

**VARIATIONS IN THE ANATOMICAL ORIGIN AND DISTRIBUTION OF
CORONARY ARTERY AMONG BLACK AFRICAN POPULATION:
A CADAVERIC STUDY IN WESTERN KENYA.**

BY

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FOR THE DEGREE OF MASTER OF SCIENCE IN HUMAN ANATOMY**

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DECLARATION

This research thesis is my original work and has not been presented for award of degree in any university.

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God bless you all.

DEDICATION

I dedicate this research thesis to my dear husband Bornface Juma, for his unwavering support all through, our children Kibali, Pendo, Ushindi, Baraka, Meshack and Amani Ibada thank you for enduring the long absence during my studies. To my Mum and Dad thank you for your prayer. To Mr and Mrs. Alinyo Omuga, thank you for holding my hand during the most difficult time of my studies.

ABSTRACT

The coronary artery and its branches is the main blood vessel that supplies the myocardium. The principal branches of ascending aorta are the right and left coronary artery. Variations of the coronary arteries are vessels that do not conform to the normal anatomy of coronary arterial branching tree. These variations can be compensatory, collateral, alternate or a duplication of another vessel and can have both positive or negative attributes. Cardiac dominance is depicted with the artery that gives rise to the posterior descending artery which is key in the perfusion of the intraventricular septum. Social demographic factors may influence diseases like diabetes and hypertension due to these variations. Variations in coronary arteries are thought to be among the leading cause of sudden death thus giving cardiologists and heart surgeons challenges during the management of heart conditions. This study sought to determine these variations among the black African population in Western Kenya by assessing the variations in origin and distribution of the principal coronary arteries, investigating the dominance of the heart and associating the variations to demographic characteristics of the study population. Crosssectional study design was adopted. The study sites were Maseno University, Uzima University and Masinde Muliro University anatomy laboratories. The sample size of 89 cadavers was estimated using Crochan's formula leading to 72 samples in total. Data sheets were designed to capture the variables while descriptive statistics was used to determine the mean, mode, median and standard deviation of the variations. Chi square test was used to test the association between the right, left and co dominance while Pearson's correlation test was used to analyze the relationship between the variables with a $P \leq 0.05$ considered as significant. All ethical considerations were observed. Luo were the leading ethnic group in the study ethnicity at 54.2% while being the Kuria and Kalenjin were the lowest and at 2.8%. Dual aortic origin had the most common occurrence at 55.6%. Both coronary arteries showed bifurcation with a mean length of 12.22cm on the right artery and 9.32mm on the left. Termination of the left coronary artery was at the crux while on the right coronary artery was between the crux and the obtuse margin of the heart. There was right dominance of the heart with statistical significance between gender and right heart dominance at $P \leq 0.0260$. There was no statistical significance between gender and ethnicity to the variations There were variations in the origin of the coronary artery with right dominance being more expressed. Population specific variation like race and geographical location to be considered for further study.

Key words: *Cadaver, Coronary artery, Dominance and Variation,*

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ABBREVIATIONS AND ACRONYMS

AVNA:	Atrioventricular node artery
CA:	Coronary artery
CAD:	Coronary artery disease
CHD:	Coronary heart disease
CM:	Centimetres
ERC:	Ethical Review Committee
GOK:	Government of Kenya
ISD:	Ischemic heart disease
LCA:	Left coronary artery
MOH:	Ministry of Health
NACOSTI:	National Commission for Science, Technology and Innovation
PA:	Pulmonary artery
PDA:	Posterior descending artery also PIA (Posterior intraventricular artery)
PIS:	Posterior intraventricular septum
PIVA:	Posterior intraventricular artery
PV:	Pulmonary vein
RCA:	Right coronary artery
MA:	Marginal artery
SANA:	Sino-atrial node artery.
SVC:	Superior venacava
WHO:	World health organization.
LCA:	Left coronary artery.
LADA:	Left anterior descending artery
CMx:	Circumflex artery
MA:	Marginal artery

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CHAPTER ONE

INTRODUCTION

1.1 Background information

The coronary artery (CA) which is the first blood vessel with its origin being the ascending aorta. It is the key vessel that supplies the heart with oxygen and nutrients (Figure 1). The principal branches of coronary artery are the right (RCA) and the left coronary artery (LCA) (Rehman *et al.*, 2011). However, Olabu *et al.*, (2007) notes the presence of a third CA among other variations in approximately 10-15% of the population as a continuous branch of the right aortic sinus (RAS) which is significant in the perfusion of the posterior part of the heart and the right ventricle (RV). The purpose for the occurrence of the variations in the coronary blood vessels is thought to be either compensatory, collateral, alternate or a duplication of another vessel and can be attributed either positively or negatively depending on their location, distribution and function (Table 1). According to Gouda *et al.*, (2009), the existence of the third CA is vital in the formation of a bridge between the RCA and LCA circulation (Vieussen's arterial ring) which gives an alternate pathway during coronary insufficiency. Even so, its role in the coronary circulation as a variant still remains dim due to the changes in coronary arterial pressure it causes. Its safety is not also guaranteed due to functional and structural alteration in arterial hypertension secondary to interference with coronary blood flow leading to systemic hypertension (Strauer *et al.*, 1998). CA variations are the commonest cause of unpredicted fatalities worldwide especially in the young professional athletes. The sudden death committee a branch of the American heart association highlights that approximately 19% of fatal heart conditions are caused by coronary artery variations (Gač *et al.*, 2022). In Africa there is little literature on variations in the anatomy of

coronary artery although its effects can be highly felt by the increase in cardiovascular mortality and morbidity. As a result, coronary artery disease/ischemic heart diseases and atherosclerosis has led to increased hospitalization and revascularization procedures (Khan *et al.*, 2020).

Asiki *et al.*, (2018) in the Kenya national guidelines for cardiovascular diseases notes that 25% of Kenyan population admission and 13% of deaths are due to cardiovascular diseases with coronary artery diseases leading as a cause. Olabu *et al.*, (2007) noted that studies on third coronary artery in a Kenyan population is among the few studies done on variations in coronary artery in Kenya highlighting the significance of this variant both in perfusion of the myocardium and in cardiac surgery. The Western part of Kenya initially had a low prevalence of ischemic heart diseases because of the few risk factors associated with it like hypertension and diabetes, however recently studies point to an upsurge MI due to the aggravated risk factors which could have been by caused by variations (Chege, 2016).

Papagiannis *et al.*,(2018) explains the relevance of the origin, branching pattern, length and termination of the blood vessel in relation to overall distribution of blood to the heart muscles and other heart important structures. He notes the formation of an obtuse marginal artery which contrary to the normal course and termination ends up supplying different part of the myocardium. The literature above asserts that it is obvious that there are variations in coronary blood vessels, however the significance is yet to be appreciated.

Notably the anatomy and distribution of the blood vessels is key in the maintainance of coronary arterial circulation (CAC) to the myocardium, ventricle and atria which otherwise can lead to serious fatal conditions like ischemic heart diseases (IHD), atherosclerosis, myocardial infarction (MI), atrial fibrillation (AF) and tachyarrhythmias if not maintained (Boppana *et al.*,2011). These

variations alter the blood supply to the myocardium predisposing it mostly to ischemic heart diseases /coronary artery disease (CAD).

The sub Saharan Africa including Kenya is currently facing an increase in heart conditions. Diseases like diabetes and hypertension were more in the western countries but slowly they are increasing in the third world countries due to adoption of sedentary lifestyle like smoking, obesity and dyslipidemia (Saidi *et al.*, 2002). Atherosclerosis is one example of IHD caused by the accumulation of cholesterol in the lumen of the coronary arteries. Its effects are reduced blood flow to the heart muscles and rupture of the plaque clots which causes blockage of coronary vessels leading to acute coronary syndrome, insufficient oxygen then dysfunction or death of the cardiomyocytes (Błyszczuk & Szekanecz, 2020).

Ogeng'o (2014) in his study notes the role of geographical and ethnic variation in relation to intima media thickness as an important factor for predicting atherosclerotic cardiovascular conditions. While also agreeing with him, Ferdinand (2006) notes the racial factor as a key phenomenon in variation of coronary artery and indicates that it can be attributed to the increased levels of inflammatory marker, high sensitivity and elevated C reactive proteins.

Coronary arterial dominance (CAD) is another key factor in the blood supply to myocardium. It is associated with the blood vessel which generates the PDA. This artery is key in the perfusion of the muscles of the heart and other important structures like the sinoatrial node (SAN), atrioventricular node (AVN) and the muscles of the lower third of the interventricular septum (IVS). This artery has its origin from either the right therefore right dominance (RD), from the left leading to left dominance (LD) or from both RCA and LCA hence codominance (CD) (Kaimkhani *et al.*, 2005). Meaning it can also be affected if there is occlusion of either or both of the main arteries

Dominance determines the amount of blood that will reach the myocardium at any particular time. The myocardium perfused by the RCA is frequently prone to ischaemia leading to death due to its blood supply which basically is less than half of the coronary blood flow. Contrary to this, it has more branches which supply blood to key structures of the heart like the SAN, AVN and the intra-ventricular septum (IVS) (Rehman *et al.*, 2011; Diwan *et al.*, 2017). This could be dangerous since the slightest alteration to the right coronary circulation can render most of these structures functionless.

1.2 Problem statement.

Variation in the origin and distribution of the coronary arteries is the second most common cause of sudden death in the world are (Angelini *et al.*, 2002). In Africa, variations in the coronary arteries are among the leading causes of abrupt morbidity and mortality in the population due to the changes they cause in the coronary blood vessels. They cause changes and anomalies in the normal anatomy of the blood vessels supplying the muscles of the heart (Angelini *et al.*, 2002; Gać *et al.*, 2022). Asiki *et al.*, (2018) in the Kenya national guidelines for cardiovascular diseases notes that 25% of Kenyan population admission and 13% of deaths are due to cardiovascular diseases with coronary artery diseases leading as a cause. As a result, they cause differences in coronary blood flow which affects the perfusion of the myocardium, the atria, ventricles, sino-atrial node (SAN). The difference in perfusion can have a positively or negatively effect to myocardium which can cause or further complicate the management of heart diseases. The different branches of coronary artery supply different parts of the myocardium and maintain different mechanism of retaining their blood flow even in emergency, however variations have changed the pattern of myocardial perfusion predisposing the myocardium to ischaemia and even sudden death (Gać *et al.*, 2022).

During heart procedures like cardiac catheterization, coronary bypass procedures, cardiologists and cardiothoracic surgeons may experience difficulties dealing with these variations which could lead to fatal mistakes. This has further been complicated by the current upsurge of lifestyle diseases like hypertension and diabetes which are more likely to interfere with coronary circulation leading to atherosclerosis, myocardial infarction, then ischemia of the cardiomyocytes has made the effects of these variations worse.

Notably, there is scarce documenting concerning these variations among black African population necessitating this study on variations in relation to CA. The study present study seeks to understand these variations in relation to blood supply to the heart.

1.3 Justification

The current increase in sudden death due to the abnormal patterns of coronary arterial circulation to the myocardium is of great concern because of the increased mortality and morbidity associated to the heart diseases (Gać *et al.* 2022). There is need for information to all health service providers on these variants which will further help in understanding the clinical presentation, investigation and management of heart related diseases. Knowledge on variations is also vital to cardiologist and heart surgeon when prescribing drugs or during surgeries like coronary bypass or cardiac catheterization hence they will also benefit from this study. Information on which blood vessel/variants they are dealing with during surgeries will help avoid targeting the wrong vessel. Moreover, it is important for the population to know the risk they are exposed to as result of this variations and how they can go about to avoid the mortality and morbidity associated with them

1.4 Significance of the study

There is need for health care providers and workers to be continuously informed on these variations due to the delicate nature of the heart. This will significantly improve the understanding of clinical presentation and management of coronary artery diseases. It will also help in advocacy, policy formulation of heart related conditions which in turn reduces morbidity and mortality related to heart conditions. It will also form a basis for creating awareness among the population on these variations and their effect.

1.5 Objectives of the study

1.5.1 Broad objectives

To determine variations in the anatomical origin and distribution of coronary artery among black African population in western Kenya.

1.5.2 Specific Objectives

- a) To assess the variations in the origin and distribution of CA among the black population in Western Kenya.
- b) To describe coronary artery dominance among the black African population in Western Kenya.
- c) To associate the variations in origin, distribution and termination of coronary artery distribution to demographics characteristics of study population.

1.6 Research Questions

- a) What are the variation in the origin and distribution of coronary artery among the black population in Western Kenya.?
- b) What is the coronary artery dominance among the Western population in Kenya?
- c) What is the relationship between variations in coronary artery distribution and social demographics characteristics in Western Kenya population?

1.7 Assumptions

There is a relationship between coronary artery variations and changes in the distribution of blood supply to the myocardium which can affect the functioning of the heart.

1.8 Possible Limitations and delimitations

- a) Few cadavers – The 3 universities were chosen to enhance the number of cadavers.
- b) Difficulty in acquisition of cadavers – The 3 Universities were chosen to ensure that the subjects will be enough for the study.
- c) Difficulty in getting gate keepers letters – Seeking approval letters from universities administration will help in the above case.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin of main CA and its branches

The CA is an enlarged vasa vasorum found in the epicardium. It originates from the bulbus of the arch of the aorta with a dual flow from the right and left ostia to ensure adequate perfusion of all the cardiac regions (Alam, 2017) The RCA and LCA are the only branches that originate from the valvula's sinus of the ascending aorta and the principal branches of CA (Figure:1). As they course towards the cardiac apex, they form branches which supply the myocardium with nutrient and oxygen to enable it pump blood into the systemic circulation (Alam, 2017; Fazliogullari *et al.*, 2010).

