VARIATION IN MORPHOLOGY OF BRACHIAL ARTERY AND ITS BRANCHING PATTERN AMONG BLACK AFRICAN POPULATION: A CADAVERIC STUDY IN WESTERN KENYA

BY

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DECLARATION

This research thesis is my original work and has not been presented to any other University. This research proposal should not be reproduced without the author's consent or that of Maseno University.

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DEDICATION

I dedicate this research paper to Mr. and Mrs Ayonga for their unconditional and moral support.

ABSTRACT

The brachial artery (BA) is the main arterial supply to the upper limb, BA commences at the inferior border of teres major muscle as a direct continuation of the 3rd part of axillary artery and courses to the arm anterior to triceps and brachialis muscle, it terminates at the neck of the radius, about 1cm by dividing into its two terminal branches, radial and ulnar arteries. There is paucity of data on its anatomical variations and its branching pattern among black African population, thus the purpose of the study was to evaluate anatomical variations of the BA and its branching pattern among black African population. Specifically, the study focused on establishing variation in origin and termination of BA, its branching pattern, length, correlation of variation, and branching pattern between laterality and gender among the black African population. The current study adopted a cross-sectional descriptive study design with purposive sampling as a sampling technique. The study was carried out in three universities in western Kenya due to their functional human anatomy laboratory. The study involved 77 cadavers (38 females and 39 males) with a total of 154 upper limb specimens. It was observed that there were 3.8% variation in origin of BA, the most common variation was superficial origin of BA. In termination of BA 89% terminated at radial neck,7.8% at radial tuberosity,1.9% at proximal arm and 1.3% midarm. 93.4% of the specimen had bifurcation of BA into radial and ulnar arteries, trifurcation was seen in 4.1% of the specimens, High bifurcation of BA was seen in 2.4% of the specimens. Mean length of BA was found to be 26 cm. There was no statistically significant difference variation ($p=>0.05$) in the origin of BA when compared with the normal origin, however there was statistically significant variation in termination of BA between the right and left upper limbs ($p=0.000$). The BA is of clinical importance for health care professionals worldwide, it is used clinically for brachial pulse identification, blood pressure monitoring, arteriography, percutaneous arterial catheterization, and arteriovenous fistula (AVF) for dialysis patients, various surgical and radiological procedures thus clinicians should treat each patient as special case to avoid mismanagement, misdiagnosis and improve clinical outcome on procedures involving BA.

TABLE OF CONTENT

ACRONYMSAND ABBREVIATIONS

ABA	Accessory brachial artery.
AVF	Arteriovenous fistula.
BA	Brachial artery.
CUE	Commission for university education.
IUC	Inferior ulnar collateral.
IV	Intravenous.
MP	Megapixel.
MUERC	Maseno University ethical review committee.
NACOSTI	National commission for science technology and innovations.
SEM	Standard error of margin.
SOPS	Standard operating procedures.
SPSS	Statistical package for social sciences.
SUC	Superior ulnar collateral.

OPERATIONALIZED DEFINITION

Variations Any deviation/ change observed from the normal arrangement.

Anatomical variation Change from known normal arrangement of the anatomical structure.

Cadavers Dead human body used by medical students to study human anatomy.

Arteriogram Imaging of blood vessels used for diagnostic purposes i.e., to detect blockage or narrowing of the vessels.

Iatrogenic Condition, illness, or injury resulting from the process of medical

Paucity Scarcity, presence of something in small or insufficient quantities/amount.

Embalming The process of preserving the human body by use of chemicals, to prevent decomposition/decay.

Dissection Cutting up/cutting open a cadaver to identify different structures.

The cubital fossa Triangular depression /area located anteriorly to the elbow joint.

Bicipital aponeurosis Broad medial expansion of the tendon of the biceps tendon at the elbow.

Profunda brachii One of the branches of BA, it's the first and largest branch of BA.

Black African population Black people of African descent born and living in Africa excluding Arabs Asians and white immigrants.

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CHAPTER ONE

INTRODUCTION

1.1 Back ground of the Study

Arterial variations in the upper limb were first noted by Von Haller in 1813 (Bidarkotimath *et al*., 2011). Quains (1844) was believed as the first person to provide sufficient data for useful statistical evaluation regarding the brachial artery(Tsoucalas *et al.,* 2020a).The brachial artery (BA) is the major arterial supply of the upper limb, it commences at the inferior border of teres major muscle as a direct continuation of the 3rd part of axillary artery and courses to the arm anterior to triceps and brachialis muscle, it terminates at the neck of the radius by dividing into radial and ulnar arteries (Tsoucalas *et al.,* 2020a).

In the arm, its superficial in its course and gives off the following branches, profunda brachii which is the largest branch and supplies triceps brachii, superior and inferior ulnar collateral(SUC&IUC) arteries, muscular branches to supply muscles of anterior compartment of the arm i.e. biceps brachii, coracobrachialis and brachialis, nutrient artery to the humerus, and terminates into the ulnar and radial arteries (Shivanal & Gowda, 2015).

The BA is of clinical importance to health care professionals for its use clinically for, brachial pulse identification, blood pressure monitoring, arteriography, percutaneous arterial catheterization, and arteriovenous fistula (AVF) for dialysis patients and various radiological interventions. Variations in the morphology and branching pattern in the BA and its course may lead to misdiagnosis i.e., pulse, blood pressure monitoring and in interventional radiological procedures.

There are several variations in origin and distribution of BA for example, the artery can divide into two trunks proximally, which then reunite, it can course superficially, in front rather than behind the median nerve, it may have a high division into its terminal branches, most commonly seen as radial artery arises first (high origin of radial artery-brachioradial artery) while ulnar artery and common interosseous continuous as a common trunk (Kaur *et al.,* 2017).

Study conducted on 70 cadavers, where 140 upper limb specimens were dissected, found out that there was an accessory brachial artery arising from the axillary artery along with the main brachial artery in (14.3%) of specimens. Accessory brachial artery (ABA) did not have any branches and profunda brachii was seen originating from of axillary artery in 6 cadavers (8.57%) (Chakravarthi *et al.,* 2014).

A study on surgical significance of BA on 162 upper limb specimens found out that, (12.3%) of specimens had superficial brachioradial artery, (6.1%) had superficial brachial artery, termination of brachial artery varied, radial neck (79%), radial tuberosity (8.6%), proximal arm (11.1%) and mid-arm (1.2%) of the specimens. Termination pattern was either bifurcation into radial and ulnar arteries (90.1%), trifurcation into radial, ulnar and common interosseous arteries (9.3%) or trifurcation into profunda brachii, radial and ulnar arteries (0.6%) (Pulei *et al.,* 2012).

Due to its clinical importance, knowledge on BA variation is important to health care professionals, specifically surgeons, and radiologists including anatomists as the brachial artery is used in various diagnostic procedures e.g. blood pressure monitoring, arteriovenous fistula for dialysis in patients with chronic kidney injury, interventional/surgical procedures of the upper arm to avoid complications such as Volkmann's ischemic contracture (Narayanan & Murugan, 2018). Due to inadequate data on brachial artery and it's branching pattern among black African the population and specifically in western region it's important to carry out this study.

1.2. Statement of the Problem

There is insufficient data and knowledge of variations in the anatomy of brachial artery and its branches especially among black African population and due to these variations clinicians may find it difficult to locate BA pulse or blood pressure monitoring. BA is of great significance due to the clinical procedures performed in the upper arm. Locally brachium is the most commonly used part, in blood pressure monitoring, blood sample collection for investigations and cannulation to administer intravenous drugs. Brachial blood pressure and pulse results can differ during monitoring of patients due to these variations. This can lead to misdiagnosis of patients due to either absent, abnormal pulse or inability to locate the brachial artery. Vascular Surgeons, orthopedic surgeons and interventional radiologists, may also encounter problems during procedures such as open reduction and internal fixation (ORIF) of upper limb fractures, arteriography secondary to these variations which can be fatal to the patients. Clinicians may also confuse between superficial BA and cubital veins during cannulation and administration of IV (Intravenous) drugs thus leading to ischemia and gangrene of the arm.

Procedures like arteriovenous fistula of brachium is currently preferred for dialysis of patients, though there are reports of failures of this procedure due to BA variations (Tsoucalas *et al.*, 2020).This study therefore sought to understand these variations to help avert any injuries, fatalities, misdiagnosis or misreporting during diagnostic procedures and triage of patients.

1.3 Broad objective of the Study

To evaluate the variation in morphology of brachial artery and its branching pattern among the black African population.

1.3.1 Specific Objectives

i. To assess the variation in origin, and the termination of brachial artery among black African population, from western Kenya.
ii. To assess the variation in the branching patterns and the length of brachial artery among the black African population, from western Kenya.
iii. To compare the variations of brachial artery between gender and laterality among the black African population, from western Kenya.

1.4 Research questions

The study was guided by the following research questions:

i. What are the variations in the origin, and the termination of the brachial artery among the black African population, from western Kenya?
ii. What are the variations in the branching patterns and the length of the brachial artery among the black African population, from western Kenya.?
iii. What's the comparison in the variations of brachial artery between gender and laterality among the black African population, from western Kenya.?

1.5 Justification of the study

Studies done in various Asian and European countries had showed variations in brachial artery and its branching patterns however there was paucity of data on black African population hence the need to carry out the study. Availability of adequate data from various studies on the black African population enhances clinicians knowledge into understanding upper limb arterial variants during radiological diagnostic and surgical procedures, thus minimizing diagnostic and surgical errors, complications and improving patient management and outcome of care.

1.6 Significance of the Study

Documenting anatomical variations on morphology of brachial artery and its branching pattern among black African population, is of help to clinicians in their daily practice. It gives important data and basis for other researchers, thus the study findings added more knowledge on the variations of brachial artery and its branching pattern and formulation of standard operating procedures during surgical and interventional diagnostic radiological procedures involving the upper limb.

1.7. Assumptions of study

Study Cadavers are true replica of black African population and variations of the brachial artery and branching pattern found in the study was a true replica of the black African population.

1.8. Scope of the Study

The study was limited to anatomical variation in the brachial artery and its branching pattern among black African population on sampled cadavers from Maseno, Uzima, and Masinde Muliro Universities human anatomy laboratory.

1.9. Possible Limitations and delimitation of the study

Difficult in cadaver acquisition as there are few cadavers, thus three universities were used to achieve required sample size. Few female cadavers, thus three universities were used to get desired sample size of female cadavers. Access to institutions of study may be an issue of concern specifically in getting access to anatomy laboratories, formal request was made to laboratory administration on time to overcome the challenge.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

2.1.1. Anatomy of brachial artery

Arterial variants in the upper limb were first discovered by Von Haller in 1813 (Bidarkotimath *et al*., 2011). Quains (1844) was believed to be the first person to provide sufficient data for useful statistical evaluation in variations of the brachial artery (Tsoucalas *et al.*, 2020). The brachial artery (BA) is the major arterial supply of the upper limb, it commences at the inferior border of the tendon of teres major as a direct continuation of the 3rd part of axillary artery and courses to the arm anterior to triceps and brachialis muscle, it terminates about 1cm at the neck of the radius by dividing to radial and ulnar arteries (Tsoucalas *et al.,* 2020).In the arm, its superficial in its course and gives off the following branches, profunda brachii which is the largest branch of BA and supplies posterior compartment of the arm (triceps brachii), superior and inferior ulnar collateral arteries, muscular branches to supply muscles of anterior compartment (biceps brachii, coracobrachialis and brachialis), nutrient artery to the humerus, and terminates into the ulnar and radial artery (Shivanal & Gowda, 2015).

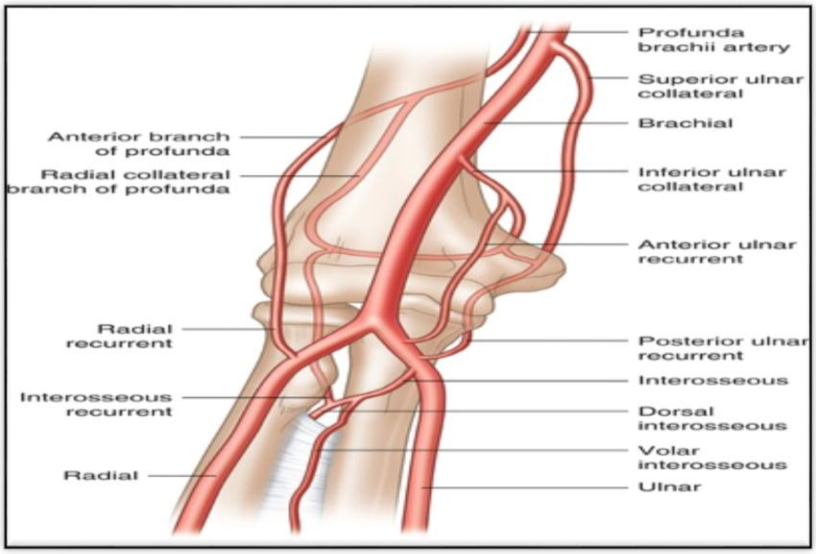

Figure 2. 1.Brachial artery and branches Adopted from (Netter, 2010)

Knowledge regarding the known normal anatomy and variant arterial anatomy of the upper limb, has significant importance, it can guide vascular radiologist, surgeons, and clinicians for accurate diagnostic interpretation as well as in the conduct of interventional and surgical procedures of upper limb (Ogeng'o, 2013).This knowledge is of great importance during percutaneous catheterization to prevent complications arising from accidental damage, it is important for plastic surgeons using flaps for reconstructive surgery (Udainiya et al., 2018).BA and ante-brachial arteries are currently arteries of choice for arteriovenous fistula between radial artery and cephalic vein for dialysis in treatment of chronic kidney injury as it lasts longer and needs less maintenance (M. Singh *et al.*, 2020).

