MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES (MUHAS)

SCHOOL OF MEDICINE

DEPARTMENT OF ANATOMY/HISTOLOGY

THE ORIGIN, NORMAL BRANCHING PATTERN AND VARIATIONS OF CORONARY ARTERIES AMONG TANZANIAN POPULATION

BY

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MSc (Anatomy)

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(August 2009)

DECLARATION

I here by confirm that this dissertation is my original work and has not been presented elsewhere for examination

Dr. Hortensia, Nondoli

Signature.....Norty..... Date..26. 08. 2009

This dissertation is being submitted with my approval as University Supervisor:

Prof. Ainory Peter Gesase (MD, PhD)

Signature ..... Date..26. 08. 09

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GLORY IS TO THE LORD.

DEDICATION

This work is dedicated to my lovely and wonderful husband Mr. Pascal Stephan for his tenderness, care and love he has shown me, his confidence and strength he gave me to pursue my studies at MUHAS. To my lovely daughters Christiner and Judith; Sons Gasper, Gabriel and Fred may God bless you all.

Also dedicated to my parents late Mr. Gasper Nondoli and Mrs. Mary Uhwello; my parents in law late Mr. Steven Masiringi and Mrs. Christiner Makang'a.

Dedication should be also to Dr Habiba Madjapa, Dr J.J Malago, and sister Delfina, Leodger (my brother), Agnetha, Evodia and Fortunatus.

ABSTRACT

Background: The left and right coronary arteries take their origin from the ascending aorta as it leaves the left ventricle from the corresponding left and right coronary ostia. The two coronary arteries show differences in their branching pattern once they have emerged from their ostia. The left coronary artery gives rise to two branches left anterior interventricular (descending) coronary artery and left circumflex artery. Left anterior interventricular artery gives off two to three superficial diagonal branches and multiple deep septal branches. Left circumflex artery gives off atrial branch and three to four obtuse marginal branches. The right coronary artery branches into sinoatrial nodal artery, conus artery, atriaventricular nodal artery and posterior interventricular (descending) arteries. Coronary artery disease is one of major causes of death in developing countries. The increasing use of diagnostic and therapeutic interventional procedures necessitates that a sound and basic knowledge of coronary artery patterns be known. Therefore this study aims at establishing data on the origin and branching pattern of coronary artery taking into consideration the predominance and variations. **Objective**: To describe the origin, normal branching pattern and variations of coronary arteries among Adult Tanzanian population. **Methodology**: Study design: A descriptive cross-sectional study of 89 adult human hearts (84 males, 5 females) obtained from the Muhimbili National Hospital mortuary during autopsy and cadavers from anatomy dissection room, Muhimbili University of Health and Allied Sciences regardless of the age, sex and cause of death. Manual dissection of the heart tissues was performed to expose the origin of coronary arteries, coronary ostia and arising arteries, branching pattern and Anastomosis. **Results**: Right and left coronary arteries took origin from right and left aortic sinuses. Right coronary sinus revealed a single ostium in 73 specimens, two ostia in 12 specimens, three ostia in 2 specimens and four ostia in 2 specimens. The left coronary sinus revealed a single ostium in 88 specimens, two ostia in 1 specimen. The right coronary artery arises as a single vessel branching into sinuatrial nodal, conus, anterior ventricular, marginal, atrioventricular nodal and posterior interventricular (descending) arteries in 72 specimens. The right coronary artery started on its own with either one (13 specimens), two (2 specimens) or three (2 specimens)

vessels from ascending aorta and not as right coronary artery branches. In 83 specimens the posterior interventricular (descending) artery arises from the right coronary artery. Left coronary artery branched into two in 52 specimens, three in 30 specimens and four in 6 specimens, which are Left anterior interventricular (descending) (LAD), Left Circumflex (LCx), Median and one unnamed vessel; in 1 specimen there was no main trunk, left anterior interventricular (descending) and left circumflex branches took their origin from the ascending aorta. Left coronary artery gave branch to left atria appendage in 1 specimen. **Conclusions**: Left coronary artery and right coronary artery take origin from left and right aortic sinuses. A single left coronary artery from left aortic sinus and a single right coronary artery from right aortic is the commonest among Tanzanian specimens. Left coronary artery branching into two and three branches; and that of right coronary artery giving branches to sino atrial node artery, conus, anterior ventricular, anterior interventricular and posterior interventricular arteries were the common branching pattern observed in the current study. Right dominant circulation was observed to dominate among the Tanzanians which differ from those described in other populations.

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ABBREVIATIONS

AVNA ..... Atrioventricular nodal artery

LMCA ..... Left Main coronary artery trunk

LAD ..... Left anterior Interventricular (descending) coronary artery

LCx ..... Left circumflex coronary artery

PIVA ..... . Posterior interventricular (descending) coronary artery

RCA ..... . Right coronary artery

SANA ..... Sinuatrial nodal artery

STJ ..... Sinotubular junction

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CHAPTER ONE

1.2 INTRODUCTION

The heart is supplied by the left and right coronary arteries that arise from ascending aorta from the corresponding left and right coronary ostia as the aorta leaves the left ventricle. They run subepicardially, in the interventricular and coronary sulci, and in most cases are covered by fat tissue. During their course they give rise to branches that supply blood to all structures within the pericardial cavity

The coronary ostia are openings that lead into the lumen of coronary artery and can be traced in the corresponding pocket-like dilation known as the aortic sinuses. There are three aortic sinuses between the aortic valves and the wall of the aorta; these are the left, right and the posterior aortic sinuses. The left and right coronary arteries originate from the left and right aortic sinuses. Usually, no vessels arise from the posterior aortic sinus, which is therefore known as the non-coronary sinus. Each coronary sinus can also be referred to as the sinus of Valsalva, the sinus of Morgagni or Petit's sinus.[40,41]

The two coronary arteries show differences in their branching pattern once they have emerged from their sinuses. The left coronary artery gives rise to two branches, the left anterior descending (LAD) and the left circumflex (LCx) coronary arteries.[12,40] The left anterior interventricular (descending) coronary artery runs along the anterior interventricular sulcus, providing several superficial (diagonal) and multiple deep (septal perforator) branches, and usually reaches the apex. Occasionally continues through the posterior interventricular groove,

where it is known as Posterior recurrent interventricular artery. The Left anterior interventricular (descending) coronary artery supplies blood to the anterior left ventricular wall through its diagonal branches, the anterior two thirds of the interventricular septum through its septal perforator branches, and commonly the cardiac apex by its terminal branches.[10,37,41]

The left anterior interventricular (descending) artery is the commonest site of coronary atherosclerosis in both young and old. This pathology has shown high incidence in developed world as compared to the incidence in Africa specifically the black races[34]. However recent report has shown an increasing incidence of atherosclerosis in developing counties.[11,23,25,32]

The Left circumflex coronary artery supplies blood to the left atrium, left ventricular, lateral and posterior walls through its obtuse marginal branches. Left circumflex coronary artery passes below the left appendage and runs in the left atrioventricular groove and usually gives off one or more branches that reach the obtuse margin of the heart (obtuse marginals). During its course, it may reach the left atrium and the posterior atrioventricular groove; in this case it passes below the coronary sinus.[10,12,18,37,41]

Observations have shown the presence of differences in branching of the left main coronary artery such that the left main (LM) coronary artery gives rise to three branches[20] instead of dividing into two branches. In this case, the additional artery arising from the Left main coronary artery originates in between the Left anterior descending artery and Left circumflex coronary arteries and is called the median coronary artery. Also there are reports where left

main trunk coronary artery divides into four branches instead of two branches.[20,33,37] These additional branches provide blood supply to the anterior left ventricular free wall.

