ANATOMICAL VARIATIONS IN MORPHOLOGY OF THE BRACHIAL PLEXUS 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 for award of degree in any university.

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DEDICATION

I dedicate this research thesis to my beloved wife Dr. Dorice Akoth, and my children Beryl, Jack, Mercy, and son-in-law Peter for all the support and prayers they offered me during the entire period.

ABSTRACT

Brachial plexus (Bp) is a network of nerve bundle in the spinal cord around neck and axillar formed by union of ventral primary rami of C5 - C8 and T1. Bp may be affected by trauma, irradiation, neoplasm, infection, and autoimmune inflammatory disease. Aim was to identify anatomical variations in morphology of Bp among black African population in western Kenya. The specific objectives were to find out variation differences in demographic characteristics (male and female); determine variation differences of right and left, investigate anatomical variations in origin, course, and distribution. Descriptive Cross-sectional design adopted. The sample population of 86 cadavers (Maseno 43, Uzima 23 and Masinde Muliro 20) calculated based on Yamane taro formula giving sample size of (35,19,16) 70 respectively. Descriptive statistics used to determine mean, mode, median and standard deviation. Chi- square test used to find statistical significance between variables with *p*–value of (α = 0.05). Pearson's correlation test used to analyze statistical evidence for a linear relationship among variables. Ethical consideration observed. Posterior neck & axillar incisions made exposing and identifying variations at roots, trunks, divisions, cords, and terminal branches. Gender variable, 50% (35) female and 50% (35) male. Most frequent variation was the pre-fixed 20.9% least at division 2.2%. Highest variation in branching was musculocutaneous at 18.6% whilst lowest was radial 5%. The total 17.8% variations in the origin and segments of Bps, majority were from left whilst 7.9% from the right. Highest frequency occurred at pre-fixed root with 8.6% left and 12.1% right. The lowest was division with anterior division of the medial trunk connecting with medial nerve. Females had highest variations of terminal branches at 37.8% followed by males at 32%. There was statistical significance difference (p=0.008) in variation distribution of median nerve in relation to the sexes. No statistical significance variation observed in all the branching patterns. Levine's test didn't show any strong variation from the normal anatomical standards. Musculocutaneous nerve variations were most common and occurred on right-side affecting females hence gender specific variations should be considered for further studies. Study has prospective to enhance clinical correlation and medical research diversity.

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LIST OF ABREVIATIONS

BPS: Board of Postgraduate

CDC: Centre for Diseases Control and prevention.

C5-Cervical Spinal nerve 5

C6-Cervical Spinal nerve 6

C7-Cervical Spinal nerve 7

C8-Cervical Spinal nerve 8

T1-Thoracic Spinal nerve 1

ECRI: Emergency Care Research Institute

ERC: Ethical Review Committee

GOK : Government of Kenya

HC: Health Care

HDSS: Health Data Standards and Systems

NACOSTI: National Commission for Science, Technology, and Innovation

OBPP: Obstetric brachial plexus palsy

SGS: School of Post Graduate studies

T1: Thoracic spinal nerve 1

WHO: World Health Organization

OPERATIONAL TERMS

Anatomy: The science which deals with the structure of human body

Anomaly: Used for variations that deviates from normal occurrence of the general population

Anterior: Frontal surface of a body

Brachi: Arm (upper arm) of human

Bp: Brachial plexus.

Cadaver: Dead body which is dissected in a medical school laboratory.

Clinician: Any health professional attending to clients/ patients

Health professionals: One who give health services with application of evidenced based practice

Health care provider: Is an individual trained on health issues and licensed to provide healthcare diagnosis and treatment services.

Plexus: Network of nerves or vessels in the body

Rami: Branches of nerves

Ventral: Pertaining to anterior surface of the body

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CHAPTER ONE

INTRODUCTION

1.1 Background

Brachial plexus is a collection of nerves of spinal cord at the brachium (humerus) Rasulić *et al.* (2020). It carries motor and sensory impulses emanating from the spinal cord to the upper limbs and passes by the inter-scalene triangle through the anterior scalene and middle scalene muscle and then posterior neck triangle Vaid and Vaid (2015). The union of C5, C6, C7, C8 and T1 forms it. There are different sections thus the roots, trunks, divisions and cords (M. Emamhadi *et al.*, 2016; Mohammadreza Emamhadi *et al.*, 2016).

Studies done indicated that it is found in the upper limbs in human body with embryological origin history being the initial differentiation of mesenchyme that occurs in the fourth week of embryologyStandring (2016). Primordial of dorsal nerves reach length of zonal distal stretch regarding humerus inside growing primordial sheath of arm muscle nerves as from C5 to T1 that begin to extend on day 32 of human life, where the nerves merge and form brachial plexus (Bala, Sinha, Tamang, & Sarda, 2014; Rasulic *et al.*, 2020).

The nerves networks relays signal from the spinal cord to glenohumeral region, arm, and hands. Damage to brachial plexus is due to injuries at the same site. Usually symptoms may comprise of paralyzed arm or forearm impaired muscle coordination of the arm, fist, and or wrist and absence of feeling in the upper arms, fore arms, and or hand (Sachar, Landau, Ray, Brogan, & Dy, 2020).

Pizzo *et al*., (2019) found that it's very significant to neurosurgeons, anatomists, and anesthesiologists to grasp the technical awareness of anatomy of human neuron complex interconnecting network leading to a good outcome in critical and emergency patient care and better prognosis. The greatest significant challenges in human anatomy are nerve variations particularly in extreme is found in the upper limb. Due to sports, car accidents or motorcycle

falls, medical conditions, and physical activities the upper limbs are vulnerable to traumas. It's all important to note that brachial plexus anatomical variations are very common. Most cadaveric anatomical studies of human nerves network is reported to manifest from the brachial plexus (Hardcastle *et al*., 2020; Verma *et al*., 2020)

Rastogi, Budhiraja, and Bansal (2013) Indicated that brachial plexus injuries may be as a result of delivery complication when delivering a newborns head, the anterior shoulder of the infant cannot pass below the pubic symphysis without manipulation (Bahm, Bouslama, Hagert, & Andersson, 2020; El Falougy, Selmeciova, Kubikova, Stenova, & Haviarova, 2013). This manipulation can cause the baby's shoulder to stretch, which can damage the brachial plexus to varying degrees (Feigl, Litz, & Marhofer, 2020; Singh, Das, Deora, Jaiswal, & Behari, 2020).

