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ORIGIN, COURSE AND VARIATIONS OF CORONARY ARTERIES IN POSTMORTEM CASES AT THE UNIVERSITY TEACHING HOSPITAL,LUSAKA, ZAMBIA.

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ABSTRACT

ORIGIN, COURSE AND VARIATIONS OF CORONARY ARTERIES IN POSTMORTEM CASES AT THE UNIVERSITY TEACHING HOSPITAL (UTH), LUSAKA, ZAMBIA.

Background: Coronary arteries play an important role in supplying blood to the muscular walls and tissues of the heart. With increase in the rate of cardiovascular diseases, knowledge of the normal and variant anatomy of coronary arteries is indispensable and imperative both in diagnosis, treatment and implementation of interventional measures. An anatomical understanding of the possible coronary artery anomalies is essential for accurate angiographic interpretation and also for cardiologists performing cardiac surgery. The aim of this study was to describe the origin, course and variations of coronary arteries in post-mortem cases at the University Teaching Hospital in Lusaka, Zambia.

Materials and methods: The study design used was a descriptive cross-sectional study in which 127 human hearts from post-mortem cases were dissected and examined. The hearts were obtained from cases of ages between 17 and 86 years and of the 127, 96 were males and 31 females. The costochondral joints were cut to remove the sternum and the cartilage part of the ribs. The aortic sinuses of the ascending aorta were all examined for presence coronary ostia and an incision made through the non-coronary aortic sinus to enable visualisation of the coronary ostia which are origins of coronary arteries in the aortic sinuses. Measurements of the width and height of coronary ostia were taken using a digital vernier caliper. The hearts were examined grossly and dissected to follow the coronary arteries in their subepicardial course.

Results: The age ranged between 17 and 86 years. Out of the 127 hearts, the left coronary artery (LCA) arose from : the left aortic sinus (LAS) in 90 (70.9 %) hearts, the sinutubular junction (STJ) in 33 (25.9 %) hearts, a common trunk with right coronary artery (RCA) whose ostium was located in the right aortic sinus (RAS) in 1 (0.8 %) heart, a common ostium with the RCA in tubular part of ascending aorta above the RAS in 1 (0.8 %) heart, the RAS in 1 (0.8 %) heart. The left main coronary artery (LMCA) was absent in 1 (0.8 %) heart. The right coronary artery arose from: the RAS in 97 (76.4%) hearts, the STJ in 25 (19.7 %) hearts, the LAS in

2 (1.6 %) hearts, a common ostium with the LCA in tubular part of ascending aorta above the RAS 1(0.8%) heart, a common trunk with LCA whose ostium was located in RAS in 1 (0.8 %) heart and STJ of LAS 1 (0.8%) heart. Six (6) (4.72%) hearts out of the 127 had coronary artery anomaly/variations in origin and course of the main trunk right and left coronary arteries. Of the six (6) hearts with coronary artery anomalies only one (1) was from a female and the five (5) from males.

The left coronary ostium width range was 1.6 – 7.9 mm with a mean of 4.62 (± 1.104) mm whilst the left coronary ostium height range was 1.5 – 4.9 mm with a mean of 2.64 (± 0.719) mm. The right coronary ostium width range was 1.6 – 9.6 mm with a mean of 3.66 (± 1.40) mm whilst the right coronary ostium height range was 1.1 – 4.9 mm with a mean of 2.27 (± 0.72) mm. The mean cross sectional areas of the left and right coronary ostia were found to be 9.70 mm^2 and 6.99 mm^2 respectively and when compared using t-test and the left coronary ostium was found to be significantly larger p-value 0.000000000 ($p < 0.05$).

Conclusion: The location of coronary ostia (origin of coronary arteries) were described and seen that the majority of the coronary ostia were located in their respective aortic sinuses. Coronary ostia dimensions i.e. width, length and cross sectional area were analysed and seen that the left coronary ostium is significantly larger than the right coronary ostium (p-value 0.000). Incidence of coronary artery anomalies/variations of origin and further course was found to be 4.72% (6/127 hearts).

DEDICATION

To my family.

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DEFINITIONS OF TERMS USED

Anastomosis means a direct or indirect connection of separate parts of a branching system to form a network, especially among blood vessels.

Anomaly refers to an abnormality or aberration from common finding of an anatomic structure.

Aortic root refers to the section of the aorta closest to and attached to the heart and consists of the aortic valve and the openings for the coronary arteries.

Aortic sinus refers to the dilatation of the aortic lumen at the level of each of the three aortic valvular cusps.

Autopsy/Postmortem refers to inspection and dissection of a body after death in order to determine the cause of death.

Cadaver: A dead human body that may be used by physicians and other scientists to study anatomy identify disease sites and determine causes of death.

Cardiovasculardiseases refers to a group of conditions that affect the circulation of blood to the heart, causing limited or no blood flow to affected areas of the heart.

Coronary ostia refer to either of the two openings in the aortic sinuses that mark the origins of the left and right coronary arteries.

Crux of the heart (from Latin "**crux**" meaning "cross") is the area on the posterior surface of the heart where the coronary sulcus (the groove separating the atria from the ventricles) and the posterior interventricular sulcus (the groove separating the left from the right ventricle) meet.

Ellipse refers to the type of shape in which the major and minor axes are diameters (lines through the centre) of the ellipse. The major axis is the longest diameter and the minor axis the shortest. If they are equal in dimensions then the ellipse is a circle.

Sinutubular junction refers to the region of the ascending aorta between the aortic sinuses (of Valsalva) and where the normal tubular configuration of the aorta is attained.

Variations means a difference or deviation (e.g. in structure, form, function) from the recognised norm or standard.

ACRONYMS AND ABBREVIATIONS

ERES	Excellence in Research Ethics and Science
UNZA	University of Zambia
UTH	University Teaching Hospital
CCA	Congenital Coronary Anomalies
CAA	Coronary Artery Anomalies
CVD	Cardiovascular Disease
MDCTA	Multi Detector Computed Tomography Angiography
CAG	Coronary Angiography
RAS	Right Aortic Sinus
LAS	Left Aortic Sinus
STJ	Sinu-tubular Junction
RC	Right Coronary Artery
LC	Left Coronary Artery
LMCA	Left Main Coronary Artery
LAD	Left Anterior Descending
CX	Circumflex artery
PIV	Posterior Interventricular Artery
RM	Ramus medianus
USA	United States of America
SPSS	Statistical Packages for Social Sciences

CHAPTER ONE

INTRODUCTION

The heart is an important organ that pumps blood into the pulmonary and systemic circulations. Through its action of pumping blood into arteries, capillaries and veins it ensures that the body organs such as the brain, kidneys are adequately supplied with oxygen and nutrient rich blood vital for these organs to adequately perform their functions. For the heart muscle to be able to pump blood it also must have adequate blood supply (Scanlon and Sanders, 2007). Blood supply to the muscle of the heart is by the coronary arteries. The right and left coronary arteries arise from the ascending aorta in its right aortic and left aortic sinuses respectively (Agur and Dalley, 2013). Although the heart is filled with blood, the heart walls are too thick to obtain much nutrition by diffusion from the contained blood (Marieb *et al*, 2012).

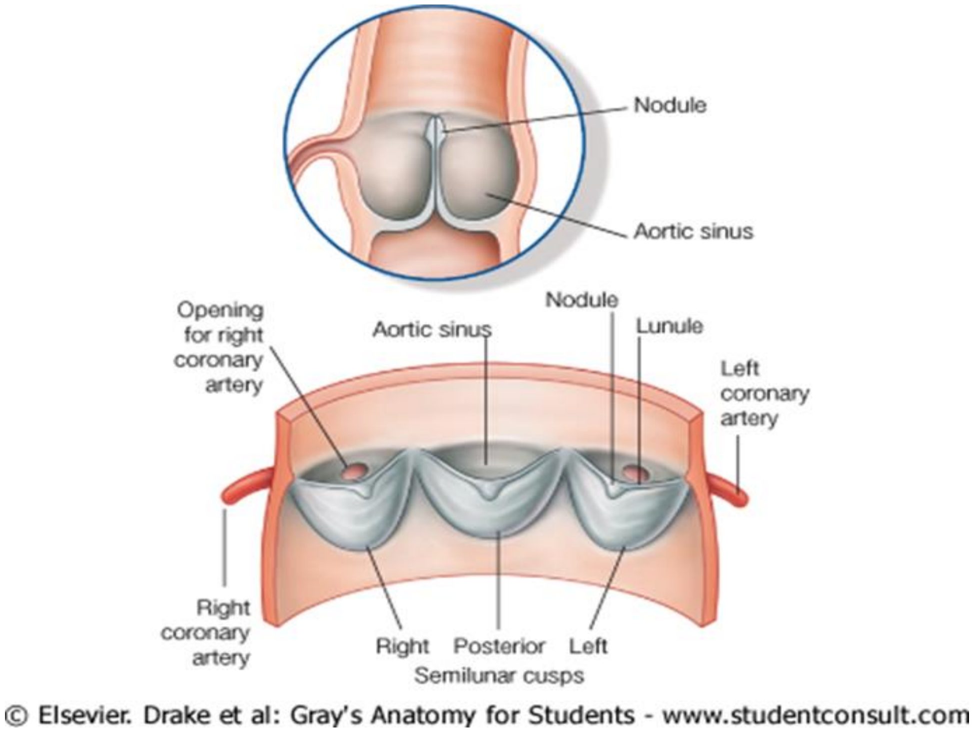

Figure 1: Anterior view of aortic valve (Drake et al, 2009)

The origins of these arteries can vary significantly in relation to the sinutubular junction, and also in their proximity to the zones of apposition between the valvular leaflets, the so-called commissures (Muriago *et al*, 1997). The right coronary artery passes at first anteriorly and slightly to the right between the right auricle and pulmonary trunk, where the sinus usually bulges. It reaches the atrioventricular groove and descends in this almost vertically to the right (acute) cardiac border, curving around it into the posterior part of the groove, where the latter approaches its junction with both interatrial and interventricular grooves, a region appropriately termed the crux of the heart. The artery reaches the crux and ends a little to the left of it, often by anastomosing with the circumflex branch of the left coronary artery (Standring, 2008).

The left coronary artery originates from the left aortic sinus of the ascending aorta and passes between the pulmonary trunk and the left auricle before entering the coronary sulcus. While still posterior to the pulmonary trunk, the artery divides into its two terminal branches, the anterior interventricular and the circumflex arteries. The anterior interventricular branch (left anterior descending artery-LAD) continues around the left side of the pulmonary trunk and descends obliquely toward the apex of the heart in the anterior interventricular sulcus. During its course, one or two large diagonal branches may arise and descend diagonally across the anterior surface of the left ventricle. The circumflex branch courses toward the left, in the coronary sulcus and onto the base of the heart, and usually ends before reaching the posterior interventricular sulcus. A large branch, the left marginal artery, usually arises from it and continues across the rounded obtuse margin of the heart (Drake *et al,* 2007).