The right coronary artery after taking its origin from the right aortic sinus of the ascending aorta, courses downward in the coronary groove, between right atrium and right ventricle, to reach the junction of the Atrioventricular groove and the posterior interventricular sulcus of the heart also known as the crux.[18,20,41]

Right coronary artery gives off several branches during its course. An early atria branch is Sinuatrial nodal branch which supplies the atria musculature and the infundibular (or conal) artery into the ventricular muscle mass.[15,35] The artery then runs to the inferior (acute) margin of the heart where it gives branch to the right marginal artery of the right ventricle and, usually, a lateral atrial artery. As the right coronary artery approaches junction area of the posterior interventricular and the atrioventricular grooves it gives off its final major branch, the posterior interventricular artery that lies in the posterior interventricular sulcus.[12,41,46] The posterior descending branch of the right coronary artery supplies blood to the posterior one third of the interventricular septum. A posterolateral branch of the right coronary artery provides blood supply to the basal most of the posterolateral left ventricular wall.[35,37,40,41]

The two arteries, left and right coronary arteries, converge posteriorly forming anastomotic circle in the atrioventricular groove connected by marginal and interventricular (descending) loops that intersect at the cardiac apex.[10,39] Anastomosis between branches of coronary arteries, subepicardial or myocardial, and between these vessels and extra cardiac vessels do

exist but are not physiologically important. Clinical experience has shown that anastomoses cannot provide collateral roots sufficient to circumvent sudden coronary obstruction and coronary circulation is assumed to be end- arterial.[10,41] A sudden lock of one larger branches of either coronary artery usually leads to myocardial death (myocardial infarction), although sometimes the collateral circulation is enough to sustain the muscle[39]

The phenomenon of Left or right coronary artery dominance occurs when the branching pattern of coronary arteries are disturbed. It is determined by the origin of the atrioventricular nodal artery at the crux of the heart and also the coronary artery that gives off the posterior descending coronary artery. Also there are observations in which, both the right coronary artery and the Left circumflex artery reach the crux and jointly give rise to the posterior descending coronary artery. In such case, the coronary arterial system is referred to as co dominant or a balanced circulation.[12,18,45]

Knowledge of the normal and variant anatomy and anomalies of coronary circulation is an increasingly vital component in the management of congenital and acquired heart diseases. Congenital, inflammatory, metabolic and degenerative diseases may involve the coronary circulation and increasingly complex cardiac surgical repairs demand enhanced understanding of the basic anatomy to improve the operative outcomes.[41]

The incidence of congenital coronary artery anomalies is 5-6%. By definition, the term anomalous or abnormal is used to define any variant form observed in less than 1% of the general population.[1,2,34,38] Because normal subjects reveal an extreme variability in coronary artery anatomy, a precise definition of normality will require statistical evaluation of all possible anatomic variations to determine a minimum common denominator. These will have significant impact on the understanding of the boundaries between normal and abnormal coronary artery anatomy.[37]

There are variations or occasional anomalies of the cardiac vessels that have been reported, but they are not common. When they do occur they involve the number of vessels, abnormal origin, or both[6]. Past studies have shown for example, separate origin from the aorta of the anterior descending and the circumflex branches of the left coronary artery have; 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 normal circumflex branch.[18,41]

Both coronary arteries have been reported as arising by a single stem. Also both have been reported as arising separately from the left aortic sinus[110,18,41] The circumflex branch of the left coronary artery has been described as arising from a branch of the right coronary artery.[18]

The right coronary artery may arise from the pulmonary trunk as may an accessory (supernumerary) coronary, but left coronary arteries of pulmonary origin are apparently more common.[18,41] The ischemia of the ventricle resulting from this abnormal origin apparently

stimulates the formation of intercoronary anastomoses, and after they have well developed a left-right shunt that decreases the circulation to the left ventricle occurs.

Abnormalities of the origin of coronary arteries with subsequent normal epicardial course relate to the anomalous origin of one or both coronary ostia. In addition, coronary arteries may originate directly from the left or right ventricles; the bronchial, internal mammary, subclavian, right carotid, or innominate arteries; the aortic arch; or the descending thoracic aorta.[10,18]

Proficiency in the normal anatomy of coronary arteries and their variations is significant for proper interpretation of the coronary angiographies, assessment of the complexity and result of the coronary insufficiency as well as surgical myocardium revascularization

1.1 STUDY JUSTIFICATION

Knowledge of the normal and anomalies of coronary artery branching pattern is an increasingly vital component in the management of congenital and acquired heart diseases. Congenital, inflammatory, metabolic and degenerative diseases may involve coronary circulation and increasingly complex cardiac surgical repairs demand enhanced understanding of the basic anatomy to improve the operative outcomes.

Coronary artery disease is one of the major causes of death in developing countries. The recent introduction of selective coronary arteriography that provides an accurate localization of the anatomical variations and underlying pathology ,the advances made in coronary arterial bypass surgeries and modern methods of myocardial revascularization makes it imperative that a thorough, sound and complete knowledge of the normal and variant anatomy of the coronary artery and the branching pattern is required, which led to this study.[12] There is no data in Tanzania on the origin and branching pattern of coronary arteries. Therefore, this study aims at establishing data on the origin and branching pattern of coronary artery taking into consideration the predominance and variation

1.2 OBJECTIVES

1.2.1 Main objective:

To study the origin, normal branching pattern and variations of coronary arteries among adult Tanzanian population.

1.2.2 Specific objective:

1. To study the origin of coronary arteries.
2. To establish the branching pattern of the right coronary artery.
3. To establish the branching pattern of the left coronary artery.
4. To describe the anastomosis pattern and the vessels that involve in anastomosis.

CHAPTER TWO

2.2 METHODOLOGY

2.1 Study design:

This is a descriptive cross sectional study

2.2 Study population and area:

This study was conducted among native Tanzanians and Muhimbili National hospital was taken as Center for study during the research.

2.3 Materials and methods:

Sample size was calculated by the following formula

$$n = \frac{Z^2 Pq}{d^2}$$

Where n =sample size

Z = Standard normal distribution set at 1.96 (confidence interval 95%)

P = Proportion of the variation in branching pattern of coronary arteries in The study population (but it is not known so we used 50%)

q = Power of study (i.e. 1-P)

d = Degree of accuracy desired, set at 0.10

NB: sample size used was 89 human subjects.

This study was carried out on 89 heart specimens of adults (84 males, 5 females) obtained from Muhimbili National hospital (MNH) mortuary in Dar es Salaam during autopsy, and also

from cadavers of anatomy dissection room at the department of anatomy, Muhimbili University of Health and allied Sciences (MUHAS). The specimens were collected regardless of the age, sex, socio-economic status, religion or pathological basis.

The heart was removed after resection of the costosternum; the chest cavity was opened along the costal cartilages and the sternum removed to expose the middle mediastinum. The pericardium was incised longitudinally to expose the heart which was collected by dividing it from the great vessels 2cm from its base and placed in 10% formaldehyde for a period of 5-10 days. These specimens collected were serially numbered 1-89.

Of the various methods available, manual dissection of coronary arteries was followed. The gross anatomy of coronary arteries was studied in a sample of 89 formalin-fixed hearts. All individuals included in this study had died from non cardiac causes.

Visceral pericardium was removed to expose the coronary arteries. The right and left coronary arteries were carefully exposed to reveal the origin, branches, length, diameter and anastomosing vessels. Also the dominant vessel was followed through dissection of vessels on posterior interventricular groove. Coronary artery giving rise to the posterior descending branch was designated the dominant artery.

After examining the external features of the coronary vessels including branches, the aorta was opened to expose the aortic sinuses at the coronary ostia.

CHAPTER THREE

3.0 RESULTS

A total of 89 heart specimens from adults (84 males, 5 females) aged 18-80 years were used to study the origin, branching pattern and anastomosis of coronary arteries. The specimens were collected from the Mortuary Department of the Muhimbili National hospital and the Anatomy dissection room of the Muhimbili University of Health and Allied Sciences. Heart specimens were taken regardless of the age, sex or cause of death.

3.1. Origin of coronary arteries

The origin of left coronary artery was from left aortic sinus (of Valsalva) of the ascending aorta. The coronary Ostia of left coronary artery was below the sino-tubular junction in 78 specimens and at the level of junction in 11 of the specimens observed. The right coronary artery arose within the anterior or right aortic sinus; of which the coronary ostia were below the sino-tubular junction in 75 specimens, and at the junction in 14 of the studied specimens.

3.2 Number of coronary ostia and arteries arising from ascending aorta

Observations of the right coronary artery and left coronary artery showed significant features in relation to the number of coronary ostia.