This kind of injury maybe as a result of shoulder dystocia. Shoulder dystocia can cause obstetric brachial plexus palsy (OBPP), which is the actual injury to the brachial plexus. These cases of OBPP in the United States is 1.5 per 1000 births, while it is high in the United Kingdom and the Republic of Ireland (0.42 per 1000 births). While there are no known predisposing factors or etiology for OBPP, if a newborn does have shoulder dystocia it increases their risk for OBPP 100-fold (Menticoglou, 2018)

Nerve damage has been connected to birth weight with larger newborns being more susceptible to the injury, but it also has to do with the delivery methods. Although very hard to prevent during live birth, doctors must be able to deliver a newborn with precise and gentle movements to decrease chances of injuring the child (Fakoya *et al.*, 2019; Tay *et al.*, 2021).

Vajapey *et al*., (2021) explored human cadavers aged above 18 years where 32 cadavers were contained in the study and assessment of sixty-four bilateral upper limbs eventually done. It was evident that the brachial plexus of male cadavers was normal on both sides E. Martin, J.

T. Senders, A. C. DiRisio, T. R. Smith, and M. L. D. Broekman (2018). Median nerve was formed on both the left and right side in distance of 45mm from the coracoid process. The musculocutaneous nerve entered to the coracobrachialis muscle on the side point of the right in distance of 83mm while left side at 105mm away from the coracoid process. While in another male cadaver the brachial plexus was normal on both sides, the median nerve was formed on right edge in distance of 93mm and left part in distance of 99mm away from the coracoid process. The musculocutaneous nerve entered coracobrachialis onto the right edge in a distance of 83mm whereas the left part in a distance of 105mm away from coracoid process (Pinto *et al.*, 2019).

Socolovsky *et al.* (2015), in contrast found a sex difference of two common origin of two or more branches being more frequent in females but no significance between the males. The comprehensive understanding of the variations is essential for surgeons factoring into occurrence of series of procedures accomplished in the original pathways. Of note is the surgical interventions done in the pectoral sites and axillar for presence of abnormal branches must be retained into the mind. The knowledge of normal brachial plexus is important in reparative surgery.

According to a study done by Ogeng'o (2013), on variations of posterior cord of brachial plexus in Kenya, it was noted that 8 of 75 translating to (10.7%) of the posterior cord indicated typical branching. The axillary nerve gave rise to 43(57.3%) of lower subscapular, 8 (10.3%) of upper subscapular and eight (10.3%) of thoracodorsal as opposed to originating from posterior cord. There was a revelation in four (5.3%) of medial cutaneous nerves of the arm and three (4%) of the medial forearm begun from posterior cord as opposed to the normal origin of medial cord (Ogeng'o, 2013).

The first specific objective is to find out the difference in the demographics of brachial plexus among black African population in western Kenya. In this regard, the parameters are varied,

that is, Age, gender, genetics and environmental just to name a few. In Kenya the legal procedure of acquiring a cadaver is tedious and takes a long time making it difficult to ascertain the age or genetic footprint. In addition, most of the cadavers, if not all, are unknown and cannot be proven in terms of tribe, age, or geographical inclination. It is with this in mind that necessitated use of a more definers like gender variable (male and female) and laterality as demographic characteristic.

Brachial plexuses have segments in terms of 5 roots, 3 trunks, 6 divisions, 3 cords and 18 branches. Ogeng'o, (2013) described variations in branching of one of the cords, the posterior cord of brachial plexus in a Kenyan population. This study is specifically focused on the anatomical differences in origin, course, and distribution in brachial plexus of the 5 main terminal branches thus musculocutaneous, ulnar, radial, median, and axillary nerve. In addition, focused on demographic differences in terms of gender (male and female) of the black Kenyan population in western region and the difference in variation of right and left side of brachial plexus of the same study population.

This study presents new knowledge to the international academic community for there could be erratic unusual origin of some of the terminal nerves that may have not been proclaimed and this could translate to unexpected clinical syndromes. This study will find out whether there is no consistency in the brachial plexus neuroanatomical variations with those in the white population and to correlate analysis between the variations and demographic features therefore the surgical perspective should be manipulated differently by the surgeons. There could be a typical origin or course of either of the nerves in relation to certain gender and/or left or right side of brachial plexus that has not been reported internationally. The unusual cadaveric variations of brachial plexus could improve extensively the knowledge of anatomist, radiologists, anesthesiologists, and surgeons could achieve successful results in surgical

operations. The results could also form a basis for policy formulation and guideline on neuromuscular procedures.

1.2 Statement of the problem

Globally, studies have centered in anatomy of brachial plexus variation but there is little literature on the same among African population in Kenya. Variation in human anatomy of brachial plexus constitute the most vital challenges Ogen'go, (2013).Upper limbs are capable of sustaining injuries, whereby a complete injury as main problem to Bp usually means patients lack feeling sensation and at times unable to lift the arm rendering it non-functional Rasulić *et al.* (2020). Different peculiarities of the brachial plexus may lead surgeons to possible act of omission throughout the procedure and surgical processes of tumors around injuries to brachial plexus. Understanding of the anatomy of brachial plexus instill clinician promptly with knowledge thus the need for this study (Ogen'go, 2013).

1.3 Objectives

1.3.1General Objective

To identify anatomical variations in morphology of the brachial plexus among black African population.

1.3.2 Specific objectives

i. To find out the morphological differences in the demographic characteristics of brachial plexus in gender (male and female) among black African population.
ii. To determine the anatomical morphological differences in variation of right and left brachial plexus of the study population.
iii. To investigate anatomical morphological variations in the origin, course, and the distribution of the main terminal branches of brachial plexus.

1.4 Research Questions

i. What are the morphological differences in variation in terms of demographic characteristics for example gender (female and male) of the study population?

ii. What are the morphological differences in variation of right and left side of brachial plexus of the study population?

iii. What are the anatomical morphological differences in origin, course, and the distribution in main terminal branches of brachial plexus?

1.5 Justification of the study

Various studies have shown that anatomical variations in morphology of brachial plexus are common and crucial thus skills of the variations are vital to the clinicians particularly radiological diagnosis, surgical operation, and regional anesthesia. However, there is scarcity of data that shows the pattern of distribution of variation of the brachial plexus among the black African population in western part of Kenya. The variations are of common occurrence, and this left a gap of knowledge where standard textbooks expression should be dealt with skillfully particularly regarding surgical procedures. It can also lead to a satisfactory comprehension of brachial plexus variation leading to facilitation of nerve healing or injury (Standring, 2016).

It is essentially crucial to have an upper front basic knowledge of the anatomical variations, this translates to a better prognosis post operatively Li, Rai, Liu, Xu, and Hong (2020). It's equally all important to assess sectional anatomical variations in a cadaveric brachial plexus. These skills are vital to surgeons, anesthesiologists, radiologists, and anatomists. This anatomical variations of the nerve fibers is used to project unforeseen clinical symptoms and signs Pizzo, Lynch, Adams, Yoon, and Liporace (2019). Absolute ability to understand the anatomy of brachial plexus equip clinician with knowledge leading to a good outcome in critical and emergency patient care and good prognosis thus the need for this study.

