens.

VI. Anterior interventricular artery

Left coronary artery was replaced by anterior interventricular artery which commenced from left posterior aortic sinus and travelled in anterior interventricular sulcus where it gave rise to left circumflex branch (Keshaw Kumar, 2006).

It originates in the retropulmonary portion of left coronary artery, passes above the interventricular groove, adopting an S shape, and in most cases reaches the apex. It occasionally continues through the posterior interventricular groove known as Mouchet's posterior interventricular artery.

In this present study, anterior interventricular artery was seen in all fifty specimens.

VII. Branches of anterior interventricular artery

- Left conus artery which is the first ventricular branch of anterior interventricular artery usually forms an anastamosis with the likewise branch of the right coronary artery. This anastamosis lies on the distal part of the arterial conus and pulmonary trunk and is known as the ***vieussens arterial ring***. The functional significance of this anastamosis is still under question. However, several authors have proposed that it functions as an important

collateral path between the right coronary artery and left coronary artery. (Reig Vilallonga, 2003)

In this present study, left conus artery was present in all fifty specimens.

- The diagonal artery which runs parallel to the anterior interventricular artery never reaches the anterior interventricular groove (Spindola – Franco *et. al.,* 1983). The importance of it is above all surgical, since if it is ignored, during coronary bypass there is a risk that only a part of the vessel affected will be revascularised.

Anterior interventricular artery ramifies into two to nine large branches and one is often large and may arise separately from the left coronary artery (which then ends by trifurcation). This diagonal artery reported in 33-50% or more cases is occasionally duplicated (20%) (Gray's Anatomy, 2005).

Diagonals are branches of anterior interventricular artery that run diagonally away from the anterior interventricular artery and towards the left edge in front of heart (Kaimkhani *et.al,* 2005)

'Intermediate' and 'Median' refer to the origin but 'diagonal' refers to the course of artery (Cenk kilic *et.al,* 2007). In this study, diagonal artery was seen in all 100% specimens. Out of the 50 specimens, diagonal artery

was seen at the junction of branching appearing as trifurcation in 10% specimens (Sp. 13, 20, 30, 41, 42) and in 4% specimens (Sp. 31 and 37) there were parallel branches to diagonal artery.

- Small atrial and ventricular rami were seen in all 100% specimens.

VIII. Termination of anterior interventricular artery

Situated in the incisura apicis cordis, some 1-3 cm to the right of the apex cordis (Bosco, 1935) this artery may end before reaching the apex, in the apex itself or more frequently pass around the apex and reach the posterior interventricular sulcus.

According to James (1961), termination of anterior interventricular artery was as follows

Table – 17 : Termination of anterior interventricular artery

Termination of anterior interventricular artery	Number	Percentage
Anterior apex	18	17
Posterior apex	24	23
2.5cm up PIVS	44	42
>5cms up PIVS	20	18
Total	**106**	**100**

PIVS – Posterior interventricular sulcus

According to Gray's Anatomy (2005), it reaches the apex almost always terminating there in one third of specimens, but more often turning round the apex into the posterior interventricular sulcus in which it traverses one third to half of its length.

In this study, it terminates before apex in 4% specimens, at the level of apex in 36% specimens, beyond the apex in 56% specimens and at the junction of posterior two third and anterior one third of posterior interventricular sulcus in 4% specimens.

IX. Myocardial Bridges over anterior interventricular artery

It was first described by Reyman in 1737 and the artery coursing in the myocardium is called the ***Tunnelled Artery*** or coronary mural (Geiringer, 1951).

Polacek and Kralove (1961) found that relative frequency of myocardial bridges exclusively involving the anterior interventricular artery was 70%.

Ozlem soran *et. al.*, (2000) showed the incidence of myocardial bridges between 15 and 85% in pathologic series but angiographic evidence is substantially less (0.51 to 2.5%).

Vanildo Junior (2002) found that myocardial bridges are more frequently found in the middle one third of anterior interventricular artery. The diameter of anterior interventricular branch of left coronary artery under the myocardial bridges may be smaller than after the bridge.

Ji – Shen chen (2003) found myocardial bridges in 5-86% in anatomic studies but only observed in 0.5 – 12% of patients undergoing coronary angiography.

Andrew N Pelech (2006) showed myocardial bridging in 5-25% of patients as normal variant.

According to Angelini (2007), the fact that such bridges are surely present in >1% of the general population suggest that they may be a normal variant.

Angiographic study by Huxin – Ying (2007) suggest the incidence of myocardial bridges is <2% in general population.

Myocardial Bridges is only 0.5-1.6% in the general population. It is reported 28% in children and 30-50% in adults with hypertrophic cardiomyopathy (Hurst, 2008).

Various studies carried out regarding myocardial bridges by dissection and angiographic methods are as follows:

Table – 18 : Myocardial bridges over anterior interventricular artery (AIVA)

Study of myocardial bridges over AIVA by			
Dissection method		**Angio study**	
By	**%**	**By**	**%**
Geiringer (1951)	23%	Kramer (1982)	12%
Penther et al (1977)	17.6%	Irvin (1982)	7.5%
		Angelini (1983)	5.5%

This study showed 30% occurrence of myocardial bridges (15 specimens) over anterior interventricular artery.

X. Left Circumflex Artery (LCX)

The next major branch of left coronary artery which presents the greatest variability in terms of length and distribution was present in all fifty specimens.

XI. Branches of left circumflex artery

a) Sinoatrial (SA) Nodal Artery

Sinoatrial nodal artery arises from the right coronary artery (54%) from circumflex artery in (42%) from both arteries in (2%) and in 2% origin is undetermined (James, 1961).

The origin of the artery of sinoatrial node from the proximal portion of trunk of left coronary artery was 12% and from left circumflex artery (30%) (Didio *et. al.,* 1995).

Among its branches, sinoatrial nodal artery which is responsible for irrigating the structure which is in charge of initiating each heart beat is one of the most important branch (Sanudo *et. al.,* 1998).

In this study, sinoatrial nodal artery was seen in 24% specimens.

b) Left Marginal Artery (LMA)

The left circumflex artery commonly extends to the left ventricular margin where it often terminates as left marginal branch. Occasionally, the left circumflex artery passes round the margo sinister to reach the diaphragmatic surface of the left ventricle (Angelini *et. al.,* 1989).

In this study, left marginal artery was seen in 100% specimens but with some variations. In specimen 22, the left marginal artery was much bigger than the left circumflex artery. It appeared very small in specimens 23 and 30. Parallel branches to left marginal artery was seen in 20% specimens. Left circumflex artery terminated as left marginal artery in nearly 20% specimens.

c) Posterior Interventricular Artery (PIVA)

The origin of posterior interventricular artery is one of the parameters on which Schlesinger (1940) system of arterial dominance is based. In rare cases, the posterior interventricular artery is entirely replaced by a dominant long anterior interventricular artery (Levin and Baltaxe, 1972). In most cases, the posterior interventricular artery terminates halfaway between the crux and the apex (Angelini *et. al.,* 1989) reporting single posterior interventricular artery in 70% cases. Double posterior interventricular artery accompanied by right or left branch in 6% and in 10% cases replaced by a left coronary artery.