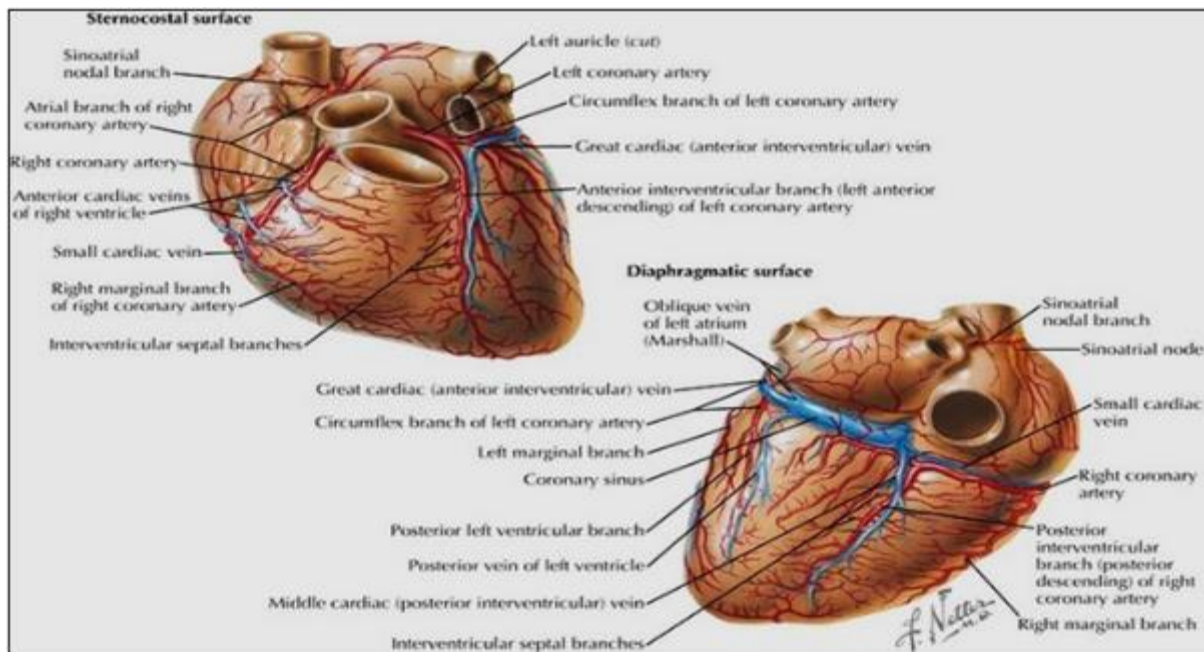


Figure 1: RCA and LCA and their branches (Adapted from Netters, 2014)

Variations may occur to the RCA and LCA leading to additional or few arteries which may have their origin from the arch of the aorta or may originate from other branches (Lujinović *et al.*, 2008).

Gac *et al.*, (2022) categorizes these variations into 3: variations of origin and course, variations of anatomy and those of terminations (Table 1). The effect of these variations vary from altered blood supply to the myocardium to changes in the circulatory pressures and even constriction of the blood vessels during strenuous activities leading to death of cardiomyocytes and myocardium. These variations range from absence of a principal artery, an abnormal origin on the aortic ostium or at an improper sinus opening. Notably the LCA has the LAD artery as its branch which often has variations in its course which can be retro aortic, interarterial, prepulmonic or septal in nature. According to data reviewed, the RCA has the PDA as its main branch while the LCA has the LADA and the CMx as its main branches (Aricatt *et al.*, 2022; Trivellato *et al.*, 1980). However, Trivellato *et al.*, (1980) notes the extreme variability even in the coronary artery anatomy of normal subjects and as a result of this, he proposes characterization of a normal definition to ensure statistical evaluation in all the anatomic variations which will help come up with a minimum common denominator which includes:

2.1.1 Variations in the anatomy of origin, branching, length and termination of coronary artery

Variations are brought about by changes in the typical coronary artery which could be in the number or structure of the main coronary artery (Figure: 2). Saidi *et al.*, (2002) in his study notes that although there is very little literature on variations of coronary artery in Africa, he highlights the impact felt by the health care systems due to increase in cardiovascular conditions caused by these variations like MI and atherosclerosis. The gradual increase of diseases that were thought to belong to western countries into the African continent like hypertension and diabetes has led to increased hospitalization and revascularization procedure

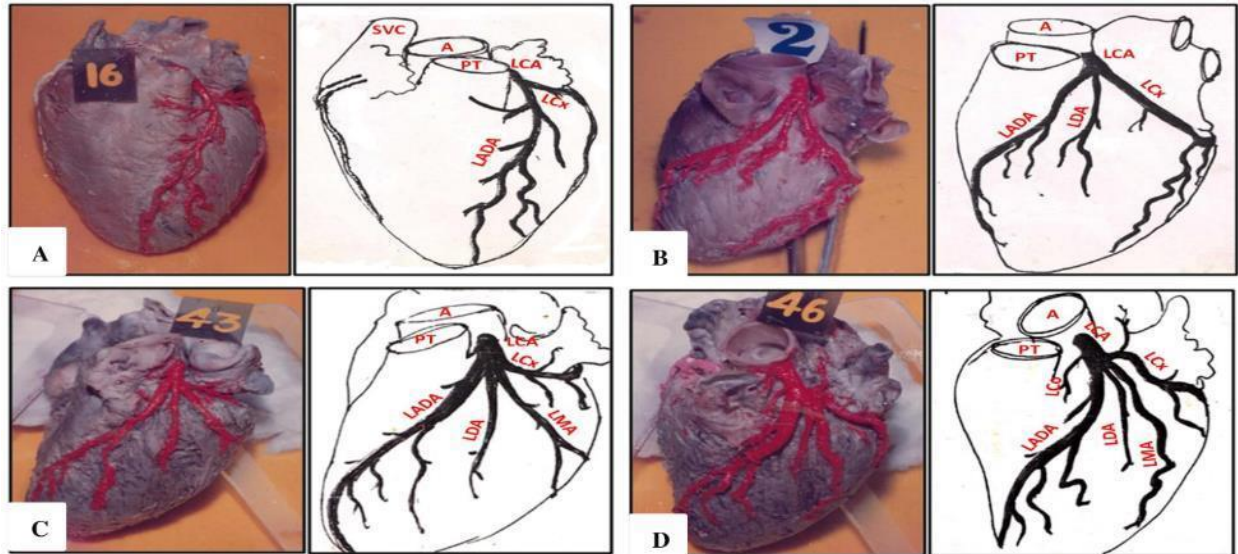


Figure 2: Variations in the left coronary arteries (Adapted from Lakshmiprabha *et al.*, 2018).

2.1.2 Least standards/ requirements for identifying normal coronary arteries:

- a) Have their origin from the right and left coronary cusps of the aorta.
- b) After the formation of branches, the RCA follows the right atrioventricular groove.
- c) The LCA which varies in length and just after its formation lies behind the pulmonary artery where it bifurcates into left anterior intraventricular artery (LAIA) also known as LADA and the circumflex artery CMx. The LADA follows the intraventricular groove which forms the septal perforator and their branches while the CMx follows the left atrioventricular groove.
- d) The PDA formed from the right or left coronary artery after which it descends to the posterior intraventricular groove (PIG). It then forms the septal perforators.
- e) The RCA and LCA course epicardially.
- f) Termination of the main CA occurs at the myocardial region (Trivellato *et al.*, 1980)

Other variations that may occur are, dominance of the heart with either a very small PDA or one that branches early leaving the RCA, CMx or the obtuse marginal artery to supply the inferior wall, Abnormality in blood vessel origin and flow, Perfusion of the inferior wall, SAN and the AVN,

Presence of separate conus branches and ramus inter-median branch or a very long LADA artery coursing beyond apex of heart reaching the inferior intraventricular groove (Kastellanos *et al.*, 2018)

2.1.3 Typical versus atypical coronary artery anatomy

Table 1: *Normal versus abnormal coronary artery anatomy adapted from (Trivellato et al., 1980)*

Typical	Atypical
1. Both the RCA and LCA originate from the aorta	Single CA. Anoumalous origin of RCA or LCA from PA
2. RCA in right atrioventricular groove	Part of the RCA originating from left ostium
3. Opening of the LCA located in the left atrioventricular groove and or anterior intraventricular groove	Anoumalous formation of LADA or Cx CA from RCA
4. PDA from RCA or Cx CA	PDA from LADA
5. Major vessel course epicardially.	Formation of Muscular bridges
6. Termination of the arteries in the myocardial capillary bed with enhanced blood supply to the myocardium	There is a communication between the coronary fistula and the RA, RV, PA, PV, LA, LV.

According to Kastellanos *et al.*, (2018), there is a difference between a typical and atypical coronary artery (Table: 1). Coronary artery anatomy can be termed to be normal when the origin of the CA occurs at the aortic wall most commonly at an angle of approximately 40-95 degrees. It should then follow a super-epicardial course enabling it to bifurcate maximally for better provision of blood to the myocardium, terminating at the capillary bed distally. It should have 2-4 coronary ostia on the upper- anterior part of right and left sinus of valsava. Occasionally the origin of the LADA and the LCMx could be different from left aortic sinus while the RCA and the conus artery which is one of its branches could also be having a different origin rather than the right sinus.

Further-more the proximal stem should divide into the left coronary circulatory system leading to the formation of the left anterior descending artery (LADA) artery and the left circumflex artery (CMx) artery as the main branches.

2.1.5 Left coronary artery

It is one of the principal branches of the main CA, approximately 2cm-4cm, formed after the bifurcation of the main stem at the left sinus of valsava (Kastellanos *et al.*, 2018) (Figure 3). It is the largest of the two principle branches of the coronary artery supplying a bigger portion of the heart muscles and the interventricular septum and most of the left part of the myocardium (Alam, 2017; Fazliogullari *et al.*, 2010). Its main division include the LADA branch, the LCx branch. Just after its origin and lies between the pulmonary trunk which sends deoxygenated blood to the lungs from the right ventricle and the right auricle. From there, this artery follows the left atrioventricular groove adjacent to the anterior interventricular septum to supply most of the left part of the myocardium. It is thus the key vessel in the blood supply to the muscles of the heart (Lakshmi Prabha *et al.*, 2018; Kastellanos *et al.*, 2018) (Figure 3).

It has significant variation in its origin, level of ostium, diameter, length, number of branches, the parts of the myocardium it perfuses and termination than the RCA (Figure 2). The length of the CA is important factor for the perfusion of the myocardium, surgery like cardiac catheterization and coronary angiography. However, there are variations in the normal length of the LCA with Hosapatna (2013) suggesting the normal length being between 5-15mm while Kulkarni (2013) notes that the average length of the LCA is approximately 7mm.

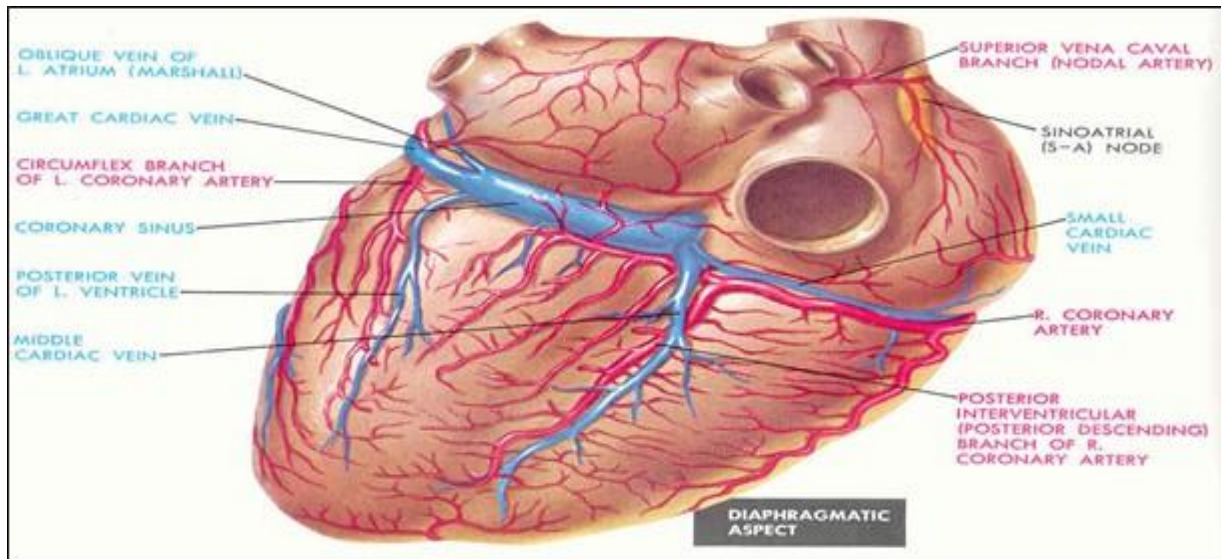


Figure 3: Posterior aspect of the heart with branches of LCA (Adapted from Netters, 2014)

The other branches of the LCA which are less common are the median/intermedian branch which can originate from the trifurcation or quadrifurcation of the left CMx branch which originates from the proximal region of the anterior interventricular branch of circumflex artery (Fazliogullari *et al.*, 2010; Lakshmiprabha *et al.*, 2018). The LAD is approximately 10-13cms and after its origin it courses towards the apex of the heart across the atrioventricular sulcus giving rise to diagonal and septal branches. This artery also supplies the ventral wall, apex and a major part of intraventricular septum while the left CMx moves towards the left atrioventricular groove with its size and extent varying depending on the dominance of the heart. It leads to the formation of 3 marginal branches which perfuse the free wall of the left ventricle (Kastellanos *et al.*, 2018).

Fazliogullari *et al.*, (2010) highlights the differences in the LCA which is wider than the RCA thus perfuses a wider portion of the muscles of the heart, intra-ventricular septum and also a bigger portion of the left heart. In his study he notes that the left coronary artery receives over half of the coronary circulation and even when the heart has right dominance, the LCA still perfuses a considerable portion of the RV, thus in case of ischemia of the LCA a bigger part of the muscles

of the heart is likely to be affected. It is however not clear if in such a case, an alternate pathway of blood circulation to the myocardium could save the heart from ischaemia and death.

The patency of this vessel is key in the perfusion of the heart muscles and any occlusion, injury or damage to the LCA reduces or stops blood supply to the myocardium via its branches which may cause ischaemia depending on the degree and the availability of a patent collateral circulation (Diwan *et al.*, 2017).