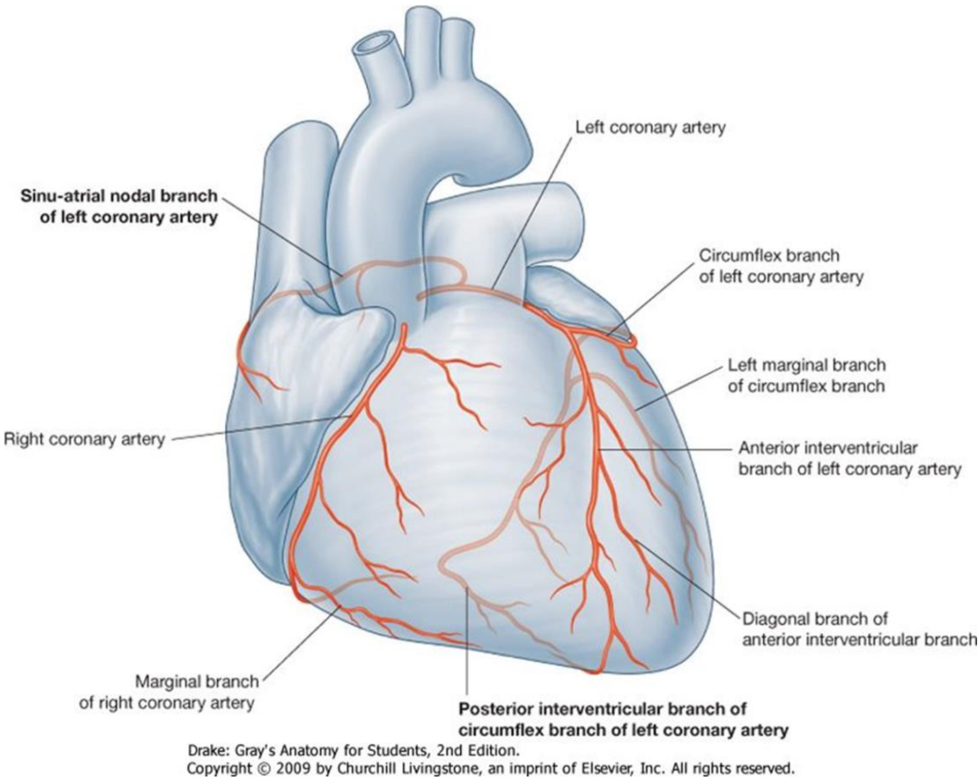

Figure 2: Coronary arteries in a left dominant heart (Drake et al, 2009)

Anatomic variations in the origin and course of the coronary arteries in otherwise normal hearts are rare, with the incidence of such variations assessed at 0.3% in a necropsy series reported by Alexander and Griffith (1956), and 1.6% in a large series of patients undergoing coronary arterial angiography (Loukas *et al,* 2009). Although these anomalies are rare, they may have haemodynamic consequences, carry a high risk for accelerated atherosclerosis, or produce symptoms varying from dyspnoea to sudden death. The milder variations can escape detection not only during life, but also at post-mortem examination (Hauser, 2005). The incidence of coronary artery anomalies (CAAs) varies from 0.2% to 8.4%. Knowledge of such anatomical variations is of importance as coronary artery procedures are increasingly being performed in hospitals (Altin *et al,* 2014).

This study described the coronary artery origin (ostia: location, number, size, course or pattern of distribution and their anomalies. Coronary artery ostia (roots) are vital since it is through these ostia that the blood enters the coronary circulation to supply the heart muscle. Therefore any disturbances or alterations in size (luminal diameter), number and location of these coronary ostia may compromise or interfere with the amount of blood reaching the heart muscle. The dimensions of coronary ostia for each heart were compared and course of these coronary arteries were also be described and compared with what is in anatomy literature.

1.1 Statement of the problem

Coronary artery disease (CAD) is the leading cause of cardiovascular mortality worldwide, with 4.5 million deaths occurring in the developing world (Okrainec *et al,* 2004). The burden of non-communicable diseases such as stroke and cardiovascular disease is increasing in Sub-Saharan Africa. Their development is most likely caused by the interaction of multiple genetic factors and known risk factors (hypertension, diabetes, dyslipidaemia and smoking). Specific polymorphisms in genes have been implicated in various complex disorders including cerebrovascular disease (CVD), coronary artery disease (CAD) and Alzheimer's disease (AD) (Atadzhanov *et al,* 2014).

As a result of life style changes the rate of coronary-artery-related diseases is on the increase. The anatomy of coronary artery has recently been re-emphasized in association with the use of coronary arteriography. The advances made in coronary arterial bypass surgeries and modern methods of myocardial revascularisation make sound and complete knowledge of the normal and variant anatomy of coronary artery indispensable and imperative. Thus the variant cardiac anatomy is of paramount importance for proper understanding and management of cardiac diseases (Singh, 2013).

There has never been a study done in Zambia on origin, course and variations coronary arteries. Several research on coronary arteries have been conducted around the world of which most health professionals in Zambia utilise. Our study was undertaken to document the anatomy of coronary arteries using post-mortem cases at the University Teaching Hospital.

The study intended to document location, size (luminal or internal dimensions) of coronary artery ostia and the course and distribution of the coronary arteries and compare with what is in literature and also determine the frequency of coronary artery anomalies in post-mortem cases. Having a greater body of knowledge on an individual patient's coronary anatomy will help researchers and medical personnel better develop and implement coronary therapies and devices.

1.2 Significance of study

Knowledge of coronary circulation and branching pattern is essential for the understanding of myocardial perfusion (Aharinejad *et al*,1998). Experience of those treating patients with atherosclerosis, ischemic heart disease and congenital cardiac malformations have demonstrated the value of this knowledge in ensuring optimal treatments (Loukas *et al*, 2009). Loukas et al (2009) further say that a comprehensive appreciation of the architecture of the coronary arterial system is crucial to optimal cardiac care. Beneficial therapeutic options are increasingly available for coronary artery disease. To take full advantage of these options, those performing the interventions require a thorough knowledge of the normal pattern, and possible anatomic variations of the coronary arterial system. A comprehensive appreciation of the architecture of the coronary arterial system, therefore, is crucial to optimal cardiac care. Simple attention to potential variations in the origin and course of the major coronary arteries can greatly enhance clinical outcomes (Loukas *et al*, 2009). An anatomical understanding of human coronary arterial and venous systems is necessary for device development and therapy applications that utilize these vessels. Recognition of the coronary anomalies is needed to ensure accurate angiographic interpretation and is important for patients undergoing cardiac surgery (Kardos *et al*, 1997).

Knowledge of coronary circulation is not only important for anatomists but a9y-h9ylso for radiologists and cardiologists performing angiographies and shunt surgeries, in diagnosis and treatment of congenital, inflammatory, metabolic and degenerative diseases involving the coronary arteries (Mamatha and Sridhar, 2014).

1.3 Research questions

What are the origins, course or pattern of distribution and variations in coronary arteries in post-mortem cases in post-mortem cases at UTH?

What are the dimensions (width and height) and location of the coronary artery ostia in post-mortem cases at UTH?

1.4 General objective

To describe the anatomical origin (coronary ostia), course and variations of the coronary arteries in post-mortem cases at the University Teaching Hospital (UTH).

1.4.1 Specific objectives

1. to describe the anatomical origin (ostia) and course of the coronary arteries
2. to determine the size (width and height) of coronary artery ostia in each heart
3. to compare the cross sectional area of the two coronary ostia in each heart
4. to describe the variations in origin (location of coronary ostium) and course of the coronary arteries

CHAPTER TWO
LITERATURE REVIEW

The anatomy of the coronary arterial and venous systems have been individually investigated in depth in the literature. To summarize, the coronary arteries provide the myocardium with oxygen-rich blood and nutrients while the cardiac veins drain the blood back to the chambers of the heart mainly via the coronary sinus (Spencer *et al,* 2014).

The calibre of coronary arteries, both main stems and larger branches, based on measurements of arterial casts or angiograms, ranges between 1.5 and 5.5 mm for the coronary arteries at their origins. The left exceed the right in 60% of hearts, the right being larger in 17%, and both vessels being approximately equal in 23%. The diameters of the coronary arteries may increase up to the 30th year of life (Standring, 2008).

The left coronary artery is larger in calibre than the right, and supplies a greater volume of myocardium, including almost all the left ventricle and atrium, except in so-called ‘right dominance', when the right coronary artery partly supplies a posterior region of the left ventricle. The left coronary artery usually supplies most of the interventricular septum. It arises from the left posterior (left ‘coronary') aortic sinus; the ostium is below the margin of the cusps in 15%, and may be double, leading into major initial branches, usually the circumflex and anterior interventricular (descending) arteries. Its initial portion, between its ostium and its first branches, varies in length from a few millimetres to a few centimetres. The artery lies between the pulmonary trunk and the left atrial auricle, emerging into the atrioventricular groove, in which it turns left. This part is loosely embedded in subepicardial fat and usually has no branches, but may give off a small atrial ramus and, rarely, the sinuatrial nodal artery. In the atrioventricular groove, the left coronary divides into two or three main branches: the anterior interventricular artery is commonly described as its continuation and the circumflex artery from which arises the left marginal artery when present (Standring, 2008).

The right coronary artery arises from the anterior right aortic sinus: the ostium is below the margin of the cusps in 10%. The artery is usually single, but as many as four right coronary arteries have been observed (Standring, 2008). It passes at first anteriorly and slightly to the right between the right auricle and pulmonary trunk, where the sinus usually bulges. It reaches the atrioventricular groove and descends in this almost vertically to the right (acute) cardiac border, curving around it into the posterior part of the groove, where the latter approaches its junction with both interatrial and interventricular grooves, a region appropriately termed the crux of the heart. The artery reaches the crux and ends a little to the left of it, often by anastomosing with the circumflex branch of the left coronary artery. In a minority of individuals, the right coronary artery ends near the right cardiac border (10%), or between this and the crux (10%); more often (20%) it reaches the left border, replacing part of the circumflex artery. Branches of the right coronary supply the right atrium and ventricle and, variably, parts of the left chambers and atrioventricular septum (Standring, 2008).