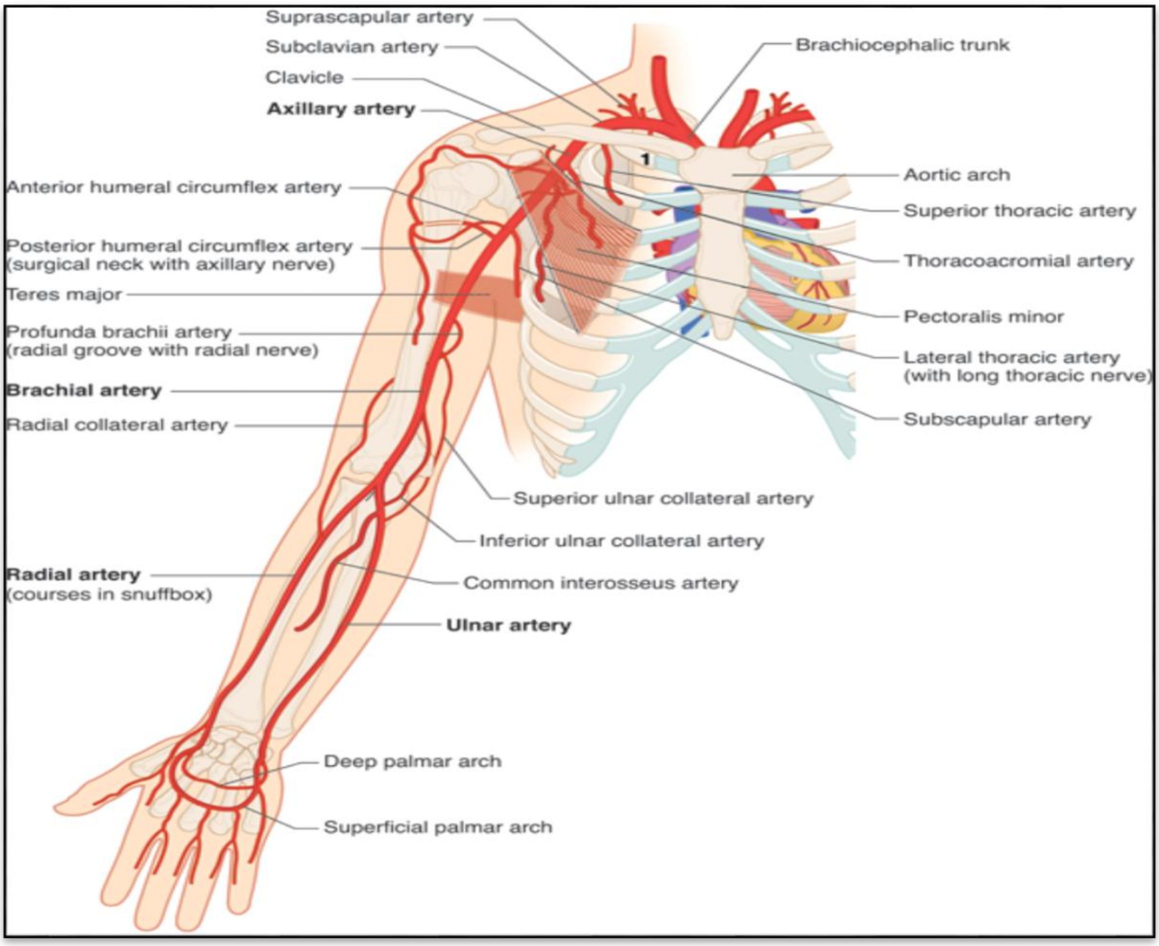

Figure :2.2.showing origin and termination of brachial artery adopted from (Hansen, 2021)

2.1.2. Relations of brachial artery

Its relations proximally, median nerve is antero-lateral, whereas median cutaneous nerve of the forearm and ulnar nerve are medially (Clarke *et al*., 2022).In upper part of the arm it's related to medal cutaneous nerve of the arm anteriorly, median nerve crosses it from lateral to medial side in the middle part and bicipital aponeurosis in the inferior part. posteriorly it lies on brachialis, long and medial head of triceps (Itoo, 2021).Medially on upper part it's related to ulnar nerve and basilic vein, on inferior side median nerve. Laterally its related to coracobrachialis an biceps brachii (George *et al*., 2019).

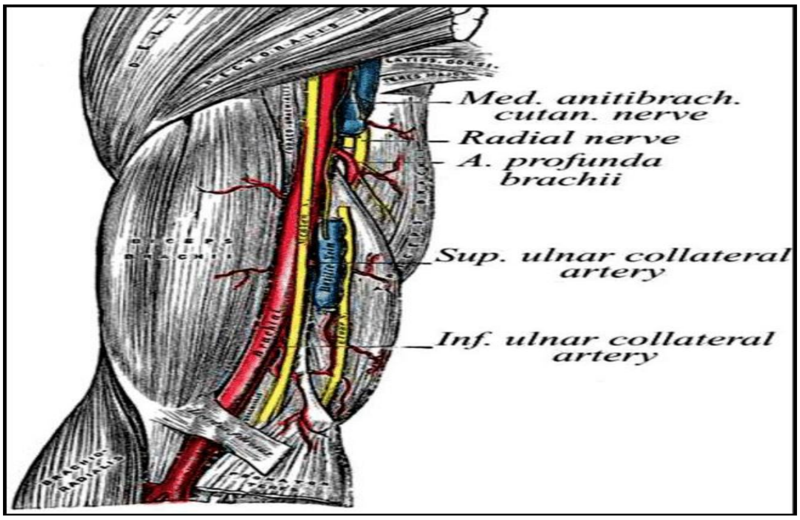

Figure:2. 3 Showing relations of brachial artery adapted from (Netter, 2010)

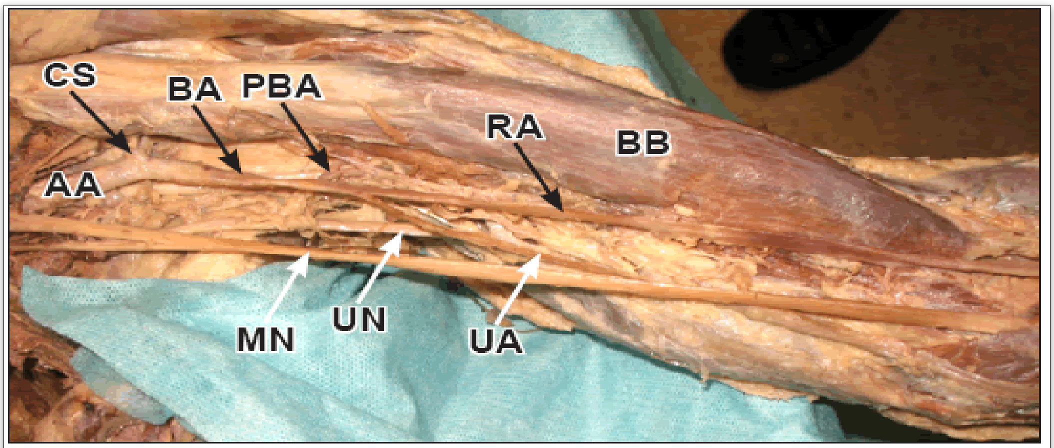

Figure 4. Photograph of the left *brachial artery* (***BA***) terminating in the upper part of arm into the *ulnar* (***UA***) and *radial arteries* (***RA***). (***AA***: *axillary artery;* ***PBA***: *profunda brachii artery;* ***CS***: *common stem of anterior and posterior circumflex humeral arteries;* ***UN***: *ulnar nerve;* ***MN***: *median nerve;* ***BB***: *biceps brachii)*

Figure: 2. 4.Cadaveric image of brachial artery branches adapted from (Aughsteen et al., 2011)

2.1.3. Embryology of brachial artery

In earlier stages limb bud is supplied by inter-segmental arteries that take part in primitive capillary plexus formation. At the tip of limb bud terminal plexus is present, that is renewed distally as the limb grows, in later stages ,lateral branch of seventh inter-segmental artery gives rise to axis artery of the upper limb bud (Jadhav & Pawar, 2018).

Main trunks on the proximal part gives rise to axillary artery, BA and its distal part persists as the anterior interosseous artery and deep palmar arch, ulnar artery develops as a branch from original brachial branch extending down the forearm on lateral side (Jadhav & Pawar, 2018).From the main trunk radial artery arises more proximally as opposed to ulnar artery, but later own anew connection is formed by radial artery with the main trunk near the origin of ulnar artery. Upper part of usually disappears thus ulnar and radial artery arise at the same level (Jadhav & Pawar, 2018).

Causes of anomalous origin of arteries may be explained by persistent genesis and disappearance/regression of an artery other than normal one, altered hemo-dynamics and environmental changes may result in arterial variations (Panagouli *et al*., 2014).

According to (Ammal, 2020), knowledge of variations of BA and its branching pattern is important for good treatment outcome i.e. in vascular surgery, plastic surgery, arterial cannulation and in avoiding surgical complications' and iatrogenic injuries. Presence of this variations may lead to misinterpretation of angiographic images, accidental puncture of superficial arteries while attempting to find a vein.

2.2. Variation in origin and termination of brachial artery

Normally it's known that BA is continuation of axillary artery at lower border of teres major tendon and terminates by dividing into ulnar and radial artery about 1cm at the neck of radius (Jadhav & Pawar, 2018). Studies done have shown variation of brachial artery at different levels, variations in the course and distribution of the main arteries of upper limb have been discovered in 25% of studied cases (Tsoucalas *et al*., 2020). BA variants can be at different level, proximally it can divide into two trunks that later reunite, it can follow a superficial course, passing anterior to median nerve rather than posterior to it, thus referred to as superficial BA which has incidence of 3.6-9.6% (Tsoucalas *et al*., 2020).

Other studies done, have shown high bifurcation of BA 8%,high origin of radial artery 15%,high origin of ulnar artery 2% and high division of a superficial BA <1% (Tsoucalas *et al*., 2020).

A study conducted on 29 cadavers, found out high termination of brachial artery in 3(5.17%), (1.72%) the middle of the arm two (3.45%) at lower 1/3 of the arm (Jadhav & Pawar, 2018). Case report on 60year old male cadaver found high division of right brachial artery, artery was dividing into ulnar and radial artery after short course in upper 1/3 of the arm (Khatun & Shah, 2021) .According to (Ahmadpour & Foghi, 2019) case study found out absence of superior and inferior ulnar collateral arteries.

A study on morphology and variations of brachial artery conducted on 30 upper limbs of 15 cadavers, that was used to asses length of brachial artery, level of termination, variation in branching pattern and course in relation to median nerve found average length to be 25.23cm (George *et al*., 2019). BA terminated at the level of neck of radius in 76.6%, radial tuberosity in 13.3%, mid arm 3.33% proximal arm 6.67% radial tuberosity 6.67%, it gave accessory brachial artery in 1case (3.3%) superficial brachial artery was observed in 2 cases (6.67%), common trunk of origin for profunda brachii and superficial ulnar collateral (SUC) artery in 3.3% (George *et al*., 2019).

A study that was done on 162 upper limb specimens found out that, 12.3% of specimens had superficial brachioradial artery, 6.1% had superficial brachial artery, termination of brachial artery varied, radial neck (79%), radial tuberosity (8.6%), proximal arm (11.1%) and mid-arm (1.2%) of the specimens (Pulei *et al*., 2012). Termination pattern was either bifurcation into radial and ulnar arteries(90.1%), trifurcation into radial, ulnar and common interosseous arteries (9.3%) or trifurcation into profunda brachii, radial and ulnar arteries (0.6%) (Pulei *et al*., 2012). As such the current study seeks determine variations in origin and termination of brachial artery in black African population.

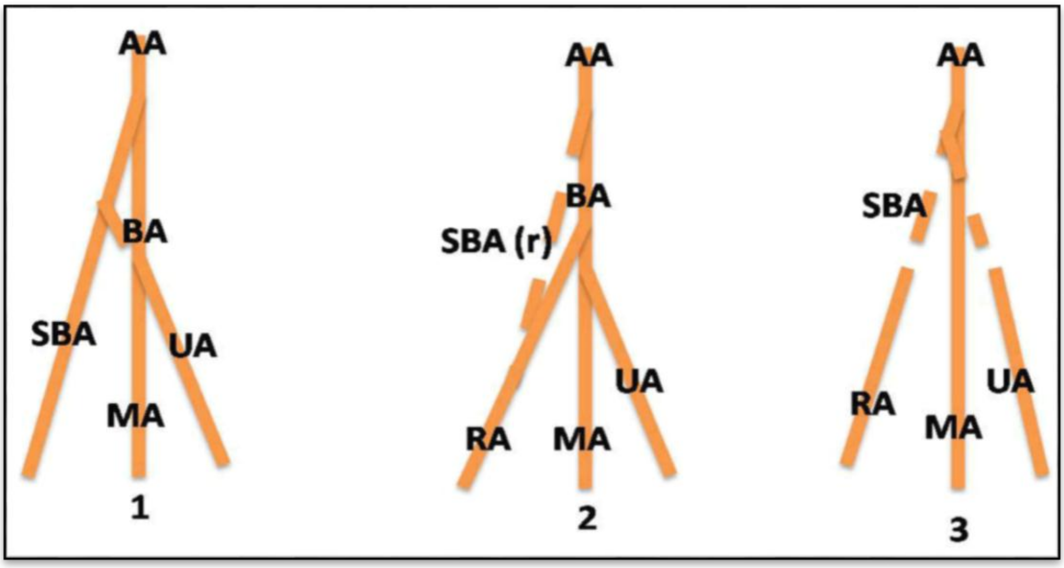

Figure: 2.5.Showing patterns of variation in brachial artery(Tsoucalas et al., 2020a).