In this study, posterior interventricular artery was seen as continuation of left circumflex artery in 10% specimens (Sp.20, 28, 38, 39 45). In 8% specimens (Sp.20, 28, 38, 39) posterior interventricular artery was found single whereas double posterior interventricular artery was seen in 2% (Sp.45).

With regard to termination of posterior interventricular artery, in specimens 38, 39 the posterior interventricular artery terminated in the middle of posterior interventricular groove whereas in specimens 20, 28 and 45 it terminated at the junction of anterior one third and posterior two third of posterior interventricular sulcus.

d. Atrioventricular (AV) Nodal Artery

Habitually, the atrioventricular node is irrigated by the artery that reaches the crux cordis and supplies posterior interventricular artery although as noted by McAlpine (1975) coronary dominance does not reflect the origin of the node artery.

This artery which is the branch of right coronary artery (86%) was seen arising from the left coronary artery (12%) or in both arteries (2%) (Petit and Reig, 1993).

In this study, atrioventricular Nodal artery was seen as a branch of posterior interventricular artery in 10% specimens.

XII. Termination of left circumflex artery

Many authors suggest that the termination of left circumflex artery as highly variable. **Table – 19 : Termination of left circumflex artery**

Authors	Year	Cases	Obtuse Border	Obtuse /Crux	Crux	Crux/Acute
Banchi	1904	100	19%		70%	
Crainicianu	1922	200	15%	75%	10%	
Mouchet	1933	100	10%	82%	81%	
Bosco	1935	135	25%	45%	12%	8%
James	1961	106	22%	60%	9%	9%
Baroldi and Scamazoni	1965	522	25%	63%	5%	7%
Present study	2009	50	26%	62%	2%	10%

This study showed the termination of left circumflex artery at obtuse border in 26%, between obtuse border and crux in 62% and at crux in 2%, beyond crux in posterior interventricular sulcus in 10%.

XIII. Coronary Dominance

The origin of posterior interventricular artery is one of the parameters on which Schlesinger (1940), reported left dominance in 18%. Cavalcanti (1995) showed left dominance in 11% of his study. In left dominance, the posterior interventricular artery originated in the circumflex artery in 10-15% of cases (Ludinhausen, 2002).

In this study, left coronary dominance was found in 10% of specimens.

Marios Loukas (2006) showed that the presence of bridges appeared to be related to coronary dominance especially in left coronary circulation. 66.6% of the hearts with bridges were left dominant.

In this present study, 20% of the hearts with bridges were left dominant.

XIV. Anomalous Left Coronary Artery

Separate origins from the aorta of the anterior descending and circumflex branches of the left coronary artery have been reported; the former arose in the proper location of the left coronary but the latter arose from the right or anterior aortic sinus close to the origin of the right coronary artery and circled the aorta posteriorly to assume the position of a normal circumflex branch (Hepburn, 1895).

The incidence of left coronary artery arising from the pulmonary trunk and then assuming the course and distribution pattern of a coronary artery of normal origin is designated as Bland – Garland syndrome (Bankl, 1977).

According to Topaz *et. al.,* (1992), 27% patients had an anomalous circumflex artery and 11% patients presented an anomalous anterior interventricular artery. In 6% patients only, the anomalous coronary artery was solely responsible for a clinical event. Coronary anomalies are found in 0.2-1.2% of the population (Lipsett *et. al.,* 1994) with left coronary artery arising from the right aortic sinus or pulmonary artery.

A very rare angiographic study of Harikrishnan *et. al.,* (2002) concluded that the most common anomaly was separate origins of the anterior interventricular artery and left circumflex artery (35%) and

anomalous coronaries are more prone to atherosclerosis which was found in 32% of patients.

Table – 20 : Anomalous left coronary artery

Left coronary anomalies	**Yamanaka *et. al.*, (1990)**	**Harikrishnan *et. al.*, (2002)**
Anomalous arteries	1.6%	0.46%
Separate origin of anterior interventricular artery and LCX	30.4%	35.3%
LCX from RAS/RCA	17.6%	17.6%
Origin of anterior interventricular artery from RCS	38/1461 pt	1 pt

LCX – Left circumflex artery

RAS – Right aortic sinus

RCA – Right coronary artery

RCS – Right coronary sinus

This study showed no anomalous origin of left coronary artery.

CONCLUSION

This current study of ***Branching pattern of left coronary artery*** was carried out in fifty specimens.

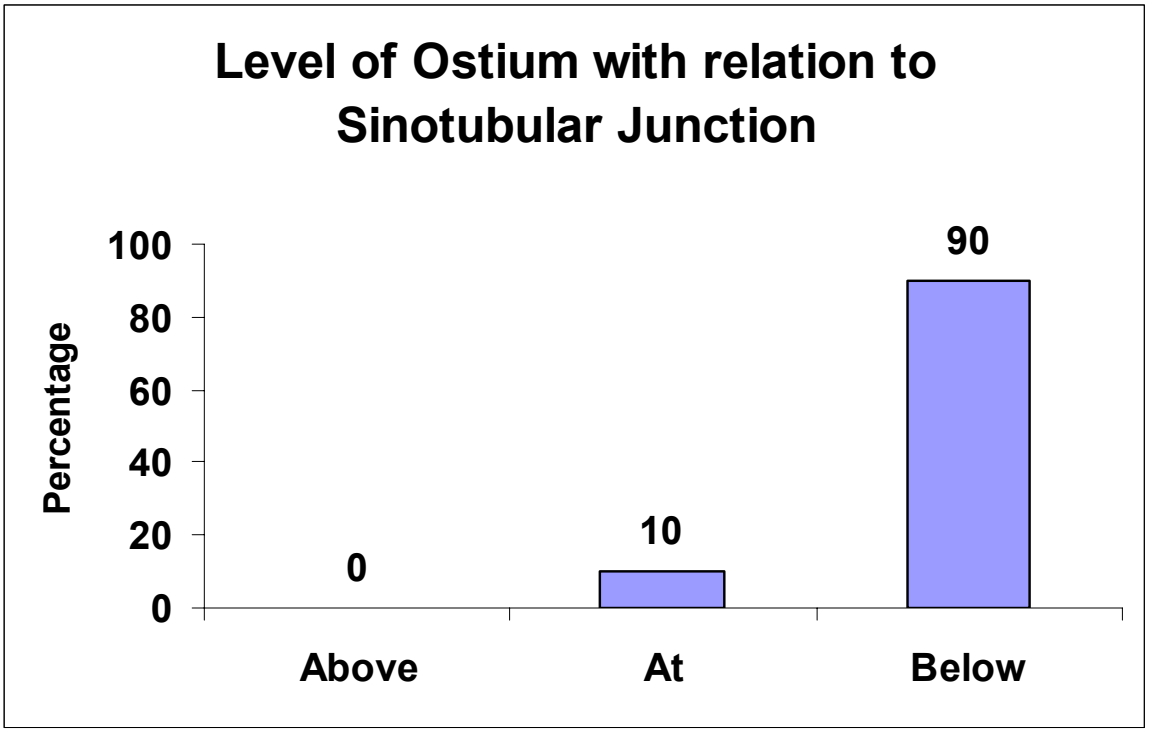
- The left coronary artery was seen to arise from the left posterior aortic sinus in all fifty specimens (100%).
- With relation to Sinotubular Junction (STJ), the ostium was found at the level of sinotubular junction in five specimens (10%), below the level of sinotubular junction in forty five specimens (90%), none was seen above the level of sinotubular junction.
- The mean length of the main trunk of left coronary artery was found to be 9.32 mm.
- Regarding branching pattern, there was bifurcation of main trunk of left coronary artery in thirty one specimens (62%), trifurcation in sixteen specimens (32%), quadrification in three specimens (6%).
- Apart from diagonal artery arising at the junction of two major branches showing trifurcation in five specimens (10%) one another branch called median artery was found in eleven specimens (22%).
- Anterior interventricular artery with all its branches was seen in all fifty specimens and it terminated before apex in two specimens (4%), at apex in eighteen specimens (36%), beyond apex in twenty eight