Normally the left coronary artery arises from the left aortic sinus of Valsalva and the right coronary artery from the right aortic sinus. Either or both of the right and left coronary arteries may arise from another aortic sinus, from the pulmonary trunk, or as an anomalous branch of another coronary artery (Waller *et al,* 1992). The absence of either the right or the left coronary ostium is a rare coronary artery anomaly, occurring in 0.6–1.6% of all cases diagnosed by cardiac catheterization (Papadopoulos *et al,* 2006). Coronary artery anomalies, especially variations in the level of origin, are frequent. Pieggar et al (2001) reported a case in which the right coronary artery arose from the ascending aorta 38 mm above the supravalvular ridge. In most cases, the origin lies just a few millimetres superior to the supravalvular ridge; ectopic origins of more than one centimetre above this border are rare (Pieggar*et al*, 2001). Coronary arteries originating in the wrong sinus of Valsalva constitutes the group of coronary artery anomalies (CAA) most commonly associated with myocardial ischemia and, in particular, with sudden death (Barriales-Villa and De la Tassab, 2006). Anomalous origins of the coronary arteries often cause heart disease in young patients and increase the risk of sudden death during physical exertion (Frescura *et al*, 1998).

A study was done by Nerantzis et al (1996) in which they injected radiopaque medium in 200 human hearts and studied them by direct observation and x-ray analysis. The right coronary artery (RC) was dominant in 178 of these hearts as characterised by giving off the typical posterior interventricular artery (PIV), the posterior descending artery. Within this group, 19 specimens had right coronary arteries that gave off both a large posterior interventricular artery (LPIV) and a branch that continued beyond the crux termed a large extension of the right coronary (LERC). The subgroup of hearts supplied thusly was termed real right dominant (RRD). The RC in these hearts supplied the right ventricle and almost half of the left ventricle. Their findings explain why proximal lesions of the RC in RRD hearts can be associated with extensive posterolateral ischemia and mitral dysfunction and should be of practical importance when considering angioplasty or by-pass surgery. The diameters and lengths of the arteries of the RC in RRD hearts were measured and compared with the same parameters in typical right dominant hearts. Their findings explain why in some lesions of the RC there is extensive ischemia and associated severe mitral dysfunction. Furthermore, surgeons and interventional cardiologists should appreciate the clinical significance of this RC variant.

Aharinejad et al (1998) analysed experimental data on branching geometry of coronary arteries. In their study, four specimens of arterial trees with diameters of less than approximately 200 µm were morphometrically analysed by using corrosion casts of human coronary arteries. Diameters and lengths of individual vessel segments were determined based on data obtained by scanning electron microscopy (SEM) of casts. On the one hand, this approach facilitated the classic description of global tree properties in terms of diameters, lengths and their derived quantities. On the other hand, bifurcations and paths connecting the root with peripheral segments could be individually traced and statistically analysed to globally characterize the structure of a whole tree. In detail, global quantities (such as sum of segmental lengths, total surface and volume of each tree) were calculated fromsingle segment measurements. The connective structure of the branching pattern was represented by the branching ratio, area expansion ratio and path analysis.

Kardos et al (1997) carried out a study on the anatomical patterns and frequency of occurrence of congenital coronary anomalies (CCA) in a Central European population in Hungary. The angiographic data of 7,694 consecutive patients undergoing coronary arteriography at the Albert Szent-Gyorgyi Medical University, Szeged, Hungary, from 1984 to 1994 were analysed. CCA were found in 103 patients (1.34% incidence). Ninety-eight of them (95.2%) had anomalies of origin and distribution, and five (4.8%) had coronary artery fistulae. The incidence was the highest for the separate origin of left descending artery and left circumflex from the left sinus of Valsalva (52.42%). Anomalous origin of the left circumflex coronary artery from the right coronary was 8.7% while from the right sinus of Valsalva 18.4%. CCA, which may be associated with potentially serious events, such as ectopic coronary origin from the opposite aortic sinus (1.9%) and single coronary arteries (3.88%), were not frequent. The incidence of CCA in the Central European cohort under study was similar to that of the largest North American study. The anatomic classification presented can be useful from both clinical and surgical standpoints.

A study was done in the United States of America at the University of Florida by Von Ziegler et al (2009) in which their aim was to investigate the prevalence of anomalous origin and course of coronary arteries in consecutive symptomatic patients, who underwent cardiac 64-slice multi-detector-row computed tomography angiography (MDCTA). Imaging datasets of 748 consecutive symptomatic patients referred for cardiac MDCTA were analysed and CAAs of origin and further vessel course were grouped according to a recently suggested classification scheme by Angelini et al. An overall of 17/748 patients (2.3%) showed CAA of origin and further vessel course. According to aforementioned classification scheme no Subgroup 1- (absent left main trunk) and Subgroup 2- (anomalous location of coronary ostium within aortic root or near proper aortic sinus of Valsalva) CAA were found. Subgroup 3 (anomalous location of coronary ostium outside normal "coronary" aortic sinuses) consisted of one patient with high anterior origin of both coronary arteries. The remaining 16 patients showed a coronary ostium at improper sinus (Subgroup 4). Latter group was subdivided into a right coronary artery arising from left anterior sinus with separate ostium (subgroup 4a; n = 7) and common ostium with left main coronary artery (subgroup 4b; n = 1). Subgroup 4c consisted of one patient with a single coronary artery arising from the right anterior sinus (RAS) without left circumflex coronary artery (LCX). In subgroup 4d, LCX arose from RAS (n = 7). They concluded that prevalence of CAA of origin and further vessel course in a symptomatic consecutive patient population was similar to large angiographic series, although these patients did not reflect general population. However, their study also supported the use of 64-slice MDCTA for the identification and definition of CAA.

In Grenada, North America, Loukas et al (2009) in a review article on the normal and abnormal anatomy of the coronary arteries discussed anomalous sinus origin, right coronary artery arising from sinus 2 (left aortic sinus), main stem of left coronary artery arising from sinus 1(right aortic sinus), circumflex artery arising from sinus 1, anterior interventricular artery arising from sinus 1, ectopic origin of coronary artery from: pulmonary trunk, right pulmonary artery, left pulmonary artery, brachiocephalic artery. Solitary coronary artery, abnormal distal connections (Fistulas): connections with a cardiac cavity, coronary arteriovenous fistulas, coronary to extra-cardiac arterial or venous connections. Miscellaneous anomalies of intrinsic anatomy: myocardial bridging and duplication of coronary arteries.

In Japan, Ishizawa et al (2006) carried out dissection courses from 1999 through to 2003 in which five specimens were found to have coronary arteries with variant roots and branches, as follows: in specimens 1–4, roots of the right coronary artery (RCA) and right conus branch arose independently from the right aortic sinus (RAS); in specimen 5, the RCA and left coronary artery (LCA) originated from the RAS. The LCA pierced the upper part of the muscular interventricular septum and appeared on the surface, then dividing into the anterior interventricular and the circumflex branches. They considered that the right conus arteries in specimens 1– 4 werethe remnant blood capillaries around the aorta towards the RAS in the embryonic stage. In specimen 5, thevessel near the left aortic sinus was poorly developed as a small thin artery. Instead, the LCA developed from the anterior and posterior interventricular septal branches.

In Turkey, Altin et al (2014) carried out a study aimed to find the coronary dominance pattern, intermediate artery (IMA) frequency and coronary artery anomalies (CAA) incidence in their clinic and compare them to those in the literature. The medical reports of 5,548 patients who had undergone coronary angiography (CAG) between 2005-2009 were retrospectively investigated. Dominance pattern, presence of IMA and CAA were recorded. CAAs were described using two different classifications: Angelini and Khatami's classification, and a new modified classification that was derived from Angelini and Khatami's classification. Some procedural details and clinical features of the patients with CAA were also investigated. Coronary dominance pattern was: 81.6% right coronary artery, 12.2% circumflex artery and 6.2% co-dominant. IMA was present in 613 (11.0%) patients. The incidences of overall anomaly were 2.7% and 1.4%, according to the different classifications. Absent left main coronary artery, which was the most common anomaly in the study, was found in 51 (0.9%) patients. Incidences of myocardial bridge, coronary arteriovenous fistulas and aneurysms were 1.1%, 0.2% and 0.3%, respectively. CAAs are generally asymptomatic, isolated lesions. Some may lead to anginal symptoms, myocardial infarction or sudden death. They found that CAA were associated with increased radiation and contrast exposure in patients who underwent CAG. This risk could be reduced if appropriate catheters were designed and training programmes on ostial cannulation were developed.

In South Africa a study was done by Ajayi et al (2014) on coronary artery anomaly of origin in which there is absence of the left main coronary artery (LMCA), where the left anterior descending (LAD), the circumflex (Cx) and the ramus medianus (RM) (when present) arteries originate directly from the left aortic sinus. The study aimed to document the prevalence of absent LMCA, discuss its possible embryogenesis and clinical relevance. A review of 407 coronary angiograms performed by cardiologists of three private hospitals in the Thekwini Municipality area of KwaZulu-Natal, South Africa, was performed. The LMCA was absent in 9.6% (39/407) of the coronary angiograms. The LAD and Cx arteries originated directly from the left aortic sinus with a single ostium in 8.6% (35/407) and separate ostia in 1% (4/407) of the angiograms. In four of the angiograms with absent LMCA, a RM artery was recorded originating directly from the left aortic sinus in additionto the LAD and the Cx arteries. Angiographic detection of the anomalies of the coronary arteries is essential in the determination of the significance of such findings and their management.

A minority of CAA, primarily due to an interarterial course, is clinically significant, and may present with symptoms of myocardial ischemia, malignant ventricular arrhythmias, and even sudden cardiac death. Until recently, CAA were primarily detected at catheter coronary angiography. With recent advances in multi-detector computed tomography (CT) technology and the use of electrocardiographic gating, coronary CT angiography provides an exquisite omni-dimensional display of the anomalous coronary arteries and their relation to the adjacent structures noninvasively, and is the diagnostic test of choice. Understanding CAA morphology and clinical significance of CAA is important for establishing a diagnosis, and is essential for appropriate patient management and treatment planning (Sundaram *et al*, 2010).

In Sub-sahara region of which Zambia is part of, cardiovascular disease is on the rise (Atadzhanov *et al*, 2014; Okrainec *et al*, 2004). For adequate treatment of the various conditions affecting the coronary vasculature and in turn cardiac perfusion, a sound anatomical knowledge of the coronary arteries is imperative. This study will investigate the coronary artery origins (ostia : size, number and location) and course in post-mortem cases at the University Teaching Hospital, Lusaka and compare them with what is in literature. From the cited articles, it can be seen that the incidence of coronary artery anomalies ranges from 0.2 to 8.6 % in studies done in different countries around the world and anomalies of coronary ostia number and location are the most common.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Study design

A descriptive cross-sectional study was used in this study.

3.2 Study setting

This study was conducted between September 2015 and February 2016 in the Department of Pathology at the University Teaching Hospital (UTH), Lusaka, Zambia. The site was selected purposely because of the convenience and ease of access to facilities.

3.3 Target and Study population

The target population included all post-mortem cases at UTH autopsy room during the time of the study.

3.4 Study sample

Post-mortem cases: Forensic and clinical cases.

3.4.1 Inclusion criteria

- Hearts used were from adults (16 years and above).
- Hearts with no evidence of significant damage.