Right coronary ostia and the arising arteries

Observations of the right coronary artery revealed a single ostium in 73 specimens. In 12 specimens the number of coronary ostia was found to be two and these were observed in

specimen's number H2 and H4 from females, and H3, H14, H19, H29, H30, H41, H56, H86 and H89 from males.

Observations also indicated the presence of three ostia in two specimens (number H10 from female and H25 from male); and four ostia in two specimens (number H31 and H83 from males). (Table II)

The ostia measured 3-5mm in diameter with an average of 3.6mm diameter.

On introduction of a blunt probe the following were observed;

a) Specimens with single ostium (H1, H6, H8, from females and H5, H7, H9, H11, H12, H13, H16, H17, H18, H20, H21, H22, H23, H24, H26, H27, H28, H32, H33, H34, H35, H36, H37, H38, H39, H40, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51, H52, H53, H54, H55, H57, H58, H59, H60, H61, H62, H63, H64, H65, H66, H67, H68, H69, H70, H71, H72, H73, H74, H75, H76, H77, H78, H79, H80, H81, H82, H84, H85, H87 and H88 from males) the probe entered into the right coronary artery (Fig. 1).

b) In Specimens with two ostia (H2, H4 from females and H3, H14, H19, H29, H30, H41, H56, H86 and H99 from males) the probe appeared to enter into two vessels; the right coronary and conus arteries (Fig. 2)

c) Specimens with three ostia (H10 female and H25 male) the probe continued into the right coronary, conus and anterior ventricular arteries (Fig. 3).

d) For the specimens with four ostia (H31 and H33 from males) the probe entered into the right coronary, conus, anterior ventricular and sinuatrial nodal arteries (Fig. 4).

Left coronary ostia and the arising arteries

Observations of the ostia associated with left coronary artery revealed the presence of a single ostium in all the specimens except specimen number H5 male which showed two ostia at the center of the aortic sinus. (Table II)

The ostia measured 3-5 mm with an average diameter of 4.1 mm.

a) In specimens with a single ostium the probe entered the left main trunk of coronary artery (Fig. 6)
b) The specimen which had two ostia the probe appeared to enter into the left anterior interventricular (descending) and left circumflex coronary arteries (Fig. 9)

3.3. Branching pattern of coronary arteries

The current study observed also the branching pattern of the right and left coronary arteries

(a) Right coronary artery;

Distance from the origin of right coronary artery to a point where it gives off branches was measured and found to be ranging from 2mm to 5mm with a mean distance of 3mm.

Right coronary artery was observed to have several branches namely Sinuatrial nodal artery, right Conus artery, anterior ventricular, the marginal and atrioventricular nodal artery in all specimens (Fig. 1)

Observations of the right coronary artery showed that in 72 specimens the right coronary artery started as a single vessel giving rise to sinuatrial nodal, conus, anterior ventricular,

marginal, anterior interventricular and posterior interventricular (descending) arteries. In the remaining specimens the right coronary artery started on its own with either one (13 specimens), two (2 specimens) or three (2 specimens) vessels directly from ascending aorta. In these specimens the sinuatrial nodal, conus or anterior ventricular arteries or all of them appeared to take origin directly from the ascending aorta. They did not appear to be branching from right coronary artery.

In 83 specimens the posterior interventricular (descending) artery was observed to arise from the right coronary artery at the crux of the heart and courses in the posterior interventricular groove to terminate near the apex.

Distributing vessels was observed on the right free margin of the right ventricle in 89 specimens.

(b)Left coronary artery

Distance from the origin of left main coronary (LM) artery to a point where it gives off branches was measured and found to be ranging from 3mm to 29mm with a mean distance of 11.21mm.

a) On observing the left main coronary artery

i) 52 specimens revealed that it gave two branches the left anterior interventricular (descending) and left circumflex arteries (Fig.6)

ii) In one specimen (H21 male) left anterior interventricular and circumflex arteries were observed to take origin directly from the ascending aorta. (Fig. 9)

iii) In 30 specimens the left main coronary artery appeared to give three (trifurcation) branches, namely left anterior interventricular (descending), circumflex and median arteries (Fig. 7)

iv) In 6 specimens the left main coronary artery gave rise into four (quadrifurcation) branches, the left anterior descending, circumflex and two additional vessels between the left circumflex and the left anterior interventricular (descending) arteries (Fig. 8) (Table I)

b) In one specimen (H80 male), the left main coronary artery was observed to give a branch to the left atria appendage (Fig. 10)

c) On observing the left anterior interventricular (descending) artery revealed to give two to four diagonal branches to the anterior left ventricular wall and several septal branches (perforator) to interventricular septum.

d) Circumflex artery appeared to give a branch to the left atrium and also three to four obtuse left marginal branches to the left ventricular musculature, lateral and posterior walls of left ventricle.

3.4. Anastomoses

Observations on the posterior interventricular groove showed that the left posterior interventricular artery and the left anterior interventricular (descending) artery closed each other and were observed to unite near the apex. Also distributing vessels from the circumflex artery united with the left anterior (descending) and posterior interventricular arteries.

Table 1: Frequency distribution table for divisions of left main coronary artery trunk.

Branches	Frequency	Relative Frequency (%)	Cumulative frequency (%)
One branch	-	-	-
Two branches	52	58	58
Three branches	30	34	92
Four branches	7	8	100
Total	89	100	

Table 2: Frequency distribution of the number of coronary ostia observed.

	Frequency		Relative frequency (%)		Cumulative frequency (%)	
Number of coronary ostia	Right aortic sinus	Left aortic sinus	Right aortic sinus	Left aortic sinus	Right aortic sinus	Left aortic sinus
One	72	88	82	99	82	99
Two	13	1	14	1	96	100
Three	2	-	2	-	98	
Four	2	-	2	-	100	
Total	89	89	100	100		

Table 3: Number of arteries arising from ascending aorta

Number of arising arteries	Left aortic sinus	Right aortic sinus
One	88	73
Two	1	12
Three	-	2
Four	-	2
Total	89	89

Table 4: Frequency distribution table for dominant coronary circulation

Dominant (posterior interventricular artery)	Frequency	Relative frequency (%)	Cumulative frequency (%)
Right	83	93	93
Left	6	7	100
Total	89	100	