2.3. Variation in the branching pattern and length of brachial artery

The normal documented branching pattern of brachial artery is by bifurcation of its terminal branches into radial and ulnar arteries, but due to variations in studies done two patterns have been identified i.e. bifurcation and trifurcation (Breihan *et al*., 2021). Studies have shown most common site for embolism is at bifurcation of brachial artery and higher bifurcation may lead to large ischemic area thus being fatal M. Singh *et al.,* (2020).

Study conducted on 15 cadavers found out in one case (3.3%) trifurcation of brachial artery into radial, ulnar and common interosseous at the level of the neck of radius (George *et al*., 2019). To understand variations in brachial artery many authors divide it into three phases, upper 1/3, and middle 1/3 and lower 1/3. Study conducted 45 upper limb cadavers found out bifurcation of BA into ulnar and radial arteries both of equal caliber at the junction between middle 1/3 and lower 1/3 of the arm (Patil *et al*., 2014).

According to documented case reports of superficial brachial artery (SBA) originating from axillary artery and terminating in different patterns, in first case it terminated by bifurcating into radial and ulnar arteries, second case SBA continued as radial artery and third case it originated from 2nd part of axillary artery and bifurcated into radial and common interosseous arteries (Nkomozepi *et al*., 2017).

A case study done in Nigeria on right upper limb adult male cadaver, found out unilateral high bifurcation of BA ,it bifurcated in proximal ½ of the arm about 7.5cm distal to the lower border of teres major muscle into ulnar and radial arteries (Auwal *et al*., 2017).

A study on surgical significance of BA, found out BA branching pattern as bifurcation into radial and ulnar arteries (90.1%), trifurcation into radial, ulnar and common interosseous arteries (9.3%) or trifurcation into profunda brachii, radial and ulnar arteries 0.6% (Pulei *et al*., 2012).

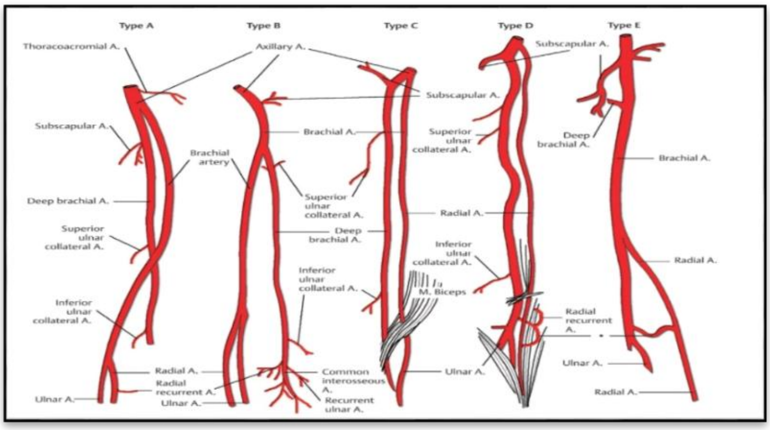

Figure:2. 6.Showing variation in termination and branching pattern of brachial artery adopted from (Themes, 2021)

2.4. Variation of brachial artery between genders and laterality

Majority of studies done have shown there might be difference in variation in terms of race and laterality but few highlight relationship in variations between gender and laterality, specifically in black African population where there is paucity of data.

Study conducted on 56 upper limb specimens, found variations only in male cadavers and variations were on the right hand, 94.4% showed normal morphological pattern of BA,5.3% showed superficial BA, 1.78% showed tortuous superficial BA trifurcating into radial, ulnar and common interosseous artery in cubital fossa, there was no any variation seen in female cadavers and on left side of male cadavers (Lalit & Piplani, 2021). The current study sought to compare variations in gender and laterality among black African population.

2.4. Conclusion

Anatomical variations in morphology of brachial artery and its branching pattern are of great clinical significance, understanding these variations in black African population will enable health care professionals minimize diagnostic and surgical related errors thus good prognosis and patient care, in majority of studies done, very few studies assessed/ compared gender and laterality and none in black African population.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study area

The study was done in the departments of human anatomy in three universities located in western region with well-established human anatomy laboratories, Maseno University, Uzima University, Masinde Muliro University. Maseno University offers science, Business, education, agriculture and health science programs, both at undergraduate and postgraduate level, it's located in Maseno town along the equator. Uzima University offers health science courses and is located in the outskirts of Kisumu city, Masinde Muliro University offers undergraduate and postgraduate courses in education, business, agriculture, engineering and health programs, it's located in Kakamega town along Kakamega, Webuye road.

3.2. Study Design

Cross-sectional descriptive study design was adopted.

3.3. Study subject

The cumulative number of cadavers acquired by three universities in 2022 academic year is 96. Distributed as follows 48,26,22 from Maseno, Masinde muliro and Uzima universities respectively. All cadavers were stored in cold room after undergoing embalming process and can be stored for two years before disposal. Cadaver acquisition process was done in line with anatomy act, tissue collection and disposal guideline.

3.4. Sample size determination

Sample size must be large enough to be representative of the universe population (Mugenda & Mugenda, 2012). The researcher used Yamane Taro (1967) formula to come up with a sample size as shown below;

$$n = \frac{N}{1 + N(e^2)}$$

Where

n is the desired sample size.

N is the study population.

e margin of error assumed to be 0.05.

$$n = \frac{96}{1+96(0.05)^2} = 77 \text{ cadavers.}$$

According to (Kothari, 2017), a representative sample size is one which is at least 10% of the targeted population. The researcher drew a sample size of 77 cadavers (n=77). It was arrived at through sampling procedure illustrated in table 3.1. The cadavers were sampled using random sampling.

Table: 3.2Sample size

Details	Sample size	population
Maseno University	38	48
Masinde Muliro university	21	26
Uzima university.	18	22
Total	77	96

3.5. Sampling method

Three universities were identified purposively and conveniently because of their functional human anatomy laboratory department as they have met commission of university education (CUE) standards for storage of human tissues in western Kenya, for uniformity in sample distribution. To ensure uniformity in distribution of samples, sampling was done proportionately with the strata population by location, where the sample size per laboratory was calculated by dividing laboratory cadavers (*d*) by total location population (96), then multiplying by the desired sample size (77).

n= (dx77/96). Due to difficulty in acquiring specimen, convenience sampling method was used, any cadaver that meets inclusion criteria was picked until total number of samples was reached.

3.6. Selection criteria

3.6.1: Inclusion criteria

All cadavers with upper limb intact, of African origin and with no any deformity.

3.6.2: Exclusion criteria

Cadavers had missing upper limb and with any deformity, on African origin cadavers.

3.7. Study variables

3.7.1. Dependent variables

Variation, Origin, Branching pattern, termination.

3.7.2. Independent variables

Brachial artery, Sex, laterality (right and left upper limbs).

3.8. Data collection tools

Data entry forms with detailed information on variations i.e., Origin, branching pattern, termination of brachial artery and were used for collection of data from coded cadavers. As shown in the appendix (IV).

INSTRUMENTS.

- Dissection kit.
- Tape measure.
- Surgical Gloves
- Digital camera-Sony 3”64megapixel (MP).

3.8.1. DATA COLLECTION PROCEDURE

3.8.2.1. Acquisition of cadavers

Cadavers for dissection by medical students both undergraduate and postgraduate, were acquired legally from public hospital mortuaries in liaison between human anatomy department and hospital administration upon notification on availability, majority of cadavers acquired are unclaimed bodies, few are donations.

Once the university had been notified of availability of cadavers, formal arrangement was made to collect the cadavers. They were transported in designated van from hospital mortuary to teaching institution laboratory where embalming is done thoroughly to prepare them for teaching purposes, well embalmed cadaver can last for a period of 2 years.

3.8.2. 2. Exposure of brachial artery

To expose the BA the following procedure were to be followed:

An incision was made along the median plane of the body from suprasternal notch to the xiphoid process and extended from tip of xiphoid process superiorly and laterally to the nipple and continue along the anterior fold of the axillae to the arm.

In the arm, incision was directed inferiorly for about 10-12cm and transversely across the front of the arm to its lateral border. Separate incision was made from upper border of the sternum along the clavicle to its acromial end and skin flaps reflected on either side.

Superficial fascia was dissected along the sternal border and extend along the deltopectoral groove. Pectoralis major muscle and clavicular head were detached and flapped towards point of insertion, dissection of its fibers was made vertically from the sternum, medial part was reflected in the direction of median plane and lateral part was reflected towards the arm in order to expose pectoralis minor.

Fascia underlying pectoralis minor muscle was cleaned and inferior part of the axillae opened up. Lateral part of pectorals minor, short head of biceps and coracobrachialis were exposed and cleaned up. Lower part of the axillae was cleaned and pectoralis minor divided midway between its point of origin and insertion and reflected. The teres major muscle was identified and brachial artery located.

Skin and superficial fascia was reflected and deep fascia dissected longitudinally along middle of biceps brachii. Transverse incision was made at the level of epicondyles and each flap reflected.

Origin of BA and its branches were located, the area was cleaned up and BA branches traced. In the cubital fossa, bicipital aponeurosis was dissected and terminal branches of BA (radial & ulnar arteries) was exposed and keenly observed.

Point of origin of the branches of BA, i.e., profunda brachii, SUC, IUC and their termination was identified.

Results/findings were entered in data entry forms and digitally photographed. Different branching patterns, variations in origin, termination and comparison in terms of gender and laterality were studied and analyzed.

3.9. Data analysis

Data forms were entered in excel sheet and statistical package of social sciences (SPSS) version 26.0 for windows, was used to analyze collected data. Descriptive statistics was applied to analyze objective 1 and 2 mean mode and median to asses' variations and branching pattern from collected data. Pearson's Chi-square was used to assess relationship between independent variable and dependent variable, standard error of mean (SEM) was determined to analyze the variation in origin and branching pattern of brachial artery from normal. Independent t-test was used to compare the variation of brachial artery between gender and laterality in the black African population.

Independent t-test was used for any significance difference noted in variations, significance of correlation and association was assumed at a $p<0.05$ and confidence interval of 95%. Data was presented inform of tables, and chart.

3.10. Reliability and validity of research instruments

Reliability of research instruments is the extent to which a research instrument gives consistent results using test- retest *(Kothari, 2017).* To ensure reliability a uniform data entry form was developed upon pretesting. A pilot study to test and retest the reliability and validity of data collection tools was done using two complete specimens, in case of any problems or errors seen the data collecting tools were adjusted to avoid errors in the process thus giving valid and reliable results all factors put into consideration.

3.11. Ethical considerations

Permit to conduct the study was authorized by the Maseno university scientific and ethics review committee (MUERC), Ref number MSU/DRPI/MUSERC/01140/22, NACOSTI license number NACOSTI/P/23/22873 and letters of approval from Masinde Muliro University and Uzima university.

3.12. Data dissemination

Findings of this study were disseminated to clinicians, policy makers and issued to relevant anatomical journals.

CHAPTER FOUR

RESULTS

4.1 Demographic characteristics

The study investigated the origin and termination of the brachial artery, branching pattern and length of brachial artery (BA) among black African population that comprised of 154 upper limbs of 77 cadavers. A total of 77 cadavers were included in the study, with 38 (49.4%) being female and 39 (50.6%) being male (Table 4.1).

Table 4.1. Gender of the cadavers

Gender	N	%	Valid percent	Cumulative percent
Female	38	49.4	49.4	49.4
Male	39	50.6	50.6	100.0
Total	77	100.0	100.0	

Cross tabulation of demographic characteristics and cumulative percentages

4.2 Variation in the origin and termination of the brachial artery

4.2.1 Origin of brachial artery in the upper limbs

The majority of the upper limbs (96.1%) had a normal origin of the brachial artery. One upper limb had both the brachial artery and profunda brachii originating from the axillary artery, while another one had profunda brachii originating from the second part of the axillary artery. Four upper limbs (2.6%) had a superficial origin of the brachial artery (Table 4.2).