1.6 Significance of study

The study has revealed that the upper extremities are vulnerable to accidents; a full injury to the brachial plexus typically results in patients losing feeling in their arms and, occasionally, being unable to move them, rendering them useless. Understanding the structural alterations in the brachial plexus' morphology gives clinicians crucial clinical information for planning, evaluating, and relevantly correlating the region's anatomical location with physical results. As a result, the patient's health status is directly improved, and problems are also reduced.

1.7 Scope of the study

The study is limited to 70 cadavers that was to be done in selected department of anatomy (school of medicine) where the brachial plexus in all upper limbs will be dissected carefully on known gender. The researcher refers to gender as male or female and sides as right side and left side of the upper limbs of the cadaver. Only cadavers from the year 2018 to 2023 and properly embalmed with formalin 40% was to be carried out during routine dissection practice in the selected laboratories.

1.8 Limitation and delimitation of the study

Some laboratories might not have as many cadavers available as required for the study, which is one of the study's limitations. This is due to the challenges in obtaining informed consent from the court fraternity for acquiring cadavers for dissection. However, this will not interfere with the value of the procedure as the researcher will identify other laboratories to select the desired sample size. The researcher would go for cadaver embalmed with formalin 40% during dissection procedure. The data will be collected during Covid-19 pandemic, and this will not interfere with data collection and analysis as the researcher will take precautions and costs of protective gears, including use of face masks, gloves, and hand sanitizers for his safety.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The Brachial plexus that can be defined as an interconnection of nerves located in the axillary region of the upper limbs. This is important anatomical structure that has an association of C5, C6, C7, C8 and T1 anterior rami of nerve root which partly contributes to either T2 or C4 Lague *et al.* (2019). The dissimilarities are not rare as studies have shown that over 50% of the anatomical variation of human cadaveric research in neurosystem is confirmed to affiliate to brachial plexus Kemp, Besler, and Boyd (2021). Brachial plexus provides both motor and sensory innervations to the upper limbs inclusive of extrinsic muscles of the thorax Zheng, Wang, Zheng, and Feng (2019). Changes of the plexus are predisposing factors to thoracic outlet syndrome. The variations cause particular syndrome like thoracic outlet and necessitate a dissimilar surgical perspective in consideration to other causes (Butz *et al.*, 2014; Feigl *et al.*, 2020).

2.2 Normal anatomy of brachial plexus

According to Alvarez and Schulz (2019) Brachial plexus is established by joining of ventral primary nerves of cervical spine of C5 to C8 and T1. Roots are five, then three trunks, six divisions then further to three cords and finally ends by terminating into 18 terminal branches. Roots include C5, C6, C7, C8 and T1 Feigl *et al.* (2020). Trunks which are three in number are formed because of a buildup of roots. These roots normally unite at different portion whereby roots C5 and C6 log together to establish the upper trunk, then C7 alone makes the trunk in the middle, C8 plus T1 together make lower trunkPages, Le Hanneur, Cambon-Binder, and Belkheyar (2020). Each trunk separates into anterior and posterior division forming 6 divisions (Connelly *et al.*, 2019).

The division's further form 3 cords thus lateral cord, medial cord, and cord of posterior surface. Anterior distribution of the upper trunk as well as anterior part of middle trunk together make up the lateral cord (Singh *et al.*, 2020). All the 3 posterior divisions together form the posterior cord The anterior division of the lower trunk alone forms the medial codes as shown (Butz *et al.*, 2014).

2.2.1 The brachial plexus

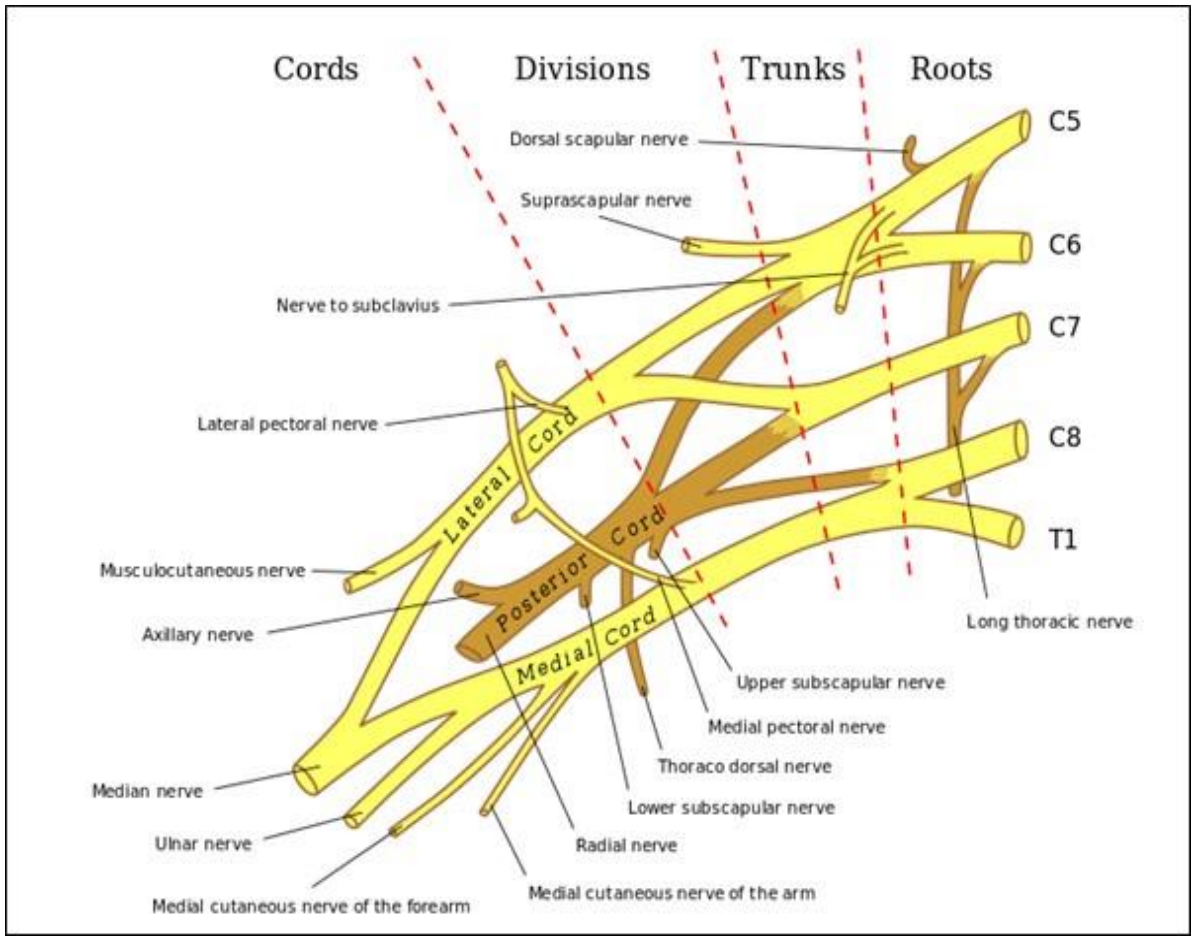

***Figure 2.1:The anatomical diagram of brachial plexus adopted from* (M. Emamhadi *et al.*, 2016).**

According to (Pickles 2019), terminal branches are 18 in number from the lateral cord has three 3 branches as follows Lateral pectoral nerve, Musculocutaneous nerve, and the lateral part of median nerve. There are 5 branches of medial cord thus, the medial part of pectoral nerve,

Medial primary part of the median nerve, Medial brachial nerve, Medial antebrachial nerve plus ulnar nerve.