3.4.2 Exclusion criteria

- Children (less than 16 years).
- Damaged and diseased hearts with significant arterial lesions interfering with coronary artery origin and course.

3.5 Sample size calculation

$$N = \frac{Z^2 \times P\,(1-P)}{(E)^2}$$

N = Sample required

Z = Z statistic for a given level of confidence = 1.96 when using a 95% CI

P = expected prevalence of the condition in the population being studied;

prevalence of coronary artery anomalies worldwide range 0.2 to 8.6%.

E = confidence interval, 0.05 (+/- 5%)

$$N = \frac{1.96^2 \times 0.086\,(1-0.086)}{(0.05)^2}$$

= 120.786

= 121

3.6 Data management

3.6.1 Data collection

Data was collected and recorded on the data collection sheet. The code number, age, sex, cause of death, coronary ostia size (width and length), location (origin) of coronary ostia (e.g. aortic sinus, sinutubular junction, tubular part of ascending aorta and other ectopic ostia origins) and name of variant coronary artery were recorded.

3.6.2 Data collection tool

Dissection kit was used during dissection and the measurements of the coronary ostium were taken using a digital Vernier caliper. Two measurements of each dimension i.e. width and height of coronary ostia were taken and the average was then recorded on a data collection sheet.

3.6.3 Data collection technique

The costochondral joints were cut to remove the sternum and the cartilage part of the ribs. An incision was made on pericardium to expose the heart and the great vessels were cut in order to free and remove the heart. The aortic sinuses of the ascending aorta were all examined for presence coronary ostia and an incision made through the non-coronary aortic sinus to enable visualisation of the coronary ostia which are origins of coronary arteries in the aortic sinuses. Measurements of the width and height of coronary ostia were taken using a digital vernier caliper and were made as close as possible to right angles to each other. The major axis of the ellipsoidal (oval) coronary ostium was taken as the width and the minor axis as the height. During measurement of the coronary ostia, the height of the coronary ostium was measured at half the dimension of the width of the coronary ostium. The hearts were examined grossly and dissected to follow the coronary arteries in their subepicardial course. The heart was then put back in its correct location in the thorax and the midline incision made was sutured. The body of the deceased was treated with all respect a human being is supposed to be accorded.

3.6.4 Data analysis

Following data collection, the pre-coded data information sheet was double checked daily for completeness, consistency, legibility and accuracy. Numerical codes were used on the data collection sheet. The data collected was entered and stored into the data editor of IBM SPSS and statistically analysed using IBM SPSS (Statistical Package for Social Sciences-Basic and Advanced Statistics) for Windows Version 20.0 (IBM Corp. Armonk, NY, and USA). Descriptive statistics of the data were obtained. The cross sectional areas of the coronary ostia were calculated using the formula of area for an ellipse for oval ostia and area of a circle for circular ostia. The independent variable are the two coronary ostia which are dichotomous data and the dependent variable are the cross sectional areas of the coronary artery ostia which are continuous data therefore the t-test (paired sample means) was used to investigate whether there are significant differences at 95% confidence interval between the ostia of the coronary arteries in same heart. Values of P <0.05 were considered to be significant. Coronary artery anomalies/variations in origin and distribution/course were recorded.

3.7 Ethical Considerations

The approval to carry out the study was sought from the Excellence in Research Ethics and science (ERES) and the Director, Directorate of Research and Postgraduate studies. Permission to conduct the study was obtained from the Senior

Medical Superintendent of UTH and the Head of the Department of Pathology at UTH. Dissection of the heart was done during the post-mortem procedure or rather as part of the post-mortem. The hearts were then put back in the thorax after the dissection.There was confidentiality and no names or any form of identification appeared on the data information sheet.

CHAPTER FOUR

RESULTS

The research findings were presented in frequency tables and figures.

Table 4.1: Demographic Characteristics of Data

	Frequency	Percent	Valid percent	Cumulative percent
F	31	24.4	24.4	24.4
M	96	75.6	75.6	100.0
Total	127	100.0	100.0	

Table 4.1 shows that 31 (24.4%) were females and 96 (75.6%) were males.

Table 4.2:Location of Left Coronary Ostium

	Frequency	Percent	Valid percent	Cumulative percent
Absent	1	0.8	0.8	1.6
CO RAS	1	0.8	0.8	2.4
CO TPAA ABV RAS	1	0.8	0.8	3.1
LAS	90	70.9	70.9	73.2
RAS	1	0.8	0.8	74.0
STJ LAS	33	25.2	25.2	100
Total	127	100.0	100.0	

RAS – Right aortic sinus, LAS – Left aortic sinus, STJ – Sinutubular junction
CO TPAA ABV RAS – Common ostium in tubular part of ascending aorta above RAS, CO – Common ostium.

Table 4.3: Location of Right Coronary Ostium

	Frequency	Percent	Valid percent	Cumulative percent
STJ LAS	1	0.8	0.8	0.8
CO RAS	1	0.8	0.8	1.6
CO TPAA ABV RAS	1	0.8	0.8	2.4
LAS	2	1.6	1.6	3.1
RAS	97	76.4	76.4	81.1
STJ RAS	25	19.7	19.7	100
Total	127	100.0	100.0	

RAS – Right aortic sinus, LAS – Left aortic sinus, STJ – Sinutubular junction

CO TPAA ABV RAS – Common ostium in tubular part of ascending aorta above RAS, CO RAS – Common ostium from RAS

Table 4.4: Size of Left and Right Coronary Ostia

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Age (years)	127	17	86	4451	35.05	12.54	157.25
LCO. W (mm)	126	1.6	7.9	582.3	4.62	1.10	1.219
LCO. H (mm)	126	1.5	4.9	332.8	2.64	0.72	0.518
RCO. W (mm)	127	1.6	9.6	464.2	3.66	1.40	1.968
RCO. H (mm)	127	1.1	4.9	287.7	2.27	0.72	0.522

LCO – Left coronary ostium, RCO – Right coronary ostium, H- height, W- Width

Table 4.5: t-Test (Paired Two Sample for Means)

	Cross sectional area of LCO	Cross sectional area of RCO
Mean	9.701175	6.9858
Variance	19.16559	27.431
Observations	125	125
Pearson Correlation	0.657127	
Hypothesised Mean Difference	0	
Degrees of freedom	124	
t Statistic	7.4825	
P(T<=t) one-tail	5.84E-12 (p<0.05)	
t Critical one-tail	1.657235	
P(T<=t) two-tail	1.17E-11 (p<0.05)	
t Critical two-tail	1.97928	

Cross sectional area of the coronary ostia were calculated using the formula for a circle ($A = \pi r^2$, for circular ostia) and an ellipse (Area $=\pi r^2 r^2$for oval ostia) and the cross sectional areas for the left and right coronary ostia in each heart were compared using the t-test (paired two sample for mean) if there were significant differences.

The table above shows that the difference in the means is statistically significant between the cross sectional area of the left and right coronary ostia within each heart with p – value less than 0.05. The results demonstrate that there was significant statistical difference in mean of cross sectional area of the left coronary ostium and right coronary ostium within each heart with a p value of .000000. Using the t-test, t statistic observed is greater than t critical hence the mean cross sectional areas of the left and right coronary ostia differ significantly.

Coronary Artery Anomalies

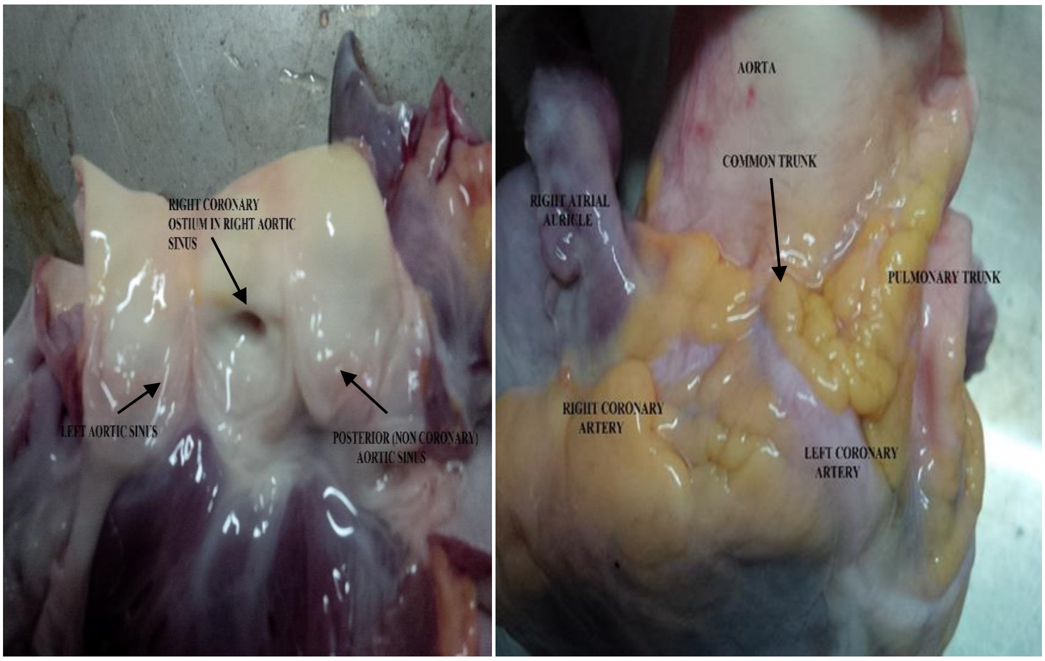

Figure 3. Single coronary artery: Common trunk ostium located the right aortic sinus.