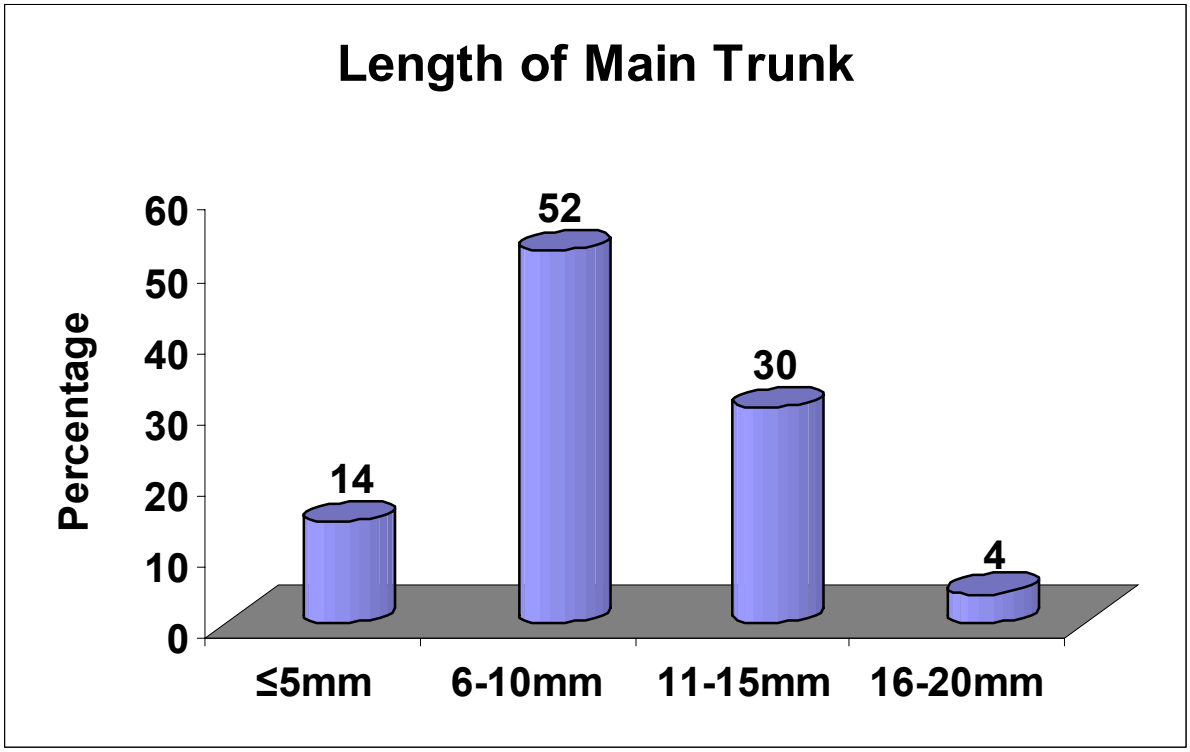
specimens (56%) and in posterior interventricular sulcus in two specimens (4%).

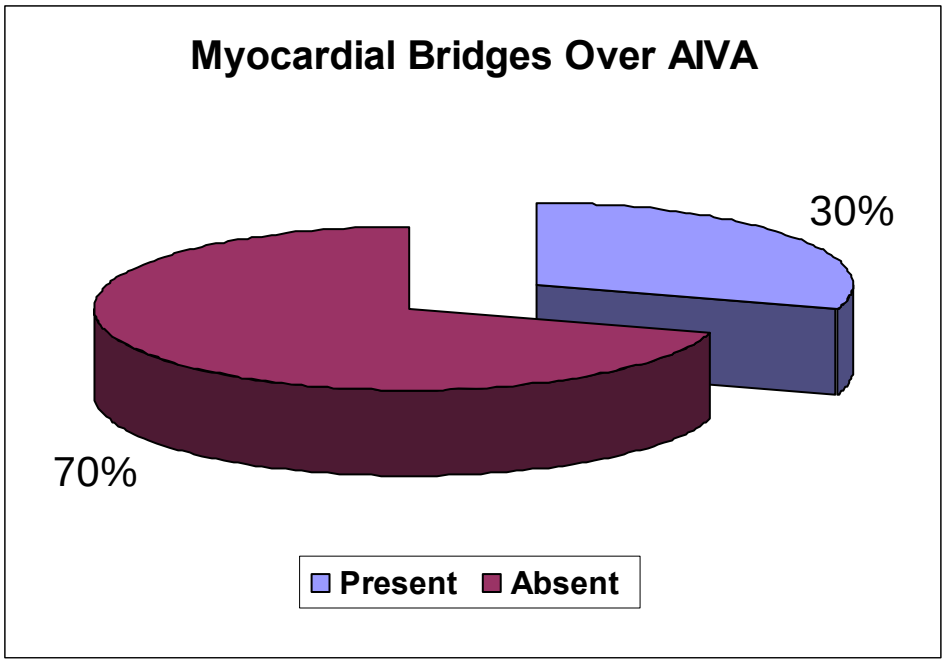
- Myocardial bridges over anterior interventricular artery was seen in fifteen specimens (30%).
- Left circumflex artery was seen in all fifty specimens (100%). Regarding its branches, sinoatrial nodal artery from left circumflex was seen in twelve specimens (24%). Left marginal artery was seen in all fifty specimens with parallel branch (1, 2 or 3) seen in ten specimens (20%) and the left circumflex artery terminating as left marginal artery in ten (20%) specimens.
- Posterior interventricular artery determining the coronary dominance was seen to arise in five specimens (10%) and in one specimen (2%) there was a parallel branch to posterior interventricular artery. Atrioventricular nodal artery from posterior interventricular artery was found in five specimens (10%).
- Termination of left circumflex artery was found at the obtuse border in thirteen specimens (26%), between obtuse border and crux in thirty one specimens (62%), at the crux in one specimen (2%) and between crux and acute border in five specimens (10%).