In cases of absence of the LCA, the LADA also known as the anterior intraventricular artery, CMx artery and the Ramus median artery usually originate from the left aortic ostium. During cardiac catheterization, this anomaly can be missed out and can be thought to be either total obstruction, atresia or congenital anomaly of the LCA. This may lead to technical problems during catheterization, misdiagnosis and complications during diagnostic intervention in surgical procedures of the heart (Ajayi *et al.*, 2015).

In his further studies, Ajayi *et al.*, (2015) highlights the danger of premature formation of branches by the LCA as a cause of preoperative occlusion of the LCA which can be enhanced by a balloon tipped perfusion cannula which may cause MI. He notes that such a surgery needs a very keen surgeon who can separately cannulate the LAD artery and the Cx artery otherwise it can cause fatality

2.1.6 The right coronary artery (RCA).

Usually approximately 12-14 cms. Originates from the right ostia of the aortic sinus in between the pulmonary artery and the right auricle and moves towards the coronary sulcus then curves towards the atrioventricular groove which occurs between the right atrium and the right ventricle. It then moves towards the inferior part of the septum supplying the RA, RV and the, posterior a third of intraventricular septum, part of left atrium, the diaphragmatic surface of the LV, AV node,

bundle of His including part of left bundle branch (Trivellato *et al.*, 1980; Lakshmi Prabha *et al.*, 2020) (Figure 1).

As it moves it bifurcates to more branches with the PDA being its main branch (Figure: 4). Other branches are the conus branch, SANA, right ventricular branch, atrioventricular nodal branch, posterior intra-ventricular artery, left retro-ventricular artery, marginal artery, anterior intra-ventricular artery and the posterolateral branch (Ballesteros *et al.*, 2011).

The different branches have different anatomical and clinical significance in relation to the regions they supply like the sino-atrial node artery supplying the sino-atrial node, right MA, the right posterior diagonal artery, and the AVNA (Ballesteros *et al.*, 2011; Kastellanos *et al.*, 2018)

(Figure 5).

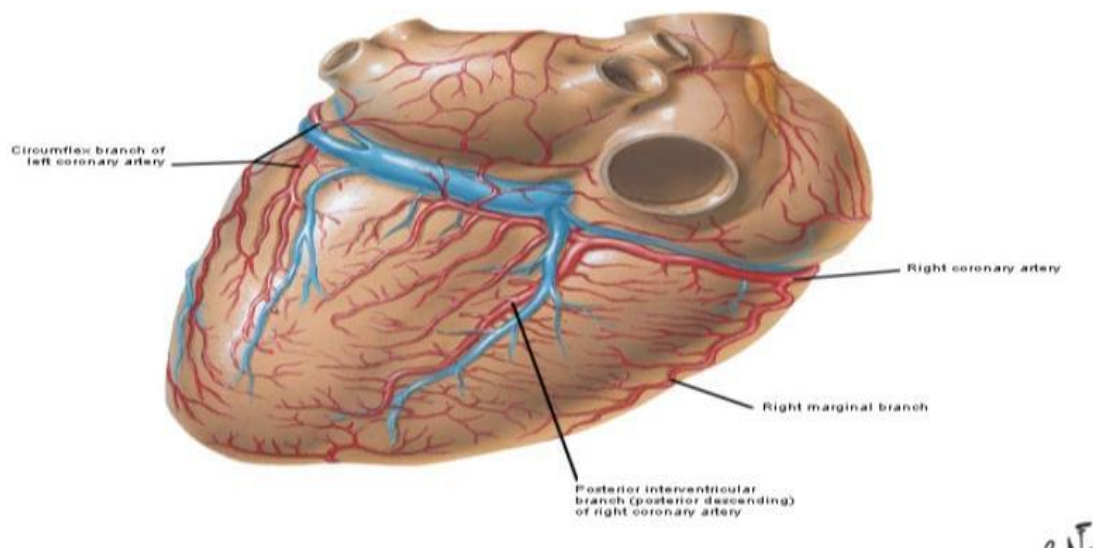


Figure 4: Posterior view of the heart: bifurcation of the RCA into PIVA and Right marginal artery (Netters, 2014)

Contrary to the above it receives less than half blood from the main coronary artery thus perfusing less than half of the myocardium with the other regions getting their blood supply from the LCA even when the dominance of the heart is strictly right, the LCA plays a major role in the perfusion

of the right side of the myocardium. It is thought that the reduced perfusion of the myocardium via the RCA with or without a variant artery could have participated in the current increase of ischemic heart diseases since majority of the population is considered right heart dominant (Ballesteros *et al.*, 2011).

2.1.7 The third coronary artery

Though not common but in the small percentage of population that has it, is thought to have developed after birth due to its high prevalence in the adult heart than the fetal heart. It originates in the aortic sinus then moves to the sub-epicardial adipose tissue to perfusing the ventral aspect of the RV. Its relevance to surgical procedures the regression of acute myocardial infarction. Although its distribution was not explored in this study, ethnic variability was noted meaning it could be highly associated with a certain ethnic community than the other (Olabu *et al.*, 2007).

From the data reviewed, the reason for its development especially after birth is not clear and more so in the population that has the two main arteries. Ideally the RCA should be the main blood supply to the ventral RV thus development of these variant when the RCA is present begs many question on its functionality of the variant. (Lujinović *et al.*, 2008).

These and many other variations of the origin, branching and termination of the coronary artery has brought massive changes in the blood supply of the myocardium while the purpose and effect of their development is not clear. These variants come with pressure differences in the blood vessels, formation of collateral circulation, anastomosis and the differences in the ability of the heart to respond to an emergency at any particular time which dictates perfusion pattern of the myocardium at any particular time.

2.1.8 Single coronary artery

Occurs as a congenital malformation which does not occur regularly, usually originating from the pulmonary trunk (Figure: 5). It is associated with angina pectoris a disease of the heart, however in most of the cases there is no atherosclerosis (Akçay *et al.*, 2008). In other cases, the RCA and LCA arise independently from a single aortic sinus and is mostly found out during angiography or postmortem. Surprisingly its relevance is not known though it is associated to sudden death (Turkmen *et al.*, 2014).

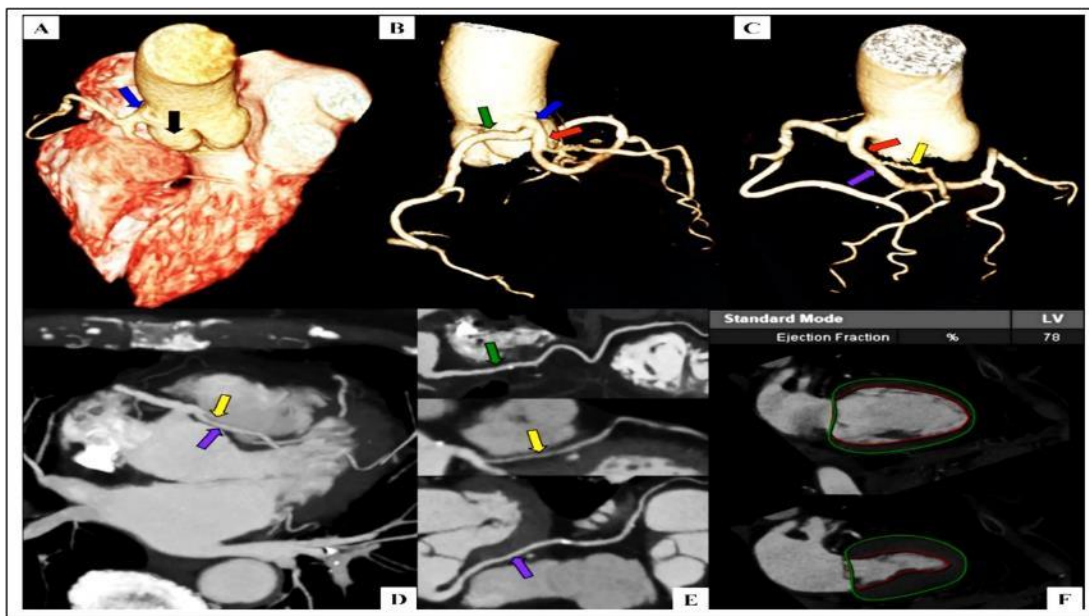


Figure 5: Anatomical variation of a single coronary artery with its origin from the ascending aorta and its branches (Gać *et al.*, 2022)

Gać *et al.*, (2022) highlights a case of a single coronary artery with its origin from the RC sinus. Its course was that of a typical RCA mixed the course of inter-arterial LCA, LAD and LCx arteries. At about 7cm-8cms it bifurcated into 2 with features corresponding to the branches of the LCA (LADA and CMx). The proximal circumflex segment was wider and deeply embedded into the myocardium than the LAD artery. At its termination it gave rise to the marginal branch which moved upwards.

2.2 Dominance of the heart

Dominance of the heart is associated with the coronary artery that leads to the formation of the PDA or the posterior intra-ventricular artery (PIV). It perfuses the myocardium and other important structures like the SAN, AVN and the muscles of the lower third of the intraventricular septum. This artery has its origin from either the right (right dominance), left (left dominance) or both (codominance) (Omerbasic *et al.*, 2015; Kaimkhani *et al.*, 2005). Knowledge on dominance of the heart is important in healthcare provision because it is associated with approximately 70% of cardiac death in developing countries leading to increased morbidity and mortality caused by non-communicable diseases (Maheshwari & Aggarwal, 2017).

After its origin either from the RCA or LCA, the PDA runs moves towards the posterior intraventricular sulcus to then to the apex of the heart where it meets the LADA artery as it moves on the anterior cardiac surfaces. The PDA is key in the perfusion of the posterior a third of the intraventricular septum and the posterior inferior wall of the left ventricle, however variations in origin of PDA have been noted with it originating from the LADA being an example. In right dominance, the PDA supplies the posterior region of the myocardium further dividing into sulcus intraventricularis posterior, right intraventricularis posterior and the sulcus coronary artery. This ensures the posterior aspect of the heart is well perfused (Omerbasic *et al.*, 2015; Shahoud *et al.*, 2020)

According to data reviewed, right dominance is the most predominant at approximately 70-80%, followed by left dominance at 8-13% and lastly codominance at 4-18% (Table 2). Left coronary system and left dominance is highly associated to diseases of the coronary artery like acute coronary syndrome and CAD due the LADA which gets stenosed easily because of its anatomical

location. The RCA is however associated with right coronary stenosis and formation of coronary vascular lesions (Wang *et al.*, 2019)

Table 2: Dominance of the heart from different authors.

Study	Dominance		
	Left (%)	Right(%)	Balanced(%)
Knaapen <i>et al.</i>, (2010)	9.1	81.2	9.7
Vasheghani-Farani <i>et al.</i>,(2008)	10.9	84.2	4.8
Hirak das (2010)	18.5	70	11.43
Maheshwari & Aggarwal (2016)	8	84	8

Shahoud *et al.*, (2020) in his study highlights the importance of the origin of the PDA in supplying the myocardium but also notes that just like any other blood vessel the PDA or its original branch can be occluded, stenosed or thrombosed. This means decreased blood supply and ischaemia to the myocardial muscles, posterior a third of the heart and the intraventricular septum which are vital in the functioning of the heart. He further notes that the after effects of the decreased perfusion depend on the dominance of the heart.

Apart from the PDA originating from the right, left or both branches of the main coronary artery, there are still other unusual variations in leading to double PDA, its premature development from the RCA, and originating from vascular ring connecting the RCA and the circumflex branch of the LCA, PDA from obtuse marginal artery, which may alter the blood supply to the other regions like the intraventricular septum by right ventricular branches (Guleria, 2021).

2.2.1 Right heart dominance

In right heart dominance, the RCA supplies the dorsal part of the IVS leading to the formation of the PDA as separate branch. This is the advantage with right dominance because in-case of occlusion of either of the branches, there will be an alternate/ collateral pathway to the basal left

anterior descending artery via septal perforators ensuring perfusion to the myocardium (Omerbasic *et al.*, 2015). Where both the right and left coronary artery branches participate in the formation of the PDA (co-dominance), the perfusion is even better because of anastomosis and the many alternate pathways created by the blood vessels (Omerbasic *et al.*, 2015; Shahoud *et al.*, 2020).

Maheshwari & Mittal (2015) further notes variations in right dominance like in a case of super-dominant artery with an added right posterolateral ventricular branch originating from the left Cx artery perfusing the lateral and posterolateral wall of the myocardium. Another variation noted is where the super-dominant RCA divides into superior and inferior right CMx, perfusing regions that were originally perfused by the left CMx artery. The occurrence of a double PDA originating from the RCA with both branches supplying regions that are supposed to be supplied by the left Circumflex artery.

This leaves many unanswered questions on the purpose of occurrence of these variations in the presence or absence of the original vessels and also an indication that variations will continue to occur in the coronary vasculature hence the need to continuously familiarize with these variants for accurate identification of the course and distribution of coronary artery. This is important because the nature of blood supply to the myocardium is integral for surgical procedures and coronary artery disease.

2.2.2 Left heart dominance

In left dominance the PDA originates from the circumflex artery which is a major branch of the LCA. The left ventricle is almost completely perfused by LADA and left CMx branches of LCA. Left dominance has no prognostic significance but reflects a disadvantage to those who have it because of the less balanced circulation which it exhibits (Parikh *et al.*, 2012). A lesion in the main LCA or the Cx artery may render the PDA not useful causing in the absence of balanced dominance

with another branch of PDA coming from the RCA. This may cause ischaemia to the regions it supplies since there are reduced chances of formation of a collateral since if there is no PDA originating from the RCA (Parikh *et al.*, 2012; Omerbasic *et al.*, 2015). This could be very dangerous in case the left coronary system suffers stenosis or occlusion. In such a scenario during a cardiac surgery or cardiac bypass procedure any slight mistake due to lack of information on the coronary vasculature could lead to changes in the blood distribution to the myocardium which can be irreversible and fatal (Omerbasic *et al.*, 2015).

2.2 3 Codominance (balanced dominance)

This is when the RCA and the LCA participate in the origin of the PDA. The RCA gives off the PDA mostly the CMx branch of the LCA gives off the PDA. It is thought that majority of the population is right dominant which is thought to be advantageous because the PDA originates directly from the RCA as to co- dominance and left dominance (Aricatt *et al.*, 2022).