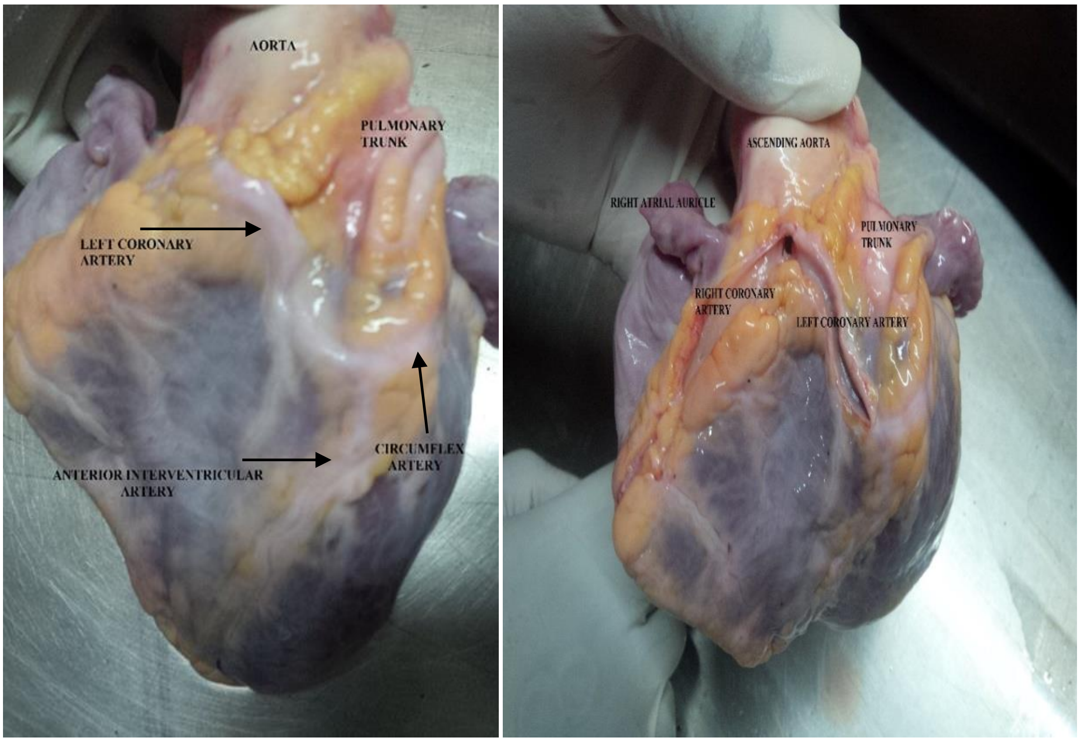

Figure 4. Anomalous course of left coronary artery anterior to the aorta and pulmonary trunk giving off the anterior interventricular and circumflex arteries.

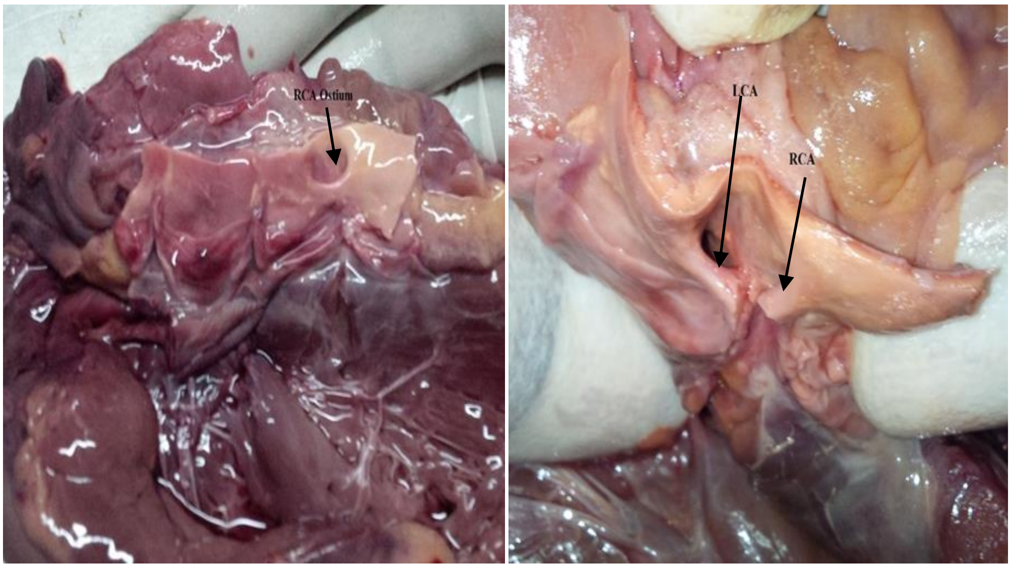

Figure 5. Coronary arteries arising from a common ostium located in tubular part of the ascending aorta above the right aortic sinus.

RCA – Right coronary artery orifice, LCA- Left coronary artery orifice.

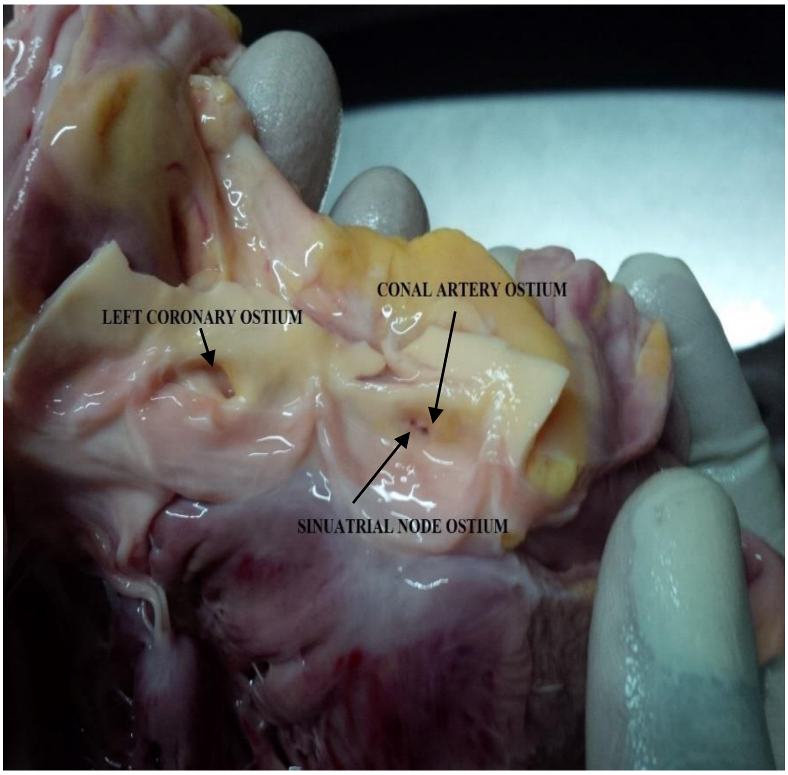

Figure 6. Right coronary artery arising from the left aortic sinus.

LCA – Left coronary ostium in LAS, Conus artery and Sinoatrial node ostia in RAS

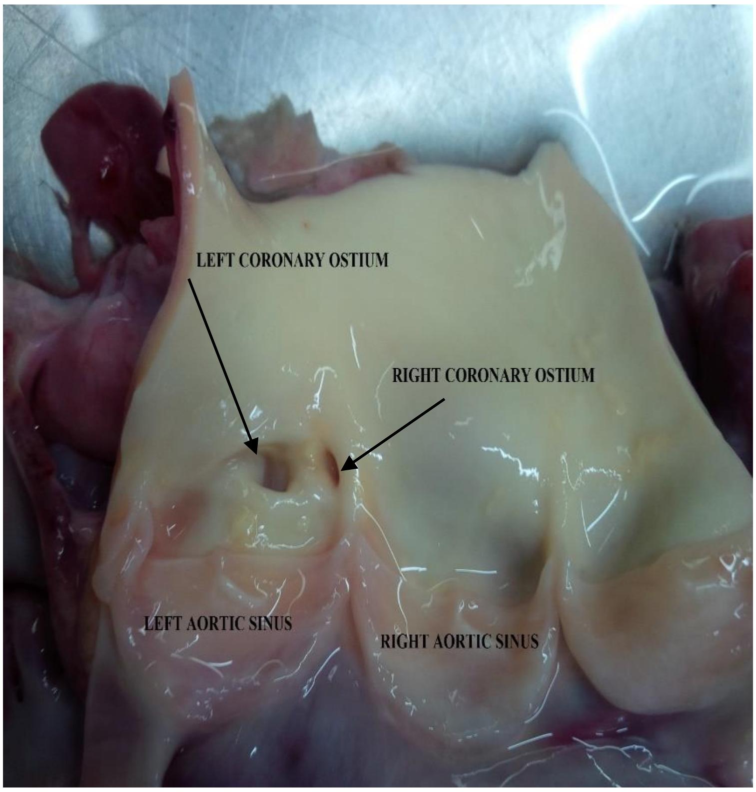

Figure 7. Right coronary artery arising from the sinutubular junction of the left aortic sinus.

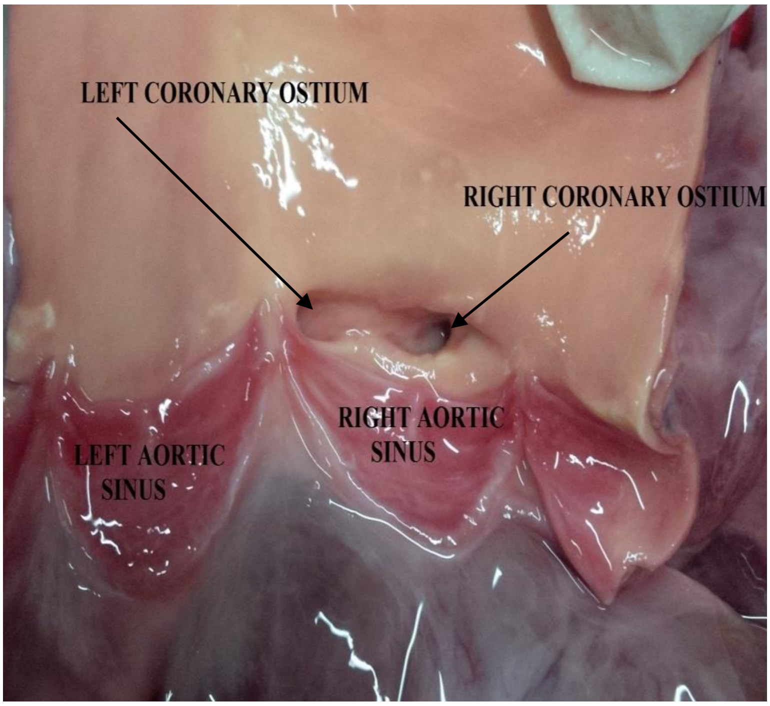

Figure 8. Left coronary ostium arising from the right aortic sinus.

