



Variations in the Branching of the Coronary Artery among Black African Population: A cadaveric study in western Kenya

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Abstract

INTRODUCTION

The right and the left coronary arteries are the principal branches of the coronary artery. These blood vessels are responsible for the overall blood supply to the muscles of the heart. Variations are anomalies in the branching pattern of the coronary arteries which can affect the amount of blood reaching the myocardium. This can lead to technical problems during procedures like cardiac catheterization causing misdiagnosis resulting in complications during diagnostic intervention in surgical procedures of the heart. This study sought to determine these variations among the black African population in Western Kenya by assessing the variations in the branching pattern of the coronary arteries.

MATERIALS AND METHODS

A cross-sectional study design was used in the Maseno University, Uzima University and Masinde Muliro University Human anatomy laboratories which were selected through purposive sampling. Branches of the coronary artery was the dependent variable while gender was the independent variable. Seventy-two (72) sample size was calculated using Cochran's formula. Data sheets were used to capture the variables while descriptive statistics was used to calculate the frequency and percentage of variation in the branching of the coronary arteries. Pearson's correlation test was used to analyze the relationship between the variables and variations with a $P \leq 0.05$ considered as significant. Ethical approval was put into consideration and a license number: NACOSTI /P/22/21905 was issued.

RESULTS

The posterior descending artery had the most variations on the left coronary at 20.8% artery while on the right the sinoatrial nodal artery varied most with 2.8% originating from the right aortic cusps while the remaining originating from the posterior descending artery.

CONCLUSIONS AND RECOMMENDATIONS

Variations were most on the left coronary artery which could jeopardize surgeries leading to misdiagnosis and fatalities. Increased awareness among the population with early routine imaging is key in managing variations is needed.

Keywords: Branching, Cadaver, Coronary Artery, Myocardium, Origin, Variations

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Introduction

The coronary artery is the first blood vessel from the arch of the aorta that supplies the heart with oxygen and nutrients. The principal branches of the coronary artery are the right coronary artery (RCA) and the left coronary artery (LCA).¹ Variations in the branching of coronary arteries are thought to be

responsible for the changes in the coronary blood vessels and the overall perfusion of the myocardium. These changes could either be compensatory, collateral or a duplication of another vessel which could have positive or negative attributes depending on their location, distribution and function².



A study by Olabu *et al.*,² is among the few studies done in Africa and specifically in Kenya on these variations. The study highlights the prevalence of the third coronary artery and its role in the acceleration and extent of myocardial infarction (MI) in cardiac surgery. It also notes the significance of this artery in the formation of collateral circulation and anastomosis. Other studies like that done by Trivellato *et al.*,³ established some of the important aspects of the branches of main coronary arteries like the left coronary artery (LCA) which after its formation lies behind the pulmonary artery where it bifurcates into left anterior intraventricular artery (LAIA) also known as left anterior descending artery (LADA) and the circumflex artery (CMx).

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 and it is thus important to note the increased incidence of the variations as a cause of sudden cardiac death^{4,5}. Procedures like cardiac catheterization, and coronary bypass procedures done by cardiologist heart surgeons require uttermost keenness and accuracy to avoid fatal mistakes. The difference caused by these variants could cause severe effects on the perfusion further complicating the management of heart diseases⁵.

In Africa, there is little literature on variations in the branching of coronary arteries. However, its effects can be highly felt by the increase in cardiovascular mortality and morbidity with increased hospitalization and revascularization procedures.⁶ Further studies by Ogeng'o *et al.*,⁷ have shown variation in luminal diameter of the left anterior descending artery a branch of the left coronary artery and its significance as a cause of stenosis among different ethnic communities. The study noted that variations were important markers in the development of atherosclerosis which is among the major causes of coronary artery diseases. Similarly, information on variations in the branching of the coronary arteries is important for

the overall perfusion of the myocardium. Data on cardiac surgeries and coronary bypass procedures due to variants is important for enhanced awareness to the patients and improved management by the healthcare providers.

The Kenya national guidelines for cardiovascular diseases note that 25% of Kenyan population admissions and 13% of deaths are due to cardiovascular diseases. In western Kenya, there has been a steady increase in the prevalence of ischemic heart diseases which is attributed to an increase in non-communicable diseases like diabetes and hypertension in the population.^{8,9} This study therefore aims at assessing and reporting the variations in the branching of the coronary artery among the black African population. The findings will play an important role to health care providers in averting possible injuries during the management of patients and the population at large.