2.3 Social demographics characteristics

2.3.1 Effect of diseases on coronary artery.

The current upsurge of lifestyle diseases like hypertension, diabetes, arthritis among others caused by lack of exercise, smoking obesity, alcohol leading to atherosclerosis and CAD. The most affected blood vessels are those of the heart and this has led to variations in the coronary vasculature to try and respond to this changes to enable the heart function normally. Currently acute MI is the commonest sign of CAD and the most common cause of death and disability globally and more so in the developing countries (Wang *et al.*, 2019).

Blood supply to the heart by RCA and CMx arteries is enhanced by either right, left or co dominance since these are the main branches that give rise to the PDA. This highly implicates the

vulnerability of these blood vessels and their branches to MI in case of any changes due to social demographic factors and diseases like obesity, smoking and hypertension there is a high likelihood of the myocardium suffering ischaemia secondary to MI. most importantly, the RCA and the CMx arteries account for approximately 40%-50% of MI, complicating with features of a blocked heart, infarction of the right ventricle and depression of ST-segment that is depressed (Wang *et al.*, 2019; Poulter *et al.*, 1990).

2.3.2 Ethnicity, race and geographical location.

Social demographic factors are important in the formation of coronary artery variants, distribution and the overall effects. Ethnicity, geographical location and the race are among the key factors that can positively or negatively influence the changes in coronary circulation. According to Njenga *et al.*, (2004), the psychosocial well-being can-not be ignored in the development and expression of CAD. There is a connection between biochemical link, cardiac events and depression leading to activation of the inflammatory process, reduced immune system and hypercoagulability. Ogeng'o (2014) in his study notes that the diameter of the lumen and the level of stenosis are key indicators of atherosclerosis. Although there is very little data about this in the black population, he notes the variance in different ethnic groups and geographical locations and relates it with the increased cases of coronary artery disease in some regions. In Ogeng'o *et al.*, (2013) he further notes the LADA as the most severely affected blood vessel and thus the influence on the stents to be inserted as corrective surgery.

This surgery is important bearing in mind that in a population that is left dominant, most of the times the PDA originates from the LADA which is highly prone to stenosis. It is therefore important that the cardiologist and heart surgeons are informed about the variations in coronary artery anatomy, distribution of the blood to the myocardium and their overall effect. This will

prepare them surgically and pharmacologically in an event that the blood supply of the myocardium is different from the norm which will further reduce morbidity and mortality related to heart conditions.

Mathenge *et al.*, (2010) asserts that the migration of people from rural areas to urban centers with approximately 40% of African population currently living in urban area has participated in the current increases in cardiovascular disease. This can be linked to increase in hypertension, diabetes and obesity brought about by lack of exercise leading to increased weight gain with a rise in systolic blood pressure approximately a month after migration to the rural areas. While most research has shown increase in arterial blood pressure most so with the advancement of age, others show the changes in blood pressure of certain ethnic communities who have moved to live in more modern environment due to adoption of sedentary life and changes in the environment (Poulter *et al.*, 1990).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study setting/area

The study took place in the laboratories of 3 Medical schools in Kakamega and Kisumu County namely Maseno university, Masinde Muliro University and Uzima University which have anatomy laboratories under the School of Medicine in the Department of Human Anatomy. The universities have cold rooms and embalming systems that can maintain cadavers for years.

3.2 Study design

This was a cross-sectional study which was conducted in the 3 university laboratories which were selected through purposive sampling according to the number of cadavers they had. In each laboratory, the following dependent variables were captured; Origin, branches, length and termination of coronary artery while the independent variables which were gender and ethnicity were used to capture the specified data and the outcome.

3.3 Study subject

The study subject were cadavers in the gross anatomy labs distributed as follows Maseno University acquired 45, Masinde Muliro 20 and Uzima University 24 cadavers. The total available specimen for the study was be 89 cadavers.

3.4 Sample Size Determination

The Cochran formula (Cochran, 1977) was used to determine the sample size.

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where n – sample size, Z is a constant (95% = 1.96, 99% = 2.58), P- estimated proportion of population, e – is the desired level of precision (In this case it is 5% or 0.05) absolute precision acceptable, q is 1-p and the z value is found in the z table.

Therefore $n = \frac{(1.96)^2 * 0.51(1-0.51)}{(0.05)^2}$

n= 384 if the population is more than 10000.

Population < 10,000.

In this case a modified Cochran formula was used because of the sample size was below 10,000

$$n = \frac{n_0}{1 + \left(\frac{n_0 - 1}{N}\right)}$$

Where n_0 = is Cochran sample size recommendation/ constant (385)

N = is the estimated total population less than 10, 000 (89)

And

n = is the new adjusted sample size when the estimated total

Population (N) is less than or equal to 10, 000.

nf = $385/1+384/89$

n = $384/1+(384/89)$

n = $384/1+(4.3)$

n= $384/5.3$

n= 72 cadavers

3.5 Sampling Procedure

This study adopted mixed methods to select the desired sample size. The study area was stratified into the existing 3 Universities (Maseno, Masinde Muliro and Uzima) according to the number of cadavers available in each laboratory. The cadavers were grouped into gender (male or female) after which the samples for each laboratory were randomly selected. To ensure equal distribution of samples, sampling was done proportionately with the strata population by location, where the sample size per laboratory was calculated by dividing laboratory cadaver (d) by total location population (n), multiplied by the desired sample size (m); $n = (d/N)m$ (Table: 3)

3.5.1 Distribution of cadavers

Table 3: Distribution of cadavers

Laboratory location	Population in laboratory(d)	Selected sample (n)
Maseno University	45	37
Uzima University	24	19
Masinde Muliro University	20	16
TOTAL	89(N)	72(m)

3.6 Selection criteria

3.6.1 Inclusion criteria

- Cadavers collected legally from black African descent.
- Cadavers with intact heart morphology were used for the study.

3.6.2 Exclusion criteria

- Cadavers with no demographic characteristic record.

3.7 Study variables

3.7.1 Dependent variables

- a) Origin of the CA
- b) Branching pattern of the CA
- c) Length of the CA
- d) Termination of CA
- e) Origin of the PDA

3.7.2 Independent variable

- a) Gender.
- b) Ethnicity

3.8 Data collection tools and procedure

3.8.1 Data collection tools

- a) A data entry sheet/form and its content attached in Appendix 5 was used.
 - i. Name of cadaver/code
 - ii. Gender
 - iii. Ethnicity
 - iv. Origin of the arteries
 - v. Number of branches produced by each principal artery
 - vi. Length of CA
 - vii. Termination of the coronary artery

- b) Dissection kit- DS14
- c) Tape measure- Open reel tapes
- d) Pens assorted- Bic
- e) Paper- Fullscaps (Karatasi brand)
- f) Scissors- stainless steel straight dissection scissors 6inch
- g) Gloves – Clean gloves large 9.5 – 10.5 inches
- h) Camera

3.8.2 Data procedure (images and pictures)

3.8.2.1 Acquisition of cadavers

There are many challenges associated with the acquisition of cadavers in Kenya just like in other countries. Most cadavers are usually unclaimed bodies from hospital mortuaries (Ongeti, 2012). Within western region there are several hospitals but due to the cultural belief the process of acquisition of bodies is usually technical with only few cadavers available (Table 3). There has to be a court order for the burial of unclaimed bodies by the state after 3 months (Ongeti, 2012). The university linked up with the hospital management and the courts in the acquisition of these bodies. In this case due to time limitation facilities that had bodies that had stayed for more than three months without being claimed were sought since they were ready to bury the bodies. After the court order, the institution made a formal request to be given bodies depending on the different specifications required. The medical schools have logistics for transportation of these bodies to the university (Table 3). They were then received in the department of human anatomy where they were coded and labeled for identification purposes. Cleaning and embalming was done

immediately in preparation for learning purposes (Habicht *et al.*, 2018). The procedure was done using dissection tools like scalpel, hemostat and dissection scissors.

3.8.2.2 Dissection of the heart.

The cadaver was put on the dissection table to lie on its back then the manubrium of the sternum and the lateral walls of the ribs were cut to reflect the anterior thoracic wall downward. A cut was made through the manubrium of the sternum which went through the parietal pleura and the first intercostal space on both sides. In the mid axillary line, a vertical cut that extends to the sternal joint was made. Elevation of the lower part of the sternum to cut the pleura where it leaves the sternum (Lisowski, 2004).

Extension of the cut through the pleura from the sternum to the mediastinum up to the lower boarder of the heart which enabled the thoracic wall to be turned down and the edges of parietal pleura traced. Stripping of the pleura and the endo thoracic fascia to expose the transverse thoracic muscle. This exposed the pericardium and the heart (Koshi, 2017).

3.8.2.3 Exposing the heart and looking for the origin and distribution of coronary artery.

Lisowski (2004) highlights the procedure to be used in exposing the heart. A probe was placed in the transverse sinus to remove the heart from the pericardial sac by severing the aorta, SVC, IVF, PA and PV. The epicardium was removed using blunt dissection which revealed the CA and their branches. The superior venacava was cut approximately 1cm into its entrance into the right atrium. To cut the inferior venacava close to the diaphragm, the apex of the heat was lifted. The four pulmonary veins and the serous pericardium in between them were cut, the heart could now be lifted out of the pericardial sac (Koshi, 2017).

Once revealed a blunt object was used to trace the RCA and LCA, their origin, the distance of bifurcation from the origin, the branches and the distribution of these branches. Each branch was also followed to termination using a blunt object branches of the RCA were followed up to their termination SANA, PIVA, right MA and AVNA. Branches of LCA were followed to their terminal end with their braches the LADA, CMx, PDA being observed (Lisowski, 2004). The regions perfused by the individual blood vessels were also noted. All through, photographs were taken

3.8.3 Reliability and Validity

According to Middleton (2020), validity and reliability helps in evaluating the quality of research by indicating how consistent and accurate a method is and thus it is key in research design. A pilot study was conducted at Maseno University human anatomy laboratory to test the reliability of the instruments and datasheet. The cadavers used for the pilot study were however not used for the main study. This helped correct errors that may occur during data collection and come up with recommendation concerning the research instruments and tools. Test and retest the data sheet and the tools was done using the selected samples in Maseno University Anatomy lab. Validity is the ability to measure accurately what is required thus establishing a trustworthy cause-and-effect relationship between a treatment and an outcome (Fleming *et al.*, 2020). This was done by randomly selecting the cadavers and ensuring close supervision of the tools by the supervisor to ensure the findings were correctly tallied as per the classification of the data tools.

3.9 Data analysis

All data was entered into pre formed MS Excel worksheet which were coded, and continuously cleaned. The data was then transferred to statistical package for social sciences (SPSS) version 26 for analysis. Descriptive statistics was used to determine the mean, mode, median, standard

deviation (SD) and percentiles of the anatomical variations in the origin and distribution of coronary artery. It was then presented in tables and graphs

Chi square test was performed to test the association of between right, left and co dominance of the heart to gender and ethnicity where each row and column represented a category of a variable. P value of ≤ 0.05 was considered to be significant.

The relationship between origin, branches, length and termination of coronary artery to gender and ethnicity was analyzed by bivariate Pearson's correlation test and P value of ≤ 0.05 was considered to be significant

3.10 Ethical consideration

- Research topic and proposal was approved by the Maseno university.
- The complete proposal was forwarded to Postgraduate research committee for further approval and request letter was sent to Uzima University and Masinde Muliro University for collection of data.
- All ethical protocols were observed and consent sought for the research.
- All the collected data was stored and processed in confidentially and was only be used for the current research. The data was collected with the authorized persons only after which the data was stored in CDs/ Flash disks with strong password that can only be accessed by the authorized people
- Approval was obtained from SGS Scientific review committee (Appendix vi)
- Ethical review was sought from MUSERC and NACOSTI

3.11 Dissemination and utilization of research findings

The results were disseminated through refereed journal papers, conferences, seminars, workshops etc

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter contains presentations and analysis of the data collected, the results of the statistical analysis and interpretation of finding. The findings and analysis are presented according to each objective with the overall study being to determine the origin and distribution of the coronary artery. It was a cadaveric study carried out in western Kenya and a total of 72 samples were selected as described in the previous chapter. Data sheets were used for collection of data. The pilot study was done at Maseno university and the cadavers used in the pilot study were not used in the main study.