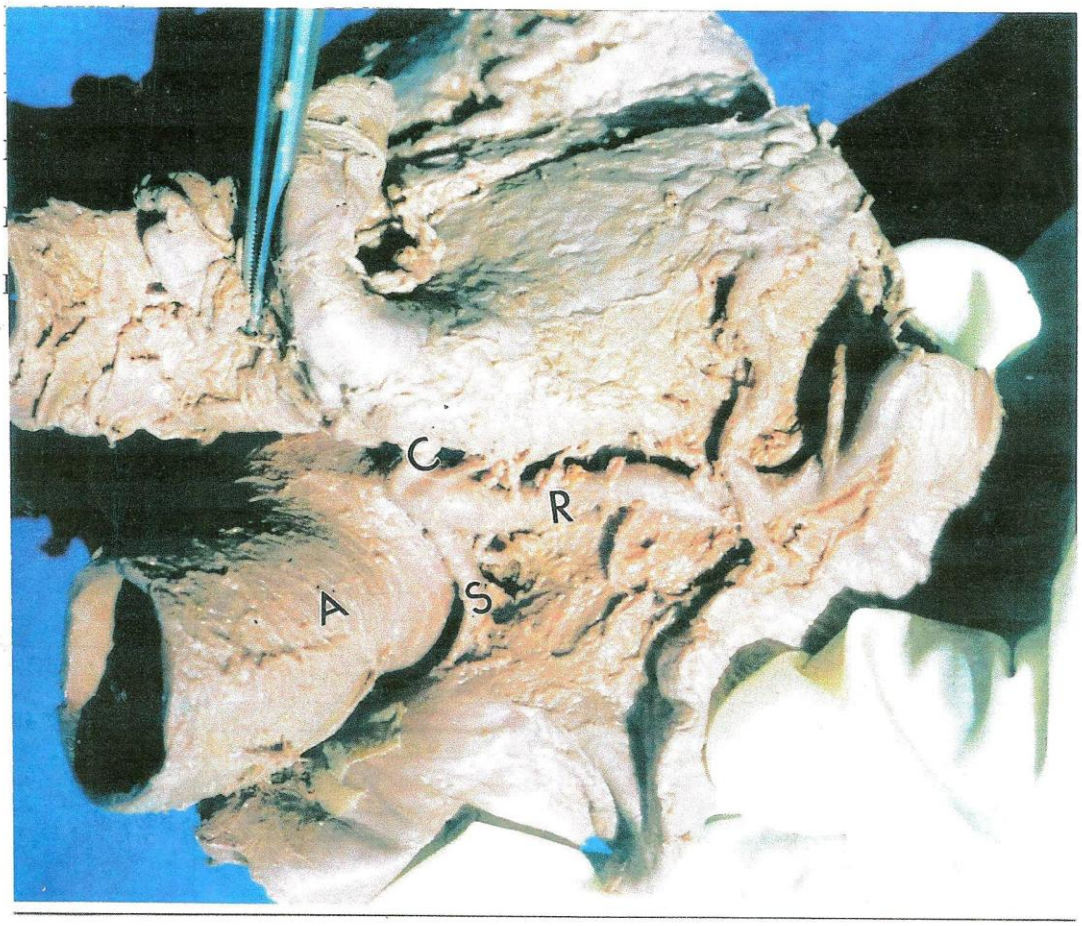


Figure 1: Photograph of the heart from a male case H73 showing the ascending aorta (*A*), right coronary artery (*R*), conus (*C*) and Sinuatrial nodal arteries (*S*). The right coronary artery (*R*) takes its origin from right aortic sinus giving off conus (*C*) and Sinuatrial nodal (*S*) branches.

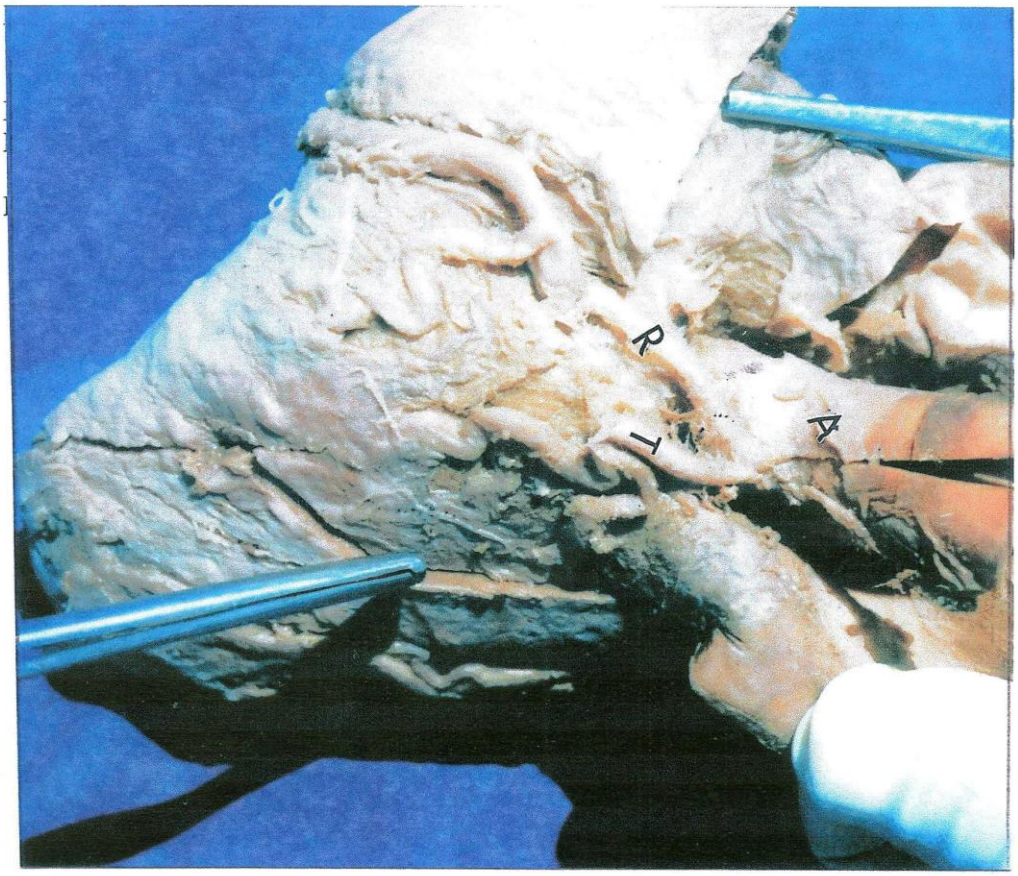


Figure 2: Photograph of the heart from a male subject specimen H56 showing a portion of ascending aorta (*A*) and the vessels arising from it. The right coronary artery (*R*) follows the normal course in the atrioventricular groove; and the third coronary artery (*T*) which has separate ostium in right aortic sinus, follows the normal course as the right coronary artery (*R*) before diverging to supply the anterior part of right ventricle. The right (*R*) and third (*T*) coronary arteries have no common trunk.

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Figure 3: Photograph of the heart from a male subject specimen H25 from a male subject showing a portion of ascending aorta (*A*) and multiple vessels arising from it. The right coronary artery (R) follows the normal course in the atrioventricular groove; the third coronary artery (T) and anterior ventricular artery (AV) arise separately from right aortic sinus supplying the right ventricle.

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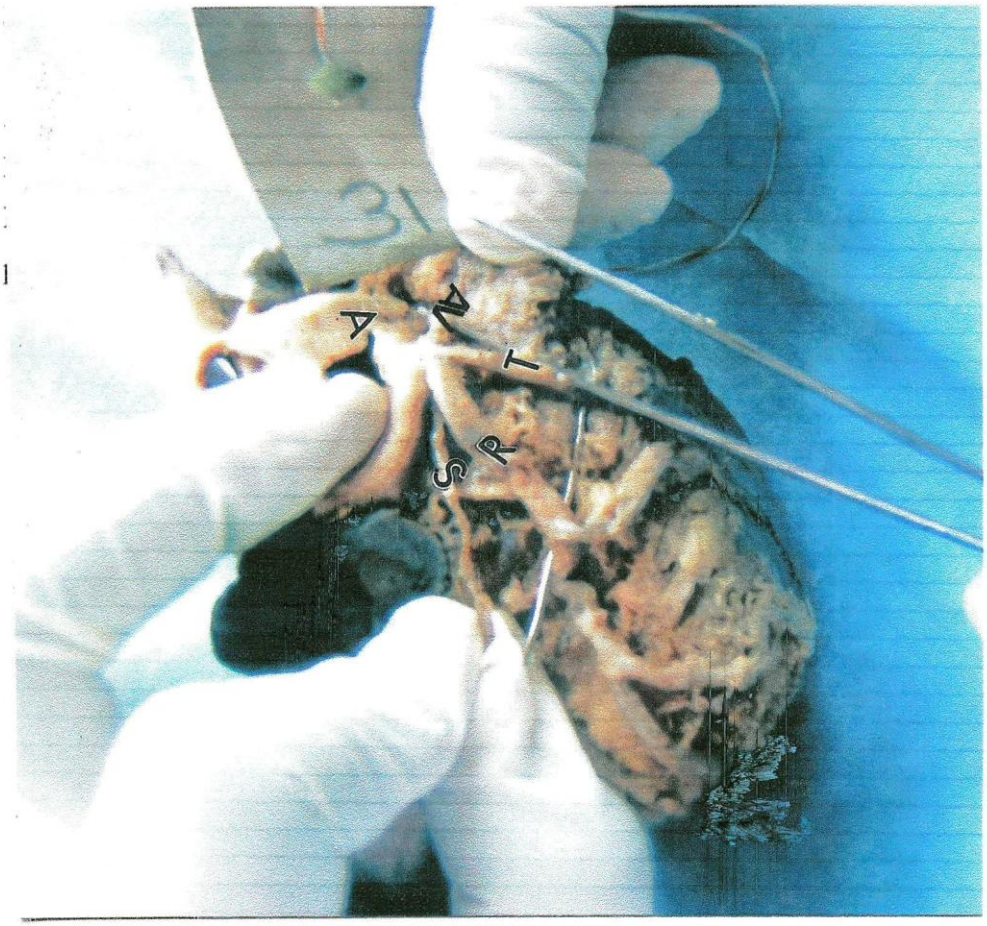


Figure 4: Photograph of the heart from a male subject specimen H31 showing a portion of ascending aorta (*A*) and multiple vessels arising from it. The right coronary artery (*R*) after its origin from the ascending aorta (*A*) follows the normal course in the atrioventricular groove; the extra coronary vessels, Sinuatrial nodal (*S*), third coronary (*T*) and anterior ventricular (*AV*) arteries arise directly from the aorta (A) and not as branches of right coronary artery (*R*).