Materials and methods

This was a cross-sectional study in which convenient sampling was used to select cadavers from three Anatomy laboratories in Western Kenya. The 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 universities) that were selected purposively 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); $n = (d/N)m$. As a result, 72 cadavers were acquired as the total actual sample size using Cochran's formula (Cochran 1967) from a total available specimen of 89 cadavers (Table 1) The cadavers were dissected to expose the thoracic cavity. Some of the data collection tools were: A data entry sheet/form with

gender, number of branches produced by each principal artery including other dependent and independent variables. Dissection kit- DS14, tape measure- Open reel tapes, scissors- stainless steel straight dissection scissors 6 inches' gloves – Clean gloves large 9.5 – 10.5 inches, camera. The pilot study was done at Maseno University using the cadavers that were not selected for the study. Pretesting of tools was done to ascertain the validity and reliability of the tools. There was no inter-observer variability.

With the help of trained laboratory technicians, the visceral pericardium was removed and the coronary artery was observed and reflected to visualize the branching of the coronary artery and its variation. The observations were recorded in a data sheet and images were taken where variations were observed. The collected data was subjected to statistical tools and descriptive statistics was used to record the incidence of variations from normal while Pearson's correlation test was used to analyze the relationship between the variations at a $P \leq 0.05$ considered as significant.

The collected data was stored and processed confidentially and was only used for the current research. Approval was obtained from the School of Graduate Studies Scientific Review Committee. Ethical review was sought from Maseno University Ethics and Review Committee (MUERC) and the National Commission for Science Technology and Innovation (NACOSTI) via license number: NACOSTI /P/22/21905.

Results

Of the total 72 hearts, 83.3% (60) had the right conus artery while 79.2% (57) had a posterior descending artery. Approximately 97.2% (70) of the sinoatrial nodal artery were branches of the right coronary artery. The acute marginal branch arose at the right border 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 the right dominance of the heart.

Table 1:

Distribution of cadavers from different universities

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)

Note: Number of cadavers available in each university versus the samples selected.

Table 2:

Branching pattern of the right coronary artery

N	Valid	RCA branching to RCA	RCA-posterior descending artery/PIA	RCA-acute marginal branch	RCA-Branching to SAN	RCA-branching to AVN
		60(83.3%)	57(79.2%)	72	70 (97.2%)	70 (97.2%)

Table 3:

Branching pattern of the left coronary artery

N	Valid	left anterior descending /LADA	Circumflex branch	Ramus branch	Left conus branch	Posterior descending branch	Left Atrioventricular branch	Obtuse marginal branch	Diagonal branch
		69(95.8%)	64(88.6%)	3(4.2%)	2(2.8%)	15(20.8%)	5(6.9%)	5(6.9%)	6(8.3%)

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). Out of 20.8% PDA frequency, 2.7% (2) were branches

of the left circumflex coronary artery while the rest were direct branches of the LCA.

Three branches of the diagonal artery were branches of the LADA artery while the other half were direct branches of the left coronary artery.

Table 4:

Statistical significance between branching of the coronary artery and gender of the study subjects

		Gender of subject	LADA/LAIA	CMx	RM	LC	PDA	A. V. Node	OM	DA
Gender of the respondent	Pearson Correlation	1	-.209*	.088	.121	-.169	-.033	.164	-.164	.101
LADA/LAIA	Pearson Correlation	-.209*	1	-.074	.051	.035	-.375**	.057	.057	.063
CMx	Pearson Correlation	.088	-.074	1	.086	.060	-.636**	.097	.097	-.053
RM	Pearson Correlation	.121	.051	.086	1	-.041	-.135	-.066	-.066	.146
LC	Pearson Correlation	-.169	.035	.060	-.041	1	-.094	-.046	-.046	-.051
PDA	Pearson Correlation	-.033	-.375**	-.636**	-.135	-.094	1	-.152	-.152	-.049
AV Node	Pearson Correlation	.164	.057	.097	-.066	-.046	-.152	1	-.075	.115
OM	Pearson Correlation	-.164	.057	.097	-.066	-.046	-.152	-.075	1	-.082
DA	Pearson Correlation	.101	.063	-.053	.146	-.051	-.049	.115	-.082	1

*. Correlation is significant at the 0.05 level (1-tailed).

** Correlation is significant at the 0.01 level (1-tailed).

Note. There was no statistical significance between sex and variation in the branching of the coronary artery.



Figure 1:

Branching of the left coronary arteries. Note: Variation in the present study where most of the Posterior descending arteries were originating from the left coronary artery hence left dominance

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 arteries had originated from the circumflex coronary artery. Two 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 arteries originated from the left coronary artery at 2.8% (2).