CHAPTER FIVE

DISCUSSION

5.1 Location of Coronary Ostia (Origin of Coronary Arteries)

The study described origin (location of coronary ostia) of coronary arteries in adult autopsied hearts. It also measured the size of the left and right coronary ostia and compared their cross sectional areas. The 127 hearts dissected and examined in this study were obtained from the ages between 17 and 86 years with a mean (SD) age of 35.05 years (±12.54). The location of coronary ostium in this study were described as those arising within the aortic sinus, sinutubular junction and in the tubular part of the ascending aorta. The left coronary ostium was located in the left aortic sinus in 90 (70.9%) and on the sinutubular junction 33 (25.9%) hearts. The right coronary ostium was located in the right aortic sinus 97 (76.4%) and on the sinutubular junction in 25 (19.7%) hearts. None of the two coronary ostia arose from the tubular part of the ascending aorta. Our results on coronary ostia located in the aortic sinus are similar to those described by Muriago et al (1997) in which of the 23 normal hearts they examined the left coronary ostium was located within the left posterior aortic sinus (of Valsalva) in 16 (69%) specimens and at the level of the sinutubular junction in 2 (9%) specimens and above the sinutubular junction in five (22%). The right coronary ostium was located within the right anterior aortic sinus in 18 (78%) specimens, at the sinutubular junction in 2 (9%) and above the sinutubular junction in 3 (13%). Cavalcanti et al (2003) in Brazil examined 51 human hearts and from which the left coronary ostium was located below the intercommissural line in 42% of cases, above that line in 40% of cases, and at the level of that line in 18% of cases and the right coronary ostium was located below the intercommissural line in 60% of cases, above that line in 28% of cases, and at the level of that line in 12% of cases. In the study done by Cavalcanti et al (2003), it can be seen that the proportion of left coronary ostia located in the aortic sinus and above the sinutubular junction are almost equal whilst for the right coronary ostia most of them are located in the right aortic sinus and followed by those located above the sinutubular junction and then those located on the sinutubular junction. Kulkarni and Paranjpe (2015) in India after examining 90 hearts found that the right coronary artery was located in the right aortic sinus in aortic sinus in 26%, sinutubular junction in 56.6% and tubular location in 16.6% whilst the left coronary artery was located in the left aortic sinus in 17.7 %, at sinutubular junction in 52.2% and tubular location in 30%. The study done by Kulkarni and Paranjpe (2015) in an Indian population shows that majority of ostia are located on the sinutubular junction whilst in our study and that done by Muriago et al (1997) most coronary ostia are located in their respective aortic sinuses.

5.2 Size of coronary ostia

The left coronary ostia ranged in width from 1.6 – 7.9 mm (mean 4.62 ± 1.104 mm) and the height ranged from 1.50 – 4.90 mm (mean 2.64 ± 0.719 mm). The right coronary ostia ranged in width from 1.6 – 9.6 mm (3.66 ± 1.40 mm) and the height ranged from 1.1 - 4.9 mm (2.27 ± 0.723 mm). These measurements are similar to what McAlpine (1975) found after analysing sizes of coronary orifices in 100 hearts in which the width of the right coronary ostia ranged from 0.5 to 7.0 mm (mean 3.7 ± 1.1 mm) and the height ranged from 0.5 to 5.0 mm (mean 2.4 ± 0.9 mm). The left coronary ostia ranged from 1.8 mm to 8.5 mm (mean 4.7 ± 1.2 mm) in width and 1.0 to 8.5 mm (mean 3.2 ± 1.1 mm) in height. In our study the mean sizes of the coronary ostia are within this range. Other studies done have measured the diameter of coronary ostia and the mean diameters were as follows:

5.3 Comparison of size of the left and right coronary ostia within the same heart

The cross sectional areas of the coronary ostia within the same heart were compared. The cross sectional areas of the coronary ostia were calculated depending on their shape. The formula for area of an ellipse (CA= $\pi r^1 r^2$)was used to calculate cross sectional area for elliptical ostia and that of a circle (CA= πr^2) for circular ostia. The mean cross sectional area for the left coronary ostia was found to be 9.70 mm^2 and that of the right coronary artery was 6.99 mm^2.The mean cross sectional areas for ostia within the same heart were then compared and were found to differ significantly with a p-value 0.0000. The cross sectional area of the left coronary ostium was greater than the right coronary ostium in 106 (84.8%) of the hearts whilst in 17 (13.6%) of the hearts the cross sectional area of the right coronary ostium was great than that of the left coronary ostium and both coronary ostia cross sectional area were equal in 1 (0.8%) heart. Standring (2008) in Grays Anatomy states that the left exceed the right in 60% of hearts, the right being larger in 17%, and both vessels being approximately equal in 23% and that diameters of the coronary arteries may increase upto the 30^{th} year of life. The left coronary artery is considered to be larger in calibre than the right coronary artery and the findings in this study also show similar results after comparing their cross sectional areas. Coronary ostium size is very important as it will give insight when designing or acquiring of catheters suitable for our population.

5.4 Coronary artery anomalies/variations

Congenital coronary artery anomalies of origin and further vessel course were found in 6 (4.72%) of the 127 hearts dissected during autopsy. In Texas in The United States of America, Angelini et al (1999) investigated 1950 angiograms from which they found the incidence of coronary artery anomalies at 5.6%. A study done in Germany by Von Ziegler et al (2009) found the incidence of these coronary artery anomalies in 2.3% (17/748) consecutive symptomatic patients, who underwent cardiac 64-slice multi-detector-row computed tomography angiography (MDCTA). Kardos et al (1997) analysed angiographic data of 7,694 consecutive patients who underwent coronary arteriography at the Albert Szent-Gyorgyi Medical University, Szeged, Hungary, from 1984 to 1994 and found congenital coronary anomalies (CCA) in 103/7,694 patients (1.34% incidence).

Among the coronary artery anomalies in our study was absence of left main coronary artery (LMCA) 1 (0.79%) of the hearts. In a study done by Ajayi et al (2014) in South Africa the LMCA was absent in 9.6% (39/407) angiograms. Our observed percentage of this rare anomaly in our study falls within the 0.6-1.6% range stated by Papadopoulos et al (2006) in cases diagnosed by cardiac catheterisation in Greece. In Turkey, Altin et al(2014) found this anomaly in 0.9% (51/5548) patients who had undergone coronary angiography. Angelini et al (1999) found the incidence of absence of the left main trunk in 13/1950 (0.67%) angiograms. The right coronary artery arose from the left aortic sinus in 2/127 (1.6%) hearts and on the sinutubular junction of the left aortic sinus in 1/127 (0.8%) hearts. An exact percentage incidence (1.6%) of origin of right coronary artery from the left aortic sinus to what we found was reported by Jim et al (2005) among patients with first time cardiac catheterization. In other studies this CAA was found in:18/1950 (0.92%) by Angelini et al (1999), 7/748 (0.94%) by Von Ziegler et al (2009), 5/18950 (0.026%) by Alexander and Griffiths (1956). Matsumura et al (2016) also documented this anomaly after treating a patient who presented with sudden cardiac arrest associated with an anomalous right coronary artery originating from the left sinus of Valsalva. In Israel, Yuan et al (2009) diagnosed this coronary artery anomaly in a patient who presented with chest pain. The left coronary artery arose from a separate ostium in the right aortic sinus in 1/127 (0.8%) hearts. In the study done by Angelini et al (1999) this anomaly was seen in 3/1950 (0.15%) angiograms while Alexander and Griffiths (1956) found this anomaly in 2/18950 (0.011%) hearts in an autopsy based study. Anomalous origin of the coronary artery from the opposite sinus of Valsalva (ACAOS) with a course of that artery between the ascending aorta and the pulmonary artery is a rare congenital anomaly that can cause myocardial ischemia, syncope, and sudden cardiac death in young people especially during exercise. Other possible manifestations of ACAOS include not only sudden death but also dyspnoea, palpitations, angina pectoris, and dizziness (Frescura *et al*, 1998; Angelini *et al*, 2006: Angelini *et al,* 2007; Altin *et al,* 2014). Cheltin et al (1974) suggested that the mechanism for sudden death in these cases is as a result of the acute leftward passage of the coronary artery along the aortic wall which causes the entrance into the left coronary system to be slit-like and that under circumstances of increased cardiac activity with increased expansion of the pulmonary artery and aorta with exercise, there is stretching of the left coronary artery and a flap-like closure of the orifice of the left coronary with sudden, fatal myocardial ischemia.

Single coronary artery (also known as single coronary ostium) was seen in 1/127 (0.8%) hearts. The common trunk arose from the right aortic sinus, coursed anteriorly between the right auricle and the pulmonary trunk where it divided into the right and left coronary arteries. The left coronary artery coursed to the left of the common trunk between the ascending aorta and the pulmonary trunk and divided into the anterior interventricular and circumflex arteries. The right coronary artery coursed to the right off the common trunk anterior to the right auricle to the right cardiac border. According to Angelini et al (1999) even though the common trunk arose from the right aortic sinus, it cannot be named as the right coronary artery but should be considered as a common mixed trunk from which arose both the right and left coronary arteries. Ogden and Goodyer (1970) described single coronary artery as not the absence of a complete coronary artery, but rather the absence of a portion of one of the coronary arteries at the aortic root. Waller et al (1992) describes single coronary artery as origin of the entire coronary circulation from a single aortic ostium. Angelini (2007) described a similar case and named it as single coronary ostium since both coronary arteries are present. This CAA was also documented by Nerantzis and Koutsaftis (1998). Lipton et al (1979) described isolated single coronary artery as a rare anomaly occurring in approximately 0.024% of the population. Any congenital or acquired obstructive disease in the common trunk would deprive the heart muscle of nutrient rich blood since both coronary arteries arise from it and thus the heart muscle would become ischaemic without having any possible source of collateral circulation (Angelini *et al,* 1999).

In 1/127 (0.8%) hearts, both the right and left coronary arteries arose a common ostium located in the tubular part of the ascending aorta just above the right aortic sinus. Most studies published on this anomaly involve high origin (high take off) of only the right coronary artery. Piegger et al (2001) reported a case in which the right coronary artery arose from the ascending aorta 38mm above the supravalvular ridge. Nerantzis and Marianou (2000), reported an anomaly in which in one heart both left and right coronary arteries arose from the left aortic wall 7 mm and 19 mm respectively above the sinutubular junction among 510 human hearts they examined. In our case the left coronary artery coursed high up in the cleft between the ascending aorta and the pulmonary trunk avoiding possible compression and similarly to their case the right coronary artery also avoided possible compression. Singh (2013) reported case in which the right coronary artery arose from the anterior part of the ascending aorta 3 mm from its root. Lee et al (2009) also reported on a case in which the right coronary artery arose from the ascending aorta above the left sinus of Valsalva and coursed between the aorta and pulmonary trunk. High take-off positions are without any haemodynamic significance, but they may lead to unexpected angiographic problems while localising and engaging the orifices (Zeina *et al,* 2009). Knowledge of location of coronary ostium in aortic sinus is essential while manipulating a catheter in procedure of angiography, angioplasty and transcatheter aortic valve replacement procedures (Kulkarni and Paranjpe,2015). The cardiac surgeon should be aware that high cannulation will be required to locate the right coronary artery to avoid accidentally cross-clamping ortransecting the vessel during surgery where this anomaly may be encountered (Nerantzis and Marianou, 2000).

The variations in incidences of coronary artery anomalies/variations have been attributed to ethnicity, racial differences (Kulkarni and Paranjpe, 2015) geographic region (Loukas *et al*, 2009). Abnormal arrangement of coronary arteries maybe associated with minor genetic changes in certain growth factors (Walker and Webb, 2001; Loukas *et al*, 2009).