Table 4.2 Origin of the brachial artery in the total upper limbs (n=154)

origin of the brachial artery	n	%	Valid Percent	Cumulative Percent
Brachial artery and profunda brachii originating from axillary artery	1	0.6	0.6	0.6
Normal	148	96.1	96.1	96.8
Normal origin. profunda brachii originating from 2nd part of axillary artery.	1	0.6	0.6	97.4
Superficial origin of brachial artery.	4	2.6	2.6	100.0
Total	**154**	**100.0**	**100.0**	

Cross tabulation in origin of BA and its variants in percentage and cumulative percentage

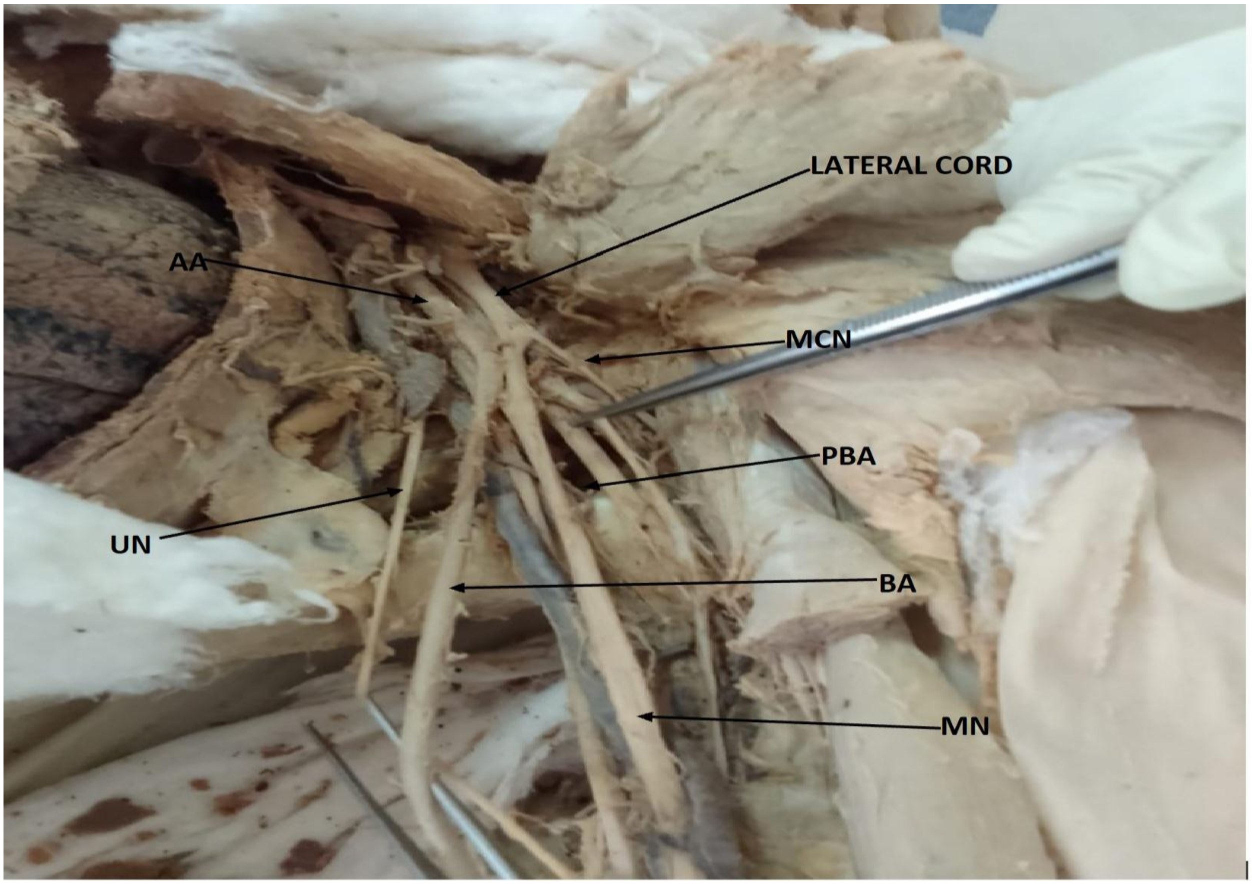

Figure 4.1: Variation in the origin of brachial artery; Origin of superficial brachial artery in relation to Median nerve (MN), Musculocutaneous nerve (MCN), Ulnar nerve (UN) and lateral cord of brachial plexus. Key: UN: Ulnar nerve, AA: Axillary artery, PBA: Profunda Brachii artery, BA: Brachial artery.

Table 4.3: Relations between the normal origin and variations in the origin of brachial artery

Chi-Square Tests		
		NORMAL.
ORIGIN LEFT.	Chi-square	0.987
	df	1
	p value	0.320
ORIGIN RIGHT.	Chi-square	5.210
	df	3
	p value	0.157

Data shows degree of freedom and p values. Both limbs were categorized in left and right BA. Statistical significance was determined by chi-square (χ^2) analysis at p value <0.05 (Table 4.3)

4.2.2 Variation in termination of brachial artery in the upper limbs

Out of 154 upper limbs studied, the majority (89.0%) had a normal termination at the radial neck, while 7.8% terminated at the radial tuberosity. A small percentage of the upper limbs (1.3% and 1.9%) had termination at midarm and proximal arm, respectively. These findings suggest that the radial neck is the most common termination site for the brachial artery in upper limbs (Table 4.4).

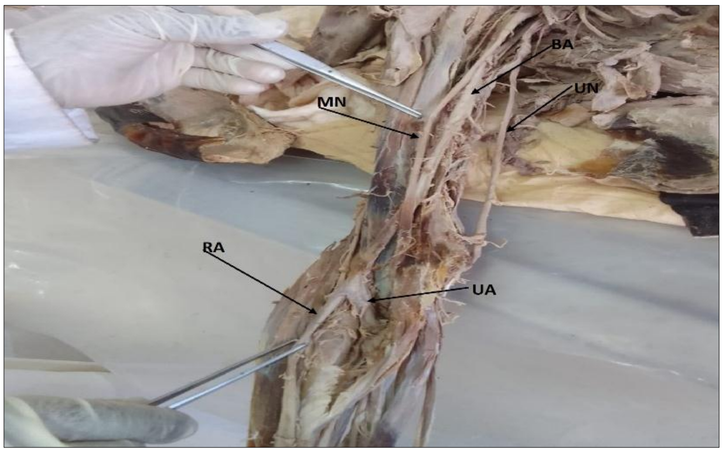

Figure:4.2: Termination of brachial artery at radial tuberosity.

KEY:BA-Brachial artery; UN-Ulnar nerve; MN-median nerve; RA-Radial artery; UA-Ulnar Artery.

Table 4.4 Termination of the brachial artery in upper limbs

Termination of the brachial artery	N	%	Valid percent	Cumulative percent
Midarm	2	1.3	1.3	1.3
Proximal arm	3	1.9	1.9	3.2
Radial neck	137	89.0	89.0	92.2
Radial tuberosity	12	7.8	7.8	100.0
Total	**154**	**100.0**	**100.0**	

Cross-tabulation of variant termination of BA and their cumulative percentages

Table 4.5: Association between the normal termination and variations in termination of brachial artery

Chi-Square Tests		
		NORMAL.
TERMINATION RIGHT	Chi-square	6.875
	df	6
	pValue	0.333
TERMINATION LEFT	Chi-square	1.145
	df	2
	pValue	0.564

There was no statistically significant difference variation (p=>0.05) in the termination of brachial artery when correlated with the normal terminating patterns

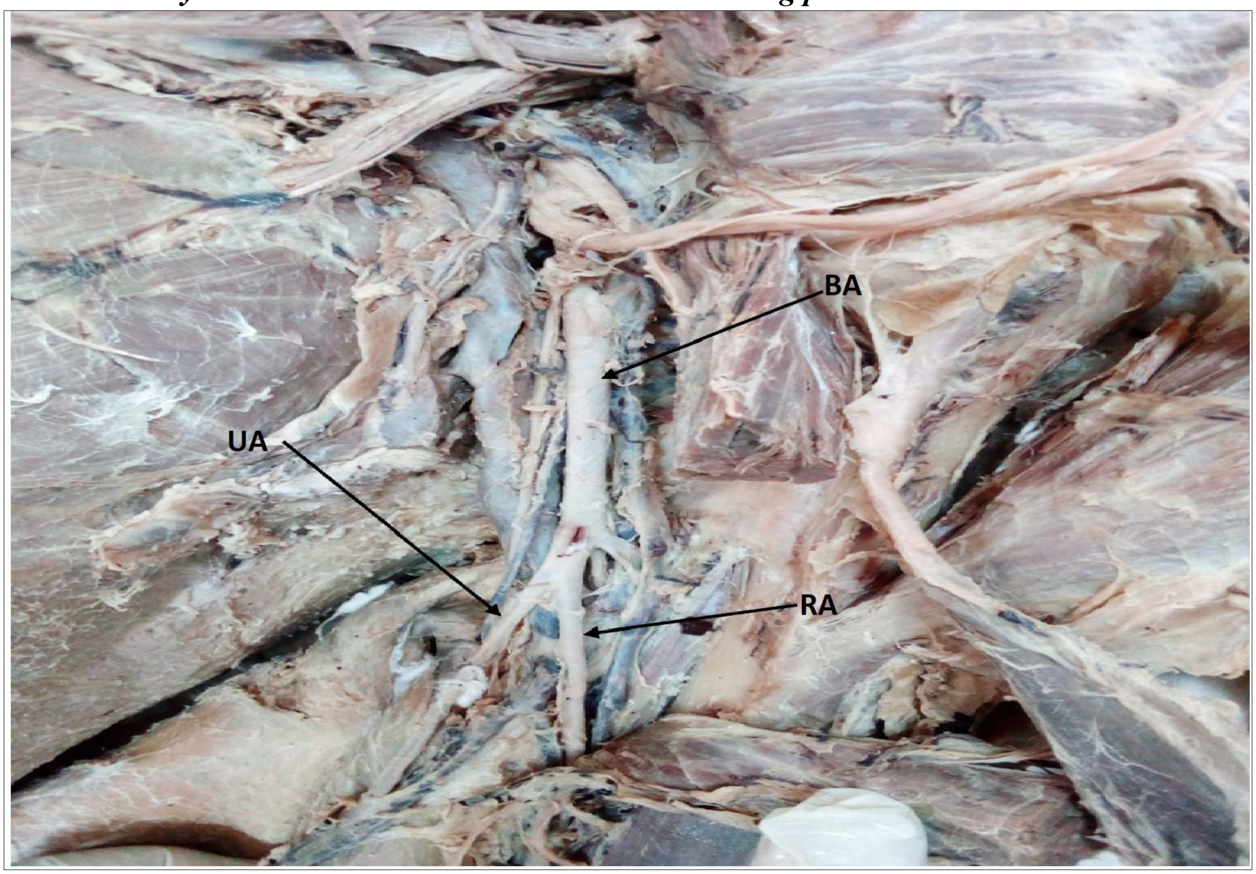

Figure 4.3: Termination of brachial artery in mid arm and High bifurcation.
Key; BA-Brachial artery; UA-Ulnar artery; RA-Radial artery.

4.3 Variations in length and branching patterns of the brachial artery

4.3.1 Branching patterns of upper limbs

A total of 154 cases were included in the study. The most common branching pattern observed was bifurcation into radial and ulnar arteries seen in144 upper limbs (93.5%). High bifurcation of the radial and ulnar arteries was seen in 4 cases (2.4%). Trifurcation into radial, ulnar, and interosseous artery was seen in 6 cases (4.1%%) (Table 4.6).

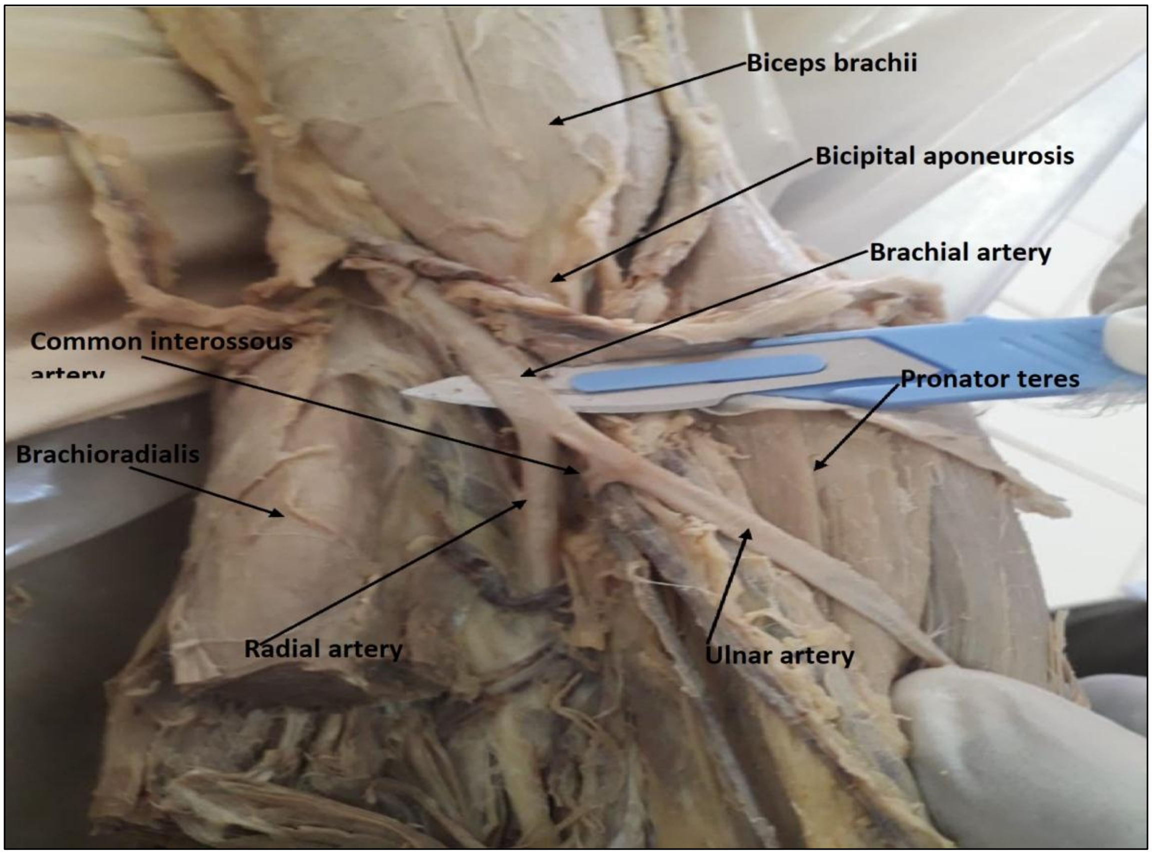

Figure 4.4: Bifurcation of brachial artery into radial and ulnar artery, Common interosseous originating from ulnar artery.