The posterior cord give rise to two subscapular nerves the upper and the lower, then thoracodorsal nerve, plus axillary nerve and finally radial nerve (Cui, Liu, Zhao, Li, & Nian, 2020; Sharma *et al.*, 2016). From C5 there are 3 nerves dorsal scapular, phrenic nerve together with long thoracic nerve. The upper trunk there is Suprascapular nerve and nerve to subclavius Muscle (Alvarez & Schultz, 2019; E. Guday, A. Bekele, & A. Muche, 2017)

Root value of lateral cord is (C5, C6, and C7). Root value of medial cord is (C8 and T1) except ulnar nerve that have a root value of (C7, C8 and T1). Root values for nerves of posterior codes are (C5 and C6) except nerve to latissimus dorsi (C6, C7 and C8). Radial nerve (C6 and T1) (Monsivais, 2020; Padur *et al.*, 2016).

Brachial Plexus have other many branches (Alvarez & Schultz, 2019) noted branches arising from the root level are; dorsal scapular nerve (nerves to rhomboids) both derived from C5. It supplies Levator scapulae, rhomboid minor and rhomboid major, phrenic nerve derived from C5 which supplies the diaphragm (C3, 4 and 5) keeps the diaphragm alive. Long thoracic nerve derived from origin of C5, C6 along with C7 enervates serratus anterior muscles. Branches to long colli and scalenus muscles arises from C5, C6, C7 and C8. Branches from upper trunk (from superior trunk only)

(Pinto *et al.*, 2019). Suprascapular nerve supplies the following two rotator cuff muscles such as supraspinatus and infraspinatus then the Nerve to subclavius- supplies the subclavius muscles. Divisions don't have any branches at all. Cords are three the lateral cord have three branches; posterior cord have 5 branches and the middle cord have five branches respectively (Alvarez & Schultz, 2019)

Branches and main functions of these nerves are the Lateral pectoral nerve-supply pectoralis major and pectoralis minor, Musculocutaneous nerve equips biceps, brachialis and

coracobrachialis, Lateral root of medial nerve Joins the medial root of median nerve, Medial pectoral nerve tackles pectoralis major and pectoralis minor (Won, Choi, & Park, 2021). Medial root of medial nerve- Joins the lateral of median nerve, medial brachial nerve carries the sensory impulses on the small medial part, and medial cutaneous nerve to the forearm carries sensory impulses from large areas on the medial side. The intrinsic muscle at the palm together with anterior one plus half muscle of forearm is enervated by ulnar nerve. The Lower subscapular nerve enervates the muscles of teres major, while subscapularis muscles are supplied by upper subscapular nerve. Thoracodorsal nerve enervates muscles of latissimus dorsi, and axillary nerve supplies deltoid and teres major muscles (Gilcrease-Garcia, Deshmukh, & Parsons, 2020).

The thickest posterior cord has a thick branch known as the radial nerve, that's as per the literature done in 2015 of the normal anatomy of brachial nerves and enervates triceps plus 12 muscles at the back of ante brachium. Desired solutions of regional anesthesia together with effective procedures in surgery at the arm and axillary area rely on exclusion recognition in the anatomy of brachial plexus. Intention of the research is to particularly acquire anatomical access of a cadaveric variations of brachial plexus. The plexus compartment should be determined preciously containing the cord branches as well as the peripheral nerve origin with description of the variations at the origin together with branches of the brachial plexus (Vaid & Vaid, 2015).

2.3 Demographic Characteristic

Studies indicated that plexuses found to be fixed were 13 representing twenty four percent in origin, with 11 from female and male settled at 2, accounting for 5 being white and 8 taking black cadavers respectively, on percentage onto the right part acquired 54% and left wing taking 46% (Leonel *et al.*, 2021)

For phrenic nerve about 11 which is twenty percent arose from brachial plexus, thus nine males plus two females in a ratio of six white and five black cadavers (seventy-three percent to the right and twenty-seven percent at the left part. A supplementary phrenic nerve was found in twelve plexuses of about fifty percent on either side, in a ratio of three female and nine males. This is in reference to seven in black and five in white cadavers. Nerves emanating from the roots at the brachial plexus were found to be 54, dorsal scapular part had 45 plexuses. It was clear that twelve (27%) were found to be outside the muscle of middle scalene in their origin and course extensively made an observation on a female cadaver where there was a variation in the brachial plexus on both sides (E. Martin, J. T. Senders, A. C. DiRisio, T. R. Smith, & M. L. Broekman, 2018).

(Mohammadreza Emamhadi *et al.*, 2016)found that frontal perspective outlook of the right side of brachial plexus with the variation of the superior trunk, C5 plus C6 root separated into posterior along with anterior division. Both posterior divisions connect to yield origin into posterior superior trunk. The anterior superior trunk was given by both anterior divisions. The dorsal scapular wing was extremely far away from scalenus Medius muscle. It was realized that 33% nerves of dorsal scapula had intramuscular stream course in cadavers of seven females together with 26 males.C5 plus C6 of 17 plexuses conforming to 33%, plus C5, C6 and C7 in 46% thus twenty-four plexuses all together with C6 and C7 of eight plexuses in 15% of those cases formed the long thoracic nerve. Of note was that no cadavers of female origin had long thoracic nerve as of the previous description. Long thoracic nerve penetrated inter middle scalene muscles into sixty-three percent of cases (M. Emamhadi *et al.*, 2016).

In a study by Sravya P Vajapey, Erik S Contreras, Gregory L Cvetanovich, and Andrew S Neviaser (2021) noted that the cadaveric median nerve being formed at the distal part of the arm making 67% in a ratio of 19 in female plus male being 29. Of these totals inferior trunk of brachial plexus gave rise to two medial cutaneous trunks all at the right part from the black

male cadavers arising through the inferior trunk part of the brachial plexus. Some of the terminal branches such as the musculocutaneous and axillary nerves of the brachial plexus were not consistent in the origin.