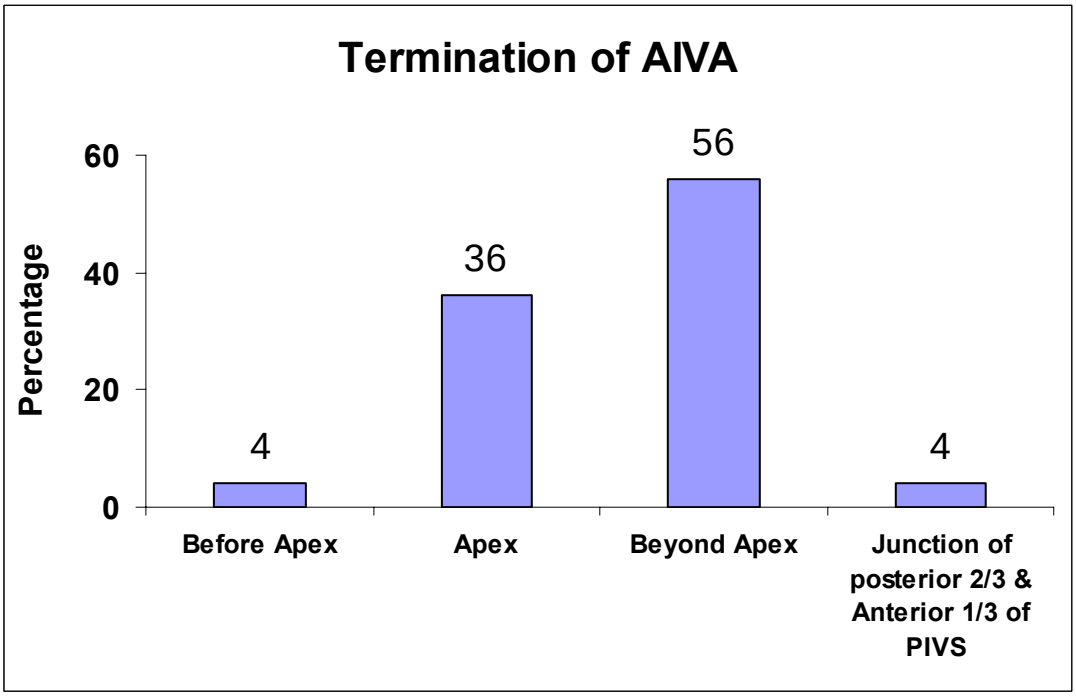
- Left coronary dominance was seen in five specimens (10%) with posterior interventricular artery arising from left circumflex artery.
- There was not a single left coronary anomaly found in this study.

Recent technical advances in the study of coronary arteries make it necessary for all angiographers and cardiac surgeons to be familiar with variants of left coronary artery, because accurate identification and delineation of coronary arteries in the presence of coronary artery disease is integral to proper surgical revascularization of myocardium as surgical problems may follow if the surgeon unwittingly incises an anomalous vessel.

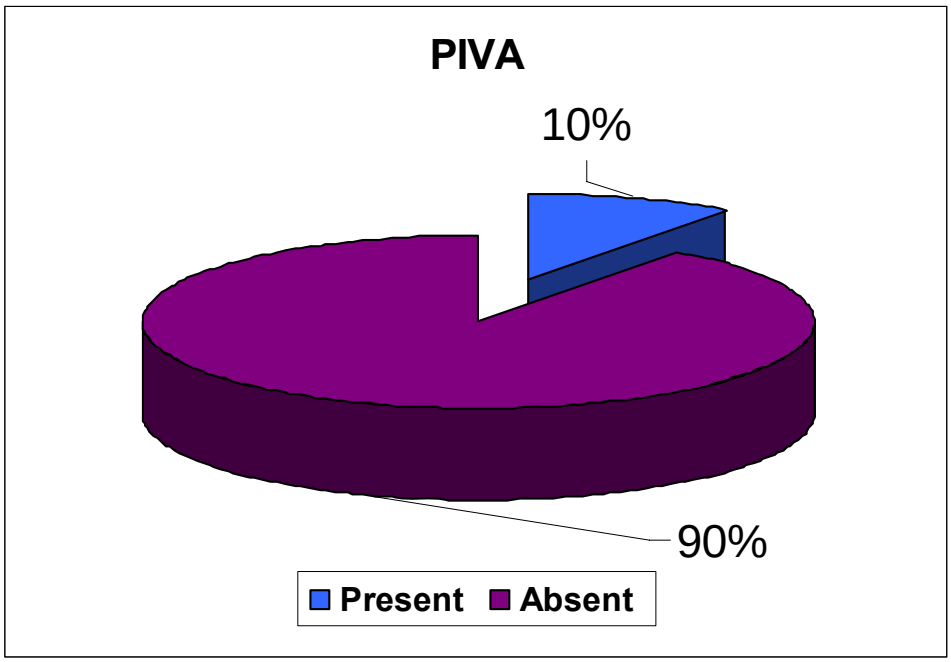

Level of Ostium with relation to Sinotubular Junction
Percentage
100
80
60
40
20
0
0
10
90
Above
At
Below


Length of Main Trunk
Percentage
60
50
40
30
20
10
0
14
52
30
4
≤5mm
6-10mm
11-15mm
16-20mm