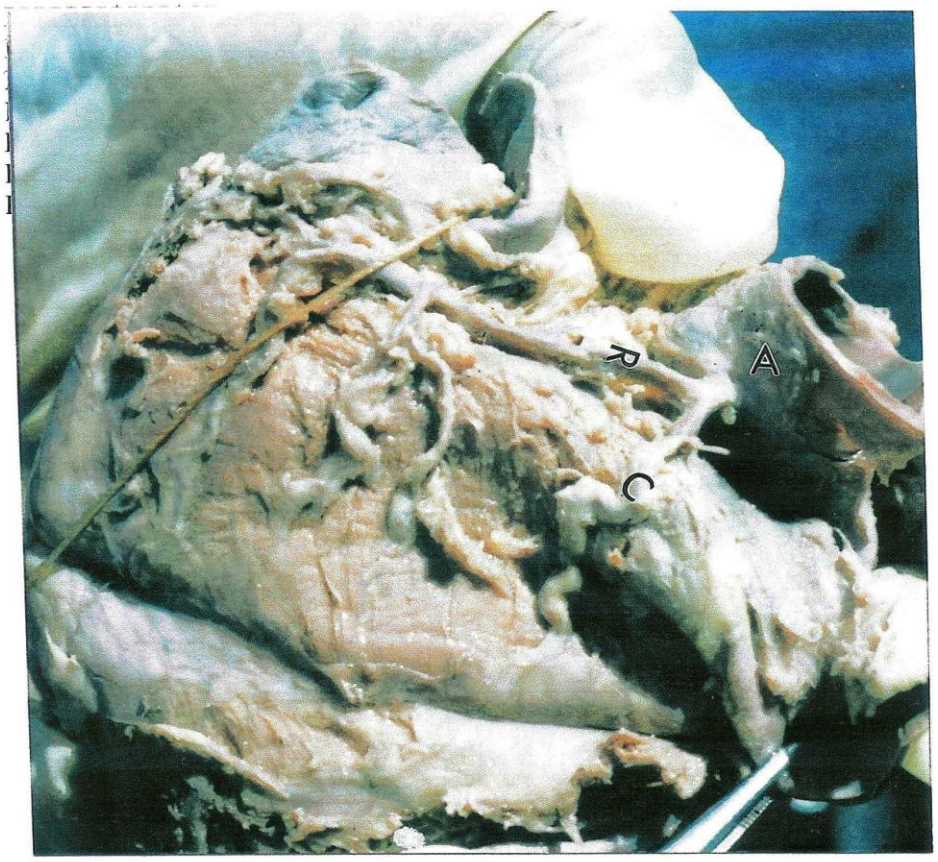


Figure 5: Photograph of the heart from a female subject specimen H10 showing a portion of ascending aorta (*A*) and right coronary artery (*R*) from a single ostium in the right aortic sinus. The right coronary artery (*R*) after emerging from the ascending aorta divides into two major branches. The right coronary artery (*R*) takes its normal course giving off branches and the other major branch, Conus artery (*C*) supplying the upper portion of right ventricle.



Figure 7: Photograph of the heart from a male subject specimen H36 showing a portion of ascending aorta (*A*) and the left coronary artery (*L*) arises from left aortic sinus of ascending aorta (*A*). After a short distance the left coronary artery branches off into three vessels (trifurcation) the left anterior interventricular (*Arrow*), circumflex (*Arrow head*) and Median (*M*) coronary arteries. Median artery is a branch in between the left anterior interventricular or descending (*Arrow*) and circumflex coronary arteries (*Arrow head*).

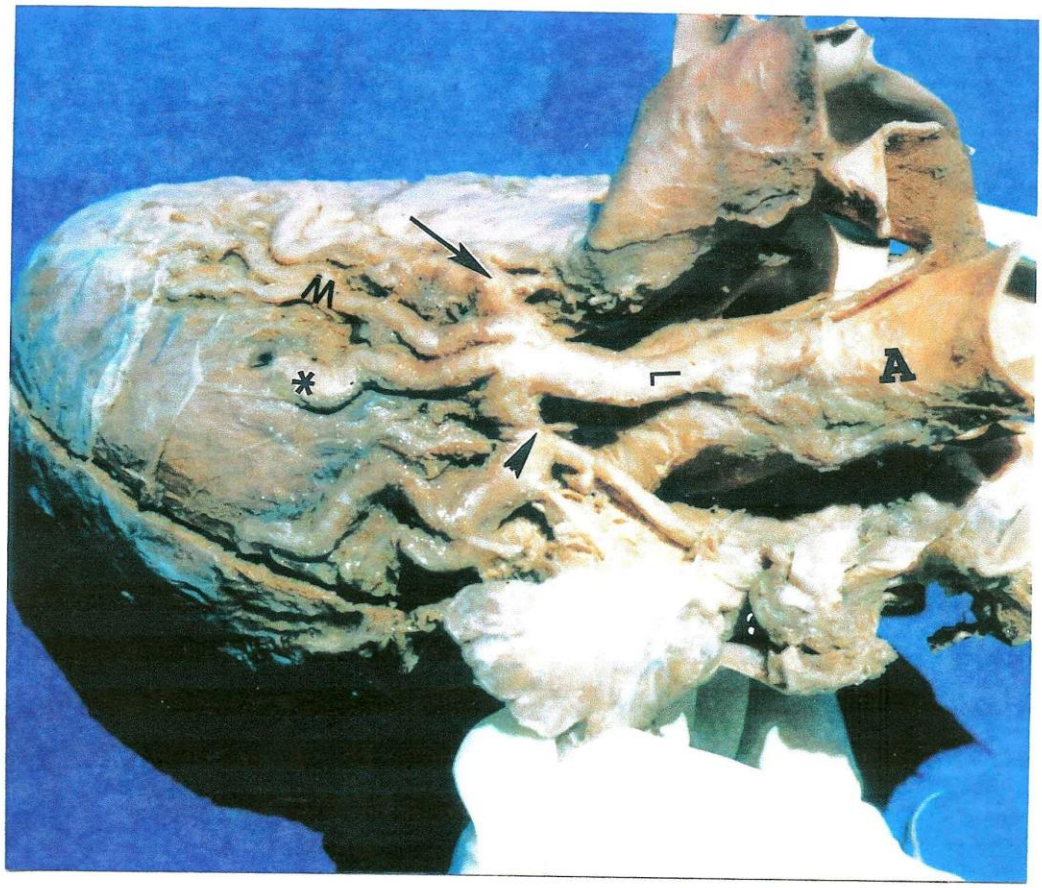


Figure 8: Photograph of the heart from a male subject specimen H56 showing a portion of ascending aorta (*A*) and the left coronary artery (*L*) arises from left aortic sinus of ascending aorta (*A*). After a short distance the left coronary artery (*L*) divided into four (quadrifurcation) branches; the left anterior interventricular or descending (*Arrow*), circumflex (*Arrow head*), Median (*M*) and the fourth branch (*Asterisk*). Median artery (*M*) and the fourth branch (*Asterisk*) arise between the left anterior interventricular or descending (*Arrow*) and circumflex (*Arrow head*) coronary arteries. The fourth branch (A*sterisk*) is unnamed so far.