Table 4.6. Branching patterns of upper limbs

Branching patterns of upper limbs	n	%	Valid Percent
Bifurcation into radial and ulnar arteries.	144	93.5	93.5
High bifurcation- radial and ulnar arteries	4	2.4	2.4
Trifurcation into radial, ulnar and interosseous artery.	6	4.1	4.1
Total	**154**	**100.0**	**100.0**

Cross tabulation of the branching pattern of BA and frequencies

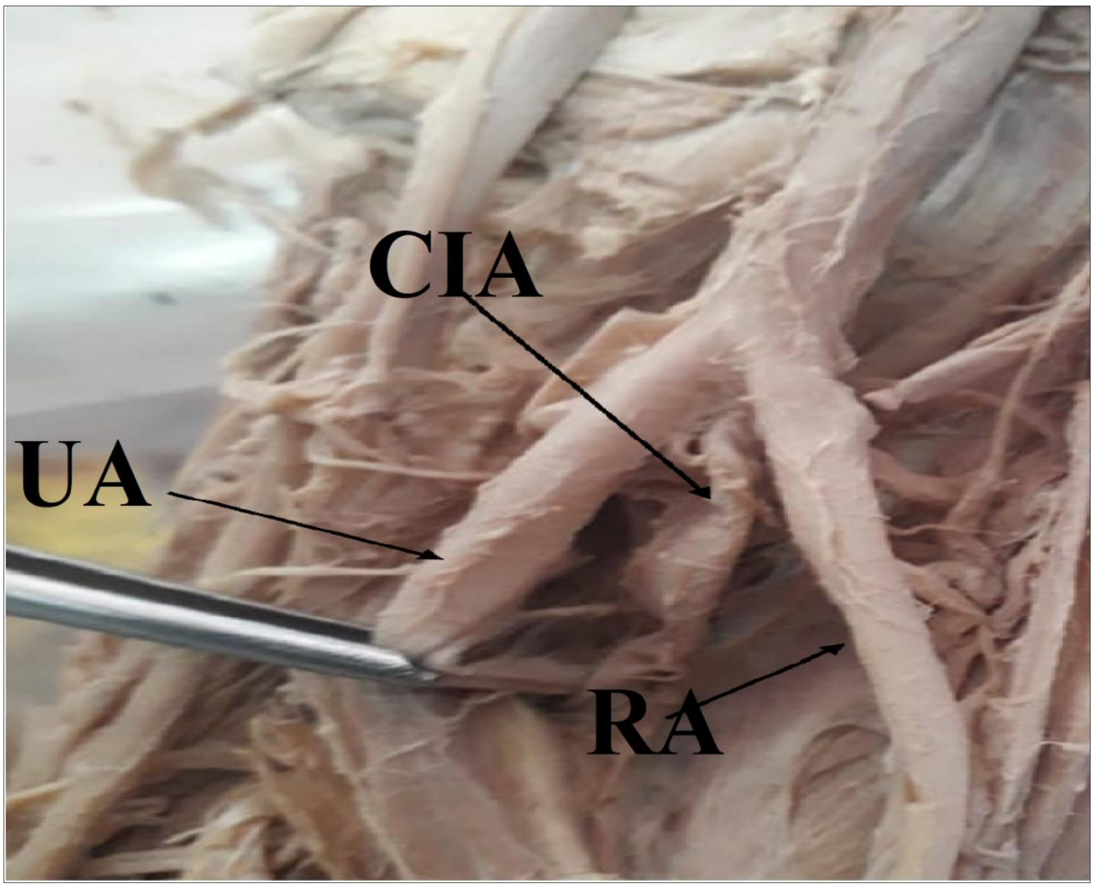

Figure 4.5: Trifurcation of BA into ulnar, radial and common interosseous artery.

Table 4.7: Relations between the normal branching and variations in the branching patterns of brachial artery

Chi-Square Tests		
		SEX.
TERMINATION RIGHT	Chi-square	6.875
	Df	6
	Sig.	0.333
TERMINATION LEFT	Chi-square	1.145
	Df	2
	Sig.	0.564

Differences in proportion of termination of BA with respect to laterality was determined using Chi-square. Statistically significant was set at p=>0.05.

4.3.2 Variation in the length of the brachial artery

The data includes measurements from 154 upper limbs of 77 cadavers, with a mean length of 26cm, median length of 26cm, and a standard deviation of 1.0 The minimum observed length was 16cm, while the maximum observed length was 30cm. These statistics suggest that the length of the brachial artery in upper limbs is relatively consistent, with little variability between measurements.

Table 4.8: Length of brachial artery in all upper limbs

Total upper limbs	Mean	Median	Standard deviation	Minimum	Maximum
Length	26	26	1	16	30

Cross tabulation of the Mean length of the BA

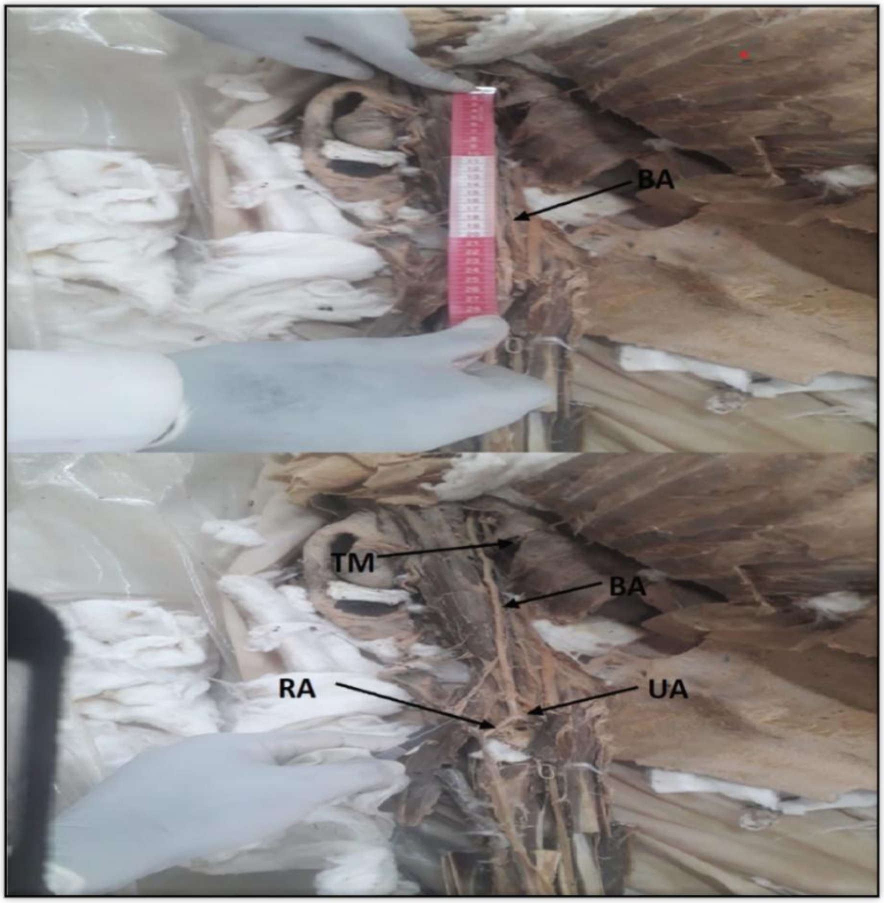

Figure:4.6 Measuring the length of brachial artery.

4.4. Comparison of variation of brachial artery between sex and laterality

4.4.1. Comparison between the origin of the brachial artery and sex

Table 4.9 also presents the correlation between the origin of the brachial artery and sex, as well as the corresponding crude odds ratios (COR), adjusted odds ratios (AOR), and p-values. The table shows the different origins and terminations of the brachial artery and the corresponding percentages of females and males. The reference group is the normal origin of the brachial artery, which is observed in 49.4% of females and 49.4% of males. The other groups are defined based on variations in the origin or termination of the brachial artery. The results show that in the group with a superficial origin of the brachial artery on the left, there were no females, but one male had this variation, representing 1.3% of males. The COR and AOR for this group were 1.21 (95% CI: 0.67-2.20) and 1.15 (95% CI: 0.60-2.20), respectively, and the p-value was not statistically significant (p=0.654).

In the group with the brachial artery and profunda brachii originating from the axillary artery, there were no females, but one male had this variation, representing 1.3% of males. The COR and AOR for this group were 0.92 (95% CI: 0.26-3.27) and 0.97 (95% CI: 0.26-3.61), respectively, and the p-value was not statistically significant (p=0.958). In the group with a normal origin of the brachial artery and profunda brachii originating from the second part of the axillary artery, there were 49.4% females and 44.2% males. The COR and AOR for this group were 0.92 (95% CI: 0.26-3.27) and 0.88 (95% CI: 0.23-3.34), respectively, and the p-value was not statistically significant (p=0.851). In the group with a superficial origin of the brachial artery on the right, there were no females, but three males had this variation, representing 3.9% of males. The COR and AOR for this group were 1.78 (95% CI: 0.57-5.55) and 1.62 (95% CI: 0.50-5.24), respectively, and the p-value was not statistically significant (p=0.406). Generally, the results suggest that there is no statistically significant correlation between the origin or termination of the brachial artery and sex after adjusting for the origin of the other limb.

Table 4.9. Relation between the origin of the brachial artery and sex

OTBA		Total		Gender				COR (95% CI)	AOR (95% CI)	P-value
				Female		Male				
		n	%	n	%	n	%			
OL	Normal	76	98.7%	38	49.4%	38	49.4%	Ref.	Ref.	
	SOBA	1	1.3%	0	0.0%	1	1.3%	1.21 (0.67-2.20)	1.15 (0.60-2.20)	0.654
OR	Normal	72	93.5%	0	0.0%	1	1.3%	Ref.	Ref.	
	BAPOA	1	1.3%	0	0.0%	1	1.3%	0.92 (0.26-3.27)	0.97 (0.26-3.61)	0.958
	NOPBOA	1	1.3%	0	49.4%	1	44.2%	0.92 (0.26-3.27)	0.88 (0.23-3.34)	0.851
	SOBA.	**3**	**3.9%**	**0**	**0.0%**	**3**	**3.9%**	**1.78 (0.57-5.55)**	**1.62 (0.50-5.24)**	**0.406**

Note: COR = crude odds ratio, AOR = adjusted odds ratio, CI = confidence interval. P-value represents the statistical significance of the Correlation between the origin of the brachial artery and sex after adjusting for the origin of the other limb.KEY; OTBA-Origin and termination of brachial artery OL-Origin on the left; OR-Origin on the right; SOBA-Superficial origin of brachial artery; BAPOA-Brachial artery and profunda brachii originating from axillary artery; NOPBOA-Normal origin. profunda brachii originating from 2nd part of axillary artery; SOBA; Superficial origin of brachial artery.

4.4.2. Comparison between the termination of the brachial artery and sex

(Table 4.10), On the left side, the brachial artery terminated at the radial in 7 individuals (9.1%), at the radial neck in 69 individuals (89.6%), and at the proximal arm in 1 individual (1.3%). On the right side, the brachial artery terminated at the radial neck in 66 individuals (88.3%), at the radial tuberosity in 5 individuals (6.5%), and at the mid-arm in 3 individuals (2.1%). The results show that in females, the termination of the brachial artery is most commonly at the radial neck, accounting for 45.5% of the cases on the left and 46.8% on the right. On the other hand, in males, the termination of the brachial artery is mainly at the radial neck, accounting for 44.2% of cases on the left and 39.0% on the right. The COR for the correlation between termination type and gender is not statistically significant for any of the termination types.

The AOR for termination at the radial neck in females is 1.23 (95% CI: 0.26-5.75) on the left and 0.255 (95% CI: 0.14-3.81) on the right, indicating no significant correlation between termination type and gender. Similarly, the AOR for termination at the radial tuberosity in females is 1.10 (95% CI: 0.25-4.81) on the left and 0.844 (95% CI: 0.54-6.81) on the right, indicating no significant correlation between termination type and gender. The AOR for termination at the mid-arm in females is 1.29 (95% CI: 0.21-5.95) on the right, also indicating no significant correlation between termination type and gender. In conclusion, the results suggest that there is no significant correlation between the termination of the brachial artery and gender after controlling for the termination type of the other limb.