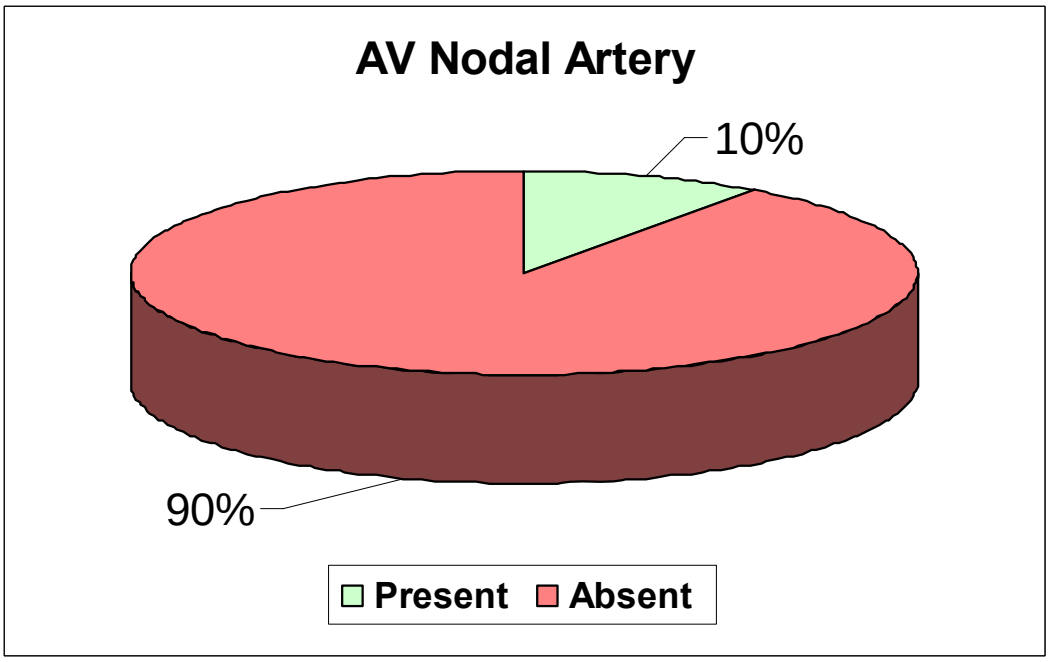




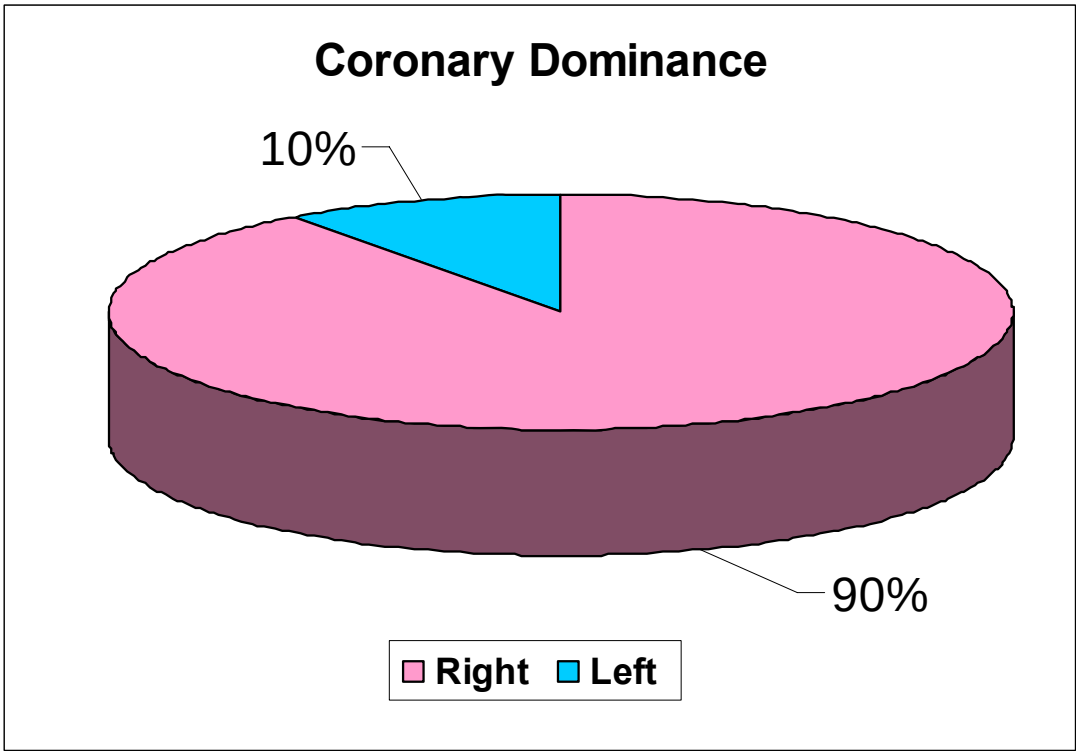
AIVA – Anterior Interventricular Artery
PIVS – Posterior Interventricular Sulcus



PIVA – Posterior Interventricular Artery



AV– Atrioventricular


Coronary Dominance
10%
90%
Right
Left

MASTER CHART ABBREVIATIONS

LCA	-	Left coronary artery
LPAS	-	Left Posterior Aortic Sinus
STJ	-	Sinotubular junction
SA	-	Sinoatrial
AV	-	Atrioventricular
LCX	-	Left circumflex artery
PIVA	-	Posterior interventricular artery
O	-	Obtuse Border
O/C	-	Obtuse / Crux
C/A	-	Crux / Acute
C	-	Crux
M	-	Median Artery
D	-	Diagonal Artery
LMA	-	Left Marginal Artery
R	-	Right
L	-	Left
Jn	-	Junction of posterior two third and anterior one third of posterior interventricular sulcus

THE 50 SPECIMENS OF THE CURRENT STUDY

Fig No : 1 – Left Coronary Ostium – At STJ

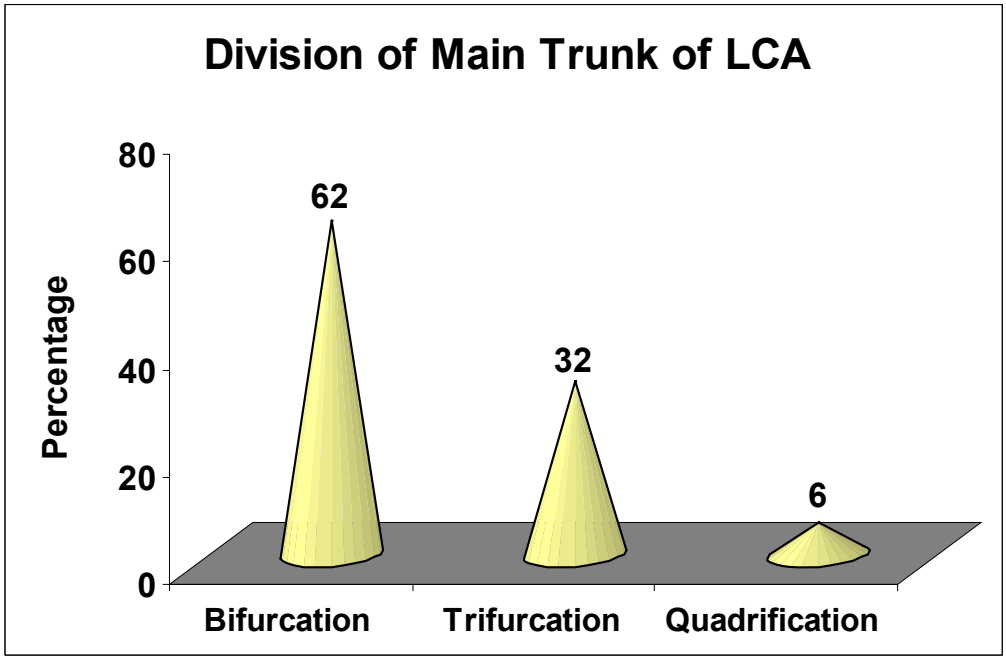
Fig No : 2 – Left Coronary Ostium – Below STJ