Figure 9: Photograph of the heart from a female subject specimen H5 showing a portion of ascending aorta (*A*) and arising vessels. In this specimen, the left anterior interventricular or descending (*Arrow*) and circumflex (*Arrow head*) coronary arteries took origin directly from the ascending aorta (*A*). Note the absence of left coronary artery (*L*) main trunk. Diagonals (*D*) and septal (*Se*) branches from left anterior interventricular or descending artery are well illustrated.

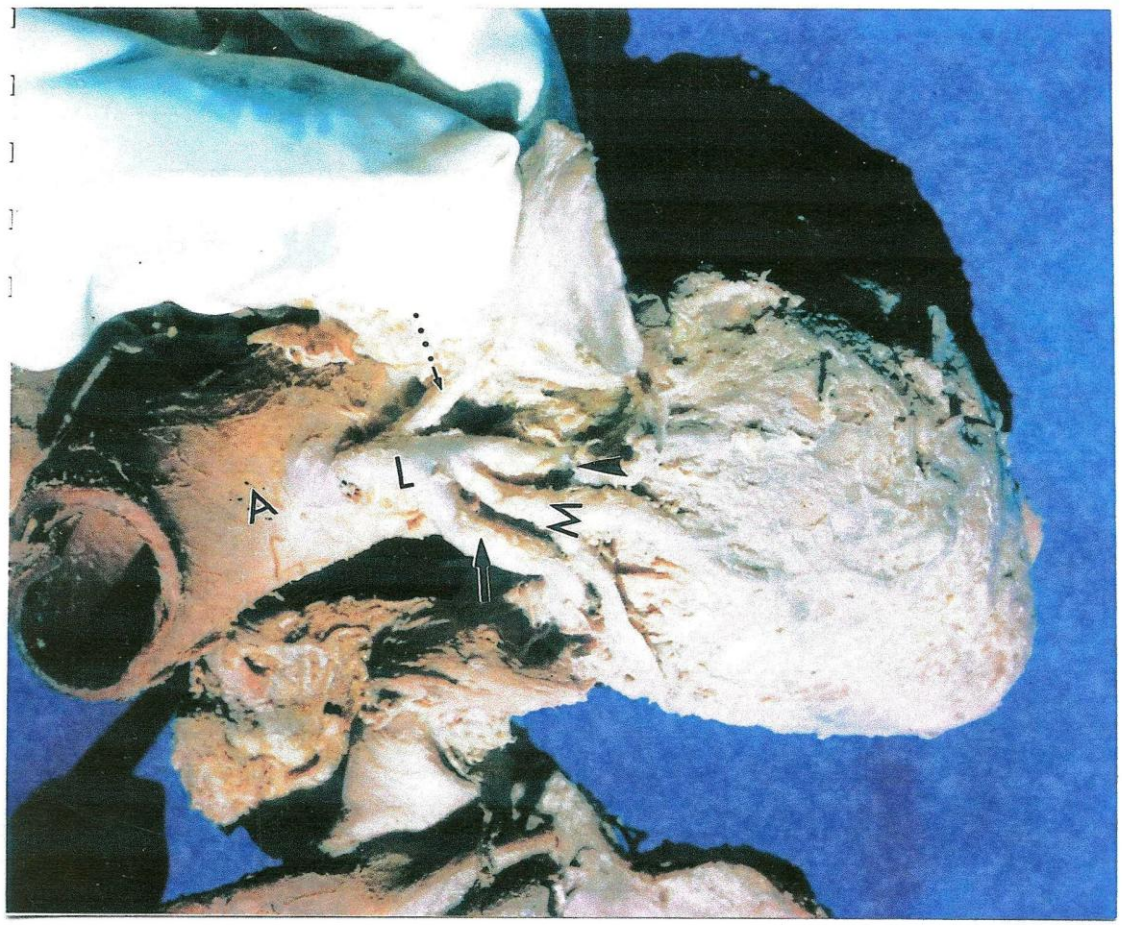


Figure 10: Photograph of the heart from a male subject specimen H80 showing a portion of ascending aorta (*A*), left coronary artery (*L*), left anterior interventricular or descending (*Arrow*), circumflex (*Arrow head)* and Median (*M*) arteries. The left coronary artery (*L*) gives off a branch, atrial branch (*dotted arrow)* to supply the left atrium.

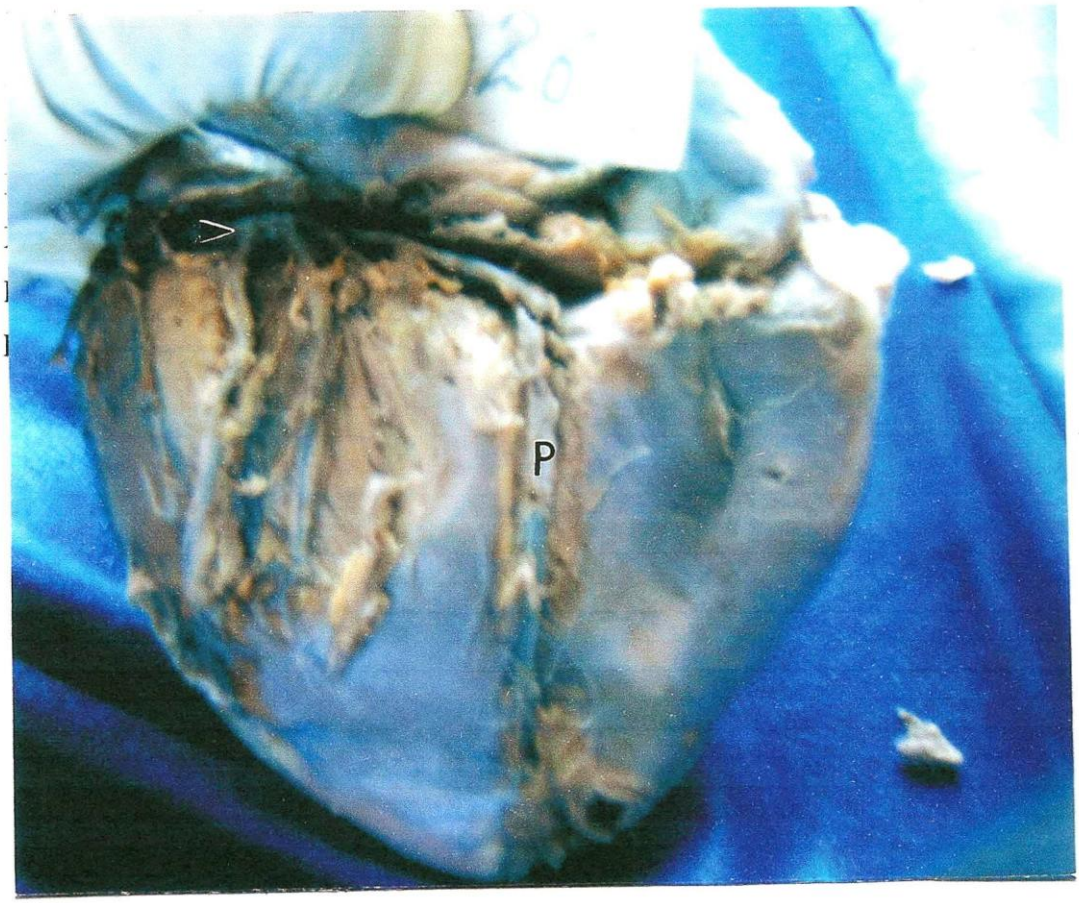


Figure 11: Photograph of the heart from a male subject specimen H26 illustrating the left circumflex artery (*Arrow head*) and posterior interventricular or descending artery (*P*). In this case, the posterior interventricular or descending artery (*P*) branches off from circumflex artery (*Arrow head*); this is known as left dominant circulation