Table 4.10. Relation between the termination of the brachial artery and sex

TOBA		Total		Gender				COR (95% CI)	AOR (95% CI)	p-value
				Female		Male				
		n	%	n	%	n	%			
TOL	Proximal arm	1	1.3%	0	0.0%	1	1.3%	Ref.	Ref.	
	Radial neck	69	89.6%	3	45.5%3.9	3	5.2%	1.13 (0.26-4.95)	1.10 (0.25-4.81)	0.891
	Radial tuberosity	7	9.1%	35	3.9%45.5	34	44.2%	1.26 (0.28-5.77)	1.23 (0.26-5.75)	0.781
TOR	Proximal arm	2	2.6%	0	0.0%	2	2.6%	Ref.	Ref.	
	Radial neck	66	88.3%	36	46.8%	30	39.0%	4.55 (0.30-69.31)	0.255(0.14-3.81)	0.255
	Radial tuberosity	5	6.5%	0	0.0%	5	6.5%	1.25 (0.13-12.70)	0.844(0.54-6.81)	0.821
	Mid-arm	3	2.1%	0	0.0%	3	3.9%	1.24 (0.22-5.27)	1.29 (0.21-5.95)	0.321

Note: COR = crude odds ratio, AOR = adjusted odds ratio, CI = confidence interval. P-value represents the statistical significance of the Relation between the termination of the brachial artery and sex after adjusting for the termination of the other limb.

KEY; TOBA-Termination of the brachial artery; TOL-Termination on the left; TOR-Termination on the right.

4.4.3. Comparison between the Branching patterns brachial artery and sex

On the left side, the brachial artery bifurcated into the radial and ulnar arteries in 75 cases (97.4%), while in 2 cases (2.6%) it trifurcated into the radial, ulnar, and common interosseous artery. On the right side, the brachial artery also bifurcated into the radial and ulnar arteries in 69 cases (89.6%). In 4 cases (5.2%), it had a high bifurcation in the midarm, while in another 4 cases (5.2%) it trifurcated into the radial, ulnar, and common interosseous artery.

For the left arm, the most common branching pattern was bifurcation into radial and ulnar arteries, observed in 48.1% of females and 49.4% of males. The OR for trifurcation into radial, ulnar, and common interosseous artery was 0.19 (CI: 0.02-1.68) compared to the bifurcation pattern. The Cramer's V value was 0.13, indicating a weak association between the branching pattern and sex. The p-value was 0.136, indicating that the association was not statistically significant. For the right arm, the most common branching pattern was bifurcation into radial and ulnar arteries, observed in 45.5% of females and 44.2% of males. The OR for high bifurcation of the brachial artery in mid-arm was 0.50 (CI: 0.03-7.79) compared to the bifurcation pattern. The OR for trifurcation into radial, ulnar, and common interosseous artery was also 0.50 (CI: 0.03-7.79). The Cramer's V value was 0.11, indicating a weak association between the branching pattern and sex. The P-value was 0.349, indicating that the association was not statistically significant.

Table 4.11. Relation between the Branching patterns brachial artery and sex

BPBA		**Total**		**Gender**				**OR (95% CI)**	**Cramer's V**	**p-value**
				Female		Male				
		n	%	N	%	n	%			
BPL	BRUA	75	97.4	37	48.1	38	49.4	Reference		
	TRUC	2	2.6	1	1.3	1	1.3	0.19 (0.02-1.68)	0.13	0.136
BPR	BRUA	69	89.6	35	45.5	34	44.2	Reference		
	HBBAM	4	5.2	1	1.3	3	3.9	0.50 (0.03-7.79)	0.11	0.349
	TRUC	4	5.2	2	2.6	2	2.6	0.50 (0.03-7.79)	0.11	0.349

Note: COR = crude odds ratio, CI = confidence interval. P-value represents the statistical significance of the Correlation between the Branching patterns brachial artery and sex after adjusting for the other limb.

KEY: BPBA-Branching patterns of brachial artery; BPL-Branching pattern on the left; BPR-Branching pattern on the right; BRUA-Bifurcation into radial and ulnar arteries; TRUC-Trifurcation into radial ulnar and common interosseous artery; HBBAM-High bifurcation of brachial artery in midarm.

4.4.4. Relation between length of brachial artery

The table 4.12 displays the descriptive statistics for the length of the brachial artery, stratified by sex and left/right side. The mean length of the left brachial artery in females was 26.47 cm with a standard deviation of 0.481 cm, while in males the mean length was 26.63 cm with a standard deviation of 0.673 cm. The standard error of the mean was 0.098 cm for females and 0.092 cm for males. The mean length of the right brachial artery was 26.39 cm with a standard deviation of 0.441 cm for females and 26.31 cm with a standard deviation of 1.598 cm for males. The standard error of the mean was 0.090 cm for females and 0.219 cm for males. Overall, there were no large differences in the mean lengths of the brachial artery between the sexes or between the left and right sides.

Table 4.12 Comparison of the length of brachial artery between sex

length of brachial artery	Sex	N	Mean	SD	SE	P value
Length left.	Female	38	26.47	0.481	0.098	0.311
	Male	39	26.63	0.673	0.092	
Length right.	Female	38	26.39	0.441	0.090	0.820
	Male	39	26.31	1.598	0.219	

Note: SD: Standard deviation, SE: standard error

4.6 Laterality of the brachial artery

The most common type was normal origin bilaterally but different length, which accounted for 57.1% of the total cadavers. The second most common type was normal origin and same length bilaterally, which accounted for 36.4% of the total cadavers. The remaining types of laterality each accounted for only 1.3% of the total cadavers.

The table shows the correlation between the laterality of the brachial artery and sex. Out of 28 (36.4%) are female and 49 (63.6%) are male. The majority of cadavers (n=28, 36.4%) had a normal origin and same length of the brachial artery bilaterally, with 15 (19.5%) females and 13 (16.9%) males. The odds ratio (OR) for this group is 1.00, indicating no significant difference between sexes. The Cramer's V is 0.057, suggesting a weak association between laterality and sex, and the p-value is 0.11, which is not significant.

The other groups have no females are represented in the groups with different lengths of the brachial artery bilaterally or with left-sided anomalies. The OR for these groups ranges from 0.43 to 1.61, but none of them are statistically significant, with p-values ranging from 0.11 to 0.349. The Cramer's V values also suggest weak associations between laterality and sex for these groups. Generally, the results suggest that there is no significant association between the laterality of the brachial artery and sex.

Table 4.13. Relation between the Laterality of the brachial artery and sex

LBA	Total		Sex.				OR (95% CI)	Cramer's V	P-value
			Female		Male				
	N	%	N	%	N	%			
NOSL	28	36.4	15	19.5	13	16.9	1.00 (reference)	0.057	0.11
NOTL	1	1.3	0	0.0	1	1.3	0.43 (0.03-5.92)		
NOBL	44	57.1	23	29.9	21	27.3	1.61 (0.06-42.20)		
NOBM	1	1.3	0	0.0	1	1.3	0.91 (0.28-2.95)		
NOSDL	1	1.3	0	0.0	1	1.3	1.61 (0.06-42.20)		
NOLBRT	1	1.3	0	0.0	1	1.3	0.43 (0.03-5.92)		
NOLS	1	1.3	0	0.0	1	1.3	0.50 (0.03-7.79)		

Note: COR = crude odds ratio, CI = confidence interval. P-value represents the statistical significance of the Correlation between the Laterality of the brachial artery and sex after adjusting for the other limb.

Key: LBA-Laterality of the brachial artery NOSL-Normal origin and same length bilaterally; NOTL-Normal origin and termination of both left and right but different length; NOBL-Normal origin bilaterally but different length; NOBM-Normal origin bilaterally but right terminated in midarm; NOSDL-Normal origin left and superficial on the left with different length; NOLBRT-Normal origin of left and right, left terminated by bifurcation and right terminated by trifurcation; NOLS-Normal origin of right brachial artery but left originated superficially.

The table 4.14, presents the results of Levene's test for equality of variances and t-test for equality of means for the length of the left and right brachial arteries. The t-test for equality of means assuming equal variances, showed no significant difference in the means between females and males (t=-1.019, df=75, p=0.311), with a mean difference of -0.156 and a 95% confidence interval of the difference ranging from -0.460 to 0.149. The t-test for equality of means not assuming equal variances also showed no significant difference in the means between females and males (t=-1.153, df=60.690, p=0.253), with a mean difference of -0.156 and a 95% confidence interval of the difference ranging from -0.425 to 0.114. For the length of the right brachial artery, the test for equality of variances showed no significant difference between the variances assumed and not assumed (F=1.339, p=0.251). The t-test for equality of means assuming equal variances, showed no significant difference in the means between females and males (t=0.229, df=75, p=0.820), with a mean difference of 0.076 and a 95% confidence interval of the difference ranging from -0.587 to 0.739. The t-test for equality of means not assuming equal variances also showed no significant difference in the means between females and males (t=.321, df=66.686, p=0.749), with a mean difference of 0.076 and a 95% confidence interval of the difference ranging from -0.397 to 0.550.

Table 4.14. Difference in length of brachial artery between males and females

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean difference	Std. Error difference	95% confidence interval of the difference	
									Lower	Upper
LL	EVA	1.929	0.169	-1.01	75	0.311	-0.156	0.153	-0.460	0.149
	EVNA			-1.15	60.69	0.253	-0.156	0.135	-0.425	0.114
L	EVA	1.339	0.251	0.229	75	0.820	0.076	0.333	-0.587	0.739
R	EVNA			0.321	66.686	0.749	0.076	0.237	-0.397	0.550

KEY: EVA: equal variance assumed, EVNA: equal variance not assumed; LL-Length of left; LR-Length of right.

Table 4.15: Relation in laterality (right and left upper limb) and origin, branching and termination of brachial artery

Chi-Square Tests									
	TERMINATION			**BRANCHING**			**ORIGIN**		
	Value	**Df**	**Sig (2-sided)**	**Value**	**df**	**Sig (2-sided)**	**Value**	**df**	**Sig (2-sided)**
Pearson Chi-Square	109.637	12	0.000*	0.445	2	0.801	0.135	3	0.0987
Likelihood Ratio	28.079	12	0.005*	0.209	1	0.648	.000	1	1.000
Linear-by-Linear Association	15.859	1	0.000*	77			77		
N of Valid Cases	77			0.238	2	0.888	0.070	3	0.995
*Statistically Significant <0.05									

There was statistically significant variation in termination of brachial artery between the right and left upper limbs (p=0.000). The branching and origin had variations but were not statistically significant (Figure 4.14)

CHAPTER FIVE

DISCUSSION

5.1: Origin of brachial artery among the black African population

Brachial artery normally originates as a continuation of third part of axillary artery at the lower border of teres major and is located below the median nerve. In the current study, out of the total 154 upper limb specimens, 3.8% (6/154) had a variant origin. These variations were lower than a study done by Shivanal (2013) who reported 16% variant origin of brachial artery. This lower proportion in variation may be attributed to geographical origin, embryological development, gender and race. A (Sharma *et al*., 2009) observed origin of superficial brachial artery from third part of axillary artery which corroborated with the findings of the current study**.**

Superficial origin of brachial artery was reported as the most common variation at 2.6% in the current study, this could be attributed to race, geographical location, gender and embryological origin, which have previously been shown to cause some of the upper limb arterial variants(Klimek-Piotrowska *et al*., 2013). Even though variant origin and course of superficial brachial artery in the current study were much lower, a study on Korean cadavers by Yang *et al*., (2008) who reported 12.2%(37) of 304 upper limbs specimens had superficial brachial artery as the most common variant in origin, which is further reinforced the current study findings. Unlike the current study, a study by Chakravarthi *et al*., (2014) recorded accessory brachial artery as the most common variant accounting for 11.43%(8)upper limbs specimens. This disparity from the current study findings could be due to number of specimens used in the study, race, gender evolutionary changes and geographical location. In a study conducted among Caucasians in South Africa, three cases had superficial origin of brachial artery unilaterally, of the three, two cases were seen on the right limb while one case was seen on the left Nkomozepi *et al*., (2017)**.** These arterial patterns can be explained by existence during developmental process of arteries of the arm of a superficial brachial artery and an anastomotic branch between the superficial brachial artery and brachial artery Nakatani *et al*., (1996). Such superficial course of brachial artery serves as a route for catheter during the radial approach to coronary procedures for catheterization Chakravarthi,*et al*., (2014).superficial brachial artery may be prone to injuries because of its superficial course and may be affected/ became ischemic during normal clinical procedures administering intravenous injections in outpatient/ inpatient set up.

There was no statistically significant difference in the normal origin of brachial artery when compared to the variant origin (Table 4.3) this shows that these variations are not significant and occurs on individual basis. This finding is reinforced by Yang *et al*., (2008) who reported no statistical significant difference between normal and variant origin of superficial brachia artery. Normally, the brachial artery terminates at the neck of radius into ulnar and radial artery respectively Drake *et al*., (2009), in instances where there are variations, it may terminate at radial tuberosity, mid arm or proximal arm. In the current study, out of 154 upper limbs of 77 cadavers,11% had variations in termination of brachial artery. This was lower than a study done by Shetty et al., (2022) who reported 22.5% variations in the termination of brachial artery, this might be due to low study sample used in the study. However, study conducted on 29 cadavers (29 upper limb specimens) at Nobel medical teaching hospital, Biratnager, Nepal by Khatun & Shah, (2021) observed lower variation in termination of brachial artery at 5.17% (3). This can be explained on basis of unusual induction and branching of primitive vascular plexuses exacerbated by vascular growth factors such as vascular endothelial growth factors and developmental hemodynamics thus resulting in variations in termination of brachial artery , taking unusual pattern and course Tsoucalas *et al*., (2020)

The common variation in termination was at radial tuberosity (7.8%), other terminations were seen at proximal arm at 1.9%, radial tuberosity 7.8%. Mid arm 1.3% respectively (Table 4.4). In concurrence with this study, Gujar *et al*., (2014) study on 30 cadavers in India also reported that the most common point of termination of brachial artery was at radial tuberosity (7.6%). Common level of termination at neck of radius correlates with majority of studies done previously(Al Talalwah *et al*., 2015; Bilodi & Sanikop, 2004; Chakravarthi, Siddaraju, Venumadhav, *et al*., 2014; Rathan & Salama, 2019). However, H. Singh *et al*., (2010) reported bilateral higher termination of brachial artery about 7.5cm above a line joining two humeral condyles. This can be explained on basis of embryological development as explained by Rohilla *et al*., (2016) that vascular variations may be due to; choice of unusual paths in the primitive vascular plexus, persistence of normally obliterated vessels, disappearance of normally retained vessels, incomplete development, fusion and absorption of normally distinct part and combination of factors i.e. race, gender and environmental and environmental factors leading to atypical pattern.