STJ – Sinotubular Junction

Fig No : 3 – Bifurcation of left Coronary Artery

Fig No : 4 - Trifurcation of left Coronary Artery

Fig No : 5 - Quadrification of left Coronary Artery



LCA – Left coronary artery

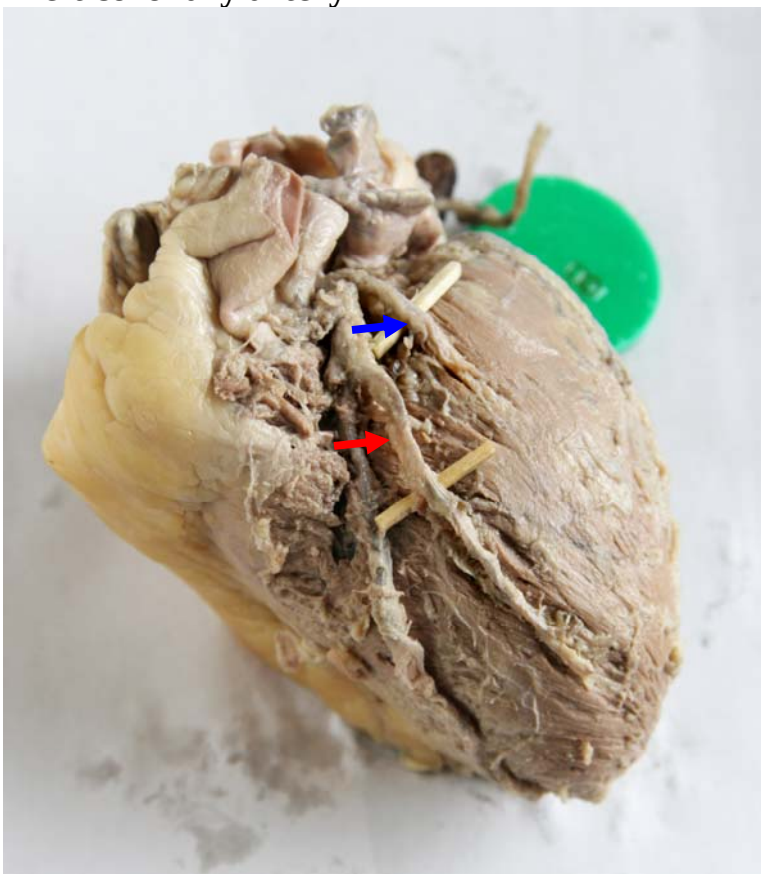
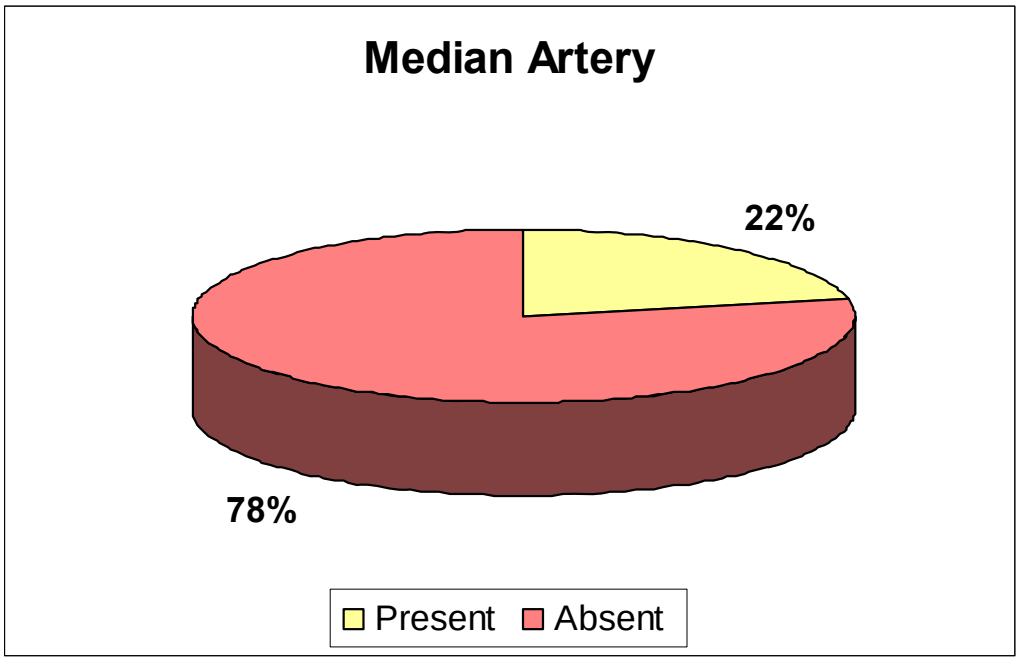


Fig No : 6 - Trifurcation of left Coronary Artery with Median Artery

→ - **Diagonal Artery from anterior interventricular artery**

→ - **Median Artery**



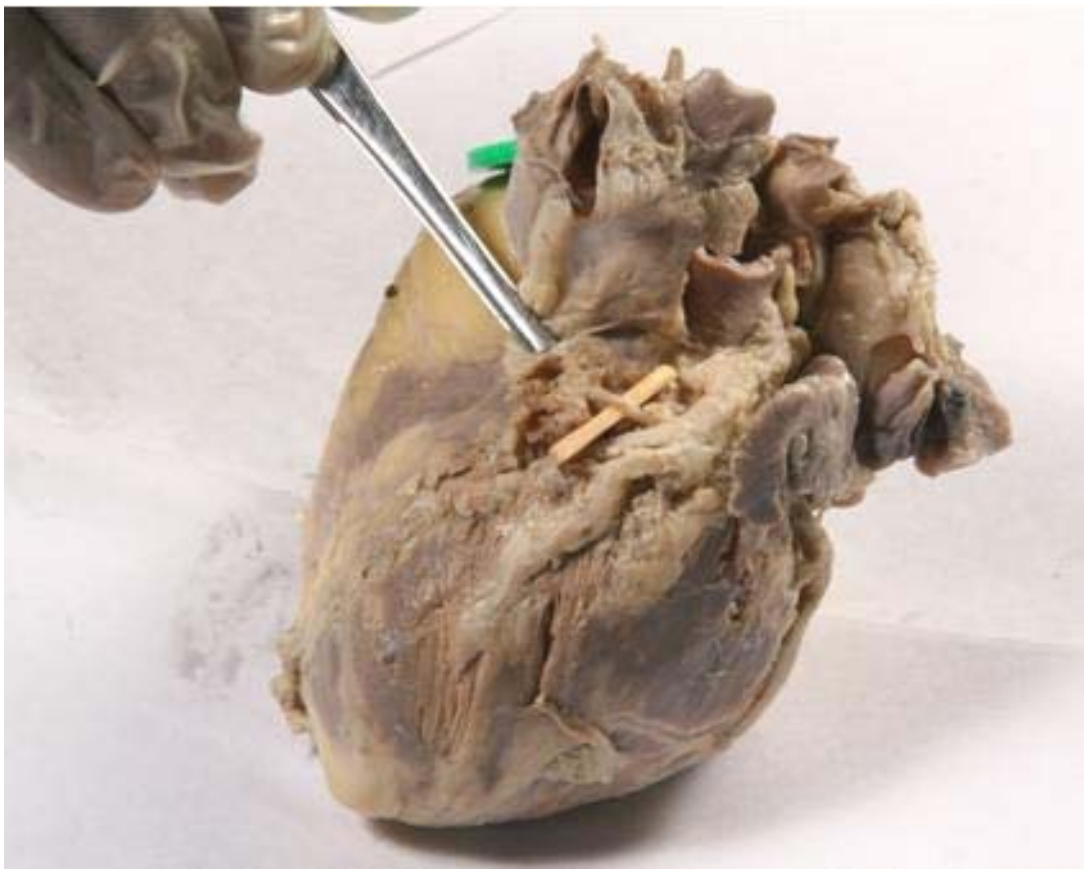


Fig No : 7 – Left Conus Artery from Anterior Interventricular Artery

Fig No : 8 – Trifurcation of left coronary artery with diagonal artery at the junction