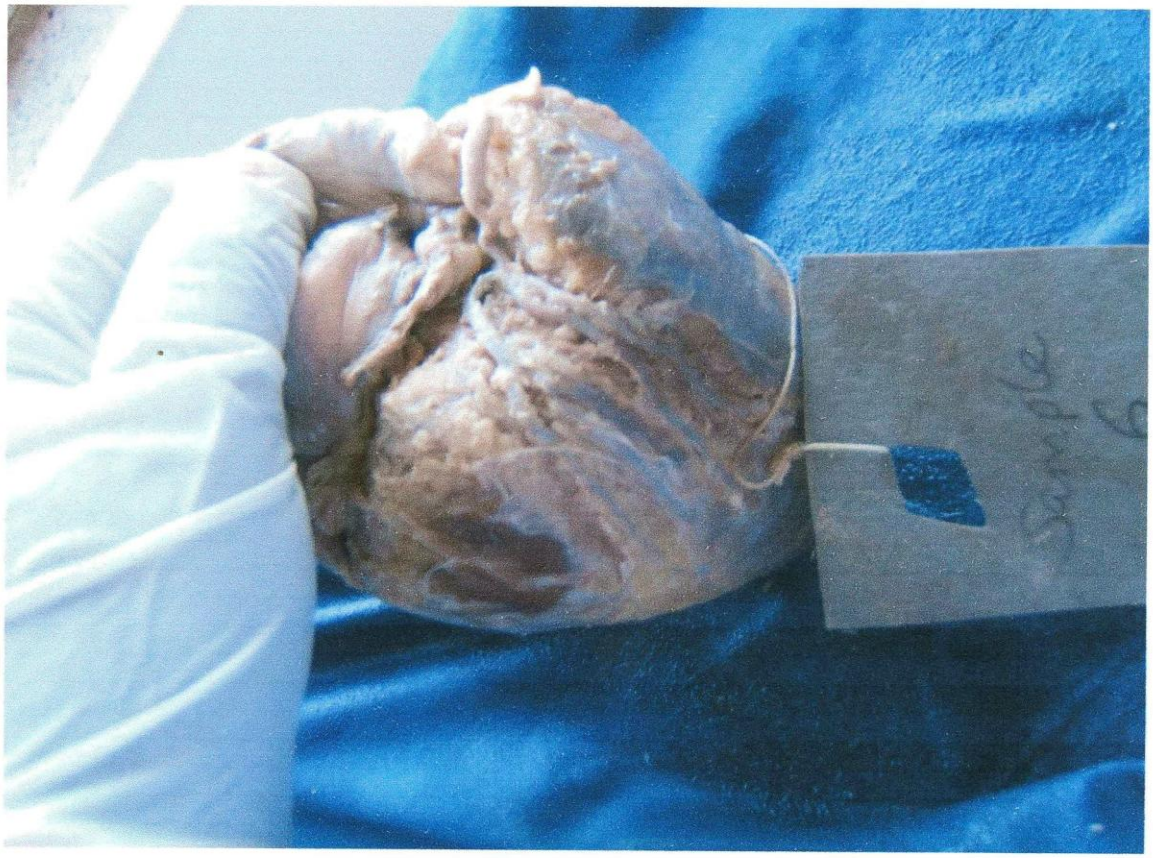


Figure 12: Photograph of the heart from a male subject specimen H6 illustrating the right coronary artery *(R)* and posterior interventricular or descending artery (*P*). In this case, the posterior interventricular or descending artery (*P*) branches off from the right coronary artery (*R*); this is known as right dominant circulation.

CHAPTER FOUR

4.0 DISCUSSION

The current work has documented the anatomy of the arterial supply to the heart from both the male and female subject and the age range was 20 to 80 years. Observations included the origin, branching pattern and anastomoses of coronary arteries. The main findings of the study include the presence of multiple coronary ostia, multiple heart vessels, and multiple branches. The anomalies involved both the right and left coronary arteries.

Coronary ostium (ostia) is an opening that gives origin to the arterial vessels that supply the heart located in the aortic sinuses. There are three aortic sinuses between aortic valves and wall of aorta, namely right (anterior), left and posterior aortic sinuses. Coronary arteries arise from the left and right aortic sinuses.[20,21] Past observations made in autopsy specimens and angiograms have showed that the number of ostia associated with the right and left coronary vessels varies from one to five and the overall frequency for the presence of more than one ostia varies between 50-23%.[24,28,33] In the present study the frequency of multiple ostia was found to be 18%; this is slightly lower than the reported frequency.[28] Muriago and coworkers in their study reported an extra coronary ostium in anterior aortic sinus in 74% of the cases and the third orifice in 22%. The significance of these findings is not known but it calls for more studies to determine the exact frequency of the right coronary ostia. A wider study involving the autopsy and radiological technique will be useful. Studies on the coronary ostia have not been done in Tanzania and there is also no evidence in other African settings. Despite this knowledge on the presence of single or multiple coronary ostia is important as it may have

clinical implications in coronary angiogram and open heart surgery. Accidental removal of the artery supplying the heart may occur if the surgeon does not know the possible existence of the extra coronary ostia giving rise to an arterial branch (Engel & Torres, 1975). These data are important for clinical and surgical practice; because it is well known that changes in coronary flow may be caused by modifications in the diameter, position, and anatomic relations of the coronary ostia.[9]

The right conal (conus) artery shows variations in terms of origin. Commonly it is known to be the first ventricular branch of the right coronary artery, supplying the infundibulum (conu) of the right ventricle, which is usually vascularized by the conal branches of both the right coronary artery and the left anterior descending coronary artery.[44] It most frequently arises from the proximal part of the right coronary artery.[42] Also it can arise from the right aortic sinus, in which case, it is considered the third coronary artery. The third coronary artery first described by Schlesinger et al. (1940) is a direct branch from the right aortic sinus without any observable common trunk with the right coronary artery. Occasionally the two arteries appear to have a common aortic ostium.[16] In the current study, an observation on the right coronary artery shows the presence of third coronary artery taking its origin from the right aortic sinus in 15% of the specimens (Fig 2). The overall frequency for the presence of the third coronary artery from other studies varies between 7.6-48%[14, 22, 26, 42] which is higher than our findings. This is an extremely rare coronary artery variation, with only a few cases being reported previously. Origin of the third coronary artery from separate ostia in the right coronary sinus has also been described by others. The largest series on coronary anomalies, which analyzed

127,000 odd angiograms, did not describe this anomaly.[46] In another study; only 1 case was found in a series of 7,400 patients. The first report in the literature was by Barthe et al[5] who defined this anomaly after injecting the contrast into the right coronary orifice, which disclosed selective opacification of two different right coronary arteries arising from a common ostium, coursing down the right atrioventricular groove.[5] The third coronary artery represents a significant way of collateral coronary circulation to apical and septal perfusion, as it frequently anastomoses with anterior interventricular branch.[26] There are no findings indicating that the presence of the third coronary artery could be detrimental or advantageous when compared to the right and left coronary arteries originating from the aortic sinuses. Based solely on the third coronary artery's morphological features, there is insufficient evidence to suggest that the presence of the third coronary artery is associated with a known clinical or disease state.[42]

In addition to giving rise to third coronary artery the right aortic sinus gave rise to multiple arteries that appeared to supply the heart. The arteries varied from three to four; and appeared to arise from different ostia within the right aortic sinus. Past records from autopsy indicate the presence of supernumerary coronary arteries in 4% of the cases.[26] These findings from previous studies agree with the current study results. Since there are few reports on the multiple coronary arteries, we suggest further studies involving large number of samples should be done to establish the exact frequency and their clinical and pathological relevancy before drawing the conclusion.

Sinuatrial node artery is the largest atrial artery supplying the node, left and right atrial free walls.[41] Detailed knowledge of blood supply to the sinus node is necessary today because of the wider practice of cardiac surgery, and also for a better understanding of the disturbances of its function caused by coronary disease. This artery typically arises from the right coronary artery but also may be a branch of left coronary artery.[10, 29] In the current study, the Sinuatrial node artery was found to take its origin from the right coronary artery in 93% of the samples and it did not take origin from the left coronary artery. Past studies have showed that it arises from both the right (60%) and the left (40%) coronary arteries.[43] Also other studies have showed that Sinuatrial nodal artery arises from right coronary artery (21.5%) and left circumflex artery (8%) of all the cases. A single study that observed male and female population indicated that Sinuatrial node artery took origin from the right coronary artery in 80% and 100% of the studied, males and females.[6] It appears that the origin of Sinuatrial node artery shows wide variation world wide with the lowest frequency reported among European and highest frequency in Tanzania and Brazil. This calls for a wider study to involve different geographical settings. Among anomalous vessels posterior interventricular (descending) and sinuatrial node arteries are one of them.