Discussion

Branching of the right coronary artery

Normally, the main branches of the right coronary artery (RCA) are the posterior descending artery (PDA) and the right conus (RC) artery with the remaining arteries being sub-branches.¹⁰ This is in agreement with the present study (Table 2). The present research observed three other branches apart from the two main ones whose role could have been to enhance the perfusion of the myocardium. Ballesteros *et al.*,¹⁰ agree with Bhele *et al.*,¹¹ on the origin of the acute marginal (AM) artery from the right coronary as a branch of the PDA. Both studies noted that although the PDA is a variant, it has a

great role in the perfusion of the lateral region of the right ventricle. It also forms an anastomosis with the posterior descending artery to supply the atrioventricular node and the sinoatrial node. A study done in Brazil on 221 hearts found out that 89% of the AM artery originated from the PDA while another study found out that 69% of the 98 hearts studied had the AM originating from the PDA^{10,11}.

In both the previous studies, the hearts were right dominant therefore the role of the variant artery could have been to assist in the perfusion of the posterior regions of the myocardium with the help of the atrioventricular nodal artery (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 which could be disadvantageous to the population with right dominance. Of importance to note in this study is that any occlusion of the PDA and the AM artery would cause damage to the posterior third of the intraventricular septum due to a lack of alternate pathways.

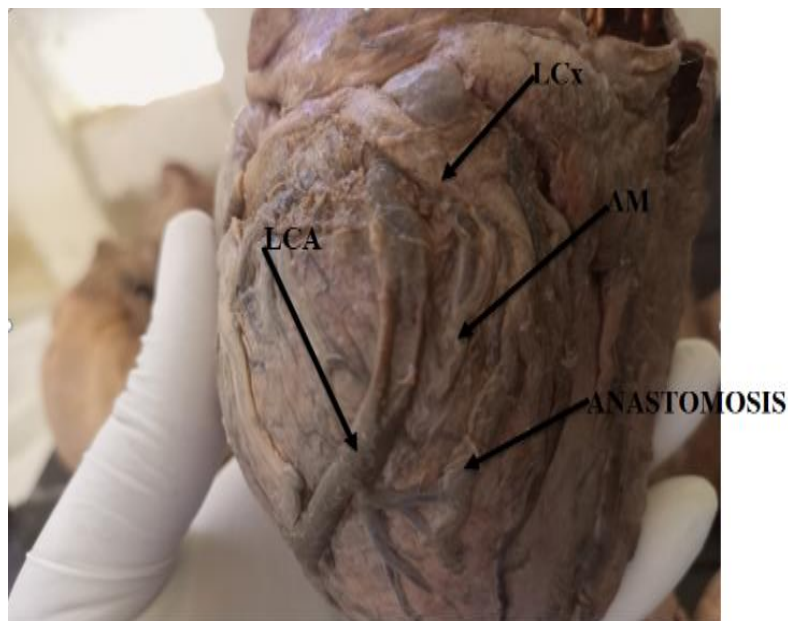


Figure 2:

Branching of the left coronary arteries forming anastomosis. *Note:* Variation in the present study where the left circumflex artery and the acute marginal arteries which are branches of the left coronary artery from an anastomosis on the myocardium

According to Bhele *et al.*,¹¹ & Kulkarni¹², the sinoatrial nodal artery (SANA) entirely originated from the RCA while in the current study, two of its branches originated directly from the right aortic cusps while the remaining were branches of the PDA. Both previous studies had more males than females while the current study had an equal number of study subjects in sex which could have led to the difference in result findings. In the present results, the two branches of the SANA though very few are thought to be very important for the blood supply of the right side of the heart in case the PDA is occluded.

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, 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.

Most studies acknowledge the danger of the SANA entirely having its origin from the RCA and note 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.¹² (Figure 2).

A Study conducted on 50 Turkish cadavers from both genders found 42% (21) of the PDA to have originated from the RCA. The previous study found that these variations in the branching pattern of the coronary artery can occur as early as during childhood or as a compensatory mechanism for an ailing heart during growth and development and to some extent linked to the X or Y chromosomes¹³. 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 myocardial blood supply. This can increase steadily in a population and especially with

the current occurrence of non-communicable diseases like hypertension and diabetes mellitus, there is a high probability of the heart developing a mechanism to enable it to survive during times of inadequacy¹³.