Radial nerve got transmitting branch from 7% in the 4 cases of inferior trunk found in the male cadaver's one on the left and three on the right part. In 30% that is 16 cases thus 12 male and 4 female cadavers permitted transmitting branch as from lateral cord to the ulnar nerve. Two lateral roots plus one medial root (medial cord) formed the median nerve that's in 28 cases reflecting 52% in a ratio of three female and 25 being male, possessing nine from white origin and 19 of black cadavers.

As found in four occurrences 1 in 2 lateral roots arose as from anterior division at the middle trunk along with 1 from lateral cord. The remaining twenty-four cases two lateral roots arose from lateral cord of brachial plexus. As of the medium nerves four of them originated at the distal end of the same arm (S. P. Vajapey, E. S. Contreras, G. L. Cvetanovich, & A. S. Neviaser, 2021).

2.3.1 Difference in laterality

According to study done by Costa *et al*., (2019) throughout the profile regular dissection by the undergraduate students, it was noted that variation into emergence of the upper trunk of brachial plexus was one sided at the right part of male adult cadaver where upper trunk established by alliance of the ventral rami in the C5 to C7 of the spinal nerve. Lower trunk was established a association of the ventral branches of C8 together with T1 of spinal nerves of note was the middle trunk that was missing (Didesch & Tang, 2019). The atypical upper trunk then was cleared entirely to establish the facial correlation amid the middle and upper trunk. The noted anomaly in the upper trunk penetrated laterally interscalenus medius and scalenus anterior muscle. After leaving those two trunks both nerves to subclavius together with suprascapular nerves, the trunk separated into posterior and anterior divisions in which

advanced the course like as the division of the normal lower and upper trunk. Other parts of the brachial plexus were found to be within the normal range (Lague *et al.*, 2019).

According to Ichihara *et al.* (2015) two plexuses had variation onto superior trunk both found at the right part. In the two cases, C5with C6roots were broken up into posterior together with the anterior division. The two anterior unite to give rise to a beginning to a" posterior superior trunk". Then these trunks unite to give a beginning of a superior trunk. Middle trunk got an association branch from C8 of the left part in a white male cadaver together with a transmitting branch as from inferior trunk on the right part of one black male cadaver, There was no variation noted on the inferior trunk amongst those cases (Leape, 2015).

In a previous study done by Vanaclocha *et al.* (2015),established that variations at the supraclavicular side of the brachial plexus regularly were found more on the left part though in our case variation was in the right part Vanaclocha *et al.* (2015) . Comprehensive understanding of the variations into the emergence of the brachial plexus is so resourceful to neurosurgeons for it would assist during surgical management of neuro fibromas, tumors and nerve sheaths as (schwannomas) (Pizzo *et al.*, 2019).

2.3.2 The variations in terms of origin, course, and distribution

The frequent variations of the brachial plexus may lead to lack of success during infiltration of local anesthesia Yee *et al.* (2019). Following invasive surgical therapy of lesions of the brachial plexus variations quite superbly usual variations into the emergence with post fixed plexus are properly documented Lam, Fufa, Chang, and Chuang (2015). The variations in the emergence of trunks of brachial plexus have effectively been described. Other studies showed superior trunk not being formed a smaller percentage of cases, inferior trunk not being formed with formation at the trunk of brachial plexus by the T1 plus T2 roots while a formation of upper trunk of the brachial plexus by C5, C6 plus C7 roots is quite scarce which is always

united with lack of middle trunk where by surgeon defend this scenario as an act of anatomical fusing of middle with upper trunks(Leonel *et al.*, 2021).

One case was documented with regards to fusion of the upper plus middle trunk found to be bilateral E. Martin *et al.* (2018).This knowledge might also help in treating non- neural tumors like lipomaLeijnse, de Bakker, and D'Herde (2020). The orthopedic therapy of cervical spine requires technical skills on normal along with abnormal emergence of the brachial plexus even though the reported variations rarely may alter the physiological function of the individual's upper limbs. All these is significant in relation to orthopedic surgeries and clinical surgery (S. Sinha, Pemmaiah, & Midha, 2015).

Martin *et al* (2018) extensively made the following observation on a cadaveric and reported that there was a variation in the brachial plexus on both side on female Another study done by Sharma *et al.* (2016) reported that the musculocutaneous nerve emanated from median nerve when it was supposed to originate from the lateral code of the brachial plexus and on laterality, the left side in distance of 75mm and on the right side in distance of 66mm away from the coracoid process In the both sides the musculocutaneous nerve passes through the coracobrachialis muscles in distance of 128mm away from the coracoid process. Bilaterally the nerve cell projections of musculocutaneous moves together with fibers of median nerves for about 21mm. The median nerve was formed on left part at a distance of 54mm and right part at a distance of 45 mm away from the coracoid process. Martin *et al*., (2018) reported no variations seen on the bilaterally aspect of the median nerves.

Studies done (Kuhn *et al*., 2015) recorded that the median nerve was formed at different distances a distance from the coracoid process while the musculocutaneous nerve passes through the coracobrachialis at different distances away the coracoid process. This kind of studies are essential and very useful for the anatomists, orthopedics, neurosurgeons, anesthetists, radiologists, general surgeons, nurses, and other carders. In items such as invasive

surgical procedures at the humerus bones plus shoulder joints, nerve blocking, plastic repair operations, diagnosis and treating post traumatic peripheral neuropathies where these structures must be identified and protected for probable injuries and so collecting information about these structures and their variations in different populations is very essential (Kuhn, Lebus, & Bible, 2015).

While other studies on the brachial plexus variations have been documented by several authors who found variations in 47.1% of their series and 53.5 of human female and on the right side. This shows the kind of variations thus it explains the clinical syndromes with effect resolution in surgical procedure post trauma. It is important to note that selective therapeutic failures, lack of success of the brachial plexus tumors are directly interconnected to the variations (Leaper, Tanner, Kiernan, Assadian, & Edmiston, 2015).

Different anomalies of the long thoracic nerve were joint at separate parameters though they did not outline a long thoracic possessing a course from C3 specifically represented in that research Kuhn *et al.* (2015). The surgeons operating on these the back of his mind is bound to understand the feasibility of proximal and or distal upper with lower root joining. Surgeons with classical skills of nerve may cause destruction. Suprascapular nerve is often prone to variable, it may begin as at C4 or C5 from posterior or the anterior division of the upper trunk and from the posterior cord (Leonel *et al.*, 2021).

Mohammadreza Emamhadi *et al.* (2016) found that most cadavers had no consistency in the infra clavicular sector, medial cutaneous nerve was disconnected from the medial cord in a sole big branch, whereas five cadavers displayed a cross connection in between aforementioned nerve with the T1 spinal root. Medial antebrachial cutaneous nerve originating from a medial cord in thirty-seven plexuses (57.81%). Nevertheless, the rest originated from the inferior trunk, in totality of male cadavers.