The posterior interventricular coronary artery has been reported world wide to take its origin from the right coronary artery, [8, 16, 19] and no differences have been observed with the current study. The difference is observed in the Sinuatrial node artery than the posterior interventricular artery. The significance of the variations of origin of Sinuatrial node artery are unknown and the excess frequency seen in few reported cases does note state the importance of this vessel. The distribution of sinuatrial nodal artery allows understanding the possible

ischemic etiology of Sinusal nodal syndrome and permits the surgeon, a safe approach to cardiac diseases.[7]

The left coronary artery begins at its ostium in the left aortic sinus and courses a short distance between the pulmonary trunk and the left auricle before dividing into the anterior interventricular and circumflex branches.[20] Sometimes the anterior descending and the circumflex arteries may originate from separate ostia in the left aortic sinus. A report from other researches indicates that the accessory coronary arterial orifices are found in the majority of the anterior aortic sinus.[28] The Left coronary artery in this study was found to originate from left aortic sinus as a main branch in 98%; branching into two vessels, (bifurcation) the anterior descending and left circumflex arteries in 58% of the specimens (Fig.6). These results agree with past studies which also observed the presence of two branches from left coronary artery with a frequency of 40-60%.[4, 8, 20] However a higher frequency (71-86%) has been reported.[21,27] In 34% of the specimens used for this study the left coronary artery presented with three branches (trifurcation), the anterior descending, circumflex and one additional vessel deriving from the main trunk (Fig 7). Trifurcation were discovered in 14% of the cases in the previous studies[21] which is lower. Results slightly above from ours have also been reported with a frequency of 30-65%.[4, 8, 16, 20,21,27,33] Also four branches (Fig.8) were observed in the current study in 7% which is slightly lower to the past 11% reported in other study.[20] (Table 5) The third branch arising in between the left anterior interventricular and Left circumflex is termed Median artery or ramus diagonalis, but the fourth branch so far has not been named with others. Further studies should be done that will include a large number of

samples and their findings be compared with others before drawing a conclusion and suggest the name for the fourth vessel.

Three to four large divisions of left coronary artery at this point are common, intervening branches of left coronary artery distributes diagonally over the free walls of the left ventricle and are usually proportionately spaced between the left descending and circumflex arteries towards the apex. Thus, left coronary artery trunk terminate by trifurcating or quadrifurcating rather than bifurcating. These branches including their anastomoses, presents important pattern of the collateral blood flow, which has special meaning under conditions of coronary insufficiency.[27]

Table 5: Table shows comparative studies of Divisions of Main Trunk of Left Coronary Artery (In percentage)

Branches	Baptista (1991)	Cavalcanti (1995)	Kalpana (2003)	Present study
One branch	-	-	1	-
Bifurcation	54.7	60	47	58.8
Trifurcation	38.7	38.18	40	32.4
Quadrifurcation	6.7	-	11	5.9
Pentafurcation	-	-	1	-

Left coronary artery main trunk may be absent, thus the anterior descending or interventricular and left circumflex arteries arise from independent ostia in the left aortic sinus.[16] In the current study we observed the absence of left coronary artery in 1% of the specimens used for this study. Previous studies has reported the same findings with the frequency of 1-2% of the cases the anterior and circumflex arteries arising directly from the left aortic sinus (Fig. 9)[4,8,14,20]

The left circumflex artery did not begin as a simple continuation of left main trunk coronary artery, but most often at an angle nearly perpendicular to it. Circumflex branch of left coronary artery circumnavigates the heart in the coronary or atrioventricular groove. This branch provides small branches to the left atrium and three to four large marginal branches to supply the left ventricle.[3,10,37] Observations of the current study showed left circumflex artery giving off a branch to supply the left atrium and this was shown in 99% of the samples. Other studies have also reported similar findings on the branches of circumflex artery. [18,35] In 1% of the specimens a different result was observed regarding the origin of vessel that supply the left atrium, the findings from the present study shows left main trunk coronary artery giving off an atrial branch slightly above, before it branches to left anterior descending coronary artery and left circumflex (Fig. 10). The circumflex artery continues in the coronary sulcus to the diaphragmatic surface of the heart where it commonly anastomoses with branches of the right coronary artery.[16] Also it was observed to give rise to posterior interventricular artery in 7% of the specimens used for this study. Results higher than the current observations have been reported with others with the frequency of 11-14%.[8,21,31]

The anterior descending artery began as a direct continuation of left main trunk coronary artery gently curves around the base of pulmonary artery to enter the anterior interventricular groove to reach the apex of the heart. It reaches the apex almost always terminating there in one-third of the samples,[18] but often turning around the apex to reach the posterior interventricular groove where it traverses a third half its length to meet the twigs of the corresponding right coronary branch. During its course often giving off septal branches and diagonal or lateral branches to the left ventricle (Fig 6)

Anastomoses do occur between the branches of the right and left coronary arteries. These anastomoses are formed by small vessels that are not large enough to provide adequate collateral circulation in the event of sudden occlusion.[10] In the current study, anastomoses involved the posterior interventricular and left anterior interventricular arteries in the posterior interventricular groove and also branches from left circumflex artery in all the specimens. Past studies reported anastomoses between the circumflex and right coronary arteries in 10% of the hearts.[8] These branches including their anastomoses, present important pattern of the collateral blood flow, which has special meaning under conditions of coronary insufficiency.[20]

The inverse relationship between the right coronary and left circumflex branch in most cases is simply expressed as right or left dominance, depending on which artery gives rise to the posterior interventricular artery.[19]

The origin of posterior interventricular artery from right coronary artery is the commonest anatomy in man, and is sometimes referred to as right dominance (Fig.11). Right dominance is the phenomenon referred when the right coronary artery gives origin to posterior

interventricular artery; when arises from left coronary artery is known as left dominance. Right dominance was observed in 93% of the specimens in the current study. These results are similar to those obtained form previous studies where the right dominance was reported to be 88%.[4,8,20] Also reported was the higher prevalence of right dominance (100%) of the studied sample.[28]

Left dominance was observed in 7% of specimens in our study. Past studies have reported left dominance in 12-15% of the cases (Fig. 10).[4,8,10,20]

CHAPTER FIVE

5.1 CONCLUSSIONS

Observations from the current study shows that left main coronary artery and right main coronary artery take origin from left and right aortic sinuses respectively. A single left main coronary artery from left aortic sinus and a single right coronary artery from right aortic is the commonest among Tanzanian specimens.

Left main coronary artery branching into two and three branches (Left anterior interventricular, left circumflex and Median arteries); and that of right coronary artery giving branches to sinoatrial node artery, conus, anterior ventricular, anterior interventricular and posterior interventricular arteries were the common branching pattern observed in the current study.

Right dominant circulation was observed to dominate among the Tanzanians which differ from those demonstrated in other populations.

The coronary arteries and their main branches present a great quantity of variations with regard to origin, distribution and anastomoses. This knowledge is important for the interpretation of coronary angiography and surgical myocardial revasculazation. In cardiology and coronary surgery, anomalies of the coronary arteries may carry a great potential risk for myocardial ischemia resulting in arrhythmia, angina pectoris, infarction and sudden death.

5.2 RECOMMENDATIONS

The third terminal branch of the LM coronary artery has been marked as median artery. Therefore I recommend that more attention need to be given to the branching pattern of left main coronary artery focusing on additional branches and the fourth terminal branch should be given a name. Also further studies should be done to resolve the problem of normal origin and branching pattern of coronary arteries. Further studies should be done on relationship of these variations with myocardial ischemia and coronary diseases.

Also I recommend interactions with other departments particularly in hospitals so that further studies can be done in patients with heart diseases and the results be compared to find the associations that exist among Tanzanian populations.

5.3 LIMITATIONS

The major limitation in this study is the small number of specimens being studied, but human material is becoming increasingly difficult to obtain for study. In developed countries such data are corrected during routine autopsy.

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