Table 5.1 Comparison of incidences of coronary artery anomalies (CAA)

Authors	**Sample size**	**Method**	**Coronary artery anomalies (%)**
Our study	127	Autopsy	4.72
Angelini et al. (1999)	1950	Coronary angiograms	5.64
Kardos et al. (1997)	7694	Coronary arteriography	1.34
von Ziegler et al. (2009)	748	64- Slice Multidetector-row computed tomographyangiography (MDCTA)	2.3
Graidis et al. (2013)	12401	Coronary angiograms	1.35
Altin et al. (2014)	5548	Coronary angiography	2.7
Alexander and Griffiths (1956)	18950	Autopsy	0.28
Srinivasan et al. (2008)	1495	64-slice multidetector row computed tomographic (MDCT) angiography	0.74
Yamanaka and Hobbs (1990)	126595	Coronary arteriography	1.3
Topaz et al. (1992)	13010	Coronary arteriography	0.61

5.5 Limitations

There was limited time to dissect the heart since we had to put it back in the thorax after post-mortem hence some other findings could have been missed out and also potential change that could have occurred in the size of the coronary ostia during post-mortem could have affected the measurements. When taking measurements of coronary ostia, difficulties in approximation of right angle between horizontal and vertical axes of the ostia may have interfered with accuracy of the results.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study showed that:

i. Most of the coronary ostia were located in their respective aortic sinuses. The right coronary ostium was located in the right aortic sinus (RAS) 97 (76.4%) and on the sinutubular junction (STJ) in 25 (19.7%) of the hearts. The left coronary ostium was located in the left aortic sinus (LAS) in 90 (70.9%) and on the STJ in 33(25.9%) of the hearts.

ii. The left coronary ostium width range was 1.6 – 7.9 mm with a mean of 4.62 (± 1.104) mm whilst the height range was 1.5 – 4.9 mm with a mean of 2.64 (± 0.719) mm. The right coronary ostium width range was 1.6 – 9.6 mm with a mean of 3.66 (± 1.40) mm whilst the height range was 1.1 – 4.9 mm with a mean of 2.27 (± 0.72) mm.

iii. The mean cross sectional area of the left coronary ostium was 9.70 $mm^2$and that of the right coronary ostium was 6.99 mm^2. The left coronary ostium was significantly larger in calibre than the right with a p-value 0.0000.

iv. Incidence of coronary artery anomalies/variations of origin and further course was found to be 4.72% (6/127 hearts). The left coronary artery (LCA) arose from: a common trunk whose ostium was located in RAS in 1 (0.8 %) heart, a common ostium with right coronary artery (RCA) in tubular part of ascending aorta above the RAS in 1 (0.8 %) heart, the RAS in 1 (0.8 %) heart and absent in 1 (0.8 %) heart. The right coronary artery arose from: LASin 2 (1.6 %), a common ostium with LCA in tubular part of ascending aorta above the RAS 1(0.8%), a common trunk with LCA whose ostium was located in RAS 1 (0.8 %) and STJ of LAS 1 (0.8%) heart. Of the six (6) hearts with coronary artery anomalies only one (1) was from a female and the five (5) from males.

6.2 Recommendations

i. With the installation of CT angiography equipment in the Department of Radiology at the University Teaching Hospital, a study can be conducted on a larger sample size. Such a study could improve upon the results presented in this study.

ii. Studies should be conducted to investigate the possible association between coronary artery anomalies/variations and gender; development of disease; and sudden death.

CHAPTER SEVEN

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CHAPTER EIGHT

APPENDICES

APPENDIX 1: Approval letter from Assistant Dean Postgraduate

THE UNIVERSITY OF ZAMBIA

SCHOOL OF MEDICINE

Telephone : +260211252641
Telegram: UNZA, Lusaka
Telex: UNZALU ZA 44370
Email: assistantdeanpgmedicine@unza.zm

P.O Box 50110
Lusaka, Zambia

21st April, 2015

Dr. Moono Silitongo
Department of Anatomy
School of Medicine
UNZA
LUSAKA

Dear Dr. Silitongo,

RE: GRADUATE PROPOSAL PRESENTATION FORUM

Following the presentation of your dissertation entitled **"A Study on the Origin, Course and Variations of Coronary Arteries in Cadavers and Postmortem Cases at the University Teaching Hospital (UTH), Lusaka, Zambia"**; your supervisor has confirmed that the necessary corrections to your research proposal have been done.

You can proceed and present to the Research Ethics.

Yours faithfully,

Dr. S.H. Nzala
ASSISTANT DEAN, POSTGRADUATE
CC: HOD, Anatomy

UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE
22 APR 2015
ASSISTANT DEAN (PG)
P.O. BOX 50110, LUSAKA

APPENDIX 2: Approval letter from ERES Converge

ERES CONVERGE

33 Joseph Mwilwa Road
Rhodes Park, Lusaka
Tel: +260 955 155 633
+260 955 155 634
Cell: +260 966 765 503
Email: eresconverge@yahoo.co.uk

I.R.B. No. 00005948
F.W.A. No. 00011697

19th August, 2015

Ref. No. 2015-May-017

The Principal Investigator
Dr Moono Silitongo
University of Zambia
School of Medicine
P.O. Box 50110,
LUSAKA.

Dear Dr. Silitongo,

RE: THE ORIGIN, COURSE AND VARIATIONS OF CORONARY ARTERIES IN CADAVERS AND POSTMORTEM CASES AT THE UNIVERSITY TEACHING HOSPITAL (U.T.H), LUSAKA, ZAMBIA.

Reference is made to your corrections. The IRB resolved to approve this study and your participation as principal investigator for a period of one year.

Review Type	**Ordinary**	Approval No. **2015-May-017**
Approval and Expiry Date	Approval Date: 19th August, 2015	Expiry Date: 18th August, 2016
Protocol Version and Date	Version-Nil	18th August, 2016
Information Sheet, Consent Forms and Dates	• English.	18th August, 2016
Consent form ID and Date	Version-Nil	18th August, 2016
Recruitment Materials	Nil	18th August, 2016
Other Study Documents	Data Extraction Tool	18th August, 2016
Number of participants approved for study	121	18th August, 2016

Specific conditions will apply to this approval. As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

Conditions of Approval

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to the IRB within 5 days.
- All protocol modifications must be IRB approved prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to the IRB within 5 working days.
- All recruitment materials must be approved by the IRB prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. Documents must be received by the IRB at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Any documents received less than 30 days before expiry will be labelled "late submissions" and will incur a penalty.
- Every 6 (six) months a progress report form supplied by ERES IRB must be filled in and submitted to us.
- ERES Converge IRB does not "stamp" approval letters, consent forms or study documents unless requested for in writing. This is because the approval letter clearly indicates the documents approved by the IRB as well as other elements and conditions of approval.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

On behalf of ERES Converge IRB, we would like to wish you all the success as you carry out your study.

Yours faithfully,
ERES CONVERGE IRB

Dr. E. Munalula-Nkandu
BSc (Hons), MSc, MA Bioethics, PgD R/Ethics, PhD
CHAIRPERSON

APPENDIX 3: Letter of permission and approval to conduct research at UTH

The University of Zambia,
School of Medicine,
Department of Anatomy,
P.O. Box 50110,
Lusaka.

REPUBLIC OF ZAMBIA
28 APR 2015

REPUBLIC OF ZAMBIA
SENIOR
MEDICAL SUPERINTENDENT
27 APR 2015
UNIVERSITY TEACHING HOSPITAL
P/BAG RW1X LUSAKA

27th April, 2015.

The Managing Director,
The University Teaching Hospital,
Lusaka, Zambia.

Dear Sir/Madam,

REF: PERMISSION TO CONDUCT A RESEARCH AT THE UNIVERSITY TEACHING HOSPITAL

Reference is made to the above captioned subject.

I am a second year student, pursuing a Master of Science Degree in Anatomy. I write to request for permission to conduct a research on the Origin, Course and Variations of Coronary Arteries in Cadavers and Post-mortem cases in Pathology Department at the University Teaching Hospital. The research will be a cross sectional post-mortem based study to be conducted at the Pathology and Anatomy departments.

Your favourable consideration regarding this matter will be highly appreciated.

Yours faithfully,

Dr. Moono Silitongo.

APPENDIX 4: Letter of permission and approval to conduct research in Pathology Department.

The University of Zambia,
School of Medicine,
Department of Anatomy,
P.O. Box 50110,
Lusaka.

Approval
To liaise with
Mr Kantenga
Dr. Sitali Ag HOD

4th April, 2015.

The Head of Department,
Pathology Department,
The University Teaching Hospital,
Lusaka, Zambia.

Dear Sir/Madam,

REF: PERMISSION TO CONDUCT A RESEARCH IN PATHOLOGY DEPARTMENT

Reference is made to the above captioned subject.

I am a second year student, pursuing a Master of Science Degree in Anatomy. I write to request for permission to conduct a research on the Origin, Course and Variations of Coronary Arteries in Cadavers and Post-mortem cases in Pathology Department at the University Teaching Hospital. The research will be a cross sectional post-mortem based study to be conducted at the Pathology and Anatomy departments.

Your favourable consideration regarding this matter will be highly appreciated.

Yours faithfully,

Dr. Moono Silitongo.

REPUBLIC OF ZAMBIA
MINISTRY OF HEALTH
UNIVERSITY TEACHING HOSPITAL
04 MAY 2015
HEAD OF PATHOLOGY
& MICROBIOLOGY DEPT
P/BAG RW1X LUSAKA

APPENDIX 5: Data collection sheet

DATA COLLECTION SHEET

Code number:

Age:

Sex:

Cause of death:

Coronary ostium size (mm)

Right coronary ostium

Height:

Width:

Left coronary ostium

Height:

Width:

Coronary ostium location

Right coronary artery

Right aortic sinus:

Other:

Left coronary artery

Left aortic sinus:

Other:

Coronary artery variations

Name of variant artery:

Variation (origin or course):

APPROVED

1 9 AUG 2015

ERES CONVERGE

P/BAG 125, LUSAKA.