Suprascapular nerve was straightly established by the C5 spinal root of six brachial plexuses. Often subscapular nerve arises at the posterior cord. A variation was noted at the beginning of upper subscapular nerve, arising at the superior trunk. Medial pectoral nerve abnormally shot up from anterior division at a medial trunk into two plexuses. Lateral pectoral nerve had no variations at all. Final findings of dissection revealed that the thoracodorsal found to vary in a sixty-year-old lady in of the two arms, emerging from axillary nerve. In some cases, thoracodorsal nerve usually arising from posterior cord as in totality spinal roots beginning at C5 to T1 formed the nerve.

Brachial Plexus terminal branches that's ulnar nerve which arises from C8 to T1 roots. Rasulić *et al.* (2020) found out that three cadavers (2 females and 1 male) had obvious variations on ulnar nerve. These cases demonstrated that ulnar nerve got interconnecting branch as from lateral cord. Median nerve had variations in twenty-two plexuses. Median nerve was established by two lateral roots beginning at lateral roots from the lateral cord with one medial root as from medial cord in six cadavers. Other five cases of importance are that either musculocutaneous nerve produced an interconnecting branch into median nerve drew one branch as from posterior cord of the mentioned plexus (Rasulić *et al.*, 2020).

It was established that lateral roots of lateral cord were exemplary united to emerge to musculocutaneous nerve. Some of the fibers at C7 roots infiltrated the nerve in the three females and five males. We revealed that radial nerve of majority cases was established by posterior cord (C5 to T1 roots),whereas salient united with division of middle a long with inferior trunks (C7 to T1 roots) straight away transmitted to produce radial nerve of the remainder in the bilateral plexus in 1 male cadaver (M. Emamhadi *et al.*, 2016).

2.4 Summary of Methodologies used in Literature Reviewed

Heydarpour *et al.* (2014) carried out a cadaveric study on five cadavers reflecting to ten upper limbs from familiar gender and did not indicate the study design or how he analyzed the data.

While Mohammadreza Emamhadi *et al.* (2016) conducted anatomical variations of the brachial plexus study on 32 fresh cadavers and used observational design to explore human cadavers where quantitative data analyzed data using SPSS software. The data was indicated was to be (N %), with mean ± SD a long with 95% confidence interval (CI 95%) was formerly described. In Egypt studies on anatomical variations of the brachial plexus on 20 cadaveric specimens was done where findings were pictured and written as actual or unusual as per classification of textbooks descriptions, results found to be descriptive with data collection presented as complete percentages and lastly numbers. The secondary data reviewed included Policy documents from various health sectors(E. Martin *et al.*, 2018).

For this study, descriptive design, structured data forms and observation was be adopted by the researcher to identify anatomical variations in morphology of the brachial plexus and its related structures where phenomena were be systematically described and measured without manipulating the variables.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study setting

This research was conducted at Maseno University School of Medicine located in Kisumu County Western Kenya The scientific rationale for conducting this study in Western Kenya was to investigate how the anatomy of the brachial plexus varies within the Black Africa population and to provide valuable insights for healthcare, medical education, and research that are relevant to this specific geographical and ethnic context. Data was collected from three anatomy laboratories: Maseno University with a total of 43 cadavers, Uzima Catholic University with 23 cadavers both in Kisumu County and Masinde Muliro University with 20 cadavers in Kakamega County during this study period (Anatomy Departmental records). This would enable understanding of the anatomical variations which is essential in performing surgical procedures and other medical managements in the population around this study area.

3.2 Research Design

Descriptive cross - sectional study design that employed data forms to collect data. Study design aimed at exploring variations in the structure of brachial plexus among black Kenyan population Vis, laterality, and demographic data.

3.3 Study (population)

Eighty-six cadavers were purchased by the trio of universities during the 2022 academic year. The cadavers could be disposed of after two more years since they were embalmed and kept in chilly rooms. The acquisition procedure was carried out in accordance with the anatomical legislation for the collection and disposal of human tissue.

3.3.1 Inclusion criteria

Only the cadavers of black African descend, with both right and left side upper limb intact were included in the study.

3.3.2 Exclusion criteria

The cadavers with no demographic characteristic records and cadavers whose upper limbs were dissected or injured.

3.3.3 Data Collection tool

Data was collected using data entry forms. The forms contained bio-graphics characteristics of the cadavers. Predetermined anomalies in origin and distribution of brachial plexus were entered in the forms for both the right and left upper limbs.

3.4 Study variables

3.4.1 Dependent variables

Anatomical variations in morphology of the brachial plexus in terms of (origin, normalcy, variant, and length in cm.)

3.4.2 Independent variables

i. The variations in demographic characteristics in terms of

   Gender; female and male

ii. The difference in laterality of right and left brachial plexus. Laterality in this context of the brachial plexus refers to the differences between the right and left brachial plexus, which are networks of nerves that control the muscles and transmit sensory signals in the upper limb(arm).

3.5 Sampling design

3.5.1 Sampling strategy

The three universities were identified purposively and conveniently because of their functional human anatomy Department that have met the CUE standards for storage of human tissue. To ensure equal distribution of samples, sampling will be done proportionately with the strata population by location, where the sample size per laboratory will be calculated by dividing

laboratory cadaver (*d*) by total location population (86), then multiplying by the desired sample size (70) as shown on (Table 3.1.) n= (*d**70)/86. Sample indicated in the table below.

Table 3.1: **Sample Size Allocation**

Locations of laboratory	Location population	Sample size per location
Maseno university	43	35
Uzima University	23	19
Masinde Muliro university	20	16
Total	86	70

Due to difficulty in acquiring the research specimen, a convenience sampling method will be used. In this case any cadaver that meets the inclusion criteria will be picked until the total number of samples is reached.

3.5.2 Sample Size determination

Since the catchment population of cadavers in western Kenya is small (less than 10,000). The sample size will be calculated using Yamane Taro formula (1967) because it provides a simplified formula that determines and calculate a reliable sample size from a given population. It also haves a high level of precision.

$$n = \frac{N}{1 + Ne^2}$$

n =is the sample size

N =is the target population

e = is the acceptable maximum error margin 5 % allowable error

In this case, the desired sample size for cadavers given that the total population of cadavers in the Western Kenya is 86 will calculated as below:

Where: n = 70

N= 86

e = 0.05

$$n = \frac{86}{1+86*0.05^2}$$

$$= 1 + 86\ (0.05)2$$

$$= 1 + \ (86\ x\ 0.0025)$$

$$= 0.215$$

$$= 1 + 0.215 \quad = 1.215$$

$$= \frac{86}{1.215}$$

= 70 cadavers

3.6 Sampling Procedure

The process of acquiring cadaver requires a legal process. There was a court order for the university to receive unclaimed bodies by the state after three months. The university then get in touch with the hospital board of directors and court to acquire the bodies. After the court order, the facility made a formal request to acquire bodies depending on different precise requirement. The medical institution then invoked transportation logistics of these bodies into the university. They were then received in human anatomy department. Then labeled and coded for easy identification proses. Cleaning and embalming with formaldehyde 40% were then done immediately in preparation for dissection purposes.