Generally, Shahoud *et al.*,¹⁴ 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 branching pattern exhibited by the LCA is the LADA and the CMx as the main branches.^{15,16} In the current study all the other branches apart from the two main ones accounted for 57.4% (36) which were variations (Table 3). The most common variation was the emergence of the posterior descending artery at 20.8% of the study specimen leading to the formation of anastomosis with other branches (Figure 2). The posterior descending artery though not one of the main branches of the left coronary artery may at times occur on the left causing a left dominance.

Other researchers observed a lower variation in branching patterns of the left coronary artery for example, out of the 50 hearts studied in Bangladesh South Asia, 28.5% (22) had variations in the branching pattern^{15,16}. Another similar study also observed that some variant branches like the obtuse marginal and the left conus were missing while others like the diagonal branch occurred at a lower frequency thus recording a much lower variation at 16% of the total 141 cadaveric hearts in the branching pattern. Furthermore, the study found out that the left conus and the obtuse marginal artery had a lower frequency than that in South Asia^{15,16}.

Khwansang *et al.*,¹⁶ noted that there were many variations in the branching of the left coronary artery which could be attributed to many factors including geographical location, sex, climate and



age. These variations could be worsened by an ailing heart, especially if the disease is from childhood. With the current increase in lifestyle diseases due to poor eating habits and lack of exercise, there is a need for population awareness and also early childhood diagnosis and management of cardiac conditions. More so, there is a need for cardiologists and heart surgeons to be informed of the continuous variations in the coronary vasculature so that during the corrective cardiac surgeries and procedures to prevent complications caused by these variants.

The frequency of the posterior intraventricular (PIA) artery was recorded at 8.2% in other studies, whereas our present study found it to be at 20.8%. Despite its lower frequency in previous research, the PIA artery is considered crucial due to its dominance in heart circulation. It perfuses the dorsal a third of the intraventricular septum and still has the SANA and the AVNA as its branches which are still important variants in the perfusion of the SANA and the AVNA¹⁶ (Figure 1). 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 LV through the arch of the aorta into the systemic circulation. Therefore, 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. Although the study found variations in the branching pattern of the coronary and noted the significance of these variants, there was no statistical significance between gender and the variation in the branching pattern of the coronary artery. This means that gender did not influence branching of the coronary arteries in any way (Table 4)

Limitations of the study

The general shortage of cadavers used for anatomical studies hindered a larger sample size and therefore, data from this study may not be generalizable to the population. Due to the sensitive nature of the study, it was challenging to obtain

gatekeepers' letters in as much as we had acquired some cadavers.

Strength of the study

The study will enhance pathological study which is key in medical research. There will also be an improved attitude towards cadaveric study further enhancing a better collaboration between anatomists and clinicians.

Conclusion

Variations in the branching of the right coronary arteries were fewer than those on the left coronary artery with over 70% of the posterior descending artery originating from the right coronary artery. The increased number of branches on the left coronary artery could be an advantage to the left side of the myocardium due to the increased demand in relation to the circulatory function of pumping blood to the systemic circulation. This enhances perfusion of the myocardium by establishing collateral circulation and anastomosis creating an alternative pathway for blood flow in case of occlusion of the main channels. However, the many branches could also be dangerous because the many arteries could cause confusion and complications during surgery.

Recommendations

Formulation of policies enhancing early routine imaging of the heart and follow-up to those affected at an early stage. This will note any changes occurring in the coronary arteries early enough and interventions can be easily put in place to avoid morbidity and mortality associated with the changes. There is also a need for collaboration in the form of meetings, seminars and conferences between anatomists/ researchers and clinicians for deliberations of the findings with proper strategies laid down for implementation.

Training of the health care providers is also an important aspect in reducing mortality and morbidity associated with these variants. This will enlighten healthcare workers on the pharmacological management and resuscitation of patients with cardiac emergencies caused by these



variants. Most importantly, cardiologists and cardiac surgeons doing procedures like coronary artery bypass procedures and aortic valve surgery should also be informed of the variations in the coronary vasculature to avoid fatal mistakes. These trainings are important to all the levels of healthcare provision staff so that they can be aware of these variations, their effect and how to manage patients.

Population awareness of the causes, signs and symptoms of heart disease caused by these variations and the importance of seeking medical attention early should also be encouraged. Adherence to proper diet, exercising, as well as continuous medical checkups, especially for those with genetic predisposition and those who develop early signs of heart diseases due to variations should also be emphasized.

Availability of data statement. The data supporting the findings of this study are available within the article while the raw data is available upon reasonable request.

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Conflict of interest statement. I declare that there is no conflict of interest regarding the publication of this paper.

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