4.2. Demographic characteristics and ethnicity of the study subject

Table 4.1: *Ethnicity of the study subjects*

		Frequency	Percent
Valid	Luo	39	54.2
	Kalenjin	2	2.8
	Luhya	21	29.2
	Kikuyu	3	4.2
	Kisii	5	6.9
	Kuria	2	2.8
	Total	72	100.0

The highest number of the study specimen were the Luo at 54.2% (39), followed by the Luhya at 29.2% (21). The Kisiis were 6.9% (5) while the Kikuyu were 4.2% (3). The Kalenjin and the Kuria were at the lowest at 2.8% (2) (**Table 4.1**)

Table 4.2: correlation between sex and ethnicity of the respondents

Gender of the respondent * Ethnicity of the respondents Crosstabulation									
			Ethnicity of the respondents						Total
			Luo	Kalenjin	Luhya	Kikuyu	Kisii	Kuria	
	male	Count	18	0	11	2	3	2	36
		% of Total	25.0%	0.0%	15.3%	2.8%	4.2%	2.8%	50.0%
	female	Count	21	2	10	1	2	0	36
		% of Total	29.2%	2.8%	13.9%	1.4%	2.8%	0.0%	50.0%
Total	Count	39	2	21	3	5	2	72	
	% of Total	54.2%	2.8%	29.2%	4.2%	6.9%	2.8%	100.0%	

The male female ration in this study was equal to ensure unbiased correlation tests (36 males, 36 female). Among the Luo the number of females were slightly higher than the males at 29.2% (21) while the males were at 25% (18). The Kalenjin and the Kurias had 2.8% (2) study subjects each with the Kalenjin being all female and the Kuria all male. The Luhya had 13.9% (10) females and 15.3% (11) males. Among the kikuyu 1.4%(1) was a female while 2.8%(2) were male (**Table 4.2**)

4.3 Variation in the origin of the coronary artery

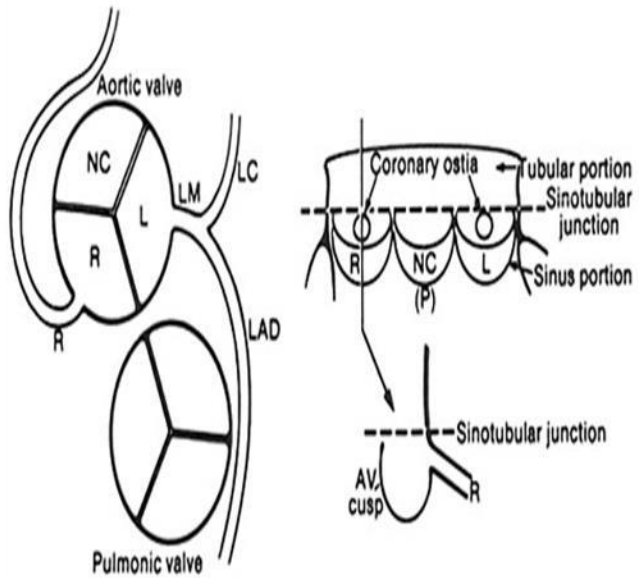
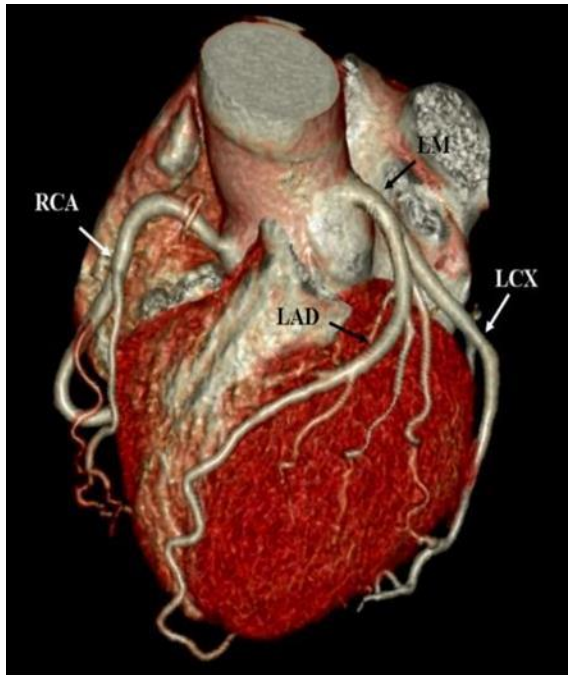
Table 4.3: *Origin of the coronary artery*

Variation in the origin of coronary artery						
	Frequency	Pecnt	Mean	Mode	Median	Std dvn
Dual aortic origin	40	55.6	1.5972			
Orifice in the left and 2 Orifice in the right	24	33.3		1.000	1.00	.798
Orifice in the left and 3 Orifice in the right	5	6.9				94
Orifices in the left aortic cusps	3	4.2				
Total	72	100.0				

Of the total 72 specimens, 40 hearts 55.6% had dual aortic origin, one on the right and the other on the left for the coronary arteries. 24 hearts 33.3% had orifice in the left and 2 orifices in the right while 6.9% had orifice in the left and 3 in the right. Among the 29 hearts, 40.2% cases which had orifice in the left and 2-3 in the right, 16.6% (12) of the orifices were associated to the right conus artery with 9 originating from the orifice in the left and 2 in the right with the remaining 3 originating from orifice in the left and 3 in the right. The sinoatrial nodal artery had 1 of its orifice originating from the right aortic cusps with 2 openings and the other with 3 openings (**Figure 4.2**). 3(4.2%) hearts had orifices all the orifices on the left aortic cusps and none on the right (**Figure 4.1**). As a result, 55.6% of the origin were normal while the remaining 44.4% were variations. The

mean was 1.5844, the mode and median were 1.00 and the standard deviation was 0.78389. Dual aortic origin was the most frequent occurrence in the variations of the origin of the coronary artery

A coronary artery from a male study subject which had 2 openings on the left aortic cusps. One of the openings formed the left coronary artery while the other while the other



A



B

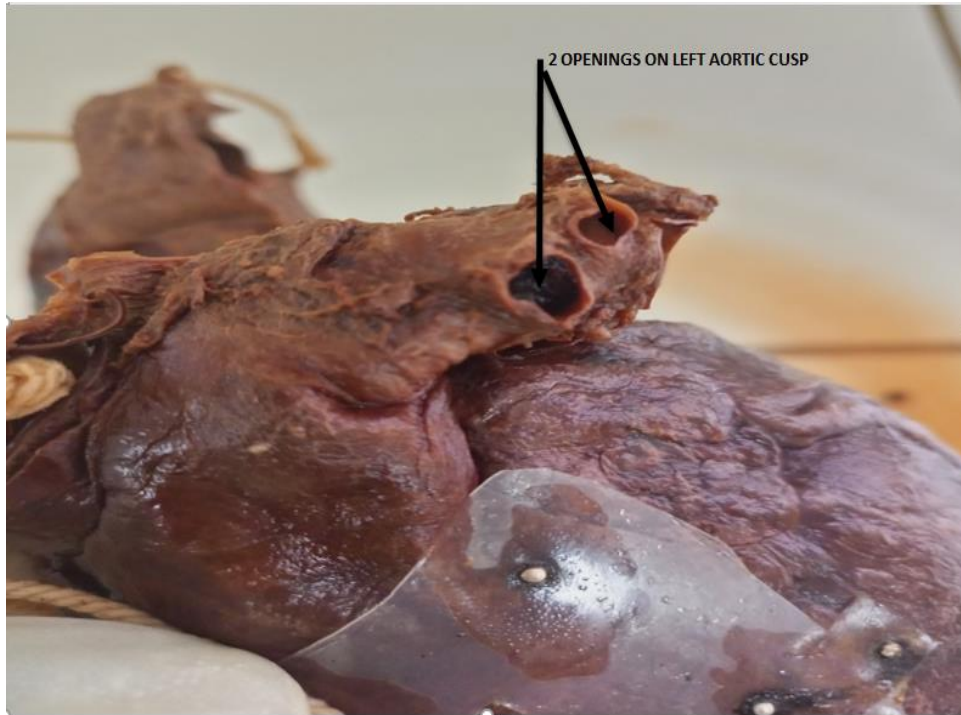


Figure 4.1: A: Normal origin of the coronary arteries on the aortic cusps by Namgung & Kim (2014) **B:** versus variation: Two openings on the right and left aortic cusps in the present study.

4.4: Variation in the branching pattern

4.4.1: Variation in the branching pattern of the right coronary artery

Table 4.4 : Branching pattern of the right coronary artery

		RCA branching to right conus artery	RCA-posterior descending artery	RCA-acute marginal branch	RCA-Branching to sinoatrial nodal artery	RCA-branching to atrioventricular nodal artery
N	Valid	60(83.3%)	57(79.2%)	72	70(97.2%)	70 (97.2%)
Mean		1.1667	1.1083	1.000	1.0317	1.0317
Median		1.0000	1.0000	1.0000	1.0000	1.0000
Mode		1.00	1.00	1.00	1.00	1.00
Std. Deviation		.37529	.35652	.00000	.00000	.00000

Of the total 72 hearts, 83.3% (60) had the right conus artery, a direct branch of the right coronary artery while 79.2% (57) had posterior descending artery. Only 2.7% (2) of the sinoatrial nodal artery had their origin from the right aortic cusps while the remaining 97.2%(70) were branches of the right coronary artery. The acute marginal branch arose at the right boarder of the heart and moved to the apex of the heart. All the branches were from the right coronary artery. 79.2% (57) of the posterior descending artery originated from the right coronary artery which depicted right dominance of the heart (**Table 4.4**).

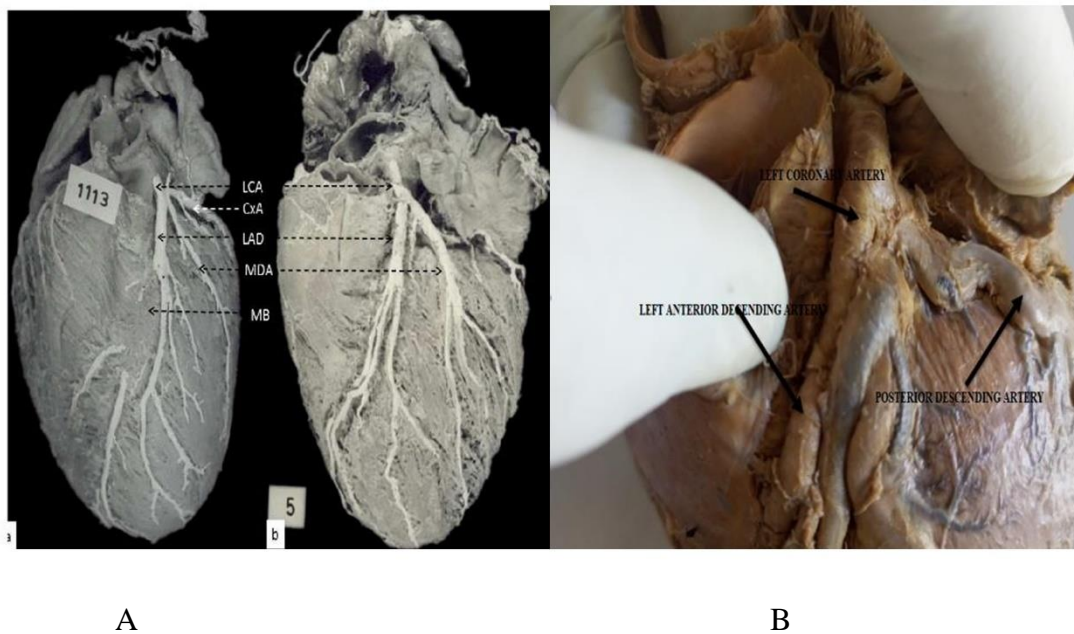


Figure 4.2 A: Normal branching of the LCA by Gupta et al., (2016) versus B: Variation in the present study

4.4.2: Variation in the branching pattern of the left coronary artery

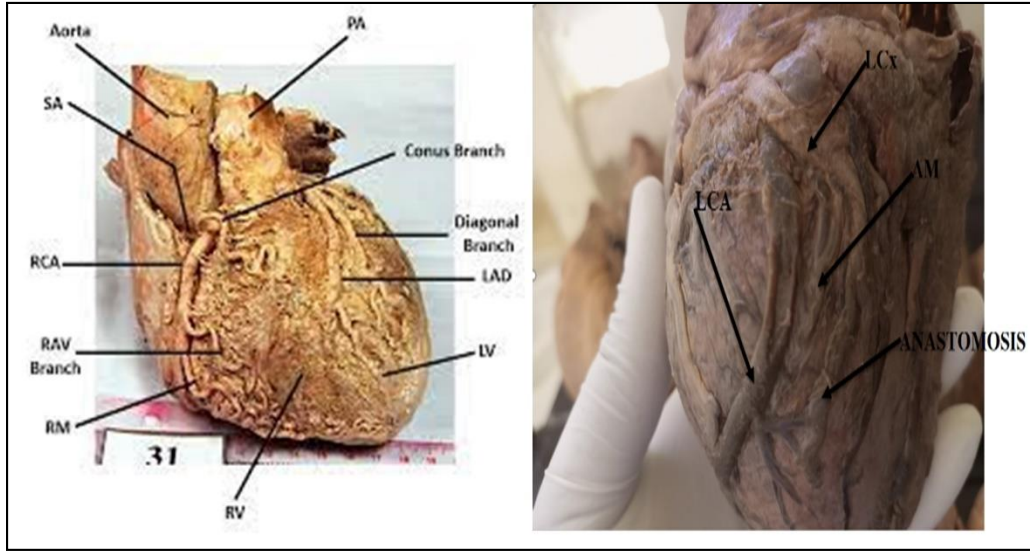
Table 4.5: *Branching pattern of the left coronary artery*

		left anterior descending artery (LADA)	Circumflex branch	Ramus branch	Left conus branch	Posterior descending branch	Left Atrioventricular branch	Obtuse marginal branch	Diagonal branch
N	Valid	69(95.8%)	64(88.6%)	3(4.2%)	2(2.8%)	15(20.8%)	5(6.9%)	5(6.9%)	6(8.3%)
Mean		1.0417	1.1111	1.9583	1.9722	1.8500	1.9306	1.9306	1.9167
Std. Error of Mean		.02372	.03730	.02372	.01950	.05139	.03017	.03017	.03280
Median		1.0000	1.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
Mode		1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00
Std. Deviation		.20123	.31648	.20123	.16549	.43605	.25599	.25599	.27832

The LADA was the most frequent branch of the LCA occurring at 95.10% (69). The left circumflex artery followed at 88.6% (64) while the posterior descending artery was at 20.8% (15) (**Table 4.5**).

The posterior descending artery dictates the dominance of the heart and in the present study the heart was right dominant because of the few PDA originating from the LCA.

Out of 20.8% PDA frequency, 2.7% (2) were branches of the left CMx artery while the rest were direct branches of the LCA. 3 branches of the diagonal artery were branches of the LADA artery while the other half were direct branches of the left coronary artery. All the branches of the atrioventricular nodal artery had their origin from the left coronary artery at 6.9% (5), while all the obtuse marginal artery had their originated from the circumflex coronary artery. 2 branches of the ramus artery originated from the LADA, while the remaining one had its origin directly from the left aortic cusp. All the left conus artery originated from the left coronary artery at 2.8% (2).