The dissection tools used were Adson forceps, hemostat, dissecting scissors, measuring tape, scalpel and blade handle, this procedure demands extreme caution to preserve the vital fine distal nerve structures. In the process, used a dissection guide (Cunningham's) to be more accurate and precise in the surgical procedure (Figure 3.1). The upper limb was put in an abducted position, then with a surgical blade skin of the pectoral region removed and an

incision made along the sternoclavicular line, another incision was made vertically superiorly to distally along the posterior neck triangle The superficial fascia was removed followed by deep fascia to expose the clavicular and sternocostal heads of the pectoralis major which reflected to get the lateral pectoral nerve piercing pectoralis muscles. Pectoralis minor muscle was then reflected to expose contents of the axilla along with the brachial plexus. Incision was extended to deltoid pectoral groove in a direction of pectoralis major with an aim of gating the starting point of subscapular, medial pectoral, thoracodorsal, lateral pectoral, medial ante brachial cutaneous and medial cutaneous nerves. An Oscillating saw was used to get rid of the middle third clavicle in order identify axillary artery.

To access brachial plexus terminal branches a vertical incision was made to expose the site between the triceps and biceps muscles. The following were exposed; roots which were located in scalene gap, trunks that were found superior to the clavicle, divisions that sit around the posterior portion of clavicle, cords and branches which were inferior to the clavicle median, axillary, ulnar, radial, and musculocutaneous nerves and locate their origin as well (Figure 3.2). Moreover, to be scrutinized were the variations of the cords, divisions, and trunks. Also, to locate the dimension from end to end of the nerves from the origin toward intent target muscles.