5.2. Branching pattern of brachial artery

The standard documented branching pattern of brachial artery in anatomy text books is its bifurcation into radial and ulnar arteries Standring, (2021). The current study established two varying branching patterns i.e., High bifurcation into radial and ulnar artery at 2.4%, and trifurcation into radial, ulnar and common interosseous arteries at 4.1% (Table 4.6). This concurs with Shivanal, (2013) report conducted on 50 upper limb specimens in India, which observed 2% of high bifurcation of brachial artery in the proximal $^{1}/_{3}$ of the arm. In another study involving 50 upper limb specimens, high bifurcation of brachial artery into ulnar and radial artery was reported Jacomo *et al*.,(2014). The incidence of variations in branching patterns observed in the present study is in line with findings from several authors from the previous literature.

(H. Singh *et al*., 2010; Tsoucalas *et al*., 2020; Varlekar *et al*., 2013). This can be explained in basis of genetic factors due to atypical configuration of vessels, embryological errors of arterial pattern during

development, environmental factors that lead into loss of arterial elasticity which become stiff thus leading into variant branching patten.

The current study, observed 6 (4.1%) incidences of trifurcation of brachial artery into ulnar, radial and common interosseous arteries. This was at the usual neck of radius in the total sampled upper limbs. This finding agrees with Ammal, (2020) who reported the incidence of 4.0% in the total 50 upper limbs. However, Shubha *et al*., (2013) reported a higher incidence trifurcation of brachial artery(26.3%) among 95 upper limbs in Indian population. This high incidence might have been possible because he included unique branching patterns such trifurcation of brachial artery into radial, ulnar and radial recurrent arteries and radial, ulnar and ulnar recurrent arteries. Another study by Vollala *et al*., (2008) reported trifurcation of brachial artery into radial, ulnar and common interosseous artery concurring with the current study in terms of pattern of trifurcation. However (Ammal, 2020; Clarke *et al*., 2022) observed trifurcation of brachial artery into radial ulnar and radial recurrent arteries, unlike the current study where brachial artery trifurcated into radial, ulnar and common interosseous arteries.

Other authors who reported lower mean length than the current study include Bidarkotimath *et al*., (2012), Chauhan *et al*., (2013) and Gautam *et al*., (2023), the mean length of brachial artery in their studies were 22.65cm , 24.56cm and 21.5cm respectively. A higher mean length wan noted by Shubha *et al*., (2013) reported mean length of brachial artery be 30.82cm, the difference the in mean length may be attributed to geographical location, genetic and racial factors of an individual.

5.3 Variation in the Laterality and sex of brachial artery

Normally, the left and right brachial artery have similar origin, course, distribution and termination (Standring, 2021). However, few variations in laterality had been reported in the previously(Lalit & Piplani, 2021; Patnaik *et al*., 2002) . In the current study, the commonest variation in terms of laterality was in superficial origin of brachial artery on the right side, with an incidence of 1.3%. This finding was similar to a study conducted on 56 upper limb specimens in India by Lalit & Piplani, (2021) who reported a 1.7% variation in origin of brachial artery occurring more on the right than the left upper limb. In another study conducted in Chennai, Madras medical college in Asia by (Gohila, 2017) on 25 adult human cadavers of 50 upper limb specimens, reported a 4%(2/154) incidence of superficial brachial artery in the right upper limb, which concurs with the current study findings. Therefore, it is apparent that more variations in the origin of brachial artery occur on the right upper limb than the left side. This could be attributable to frequent activity since majority use their right upper limb more often than the left upper limb however, this needs more exploration with respect to age of the cadaver. Though, there was no reported statistically significant variation between laterality and variant origin of brachial artery in the current study(p=0.406) and the literature reviewed.

The most common variation in termination of brachial artery was at the level of radial tuberosity (6.5%) on the right side whilst the left had only 1.3% incidences of variation. A study by Shetty *et al*., (2022) reported a 6.1% incidence of termination of brachial artery at radial tuberosity on the right side of the total 40 upper limbs, while Khatun & Shah, (2021) also noted 3.2% higher incidence as compared to the left. From the literature reviewed there is no confirmatory report as to why higher incidences occur on the right upper limb as compared to the left. However, it is believed that these variations maybe attributed to embryological development, epigenetic factors and evolutionary, which may be further attributable to frequent activity since majority of individuals use their right upper limb more often due to right dominance as opposed to the left limb, however this needs more explanation with respect to age of the cadaver which may undergo some degeneration. In addition, there was statistically significant variation in termination of brachial artery between the right and left upper limbs (p=0.000). The branching and origin had variations but were not statistically significant (Figure 4.15).

The variations in the branching patterns did not show any statistically significant variation in laterality. However, the right upper limb had higher incidences 4 (5.2%) of trifurcation of brachial artery into radial, ulnar and common interosseous artery as compared to the left. This was lower higher than Vollala *et al*., (2008) study that reported 1(1.3%) incidence of trifurcation on the right side. Other authors who recorded lower cases of variation in trifurcation of brachial artery on the right side include (Bannur *et al*., 2013; Gupta *et al*., 2014; Malcic-Gürbüz *et al*., 2002).

In comparison between males and females, variations in origin were more common in males at incidence of 2.6.%, than in females. similar studies have also recorded higher variation in origin of brachial artery among males than female although this variations, like the current study, were not statistically significant Clarke *et al.,* (2021). To the contrary, Nakatani *et al*., (1996) reported a high variation incidence in both sexes.

Males (5.2%) had more variations in termination of brachial artery compared to females (3.8%). Bilodi & Sanikop, (2004) also noted a similar trend with a higher variations in termination in males than females However a study by Gohila, (2017) reported high incidence of termination of brachial artery in females. No statistically significant variation in termination was reported in the reviewed literature. the commonest variation in branching pattern in the current study was trifurcation (1.3%) which has same incidence in both male and females in the current study. In Yang *et al*., (2008**)** study in Korean population, reported variation in branching pattern to be more in males than females which disagrees with the current study. Others authors (Al-Sowayigh *et al*., 2013; Claassen *et al*., 2016; Gautam *et al*., 2023) also had higher incidences of variations in males than females which can be explained on basis of genetics, gender, race, embryological development and to evolutionary changes related to heavy duties and vigorous exercises carried out by men as opposed to women.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion.

- There are considerable variations in origin and termination of brachial artery among the study population, however, the variation from the normal morphology was significant.
- There are considerable variations in mean length and branching pattern of brachial artery among the study population, however, the variation from the normal morphology was not significance.
- There is no significant variation between sexes however, males appeared to have more variations in origin, branching pattern and termination. In addition, no significant variation was found between the right and left upper limbs except at the termination which varied significantly from normal.

6.2 Recommendations

- Knowledge about variations in brachial artery and its branching pattern is important to Anatomist, surgeons, radiologists, cardiothoracic and vascular surgeons, due to variants in origin and termination patterns observed, thus each individual should be treated as a special case to avert complications and mismanagement of patients.
- Further population specific studies should be carried out especially on racial differences among Caucasians, blacks and Asians to guide in the developmental variations.
- Variant anatomy of brachial artery is common on the right arm than the left arm. High bifurcation of brachial artery is one of the variants that should not assumed as it occurs more in males than females, therefore, further studies on gender and laterality should be carried out.

REFERENCES

Ahmadpour, S., & Foghi, K. (2019). Bilateral Unusual Course of the Median Nerve, Variation in Branching Pattern of the Brachial and Superficial Ulnar Arteries: A Rare Case Report of Multiple Neuroarterial Variation. *Journal of Morphological Sciences*, *36*(03), 202–206.

Al Talalwah, W., Getachew, D., & Soames, R. (2015). Morphological feature of brachial artery and its clinical significance. *Journal of Morphological Sciences*, *32*(03), 129–134.

Al-Sowayigh, M. A., Zaki, A. I., El-Haggagy, A. A., IH, A. A., & Badawoud, M. H. (2013). Anatomical variation of brachial artery bifurcation. *Saudi Medical Journal*, *34*(9), 908–912.

AMMAL, A. (2020a). A study of Brachial Artery, its Variations and the Clinical Orientation. *University Journal of Pre and Paraclinical Sciences*, *6*(7).

AMMAL, A. (2020b). A study of Brachial Artery, its Variations and the Clinical Orientation. *University Journal of Pre and Paraclinical Sciences*, *6*(7).

Aughsteen, A. A., Hawamdeh, H. M., & Al-Khayat, M. (2011). Bilateral variations in the branching pattern of brachial artery. *International Journal of Anatomical Variations*, *4*, 167–170.

Auwal, A. M., Zagga, A. D., & Asala, S. A. (2017). Unilateral high bifurcation of brachial artery: A case report. *Anatomy Journal of Africa*, *6*(2), Article 2. https://doi.org/10.4314/aja.v6i2.160458

Bannur, B. M., Sahana, B. N., Hadimani, G. A., & Patil, B. G. (2013). Unilateral higher trifurcation of brachial artery-a case report. *International Journal of Current Research and Review*, *5*(11), 130.

Bidarkotimath, S., Avadhani, R., & Kumar, A. (2011). Primary pattern of arteries of upper limb with relevance to their variations. *Int J Morphol*, *29*(4), 1422–1428.

Bidarkotimath, S., Avadhani, R., & Kumar, A. (2012). An anatomical study of primary pattern of arteries of upper limb with relevance to their variations. *Journal of Health and Allied Sciences NU*, *2*(01), 08–14.

Bilodi, A. K., & Sanikop, M. B. (2004). Variations in termination of brachial artery–a case report. *Kathmandu University Medical Journal (KUMJ)*, *2*(1), 49–51.

Breihan, C., Kynard, S., & Abdulrahman, A. A. (2021). Anatomical Variation of the Brachial Artery and Iits Clinical Implications. *Int J Anat Var*, *14*(3), 68.

Chakravarthi, K. K., Siddaraju, K. S., Nelluri Venumadhav, A. S., & Kumar, N. (2014). Anatomical variations of brachial artery-its morphology, embryogenesis and clinical implications. *Journal of Clinical and Diagnostic Research: JCDR*, *8*(12), AC17.

Chakravarthi, K. K., Siddaraju, K. S., Venumadhav, N., Sharma, A., & Kumar, N. (2014). Anatomical variations of brachial artery-its morphology, embryogenesis and clinical implications. *Journal of Clinical and Diagnostic Research: JCDR*, *8*(12), AC17.

Chauhan, A., Musunuru, H., Hallett, R. L., Walsh, M., Szabo, S., & Halloran, W. (2013). An unruptured, thrombosed 10 cm right coronary artery aneurysm mimicking a pericardial cyst. *Journal of Cardiothoracic Surgery*, *8*, 1–3.

Claassen, H., Schmitt, O., Wree, A., & Schulze, M. (2016). Variations in brachial plexus with respect to concomitant accompanying aberrant arm arteries. *Annals of Anatomy-Anatomischer Anzeiger*, *208*, 40–48.

Clarke, E., Mazurek, A., Radek, M., Żytkowski, A., Twardokęs, W., Polguj, M., & Wysiadecki, G. (2021). Superficial brachial artery–A case report with commentaries on the classification. *Translational Research in Anatomy*, *23*, 100112.

Clarke, E., Olszewska, A., Zarzecki, M., Przybycień, W., Dubrowski, A., Depukat, P., Barszcz, K., & Żytkowski, A. (2022). Case report of the brachial artery trifurcation: An anatomical study and concise literature review. *Translational Research in Anatomy*, *27*, 100198.

Drake, R., Vogl, A. W., & Mitchell, A. W. (2009). *Gray's anatomy for students E-book*. Elsevier Health Sciences.

Gautam, A., Ganware, M., Jha, G. S., & Gautam, K. K. (2023). *ASSESSING THE BRACHIAL ARTERY AND ITS VARIATIONS WITH ITS ONTOGENIC BASIS: A CADAVERIC STUDY*.

George, J. R., Francis, J., Samuel, J. E., & Francis, T. (2019). Morphology and variations of brachial artery in cadavers. *Int J Anat Res*, *7*(2.3), 6680–6684.

Gohila, G. (2017). *A Study of brachial artery, its branching pattern and variations with clinical applications* [PhD Thesis]. Madras Medical College, Chennai.

Gujar, S. M., Oza, S. G., Shekhawat, J. P., Vikani, S. K., & Prajapati, S. B. (2014). A study on division of brachial artery and its clinical correlations. *Int J Anat Res*, *2*(1), 208–212.

Gupta, N., Anshu, A., & Dada, R. (2014). Trifurcation of superficial brachial artery: A rare case with its clinico-embryological implications. *La Clinica Terapeutica*, *165*(5), 243–247.