A

B

Figure 4.3: *A: Normal branching of the RCA by Namgung & Kim (2014) versus B: Variation in the present study*

4.5: Variation in the length

4.5.1: Variation in the length of the right coronary artery

Table 4.6: *Length of the right coronary artery*

	Frequency	Percent	Normal Mean Length	Median	Mode	Std. dvtn
4-8cm	11	15.3	12.22cm	2.0000	2.00	.40897
9-13 cm	59	81.9				
14-18 cm	2	2.8				
Total	72	100.0				

Of the total 72 hearts, 15.3% (11) coronary arteries were ranging between 4 to 8 cm in length, while 81.9% (59) of them were between 9 to 13 cm, while 2.8% (2) had their length between 14 to 18 cm. The length of 9-13cm at 81.9% (59) was considered to be normal while the remaining 18.1% were considered to be variations. The mean length was 1.8750 therefore, most of the hearts had the length of the right coronary artery between 9-13cms. The measurement of 9-13cm was the most frequent and it was also the median. (**Table 4.6**)

4.5.2: Variation in the length of the left coronary artery

Table 4.7: *Length of the left coronary artery*

	Frequency	Percent	Normal Mean length	Median	Mode	Std. Dvtn
2-6 mm	14	19.4	9.32mm	2.00	2.00	.56485
7-11 mm	49	68.1				
12-16 mm	9	12.5				
Total	72	100				

Of the total 72 hearts studied, 19.4% had the length of the left coronary artery between 2-6mm, 68.1% were between 7-11mm while 12.5% were between 12-16mm. The mean was 1.9306, the median was 2.00, mode 2.00 while the standard deviation was 0.56485. this showed that most of the hearts had their measurement between 7-11cms. Length between 7-11 mm was also the most repeated. (Table 4.7).

4.6: Variation in the termination.

4.6.1: Variation in the termination of the right coronary artery

Table 4.8: *Termination of the right coronary artery*

Termination	Frequency	%	Mean	Median	Mode	Std. dvt
Between acute margin and crux of the heart	2	2.6	2.9028	3.000	3.00	.56068
At posterior intraventricular septum	9	14.3				
Between crux and obtuse margin of the heart	55	74.0				
At obtuse margin of the heart	6	9.1				
Total	72	100.0				

The results of the present study showed that 2.6% had their right coronary artery terminating between the acute margin and the crux of the heart. The posterior intraventricular septum was termination point for 14.3% of the coronary arteries, while 74% of the arteries terminated between the crux and the obtuse margin of the heart. 9.1% arteries terminated at the obtuse margin of the heart. The mean was 2.8961. This indicated that most of the arteries terminated between the crux and the obtuse margin of the heart. (Table 4.8)

4.6.2: Variation in the termination of the left coronary artery

Table 4.9: Termination of the left coronary artery

Termination	Freq	%	Mean	Median	Mode	Std Dev
At the crux	8	13.0	2.986	3.000		
Between crux and obtuse margin of the heart	60	80.5	1			
At obtuse margin of the heart	1	1.3			3.00	0.54367
Between crux and acute boarder	3	5.2				
Total	72	100				

The results showed that 13% of the coronary arteries terminated at the crux while 80.5% terminated between the crux and the obtuse margin of the heart. 11.3% terminated at the obtuse margin of the heart, while 5.2% between the crux and the acute boarder. The mean was 2.986, the median was 3.000, mode 3.00 while the standard deviation was 0.59597 (**Table 4.9**)

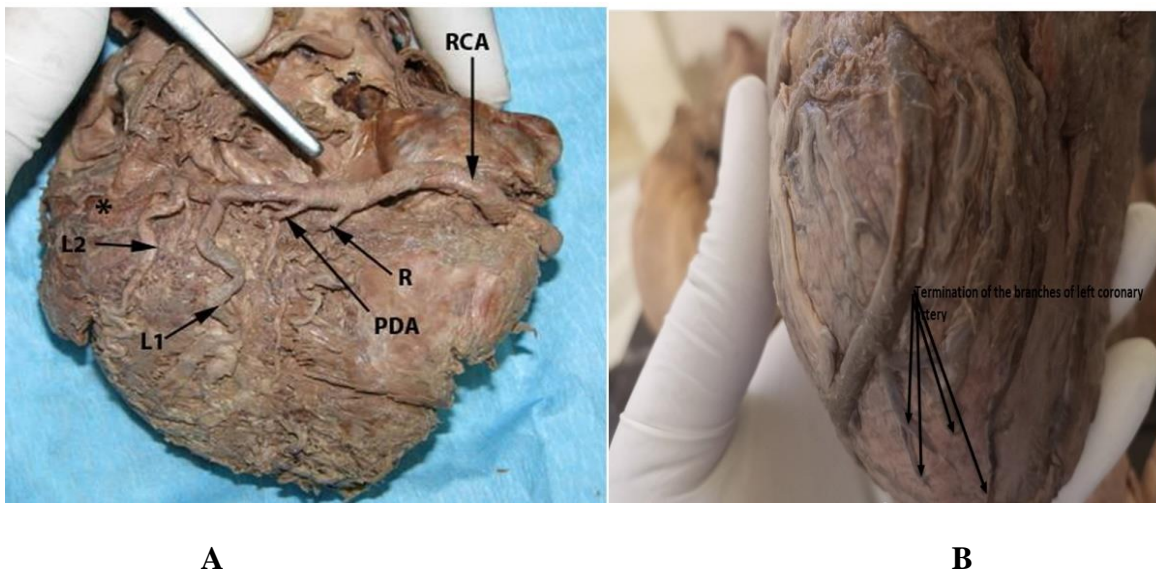


Figure 4.4: A: Normal termination of the LCA by El Sayed *et al.*, (2015) versus B: Variation in the termination in the present study leading to anastomosis at the apex of the heart.

4.7 Variation in the dominance of the heart

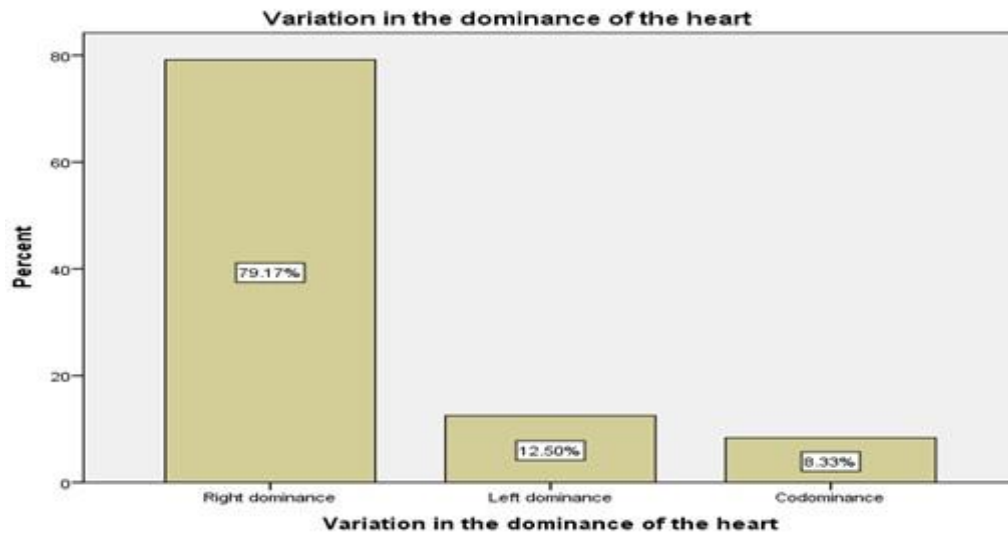


Figure 4.5: *Dominance of the heart*

The results showed that 79.2% (57) of the hearts had right dominance, 12.5% (9) had left dominance while 8.3% (6) had codominance. The results showed that most of the hearts had right dominance (**Figure 4.5**)

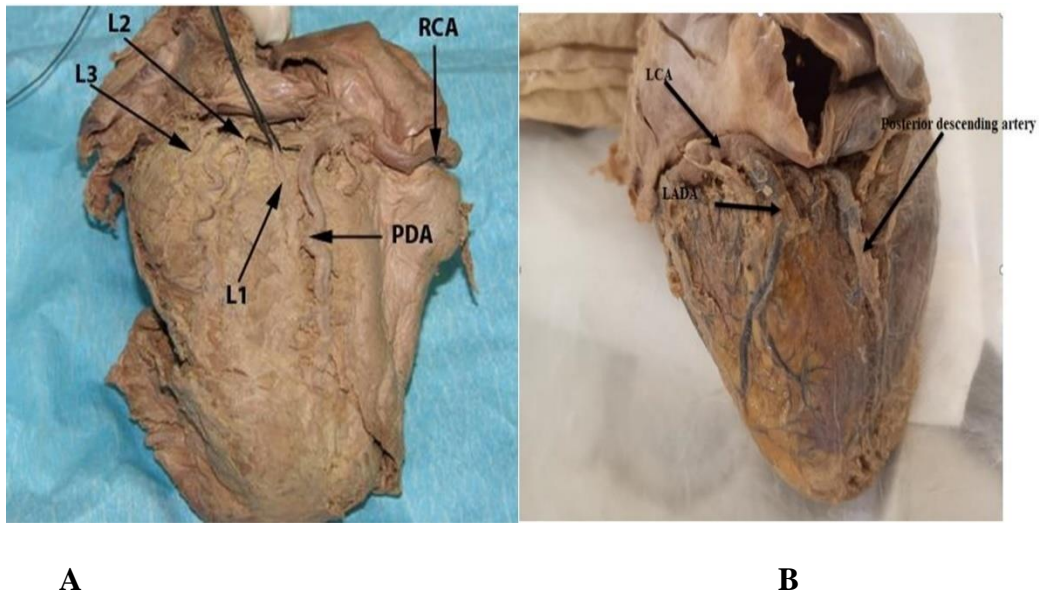


Figure 4.6: **A:** *Normal dominance of the hear by El Sayed et al., (2015) versus B:* *Left dominance of the heart in the present study.*

Table 4.10: *Dominance of the heart versus gender of respondents*

Gender of the respondent	Right dominance	Left dominance	Co dominance	Total	Percentage
Male	28	4	4	36	50
Female	29	5	2	36	50
Total	57(79.2%)	9(12.5%)	6(8.3%)	72	100

The results showed all the genders had more right dominance than left dominance and codominance. The difference between right and left dominance in both male and female was 1 with females being 29 while male were 28. The difference in the left dominance between the male and female gender is also 1 with the female having 5 while male had 4. Codominance in the male was 4 while in the female was 2 (**Table 4.10**)

Table 4.11: *Variation between Gender and coronary artery dominance*

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	0.035 ^a	2	.0260
Likelihood Ratio	2.270	2	.321
Linear-by-Linear Association	2.660	1	.103
McNemar-Bowker Test	0..23.	1.	. ^b
N of Valid Cases	72		
a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .86.			
b. Computed only for a PxP table, where P must be greater than 1.			

The present study showed that there was a statistically significant difference at $P=0.0260$ between gender and coronary dominance. This study used a P value of ≤ 0.05 meaning that there was a positive correlation between the dominance of the heart and gender of the study subjects. Right dominance of the heart was the highest followed by left dominance and finally co-dominance. As the number of respondent's increase, the dominance of the heart also increases (**Table 4.12**)

Table 4.12: *Branching of the right and left coronary artery to laterality of the respondents*

Symmetric Measures						
			Value	Asymptotic Standard Error	Approximate T ^b	Approximate Significance
Interval by Interval		Pearson's R	.074	.145	.644	.521 ^c
Ordinal by Ordinal		Spearman Correlation	.123	.120	1.071	.288 ^c
Pearson Chi square			0.071			
Measure of Agreement		Kappa	-.031	.015	-1.890	.059

There was no statistically significant difference between the branching pattern of Right and left coronary artery to gender ($P=0.521$). This means that gender did not influence the branching of the right and left coronary artery (**Table 4.12**).

Table 4.13: *Variation in the length of coronary artery and gender of the respondents*

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.263 ^a	3	.234
Likelihood Ratio	4.119	3	.249
Linear-by-Linear Association	.032	1	.859
McNemar-Bowker Test	.	.	. ^b
N of Valid Cases	77		

The present study showed that there was no statistically significant at $P=0.234$ between gender and length of the coronary artery ($P=<0.05$). The gender did not influence length of the coronary artery (**Table 4.13**)

CHAPTER FIVE

DISCUSSION CONCLUSION AND RECOMENDATION

5.1: Demographic characteristics of the study subject.

5.1.1: Demographic characteristics

The current study examined 72 cadaveric hearts with equal number of males and females to aid in correlation studies (Table 4.1). Among the study subjects, Luos were more than other ethnic groups at 54.2% (39) followed by Luhyas. there are two major ethnic groups from western region of Kenya. A study by Ndeda, (2019) observed that the Western parts of Kenya has the Bantu community (Abaluhya, Abakuria and Abagusii) and the river lake nilotes (Luo) who have interacted and borrowed cultures extensively from each other. The Luo and the Luhya communities were noted to be the main tribes in these regions while the other tribes moved to other parts of Western and Nyanza regions (Table 4.1 and 4.2)

5.1.2: Variation in the anatomical origin of coronary arteries

In the current study, 55.6% (40) hearts had normal dual aortic origin while the remaining 44.4% (32) had variations. Among the variations, 40.2% (29) had an orifice in the left and 2-3 orifices in the right, while 3 (4.2%) had orifices in the left and none in the right (Table 4.3). However, a study done by Khwansang & Chentanez (2018) on 95 hearts (48male and 47 female) in Thailand found a lower number in variation at 31% which were on the left and 2-3 orifices in the right aortic cusps. The lower number of variations from the previous study may have been due omission of origin of the conus artery from the 2-3 orifices as part of the variation. The current study considered any

other orifice which was not of the normal dual aortic origin to be a variant and noted that any differences from the above was bound to cause imbalance in the coronary arterial pressures.

One of the positive aspects of the multiple variant orifice in the origin of the CA is that in cases of blockage of either of the main orifices, anastomosis from the variants could help in the perfusion of the myocardium. Notably, during surgery like cardiac catheterization and ventriculotomy the multiple orifices can cause confusion leading to injury or damage of the blood vessels (Bhele *et al.*, 2017) (Figure 4.1)

Mutyal *et al.*, (2014) in his study on 60 Indian hearts found a much lower number in the variations at 13.33% (18) which were three to four orifices on the right aortic cusps. The study did not have any findings on orifices on the left aortic cusps as variants which could have led to the difference in the variations, but in the current study, 3 study specimens had orifices on the left aortic cusps only with none in the right. This meant that blood supply to the right side of the myocardium was purely by anastomosis of the available circulation or collateral circulation from the orifices in the left (Figure 4.1).