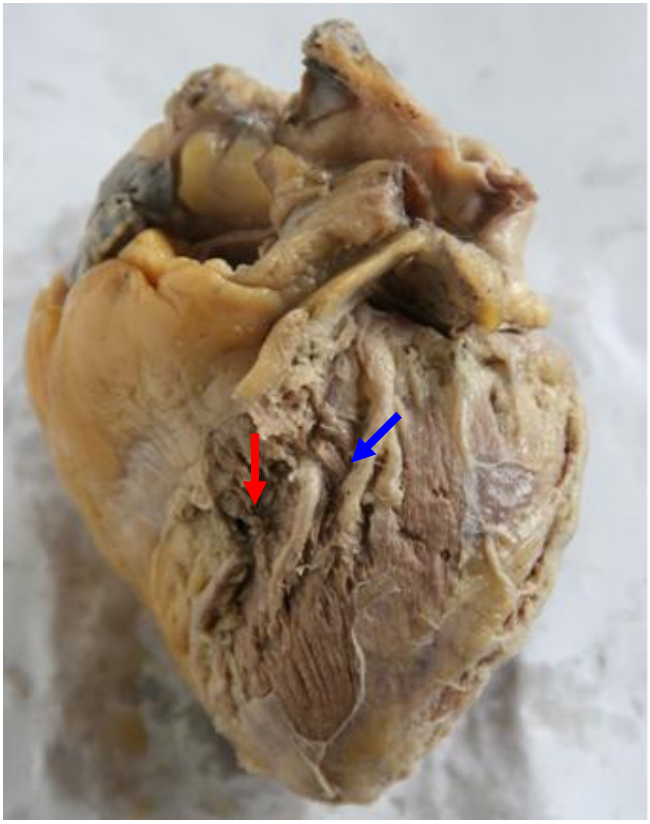


Fig No : 9 – Parallel Branch to Diagonal Artery

→ - Parallel Branch

→ **- Intramural course of anterior interventricular artery**

Fig No : 10 – Termination of AIVA over sternocostal surface before apex

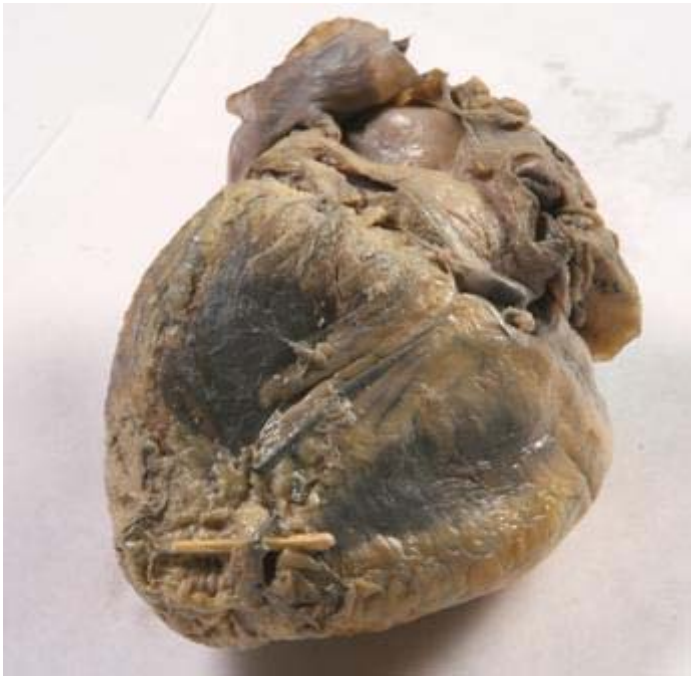


Fig No: 11 – Termination of AIVA over diaphragmatic surface beyond apex

AIVA – Anterior Interventricular Artery

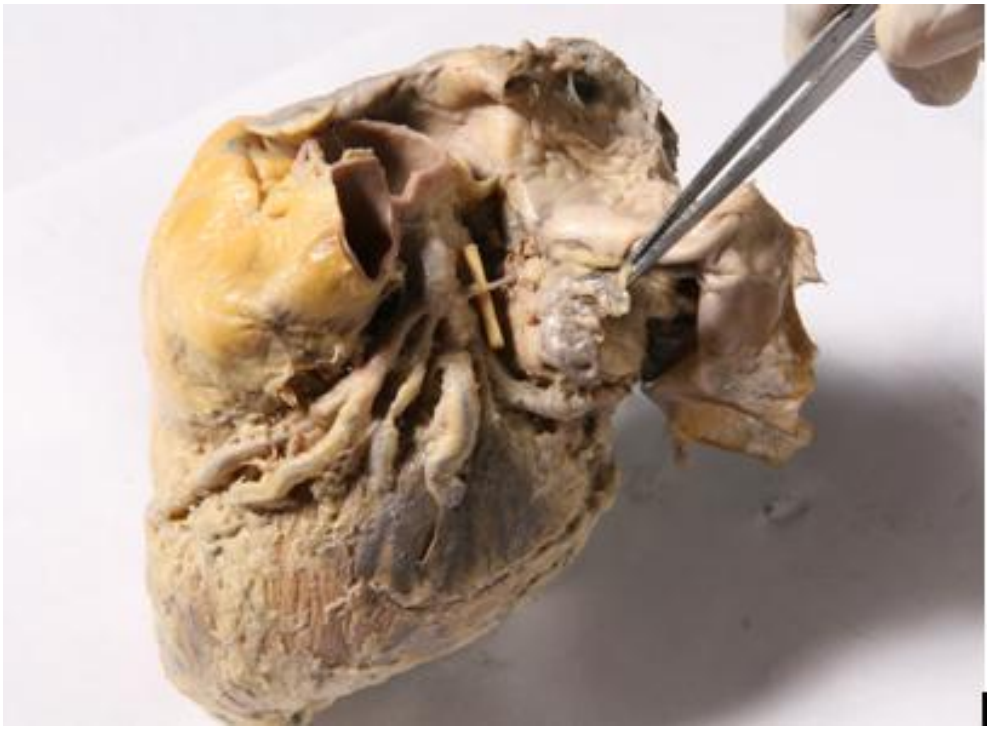
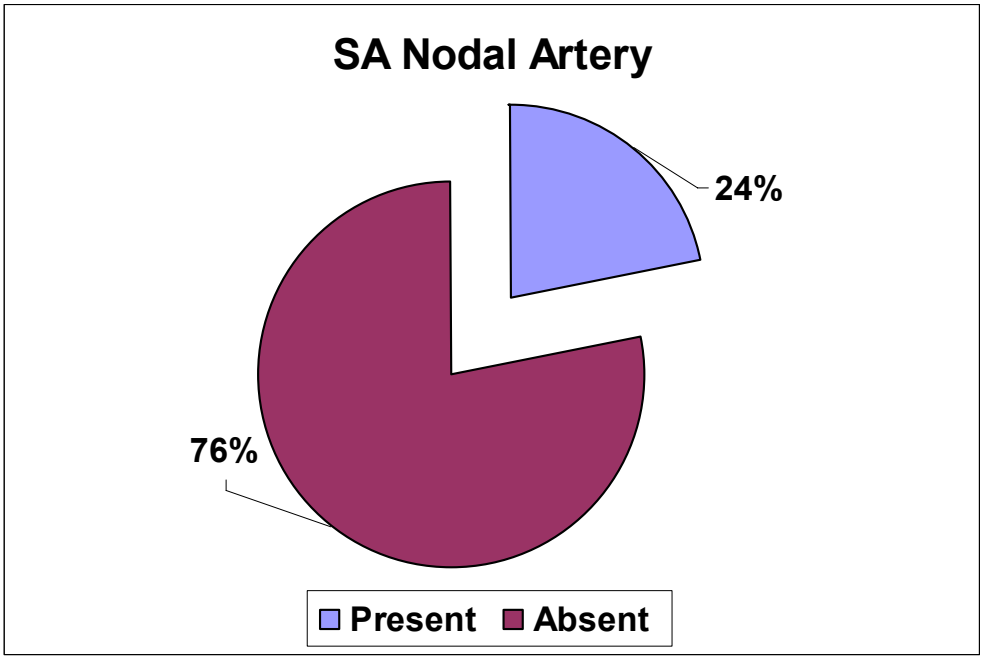