Hansdak, R., Arora, J., Sharma, M., Mehta, V., Suri, R. K., & Das, S. (2015). Unusual branching pattern of brachial artery-embryological basis and clinicoanatomical insight. *Clin Ter*, *166*(2), 65–67.

Hansen, J. T. (2021). *Netter's Clinical Anatomy-E-Book*. Elsevier Health Sciences.

Itoo, M. (2021). *Variations in Branching Pattern of Brachial Artery in Upper Limb-A Cadaveric Study and Medical Emergency*. PP. https://doi.org/10.9790/0853-2004110106

Jacomo, A. L., Martinez, C. A. R., Saleh, S. O., Andrade, M., & Akamatsu, F. E. (2014). A rare pattern of brachial artery variation-case report. *International Journal of Morphology*.

Jadhav, S. D., & Pawar, S. E. (2018). High division of brachial artery and its clinical insight: A case report. *Artery*, *15*, 16.

Kaur, A., Sharma, A., & Sharma, M. (2017). Variation in branching pattern of brachial artery. *International Journal of Scientific Study*, *5*(1), 213–217.

Khatun, S., & Shah, D. K. (2021a). Higher Termination of Brachial Artery in Cadavers in the Department of Anatomy of a Medical College: A Descriptive Cross-sectional Study. *Journal of the Nepal Medical Association*, *59*(240).

Khatun, S., & Shah, D. K. (2021b). Higher Termination of Brachial Artery in Cadavers in the Department of Anatomy of a Medical College: A Descriptive Cross-sectional Study. *JNMA: Journal of the Nepal Medical Association*, *59*(240), 763.

Klimek-Piotrowska, W., Pacholczak, R., & Walocha, J. (2013). Multiple variations of the arterial pattern in upper extremities: A case report and embryological pathogenesis. *Clinical Anatomy*, *26*(8), 1031–1035. https://doi.org/10.1002/ca.22171

Kothari, C. (2017). Research methodology methods and techniques by CR Kothari. *Published by New Age International (P) Ltd., Publishers*, *91*.

Lalit, M., & Piplani, S. (2021). A cadaveric study of brachial artery and its variations with its ontogenic basis: An anatomical perspective. *Int J Anat Res*, *9*(1.1), 7844–7850.

Malcic-Gürbüz, J., Gürünlüoĝlu, R., Özdoĝmuş, Ö., & Yalin, A. (2002). Unique case of trifurcation of the brachial artery: Its clinical significance. *Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists*, *15*(3), 224–227.

Mugenda, O. M., & Mugenda, A. G. (2012). Research methods dictionary. Nairobi. *Kenya Arts Press2012*.

Nakatani, T., Tanaka, S., & Mizukami, S. (1996). Superficial brachial arteries observed in bilateral arms. *Kaibogaku Zasshi. Journal of Anatomy*, *71*(4), 308–312.

Narayanan, S., & Murugan, S. (2018). Bifurcation of brachial artery into a common radial-interosseous trunk and superficial ulnar artery: A rare variation. *Anatomical Science International*, *93*(3), 400–403. https://doi.org/10.1007/s12565-017-0427-5

Netter, F. H. (2010). *Atlas of Human Anatomy (Netter Basic Science)*. Elsevier Health Sciences.

Nkomozepi, P., Xhakaza, N., & Swanepoel, E. (2017). Superficial brachial artery: A possible cause for idiopathic median nerve entrapment neuropathy. *Folia Morphologica*, *76*(3), 527–531.

Ogeng'o, J. (2013). Editorial: Clinical Significance of Anatomical Variations. *Anatomy Journal of Africa*, *2*(1), Article 1. https://doi.org/10.4314/aja.v2i1

Panagouli, E., Anagnostopoulou, S., & Venieratos, D. (2014). Bilateral asymmetry of the highly bifurcated brachial artery variation. *Rom J. Morphol. Embryol*, *55*(2), 469–472.

Patil, S., Channabasanagouda, M, N., & U, C. (2014). Branching Pattern of Brachial Artery: A Cadaveric Study. *Int j Med Pharm Sci*, *4*, 15–22.

Patnaik, V. V. G., Kalsey, G., & Singla, R. K. (2002). Branching pattern of brachial artery-A morphological study. *J Anat Soc India*, *51*(2), 176e86.

Pulei, A., Obimbo, M., Ongeti, K., Kitunguu, P., Inyimili, M., & Ogeng'o, J. (2012). Surgical significance of brachial arterial variants in a Kenyan population. *Annals of African Surgery*, *9*.

Rathan, R., & Salama, M. N. (2019). Termination of the Brachial Artery in the Arm and Its Clinical Significance. *International Journal of Medical and Health Sciences*, *13*(2), 65–68.

Rohilla, A., Parmar, P., Singh, K., & Rohilla, J. (2016). Unilateral high division of brachial artery and its clinical significance. *Int J Res Med Sci*, *4*(12), 5513–5515.

Sharma, T., Singla, R. K., & Sachdeva, K. (2009). Bilateral superficial brachial artery. *Kathmandu University Medical Journal*, *7*(4), 426–428.

Shetty, H., Patil, V., Mobin, N., Gowda, M. H. N., Puttamallappa, V. S., Vamadevaiah, R. M., & Kunjappagounder, P. (2022). Study of course and termination of brachial artery by dissection and computed tomography angiography methods with clinical importance. *Anatomy & Cell Biology*, *55*(3), 284–293.

Shivanal, U. (2013). *A study of variations in brachial artery and its branching pattern* [PhD Thesis]. Rajiv Gandhi University of Health Sciences (India).

Shivanal, U., & Gowda, M. S. (2015). *A study of variations in brachial artery and its branching pattern.*

Shubha, R., Sudarshan Babu, K. G., Mekala, D., Jeyanthi, K., & Lalitha, C. (2013). An anatomical study of variations in termination of brachial artery: Embryological basis and clinical implication. *J Dent Med Sci (IOSR)*, *9*(1), 68–77.

Singh, H., Gupta, N., Bargotra, R. N., & Singh, N. P. (2010). Higher bifurcation of brachial artery with superficial course of radial artery in forearm. *JK Science*, *12*(1), 39.

Singh, M., Jaiswal, S., Sharma, P. K., & Vaidya, V. K. (2020). A CADAVERIC STUDY OF THE LENGTH OF THE BRACHIAL ARTERY AND ITS CLINICAL CORRELATION. *Era's Journal of Medical Research*, *7*(1), 72–74.

Standring, S. (2021). *Gray's anatomy e-book: The anatomical basis of clinical practice*. Elsevier Health Sciences.

Themes, U. F. O. (2021, January 25). 11 Vascular Anatomy of the Upper Extremity. *Musculoskeletal Key*. https://musculoskeletalkey.com/11-vascular-anatomy-of-the-upper-extremity/

Tsoucalas, G., Eleftheriou, A., & Panagouli, E. (2020a). High bifurcation of the brachial artery: An embryological overview. *Cureus*, *12*(2).

Tsoucalas, G., Eleftheriou, A., & Panagouli, E. (2020b). High bifurcation of the brachial artery: An embryological overview. *Cureus*, *12*(2).

Udainiya, N., Sagwan, N., Herswani, I., Bhatnagar, V., & Lahange, S. M. (2018). Variant Branching Pattern Of Brachial Artery In Context To Its Higher Bifurcation: A Case Report. *Int J Anat Res*, *6*(4.2), 5926–5928.

Varlekar, P., Chavda, H., Kubavat, D., Nagar, S., Saiyad, S. S., & Lakhani, C. (2013). Higher bifurcation of brachial artery with superficial course of radial artery in forearm: A study report. *International Journal of Medical Science and Public Health*, *2*(3), 703–706.

Vollala, V. R., Nagabhooshana, S., & Bhat, S. M. (2008). Trifurcation of brachial artery with variant course of radial artery: Rare observation. *Anatomical Science International*, *83*, 307–309.

Yang, H.-J., Gil, Y.-C., Jung, W.-S., & Lee, H.-Y. (2008). Variations of the superficial brachial artery in Korean cadavers. *Journal of Korean Medical Science*, *23*(5), 884–887.

APPENDICES

APPENDIX I.DATA COLLECTION FORM.

University code: ________________________

Code of cadaver________________________

Location of laboratory___________________

Template no____________________________

Demographic factors.

1. Sex male…… female……

2. Side right…… Left…………

3.comparison____

4Findingso dissection____

5. Branching pattern.

a. Origin

Right____

Left____

b. Terminaton

right____

left____

6. ORIGIN OF BRANCHES OF BRACHAL ARTERY.

BRANCHES	RIGHT	LEFT	VARIATIONS	TOTAL CADAVER (%)
PROFUNDA BRACHII				

SUPERIOR ULNAR	
INFERIOR ULNAR	
RADIAL	
ULNAR	
OTHER	

7. Branching pattern.

TYPE	**ARTERIES**
Trifurcation	
Bifurcation	

APPENDIX II: MASENO SGS APPROVAL LETTER.

MASENO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Office of the Dean

Our Ref: MSC/SM/00018/020

Private Bag, MASENO, KENYA
Tel:(057)351 22/351008/351011
FAX: 254-057-351153/351221
Email: sgs@maseno.ac.ke

Date: 31st August, 2022

TO WHOM IT MAY CONCERN

RE: PROPOSAL APPROVAL FOR OYALE WARREN AYONGA—MSC/SM/00018/020

The above named is registered in the programme of Master of Science in Human Anatomy in the School of Medicine, Maseno University. This is to confirm that his research proposal titled **"Variation in Morphology of Brachial Artery and its Branching Pattern among Black African Population: A Cadaveric Study in Western Kenya"** has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

Prof. J.O. Agure

DEAN, SCHOOL OF GRADUATE STUDIES

Maseno University ***ISO 9001:2008 Certified***

APPENDIX:III. NACOSTI APPROVAL LETTER.

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **612343** Date of Issue: **16/January/2023**

RESEARCH LICENSE

This is to Certify that Mr.. OYALE Warren Ayonga of Maseno University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kakamega, Kisumu on the topic: Variation in Morphology of Brachial Artery and its branching pattern among Black African population: A Cadaveric study in Western Kenya. for the period ending : 16/January/2024.

License No: **NACOSTI/P/23/22873**

612343

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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

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

CONDITIONS OF THE RESEARCH LICENSE

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

National Commission for Science, Technology and Innovation(NACOSTI),
Off Waiyaki Way, Upper Kabete,
P. O. Box 30623 - 00100 Nairobi, KENYA
Telephone: 020 4007000, 0713788787, 0735404245
E-mail: dg@nacosti.go.ke
Website: www.nacosti.go.ke

APPENDIX IV. MASENO ETHICAL APPROVAL LETTER.

MASENO UNIVERSITY

FOUNTAIN OF EXCELLENCE

MASENO UNIVERSITY SCIENTIFIC AND ETHICS REVIEW COMMITTEE

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

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

REF: MSU/DRPI/MUSERC/01140/22

Date: 9th November, 2022

TO: Oyale Warren Ayonga
MSC/SM/00018/020
Department of Human Anatomy
School of Medicine, Maseno University
P. O. Box, Private Bag, Maseno, Kenya

Dear Sir,

RE: Variation in Morphology of Brachial Artery and its Branching Pattern among Black African Population: A Cadaveric Study in Western Kenya

This is to inform you that **Maseno University Scientific and Ethics Review Committee (MUSERC)** has reviewed and approved your above research proposal. Your application approval number is MUSERC/01140/22.The approval period is 9th November, 2022 – 8th November, 2023.

This approval is subject to compliance with the following requirements;

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

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

Yours sincerely

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE
09 NOV 2022
P.O. BOX PRIVATE BAG MASENO

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

MASENO UNIVERSITY IS ISO 9001 CERTIFIED

KEBS

APPENDIX V. MMUST APPROVAL LETTER.

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

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

P.O Box 190
Kakamega – 50100
Kenya

DEPARTMENT OF HUMAN ANATOMY

DATE: 23rd January 2023

TO: Warren Ayonga
Department of Human Anatomy,
PO BOX 3275-40100,
Maseno Uni ersity,

Dear Warren

SUBJECT: APPROVAL TO COLLECT CADAVERIC DATA

We have considered and noted your application received on 17th January 2023. We are glad to inform you that your request to collect data in this facility has been approved in bid of completing your MSc studies "**Variations in the morphology of brachial artery and its branching pattern among black African population; A cadaveric study in Western Kenya**'.
Kindly note that your acceptance of this approval letter confirms your compliance with our institutional policies and those of Kenya National Research Ethics Guidelines. We wish you all the best and hope to receive copy of your final report soon.

Sincerely

Dr. Ashiundu Edwin
Department of Human Anatomy

APPENDIX VI. UZIMA APPROVAL LETTER.

UZIMA UNIVERSITY
SCHOOL OF MEDICINE
DEPARTMENT OF ANATOMY

30th January2023

TO: Warren Ayonga
Department of Human Anatomy,
PO BOX 3275-40100,
Maseno University,

Dear Warren

SUBJECT: APPROVAL TO COLLECT CADAVERIC DATA

This is to inform you that your data collection request for the project titled "**Variations in the morphology of brachial artery and its branching pattern among black African population; A cadaveric study in Western Kenya'**. Has been approved.

Kindly liaise with the department to guide you during data collection. Ensure you commit to all the ethical and legal procedures during this period.

We wish you the best

T. Juma
Department of Human Anatomy

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