APPENDIX 6: Excel sheet for data entry

SN	Sex	C.O.D.	Loc. LCAO	LCAO. W(mm)	LCAO. H(mm)	Loc. RCAO	RCAO. W(mm)
1	F	R.T.A.	L.A.S.	4.9	2.5	R.A.S.	4.7
2	F	MURDER	L.A.S.	4.5	2.4	S.T.J.	6.3
3	M	S.D.	L.A.S.	3.8	3.7	S.T.J.	3.1
4	F	R.T.A.	L.A.S.	4	3.5	R.A.S.	3.3
5	F	R.T.A.	S.T.J.	6.5	3.5	S.T.J.	5.1
6	M	R.T.A.	L.A.S.	4.2	2.7	R.A.S.	2.5
7	M	R.T.A.	L.A.S.	4.1	3.8	R.A.S.	3.8
8	M	R.T.A.	S.T.J.	5.9	3.4	S.T.J.	6.2
9	M	RTA	S.T.J.	4.9	2	S.T.J.	3
10	M	S.D.	L.A.S.	4.7	2.1	R.A.S.	3.6
11	M	R.T.A.	L.A.S.	4.7	2	R.A.S.	3.4
12	M	S.D.	L.A.S.	5	2.2	R.A.S.	3.8
13	M	H.I.	S.T.J.	6.5	3.2	S.T.J.	4.4
14	M	R.T.A.	L.A.S.	3	1.5	R.A.S.	2.7
15	M	SUICIDE	S.T.J.	3.9	1.8	S.T.J.	3
16	M	R.T.A.	S.T.J.	4.8	1.5	S.T.J.	3.2
17	M	R.T.A.	L.A.S.	5.2	1.9	S.T.J.	3.8
18	M	R.T.A.	L.A.S.	5.4	2	R.A.S.	3.8
19	M	R.T.A.	S.T.J.	4.5	2	S.T.J.	3.2
20	M	R.T.A.	L.A.S.	4.5	4.1	R.A.S.	3.1
21	M	R.T.A.	L.A.S.	5.1	4.4	R.A.S.	3.7
22	M	R.T.A.	S.T.J.	5.2	2	S.T.J.	4.1
23	M	R.T.A.	L.A.S.	5	1.6	R.A.S.	2.5
24	F	SUICIDE	S.T.J.	4	1.8	S.T.J.	3.6
25	M	MURDER	L.A.S.	6.1	2	S.T.J.	3.4
26	M	R.T.A.	S.T.J.	5.6	2	S.T.J.	3.6
27	F	SUICIDE	S.T.J.	4.1	1.5	S.T.J.	3.2
28	M	R.T.A.	L.A.S.	4.8	2.1	S.T.J.	3.4
29	M	R.T.A.	L.A.S.	4.4	1.9	R.A.S.	3.1
30	M	R.T.A.	L.A.S.	4.3	2.5	R.A.S.	2.4
31	M	MURDER	S.T.J.	4.2	1.8	R.A.S.	3
32	F	BURNS	S.T.J.	4.8	2.5	R.A.S.	1.6
33	M	MURDER	L.A.S.	3.8	2.2	R.A.S.	2
34	F	R.T.A.	L.A.S.	3.4	1.7	R.A.S.	1.8
35	M	R.T.A.	L.A.S.	1.6	2.8	R.A.S.	5
36	F	R.T.A.	L.A.S.	2.2	2.2	R.A.S.	3.4
37	M	R.T.A.	L.A.S.	4.6	3	S.T.J.	2.4
38	M	R.T.A.	S.T.J.	3.9	2	S.T.J.	4.8
39	M	R.T.A.	S.T.J.	4.1	2.5	R.A.S.	2.2
40	M	R.T.A.	L.A.S.	5.2	2.3	R.A.S.	3.6
41	F	R.T.A.	L.A.S.	4.8	2.3	R.A.S.	2.6
42	M	S.M.	L.A.S.	4.3	2	R.A.S.	2.8
43	M	S.D.	L.A.S.	3.6	1.9	R.A.S.	2.1

44	M	R.T.A.	L.A.S.	4.3	2	R.A.S.	2.3
45	F	TRAUMA	L.A.S.	4	2.4	R.A.S.	2.4
46	M	TRAUMA	L.A.S.	5.8	2.2	R.A.S.	3.8
47	M	R.T.A.	L.A.S.	5.2	2.1	R.A.S.	4.2
48	M	MURDER	L.A.S.	3.6	2.5	R.A.S.	2.5
49	M	R.T.A.	L.A.S.	4.3	2	R.A.S.	3.6
50	M	R.T.A.	L.A.S.	4.7	2.2	R.A.S.	3.9
51	F	R.T.A.	L.A.S.	4.2	2.3	R.A.S.	3.3
52	M	R.T.A.	L.A.S.	2.7	2.3	R.A.S.	2.5
53	M	R.T.A.	L.A.S.	3.2	2.5	R.A.S.	3.1
54	M	R.T.A.	L.A.S.	3.8	1.7	R.A.S.	1.9
55	M	R.T.A.	L.A.S.	4.9	2.3	R.A.S.	3.7
56	M	R.T.A.	L.A.S.	3.9	2.4	R.A.S.	3.1
57	M	R.T.A.	L.A.S.	4	2.4	R.A.S.	3.6
58	F	MURDER	L.A.S.	3.9	2.1	R.A.S.	2.3
59	M	R.T.A.	L.A.S.	4.3	2.2	R.A.S.	3.7
			CO TPAA ABV			CO TPAA ABV	
60	M	R.T.A.	R.A.S.	6.3	3.3	R.A.S.	4.5
61	M	R.T.A.	L.A.S.	6.6	2.3	R.A.S.	4.1
62	M	R.T.A.	S.T.J.	6.1	2.1	R.A.S.	3.1
63	M	ASSAULT	L.A.S.	4.6	2.2	S.T.J.	5.7
64	M	R.T.A.	L.A.S.	7.9	4.1	R.A.S.	6.6
65	M	ASSAULT	S.T.J.	5.5	3.2	R.A.S.	7.6
66	F	R.T.A.	L.A.S.	5.8	3.1	R.A.S.	5.4
67	M	S.D.	S.T.J.	6.3	3.2	R.A.S.	3.9
68	M	R.T.A.	L.A.S.	5.6	2.3	R.A.S.	2.6
69	M	R.T.A.	S.T.J.	4.1	2.4	S.T.J.	2.7
70	M	R.T.A.	L.A.S.	6.9	2.5	R.A.S.	7
71	M	S.D.	L.A.S.	4.3	1.9	R.A.S.	3.7
72	F	R.T.A.	S.T.J.	4.6	2.9	R.A.S.	3.1
73	M	R.T.A.	S.T.J.	7.1	3.4	S.T.J.	6.9
74	F	R.T.A.	L.A.S.	3.4	2.1	R.A.S.	2.8
75	F	R.T.A.	L.A.S.	4.7	2.5	R.A.S.	3.3
76	M	R.T.A.	L.A.S.	5.2	2.8	R.A.S.	2.4
77	F	MURDER	L.A.S.	4.1	3.8	R.A.S.	6.8
78	F	R.T.A.	L.A.S.	4.5	2.3	R.A.S.	3.3
79	M	R.T.A.	L.A.S.	5.1	2.7	R.A.S.	2.9
80	M	R.T.A.	L.A.S.	4.8	2.4	R.A.S.	2.5
81	F	R.T.A.	S.T.J.	5.4	2.6	S.T.J.	5.3
82	M	R.T.A.	L.A.S.	6	3.9	R.A.S.	6
83	M	R.T.A.	L.A.S.	4.5	2.5	R.A.S.	2.5
84	M	R.T.A.	L.A.S.	2.2	1.9	R.A.S.	4
85	M	G/SHOT	L.A.S.	4.1	2.3	L.A.S.	2.9
86	M	R.T.A.	S.T.J.	4.9	2.7	R.A.S.	2.7
87	M	R.T.A.	L.A.S.	4.9	2.4	R.A.S.	4
88	M	R.T.A.	S.T.J.	6.6	3.2	R.A.S.	3.5

89	M	MURDER	L.A.S.	4.1	2.1	R.A.S.	2.2
90	M	R.T.A.	L.A.S.	3.3	3.3	R.A.S.	3.4
91	F	R.T.A.	L.A.S.	4.7	2.4	R.A.S.	2.4
92	M	R.T.A.	L.A.S.	4	3.8	R.A.S.	2.8
93	M	R.T.A.	L.A.S.	4.3	3.8	R.A.S.	2.7
94	F	R.T.A.	S.T.J.	3.8	2.8	R.A.S.	3.9
95	M	R.T.A.	L.A.S.	4.6	2.8	R.A.S.	3.1
96	F	ASSAULT	L.A.S.	4.2	2.1	R.A.S.	2.3
97	M	G/SHOT	L.A.S.	3.1	3	R.A.S.	2.8
98	M	MURDER	L.A.S.	3.7	3.7	R.A.S.	3.1
99	F	R.T.A.	L.A.S.	3.5	1.9	R.A.S.	2.4
100	F	S.D.	CO L.A.S.	5.6	2.4	CO L.A.S.	5.6
101	M	R.T.A.	L.A.S.	4	2.3	R.A.S.	3.9
102	F	R.T.A.	S.T.J.	5.4	2.6	R.A.S.	3.4
103	F	R.T.A.	S.T.J.	3.6	3.6	R.A.S.	2.9
104	F	S.D.	L.A.S.	3.4	3.4	R.A.S.	3.2
105	M	R.T.A.	L.A.S.	4.2	4.1	R.A.S.	6.4
106	M	R.T.A.	L.A.S.	3.8	3.8	R.A.S.	3.3
107	M	R.T.A.	S.T.J.	6.3	3.5	L.A.S.	3.6
108	M	R.T.A.	L.A.S.	4.1	2.1	R.A.S.	2.5
109	M	R.T.A.	S.T.J.	4.3	2.3	R.A.S.	2.8
110	M	R.T.A.	L.A.S.	4.2	2.5	R.A.S.	2.1
111	F	G/SHOT	L.A.S.	4.6	3.5	R.A.S.	4
112	M	G/SHOT	L.A.S.	7.6	4.9	S.T.J.	9.6
113	M	R.T.A.	L.A.S.	7.1	3.1	S.T.J.	8.3
114	M	R.T.A.	L.A.S.	4.1	4.1	R.A.S.	3.5
115	M	SUICIDE	S.T.J.	6.5	4.3	R.A.S.	3.9
116	M	R.T.A.	L.A.S.	4.2	3.1	R.A.S.	3.9
117	M	MURDER	R.A.S.	3.1	2.5	R.A.S.	2.6
118	M	R.T.A.	ABSENT			R.A.S.	4
119	M	R.T.A.	S.T.J.	5.3	2.3	S.T.J.	2.9
120	M	R.T.A.	L.A.S.	5.1	2.2	R.A.S.	3.1
121	F	R.T.A.	L.A.S.	3.5	3.1	R.A.S.	7.2
122	M	S.M.	L.A.S.	3.8	3.8	R.A.S.	4.3
123	M	S.D.	S.T.J.	4.7	2.5	R.A.S.	4.2
124	M	R.T.A.	L.A.S.	2.8	2.9	R.A.S.	2.7
125	F	MURDER	L.A.S.	4.5	2.2	R.A.S.	5.5
126	M	S.D.	S.T.J.	3.5	3	S.T.J. L.A.S.	2.2
127	M	R.T.A.	L.A.S.	6.7	3.6	R.A.S.	3.5

Loc RCO- Location of right coronary ostium, Loc LCO- Location of left coronary ostium , RCAO - Right coronary artery ostium, LCAO - Left coronary artery ostium, COD - Cause of death, SD- Sudden death, RTA - Road traffic accident, M - Male, F - Female. SM - Suspected murder, G/SHOT - Gunshot. SN - Serial number, H - Height, W - Width.

APPENDIX 7: Digital Vernier Caliper: used to measure dimensions of coronary ostia