Fig No: 12 – Sinoatrionodal artery from left circumflex artery

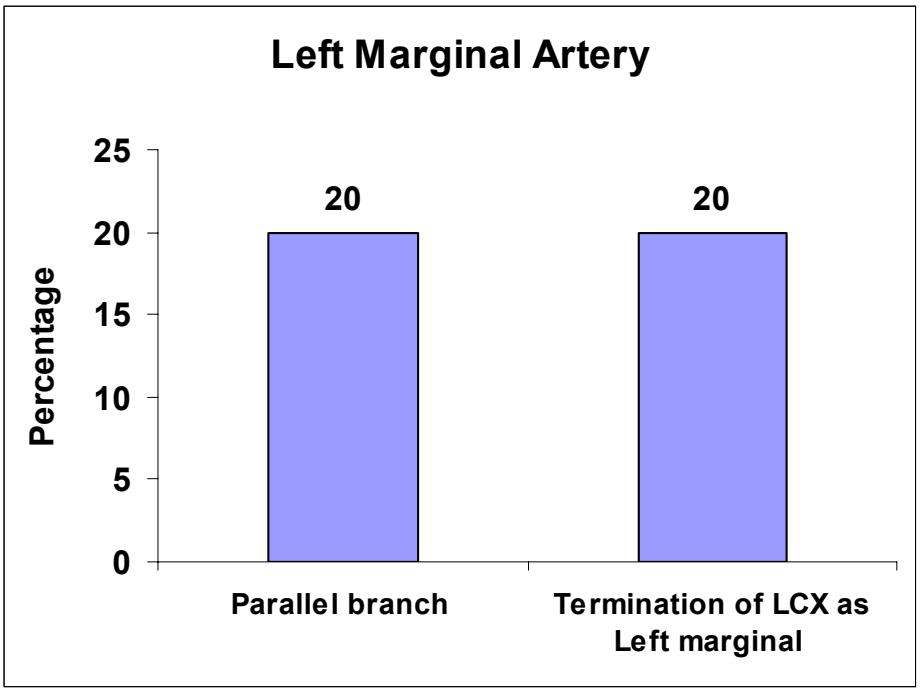


SA – Sinoatrial

Fig No: 13 – Parallel Branch to Left Marginal Artery

Fig No: 14 – Two Parallel Branches to Left Marginal Artery

Fig No: 15 – Left Circumflex Artery Terminating as left Marginal Artery



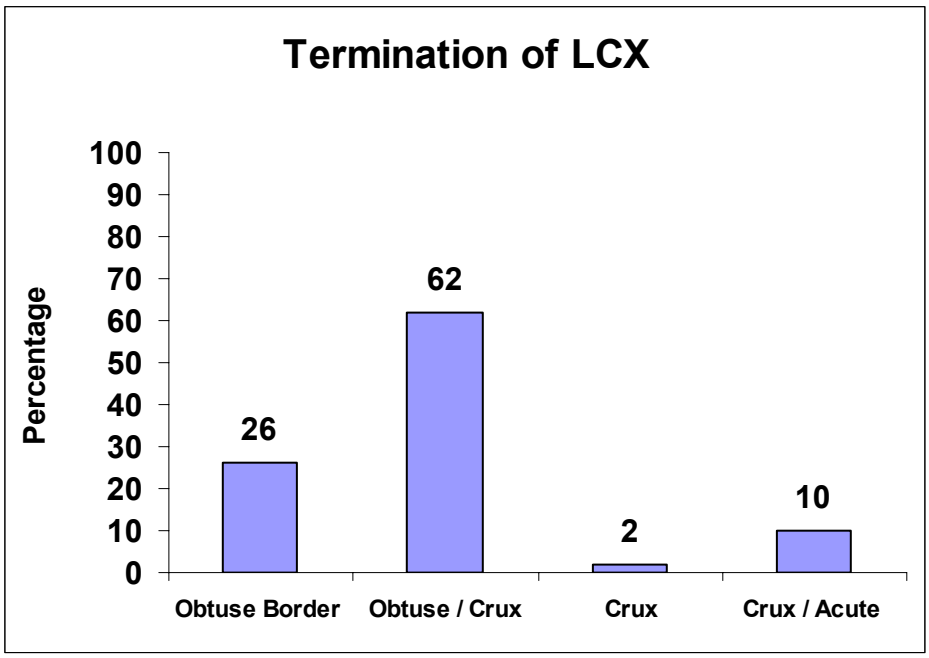
LCX – Left Circumflex

Fig No: 16 – Left Circumflex Continuing as Posterior

Interventricular Artery

Fig No: 17 –Dual Posterior Interventricular Arteries

Fig No: 18 – Termination of Left Circumflex Artery at Crux



LCX – Left circumflex

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