Results reported by Vilallonga (2003) in Spain noted a prevalence of variations in 40.3% (31) of the total 211 hearts dissected, this was in line with the current study, where the variant orifices were associated to the origin of the conus and the sinoatrial nodal artery. It was also noted that the presence of the variants could seriously jeopardize the functioning of the coronary arteries due to the alteration of different pressures that maintain coronary arterial circulation to the myocardium. However, unlike Vilallonga's (2003) findings, there was a slight difference in specific variations where 16.6% (12) of the variations were found to be the origin of the conus artery while 2.7% (2) were from the origin of the SANA. This artery had 1 of its orifice originating from the right aortic cusps with 2 openings and the other with 3 openings. The conus artery and the sinoatrial nodal

artery having their own orifice could be a saving effect to the heart such that in case of any damage or injury to the RCA with a patent aorta, the myocardium can be saved from myocardial infarction and ischaemia (Vilallonga, 2003).

This is important especially with the current increase in non-communicable diseases, these variants can ensure proper perfusion after anastomosis and collateral circulation. However, they could also make management complicated during surgeries and even radiology. The success of delicate procedures like ventriculotomy highly depend on radiological features of the arteries before the surgery. In case of the multiple orifice and lack of opacification during radiology, fatal mistakes can be made during surgery leading to catheterization of the wrong artery. This could deny the heart muscles significant blood supply therefore predisposing it to multiple damages, injury and inability of the heart to compensate (Mutyal *et al.*, 2014).

Of importance to note is that the 44.4% variations in the origin of CA in the present study could have a serious circulatory effect on the myocardium which could easily predispose the heart to myocardial infarction and probably cardiac death. Khwansang & Chentanez, (2018) therefore advices that these variations should be keenly noted when looking at the overall perfusion of the myocardium and more so during coronary angiographies and revascularization procedures. This is because they can cause confusion thus fatal mistakes.

5.1.3: Branching pattern of the right and left coronary artery

Branching pattern of the right coronary artery

Normally, the main branches of the RCA are the poster descending artery (PDA) and the right conus (RC) artery with the remaining arteries being sub-branches (Ballesteros *et al.*, 2011), this is in agreement with the present study with the additional arteries being the sub branches (Figure 4.3). According to a study done by Bhele *et al.*, (2017) & Kulkarni (2013), the SANA entirely

originated from the RCA while in the current study, 2 of its branches originated directly from the right aortic cusps while the remaining were branches of the PDA's. Both previous studies had more males than females while the current study had equal number of study subjects in gender which could have led to the difference in result findings (Table 4.4). The two branches of the SANA separately occurring from the right aortic cusp were noted to be from two male hearts and after coursing on the surface of the right ventral aspect of the myocardium whereas they later joined with the PDA which originated from the RCA to form anastomosis on the dorsal region of the myocardium to facilitate the perfusion of these regions.

Kulkarni (2013) highlights the danger of the SANA entirely having its origin from the RCA and notes that in case of occlusion of this vessel with no anastomosis or collateral circulation, the areas perfused may undergo ischaemia and thus the alternative branches originating directly from the aortic cusp could save the myocardium from ischaemia and sudden death.

Another study done by Fazliogullari *et al.*, (2010) on 50 Turkish cadavers from both genders found 42% (21) of the PDA to have originated from the RCA. The previous study further found out that these variations in the branching pattern of the CA can occur as early as during childhood or as a compensatory mechanism for an ailing heart during growth and development. The 79.2% (57) in the current study could be attributed to the changes that continuously occur to the coronary blood flow mostly due to a disease process of the heart and its muscles in a bid to maintain the coronary vasculature. This can increase steadily in a population and especially with the current occurrence of non-communicable diseases like hypertension and diabetes mellitus.

Bhele *et al.*, (2017) agrees with Ballesteros *et al.*, (2011) on the origin of the AM as a branch of the PDA. Among the 221 hearts studied by Ballesteros *et al.*, (2011) in Brazil, 89% had the AM artery originating from the PDA while 69% of the 98 hearts Bhele *et al.*, (2017) studied had the

AM originating from the PDA. In both the previous studies, the hearts were right dominant therefore the variant artery was meant to assist in the perfusion of the posterior regions of the myocardium with the help of the AVNA and the SANA. In the present study, the AM branches were all from the RCA, but still most of the hearts were right dominant. This could be disadvantageous to the population with right dominance in this study since occlusion of the PDA with no alternate circulation at any level would cause damage to the posterior a third of the intraventricular septum. Generally, Shahoud *et al.*, (2020) noted that those with pure right dominance with no other branches are at a higher risk of heart failure than their counterparts with left dominance since the RCA receives less blood than the LCA and even in right dominance, the LCA still perfuses a big percentage of the myocardium.

Branching pattern of the left coronary artery

The normal textbook branching pattern exhibited by the LCA is the LADA and the CMx. In the current study, 57.4% (36) of the branching pattern were varying from the normal (Table 4.5). The most common variation was the emergence of the posterior descending artery at 20.8% of the study specimen (Figure 4.2). Other researchers observed a lower variation in branching patterns for example, out of the 50 hearts studied by Alam (2017) in Bangladesh South Asia, 28.5% (22) had variations in the branching pattern, his study also observed that some variant branches like the obtuse marginal and the left conus were missing while others like the diagonal branch occurring at a higher frequency Khwansang & Chentanez, (2018) recorded a much lower variation at 16% of the total 141 cadaveric hearts in branching pattern. Furthermore, he found the left conus and the obtuse marginal artery in his study, their frequency was much lower than the previous study by Alam, (2017).

Unlike the current study, Alam, (2017) also recorded a much lower frequency of the posterior intraventricular (PDA) artery at 8.2%. This artery though a variant at 20.8%, is considered a very important artery because of the dominance of the heart. It perfuses the dorsal a third of the intraventricular septum and still had the SANA and the AVNA as its branches which are still important variants in the perfusion of the SANA and the AVNA. Furthermore, the left side of the myocardium was noted to be more muscular than the right region most probably because of its role in ensuring that blood is pumped from the RV through the great aorta into the systemic circulation hence with the current increase in cardiac conditions, the coronary circulation could be continuously exposed to these variations as an important measure to maintain the functions of the heart.

5.1.4: Variation in the length of the left and right main coronary artery

There are variations in the normal length of the CA with the normal length for the LCA being approximately 7-11mm with the mean length being 8.86 ± 2.96 mm while that of the RCA ranging between 8-14cm with a mean of 12.45 ± 1.88 (Hosapatna, 2013; Kulkarni, 2013). The present study found 31.9% (23) variation in the length of the LCA, among these, 19.4% were short (2-6mm) while 12.5% were longer than normal (12-16mm) with a mean of 9.32mm (Table 4.7). The right main coronary artery had 18.1% (13) variations with 15.3% being shorter (4-8cm) and 2.8% longer than normal (14-18cm) with a mean of 12.22cm (Table 4.6).

Samullah (2020) observed 100 Indian hearts and found the mean of the LCA to be 10.2mm with an average of 3-25mm in measurement while in the present study, the average length of the left main coronary artery was slightly lower than the previous study with a mean that was almost the same. He also reported that there are considerable variabilities in the length of the left and right

main coronary artery depending on the research method used, ratio of gender and even the geographical location of the study population which could cause variations

A study by Javed *et al.*, (2023) on the hearts of 1500 patients in China highlighted the significance of the length of the left main coronary artery especially during revascularization procedures and coronariographies. He observed 19.6% variation in length which was higher than the present study, but noted that the ratio of the study subjects, gender, and geographical location could have caused the variation.

On the right coronary artery, Samullah (2020) recorded the mean for the right coronary artery at 10.75 and the average length at 9.22-12.7cm, variations in his study were 12% which was almost similar to the present study. Similarly, Bhele *et al.*, (2017) recorded 16% while El Sayed *et al.*, (2015) recorded the 18%. Notably, El Sayed *et al.*, 's (2015) study measured the length of the right main artery in 2 parts, before and after branching of the right main coronary artery where the first part of the right coronary artery was 5.7-8.0 cm and the second part was 3.4-6.0 cms. He argued that the measurement of the length of the artery before or after formation of the branches is important because it highlights the probable length of the branches in relation to the surface area that they will supply. This study observed that the measurement of the whole trunk of the right main coronary artery since it was important as a key marker in surgeries, insertion of cannulas and ultimately the formation of branches. This would give a clear picture of the branches hence collateral circulation and anastomosis.

5.1.5 Termination of the right and left main coronary artery

In a normal anatomical textbook, left coronary arteries terminate at the crux of the heart while the right terminate between the crux and the obtuse margin of the heart. The termination at these levels is to ensure optimum anastomosis and collateral circulation experienced at that region which is

meant to support the thicker myocardium towards the apex (Figure 4.4) (Bhele *et al.*, 2017). In the present study, 26%(25) were considered to be variations in the termination of the right coronary artery while on the left main coronary artery 92% were variations (Table 4.8). A study by Ravitheja &Padmavathi (2018) in Spain recorded 43% variations in the termination of the right main coronary artery and 72% variation in the termination of the left coronary artery, variation in termination of the RCA was higher in the previous study while on the LCA was higher in the present study. The ratio in the gender of the study subject that participated in the study was unequal with most of the heart being of old elderly male study specimens which could have caused the variation. Notably, variations in termination may occur due to disturbance in degeneration of the vascular sprouts from the vessel during early development. Depending on when the variations occurred, the termination is highly dependent on the distribution and branching of the coronary artery. It also determines the formation of collateral circulation and anastomosis on different parts of the myocardium. Termination is therefore an important factor in relation to the surgical procedures done to the heart, imaging and cardiac catheterization (Ogeng'o *et al.*, 2014).

Termination of the left main coronary artery also took place between the crux and the obtuse margin of the heart, however on this side, the frequency was lower at 19.5% (12) (Table 4.9). Ogeng'o *et al.*, (2014) recorded 45.5% variation in a study conducted on 208 hearts in Kenya. His study observed the termination pattern of the different branches of the left main coronary artery and not the left main coronary artery alone and just like the present study, he noted that termination of both the right and the left coronary arteries occurred mostly to the left side facilitating anastomosis with the main branches of the 2 main arteries thus ensuring that the left part of the heart is well perfused (Figure 4.4).

5.2: Variation in the dominance of the heart

Dominance of the heart is depicted by the artery that gives rise to the posterior descending artery which supplies the posterior third of the intraventricular septum including the posterior inferior wall of the left ventricle, while its smaller branches supplies the AVN and the SAN (Figure 4.5). The intraventricular septum is important in the electrical conduction of the heart during the cardiac cycle hence the patency of blood vessel supplying it is important. Dominance varies from one individual to the other with right dominance being the highest followed by left then codominance (Maheshwari & Aggarwal, 2017)

However, this may vary depending on the geographical location, ethnicity, nationality among many other factors. Yan *et al.*, (2018) found right dominance to be the highest at approximately 82-89%, followed by left dominance at 5- 12%, and lastly co dominance 3-7%, while Das *et al.*, (2010) reported right dominance to be 70%, left dominance 18.57% and co dominance 11%. The results of the present study showed that 79.2% (57) of the study subjects had right coronary dominance, 12.5% (9) had left dominance while 8.3% (6) had codominance (Table 4.10) (Figure 4.6).

The present study found right dominance to be lower than that of Yan *et al.*, (2018) which was conducted in china among 1654 patients while left dominance and co-dominance were higher than the previous study. As a result, the previous noted that the patients had a positive outcome in both pharmacological and surgical management because of the efficient blood supply to the myocardium and being that the PDA was a direct branch of the right coronary artery. Another study by Das *et al.*, (2010) in India on 70 cadaveric hearts found right dominance to be 70%, while left dominance was 18.57% and co dominance 11%, respectively. In the previous study, right dominance was less than the present study while left and codominance was higher in the previous

study than the current study. Variations like these frequently occur within a community or ethnic group and may be associated with positive or negative outcomes depending on many factors. Ogeng'o *et al.*, (2014) agrees with Fazliogullari *et al.*, (2010) that although majority of the population had right dominance at any particular time, it may be dangerous to the population due to the fact that the amount of blood received by the right coronary artery is less as compared with that received by the left coronary artery and even in right dominance, the left coronary artery still perfuses a considerable portion of the right ventricle (Figure 4.6).

On left dominance, the results of the current study showed that 12.5% of the population had left dominance (Figure 4.6). This is slightly higher what Shahoud *et al.*, (2020) found in his study which was (5-10%). Notably, other studies done have also found consistency in the dominance of the heart with the right dominance being the highest while left and co-dominance being lower (Table 4.10). The current study also found out that the circumflex coronary artery a branch of the left coronary artery was more responsible for the left dominance although there were cases of the PDA originating directly from the left aortic cusps.

This is an advantage to those with left dominance since the left coronary artery receives more than half of the coronary blood meant for the perfusion of the myocardium through the CMx and the PDA while those having orifices directly from the aortic cusps were more advantageous, however, the CMx artery being a branch of the left coronary artery means that the posterior descending artery depends on it, therefore any occlusion of the CMx would alter the amount of blood received by the PDA which would affect the functioning of the posterior intraventricular septum. It is therefore important to note that left dominance could as well be a risk factor to short term mortality and myocardial infarction because of the high risk associated with atherosclerosis on the left coronary artery due to its minimal length (Lakshmiprabha *et al.*, 2018; Kastellanos *et al.*, 2018).

Codominance means that both the right and left coronary arteries equally give rise to the posterior descending artery therefore provide equal blood supply to the posterior intraventricular septum. Das *et al.*, (2010) notes that balanced dominance varies from 0 to 34%. However, the current study reported co-dominance at 8.3% (6) of the total hearts studied (Figure 4.7). The posterior descending artery being produced by both the right and left coronary artery could have some saving effect to the myocardium because in case of stenosis or blockage of either of the major branches there is an alternate pathway for the perfusion of the posterior a third of the intraventricular septum (Shahoud *et al.*, 2020).

In all the hearts with codominance examined in this study, the right coronary artery gave rise directly to the posterior descending artery, while on the left coronary artery the posterior descending artery originates from the left circumflex artery and partially on the left aortic cusps. This is beneficial to the myocardium because if the PDA originates from the circumflex artery which is a major branch of the left coronary artery, the parts supplied by the PDA are assured of efficient blood supply. It can also be a disadvantage because should the circumflex coronary artery be injured or damaged, the left part of the heart could suffer ischaemia and myocardial death (Maheshwari & Aggarwal 2017)

Table 5.1: *Dominance in comparison with other authors*

S/no	Author	Year of Study	Right Dominance (%)	Left Dominance (%)	Co-Dominance (%)
1.	Kalpana et al	2003	89	11	-
2.	Hirak Das	2010	70	18.57	11.43
3.	Maheshwari & Aggarwal,	2017	72.2	8.3	19.5
4.	Khwansang& Chentanez,	2018	88	5	2
5.	Present study	2022	79.2	12.5	8.3

Dominance in comparison with other authors (Maheshwari & Aggarwal 2017)

5.2.1 Association between Gender and variation right coronary artery dominance.

It was observed that females had (29%) incidences of right coronary dominance while males had 28% thus no significant differences. For the left dominance the females had five incidences while males had 4 incidences of coronary dominance. There was also statistical significance between gender and coronary artery dominance at $P \leq 0.0260$ (Table 4.11). A study by Omerbasic (2015) found right dominance at 22% while left dominance at 48%, among these males had more left dominance than females and this agrees with what the present study found (Table 4.11). With the posterior descending artery being a main branch of the right coronary artery, this could be an advantage to the female gender since the delicate parts supplied by the posterior descending artery are assured of efficient blood supply, while their male counterparts who had left dominance could be disadvantaged because of the short length of the left coronary artery and the fact that the posterior descending artery majorly originates from the circumflex coronary artery.

If this artery is injured or damaged, the posterior descending artery will have altered blood supply which can be dangerous to the regions perfused by the blood vessel. Left dominance is also associated with a poor outcome more so in cases where there was left dominance and left coronary stenosis combined (Ogeng'o *et al.*, 2014).

5.3 Correlation between the demographic characteristics and the variations in origin and distribution of the coronary artery.

5.3.1 Correlation between gender and laterality of the respondents.

The present study found no statistically significant difference in the variation of branching of the coronary artery to gender at ($P=0.521$) ($P=<0.05$) (Table 4.12). Therefore, the branching of the right and left coronary artery was not influenced by gender in any way. From the study, there were variations in the branching pattern of the coronary artery with formation of few main branches and

the remaining being sub branches. Both the main and the sub branches had variations in relation to their origin and distribution.

A study done by Javed *et al.*, (2023) mainly on the branching of the left coronary artery and its correlation to gender and age could not find any statistically significant association between gender and the length of the left coronary artery. Different published data from different researchers have given varied results due to difference in technique and the number of cases, however genetics and geographical location have been viewed as a cause of the varied results.

More males had significantly higher left coronary dominance than females. A study by Omerbasic *et al.*, (2015) agrees with the present study on the frequency of the different types of coronary dominance and its relation to gender where right dominance was higher than left and co-dominance in both genders. This was noted to be a predictor for increased morbidity and mortality after cardiac surgery especially among the males. In the present study the left dominance could have presented itself as a risk factor because of the overdependence of the posterior descending artery to the circumflex coronary artery and more so in the female gender who had a higher count of left dominance. Furthermore, with the increasing comorbid conditions like hypertension and diabetes due to poor eating habits and exercise the females could be more exposed to mortality and morbidity associated with coronary artery dominance.

Another study by Den (2020) noted that in both sexes, genes and hormones were important in the functioning of the heart with different cardiovascular diseases presenting differently and at different prevalence. The previous study Dan (2020) noted that the x chromosome was key in the development of inflammation and autoimmune diseases while the y chromosome was key in the inheritance of coronary artery disease. Therefore, sex hormones for both genders could have either positive or negative influence in the functioning of the heart.

With the current increase of non-communicable diseases in Western part of Kenya and the Nyanza region due to poor eating habits and lack of exercise, both genders are exposed to increased variation in dominance of the heart which can also be attributed to the genes and hormones.

5.3.2 Correlation in the length of coronary artery with gender.

In the present study, there was no statistical significant in the correlation between length of the coronary artery to gender at ($P=4.263$) ($P=<0.05$) (Table 4.13). There are few correlation research and data that have been done between gender and ethnicity to the length of the coronary arteries. This means that gender does not influence the length of the coronary artery. The length of these artery is important because it highlight the extent to which the blood vessel can work in case of damage or disease like atherosclerosis leading to partial occlusion of the blood vessel.

It also determines the number, positions and termination of the branches will be formed leading to formation of anastomosis and collateral circulations which are very important. A study by Paul *et al.*, (2018) to determine gender specific difference in coronary artery dimensions found no significant relationship between the dimensions of the coronary artery and gender. Although this is in agreement with the current study, the previous study also found out the relationship between the dimensions and BMI but could relate smaller coronary artery dimensions with an increasing BMI which could be a more predisposing factor to coronary artery diseases and especially among the females.

5.4 Conclusion

1. It was observed that there was variation in the origin branching, length and termination of coronary arteries, however only variation of the branching pattern of the left main coronary artery were the most significant statistically.
2. The right coronary artery dominance was the most common in the total sample population, and there was statistical significance between gender and right heart dominance.
3. Sex hormone were key in the development of heart diseases although there were no statistical significance coronary artery variations and the demographic characteristics.

5.5 Recommendations

1. Early routine imaging of the heart to find out the variants in coronary artery for effective management.
2. Training of health care workers on common variations of coronary arteries to reduce any interventional accidents.
3. Population specific variations such as race and geographic location to be considered for further researches.

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APPENDICES

APPENDIX I: DATA ENTRY FORM

Data sheet number.....

Cadaver details

- a. Code/tag
- b. Gender
- c. Ethnicity

Variation in the origin of coronary artery

Origin of coronary artery	Present	Absent
Dual aortic origin		
1 orifice in the left and 2 orifices in the right aortic cusps		
1 orifice in the left and 3 orifices in the right aortic cusps		
2 orifices in the left aortic cusps		

Variation in the branching pattern of coronary artery

Branch of RCA	Present	Absent
Right conus artery		
Posterior descending artery/PIA		
Branch to SAN		
Branch to AVN		
Acute marginal branch		
Branch of LCA		
Left anterior descending/LAIA		
Circumflex coronary artery		
Ramus branch		
Left conus artery		
Posterior descending artery/PIA		
Left atrioventricular artery		
Obtuse marginal branch		
Diagonal branch.		

Variation in the length of the trunk of the coronary artery

Length of RCA (in cm)	Present	Absent
4-8 cm		
9-13cm		
14-18cm		

Acute marginal branch		
Length of LCA (in mm)		
2-6 mm		
7-11mm		
12-16mm		

Variation in the dominance of the heart

Dominance of the heart	Present	Absent
Right dominance		
Left dominance		
Codominance		

Termination of coronary artery

Termination of RCA	Present	Absent
Between acute margin and crux of the heart.		
At PIS (posterior intraventricular septum)		
Between crux and obtuse margin of the heart		
At obtuse margin of the heart		
Termination of LCA		
At PIS		
At the crux		
Between crux and obtuse margin of the heart		
At obtuse margin of the heart		
Between crux and acute boarder		

APPENDIX III: ETHICAL APPROVAL LETTER



MASENO UNIVERSITY SCIENTIFIC AND ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

REF: MSU/DRPI/MUSERC/01148/22

Date: 3rd November, 2022

TO: Olga Anyango Otieno
MSC/SM/00021/020
Department of Human Anatomy
School of Medicine, Maseno University
P. O. Box, Private Bag, Maseno, Kenya

Dear Madam,

RE: Variations in the Anatomical Origin and Distribution of Coronary Artery among Black African Population: A Cadaveric Study in Western Kenya

This is to inform you that Maseno University Scientific and Ethics Review Committee (MUSERC) has reviewed and approved your above research proposal. Your application approval number is MUSERC/01148/22. The approval period is 3rd November, 2022 – 2nd November, 2023.

This approval is subject to compliance with the following requirements;

- i. Only approved documents including (informed consents, study instruments, MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by Maseno University Scientific and Ethics Review Committee (MUSERC).
- iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours of notification.
- iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours.
- v. Clearance for export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days upon completion of the study to Maseno University Scientific and Ethics Review Committee (MUSERC).

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://oris.nacosti.go.ke> and also obtain other clearances needed.

Yours sincerely


Prof. Philip O. Owuor, PhD, FAAS, FKNAS
Chairman, MUSERC



MASENO UNIVERSITY IS ISO 9001 CERTIFIED



APPENDIX IIIII: MASINDE MULIRO UNIVERSITY APPROVAL LETTER



MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

Tel: +254722815697
E-mail: deanmedicine@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
Kakamega – 50100
Kenya

DEPARTMENT OF HUMAN ANATOMY

DATE; 24th November 2022

TO: Olgah Otieno
Department of Human Anatomy,
PO BOX 3275-40100,
Maseno University,

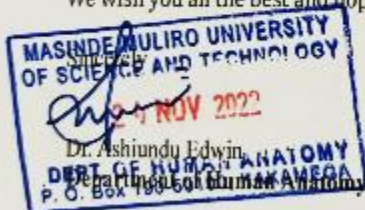
Dear Olgah

SUBJECT: APPROVAL TO COLLECT CADAVERIC DATA

We have considered and noted your application received on 17th November 2022. We are glad to inform you that your request to collect data in this facility has been approved in bid of completing your MSc studies **'Variations in the anatomic origin and distribution of the coronary artery among black African population; A cadaveric study in Western Kenya'**.

Kindly note that your acceptance of this approval letter confirms your compliance with our institutional policies and those of Kenya National Research Ethics Guidelines.

We wish you all the best and hope to receive copy of your final report soon.



APPENDIX IVII: UZIMA UNIVERSITY APPROVAL LETTER



UZIMA UNIVERSITY
SCHOOL OF MEDICINE
DEPARTMENT OF ANATOMY

21st March 2023

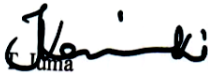
TO: Olgah Otieno
Department of Human Anatomy,
PO BOX 3275-40100,
Maseno University,

Dear Olgah

SUBJECT: APPROVAL TO COLLECT CADAVERIC DATA

Your request to collect data on "**Variations in the anatomic origin and distribution of the coronary artery among black African population; A cadaveric study in Western Kenya**". Has been approved
Kindly ensure all ethical commitments are followed to the later
We wish you all the best and hope to receive copy of your final report soon.


Sincerely


A handwritten signature in black ink, appearing to be 'Juma', written over a printed name 'Juma'.

Department of Human Anatomy

Page 1 of 1


APPENDIX VII: NACOSTI APPROVAL LETTER


REPUBLIC OF KENYA


**NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY & INNOVATION**

Ref No: **856160** Date of Issue: **08/December/2022**

RESEARCH LICENSE




This is to Certify that Ms. Olgah Anyango Otieno of Maseno University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kakamega, Kisumu on the topic: Variations in the Anatomical Origin and distribution of the Coronary artery: A Cadaveric Study in Western Kenya for the period ending : 08/December/2023.

License No: **NACOSTI/P/22/21905**

856160
Applicant Identification Number

Walter M...
Director General
**NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY &
INNOVATION**

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See overleaf for conditions

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013 (Rev. 2014)
Legal Notice No. 108: The Science, Technology and Innovation (Research Licensing) Regulations, 2014

The National Commission for Science, Technology and Innovation, hereafter referred to as the Commission, was established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

CONDITIONS OF THE RESEARCH LICENSE

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way:
 - i. Endanger national security
 - ii. Adversely affect the lives of Kenyans
 - iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
 - iv. Result in exploitation of intellectual property rights of communities in Kenya
 - v. Adversely affect the environment
 - vi. Adversely affect the rights of communities
 - vii. Endanger public safety and national cohesion
 - viii. Plagiarize someone else's work
3. The License is valid for the proposed research, location and specified period.
4. The license any rights thereunder are non-transferable
5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
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10. The Licensee shall submit one hard copy, and upload a soft copy of their final report (thesis) onto a platform designated by the Commission within one year of completion of the research.
11. The Commission reserves the right to modify the conditions of the License including cancellation without prior notice.
12. Research, findings and information regarding research systems shall be stored or disseminated, utilized or applied in such a manner as may be prescribed by the Commission from time to time.
13. The Licensee shall disclose to the Commission, the relevant Institutional Scientific and Ethical Review Committee, and the relevant national agencies any inventions and discoveries that are of National strategic importance.
14. The Commission shall have powers to acquire from any person the right in, or to, any scientific innovation, invention or patent of strategic importance to the country.
15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

National Commission for Science, Technology and
Innovation(NACOSTI),
Off Waiyaki Way, Upper Kabete,
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APPENDIX VIII: RAW DATA

Statistics

		RCA brancing at RCA	RCA- posterior descending artery/PIA	RCA- Branching to SAN	RCA- branching to AVN	RCA-acute marginal branch
N	Valid	72	72	72	72	72
	Missing	0	0	0	0	0
Mean		1.1667	1.0556	1.0000	1.0000	1.0000
Median		1.0000	1.0000	1.0000	1.0000	1.0000
Mode		1.00	1.00	1.00	1.00	1.00

RCA brancing at RCA

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid present	60	83.3	83.3	83.3
absent	12	16.7	16.7	100.0
Total	72	100.0	100.0	

RCA-posterior descending artery/PIA

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid present	57	79.2	79.2	79.2
absent	15	20.8	20.8	100.0
Total	72	100.0	100.0	

gender of the respondent * Ethnicity of the respondents Cross tabulation								
Count								
		Ethnicity of the respondents						Total
		Luo	kalenji n	Luhya	kikuyu	kisii	Kuria	
gender of the respondent	male	18	0	11	2	3	2	36
	female	21	2	10	1	2	0	36
Total		39	2	21	3	5	2	72