3.7 Procedure data (Brachial plexus Dissection procedure)

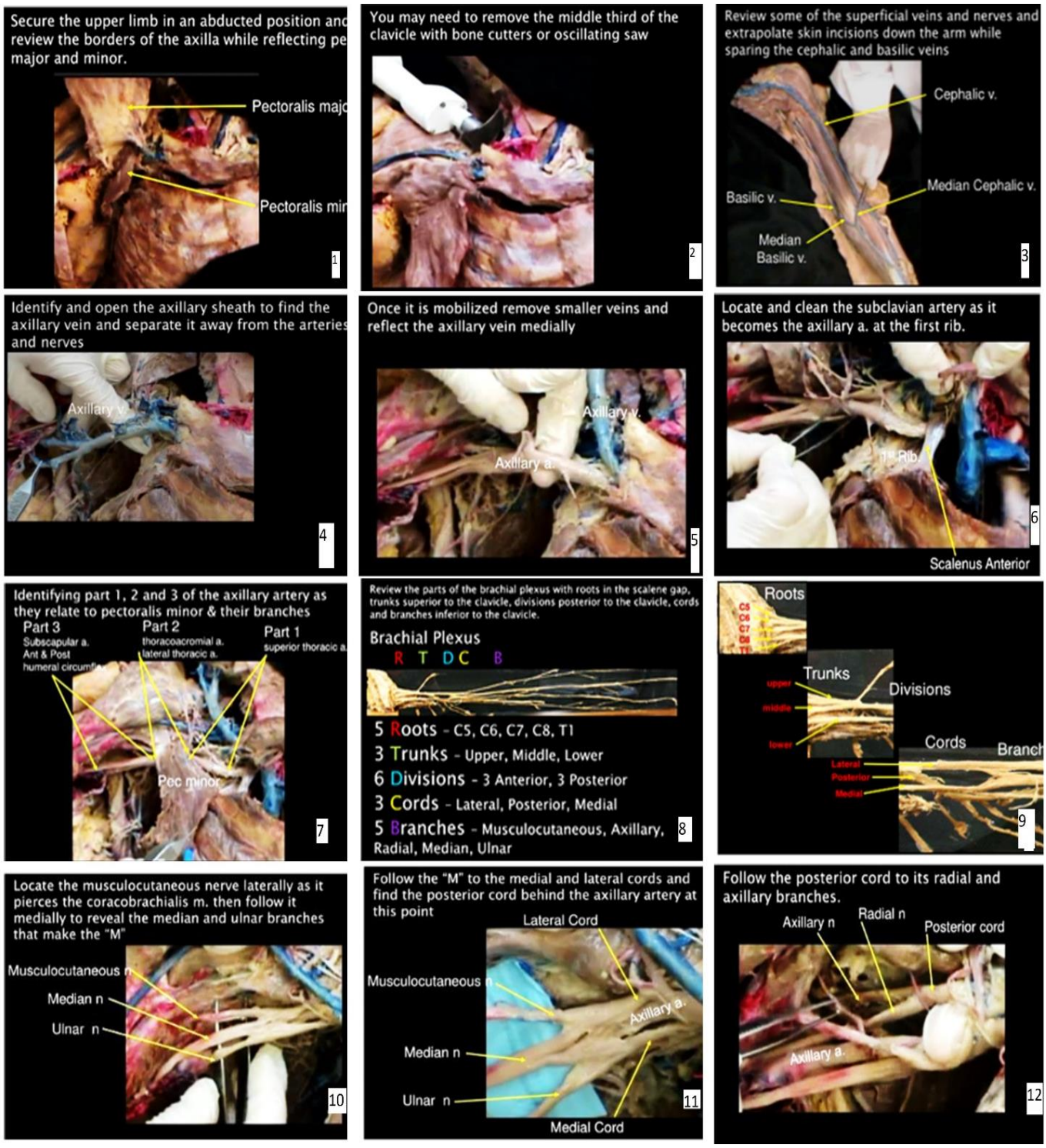

Figure 3. 1: *Brachial plexus adapted from (Pickles et al., 2019)*

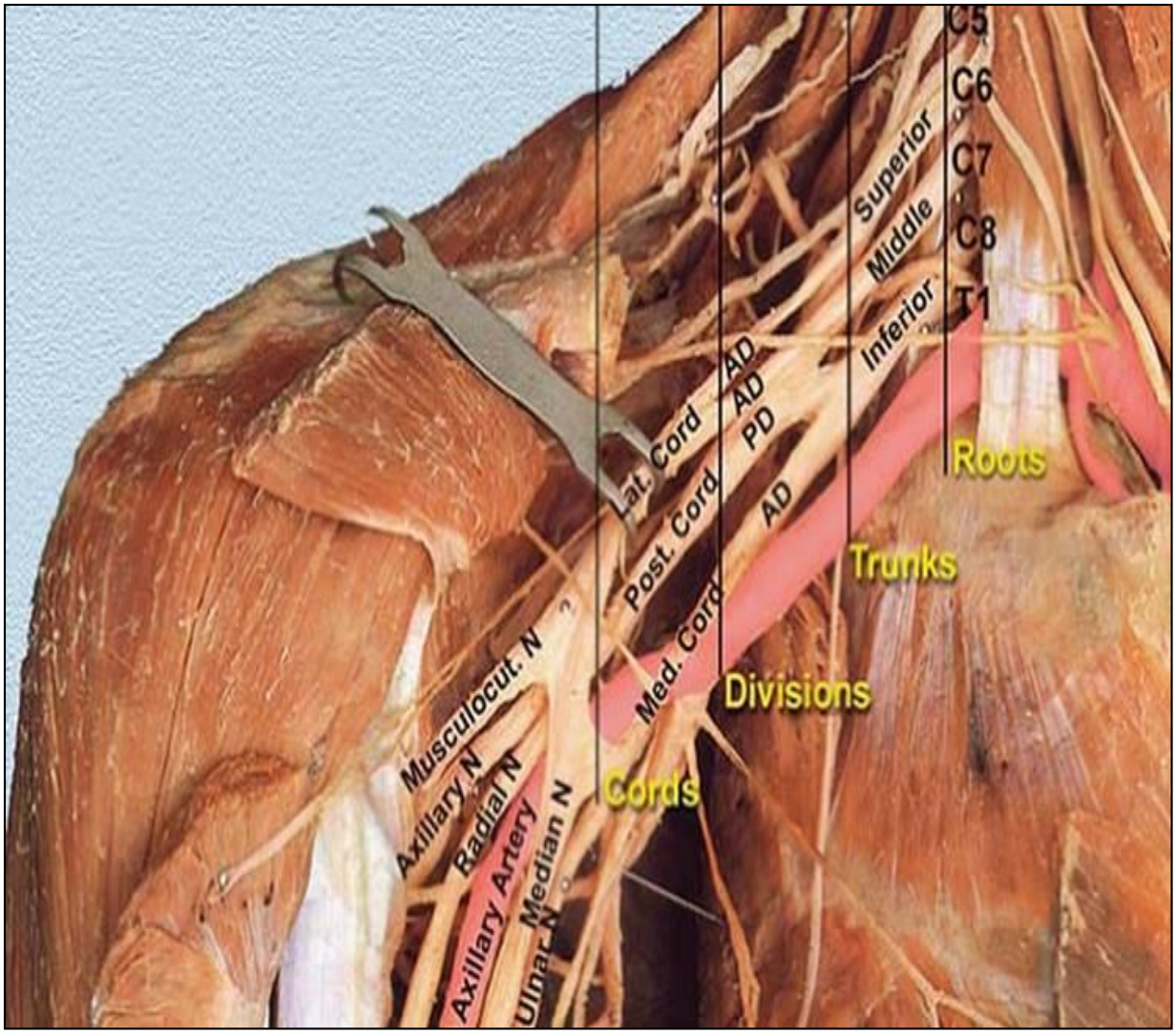

Figure 3. 2:*Brachial plexus adapted from* ***(Standring, 2016).***

3.8 Data collection instruments

The researcher collected data using data entry forms. The forms contained bio-graphics characteristics of the cadavers. Predetermined anomalies in origin and distribution of brachial plexus were entered in the forms for both the right and left upper limbs.

3.9 Data Analysis

All data was entered into preformed MS Excel worksheets, coded, and cleaned. Data was then transferred to statistical package for social sciences (SPSS) version 22.01 (2026).

Objective 1: The demographic characteristics for example gender. Descriptive statistics were used to determine the mean, mode, median standard deviation (SD) and percentiles of the anatomical variations of the brachial plexus. This was presented into tables and graphs. Chi-square test was used to compare the means of two independent groups for example (male and female) in order to determine whether there is any statistical evidence that the associated population means are significantly different. Significance was set at a *P*–value of ($\alpha = 0.05$).

Objective 2: Difference in variation between right and left brachial plexus.

The Pearson's Correlation test (a parametric statistical test) proved very useful for examining the relationship between population variations. The purpose of this is to see whether there is any statistical support for a linear relationship between similar pairs of variables in the population. The independent variables (sides) were entered into the Pearson's correlational table, and any possible relationships or associations were then examined.

Objective 3: The anatomical variations in origin, course, and distribution of brachial plexus.

Investigation of anatomical variations in the origin, course and the distribution of the brachial plexus was done by exposure of Bp using descriptive statistics to determine the mean, mode, median and standard deviation of the variations. The variations noted was significant in the formation of the roots, trunks, divisions, cords, and terminal branches.

3.9.1 Considerations for Logistical and ethical issues

The authority of carrying out this study was obtained from board of postgraduate studies, Maseno School of Medicine and request letter was sent requesting for data collection. Thereafter, the paper was forwarded to Maseno Ethics Review Committee for the purposes of acquiring ethical permission. Powers to conduct this study was sought from NACOSTI and

department of health Kisumu County, as well as management of the selected university laboratories. The administration was requested to allow the research to be done within the institution before the start, the purpose of the study was explained to administration for signing of the consent.

3.10 Presentation of results

The findings of this study were published in a journal on anatomical brachial plexus variation and presented at conferences, research seminars, and other relevant events.

CHAPTER FOUR

RESULTS

4.1 Introduction

The collected data was subjected to various analytical tests including, Pearson's correlation test and Levene's test. Frequency distribution tables were used to provide a clear picture of variations in the origin, branching and termination of the brachial plexus. Significant test results have been highlighted, in addition, the highest and lowest incidences of variations have been noted and correlated with gender and laterality.

4.2 Incidence of Occurrence of Variations in The Total Upper Limb Specimen (N=140)

Table 4. 1: Demographic characteristics of the study sample.

		Frequency	Percent
Gender	Female	35	50.0
	Male	35	50.0
	Total	70	100.0
University	Maseno University (Male)	18	25.7
	Maseno University (Female)	18	25.7
	Sub total	36	51.4
	Masinde Muliro University (Male)	7	10.0
	Masinde Muliro University (Female)	10	14.3
	Subtotal	17	24.3
	Uzima University (Male)	10	14.3
	Uzima University (Female)	7	10.0
	Subtotal	17	24.3
	Grand Total	70	100.0
Side of arm	Left	70	50.0
	Right	70	50.0
	Total	140	100.0

A total of 70 cadavers with intact right and left upper limbs (UL) were used in the study, therefore, a total of 140 UL samples were used as the study samples. For the gender variable,

there were 35 (50%) female cadavers and 35 (50%) male cadavers in the sample. The equal gender distribution was intentional to reduce bias during correlation tests (Table 4.1)

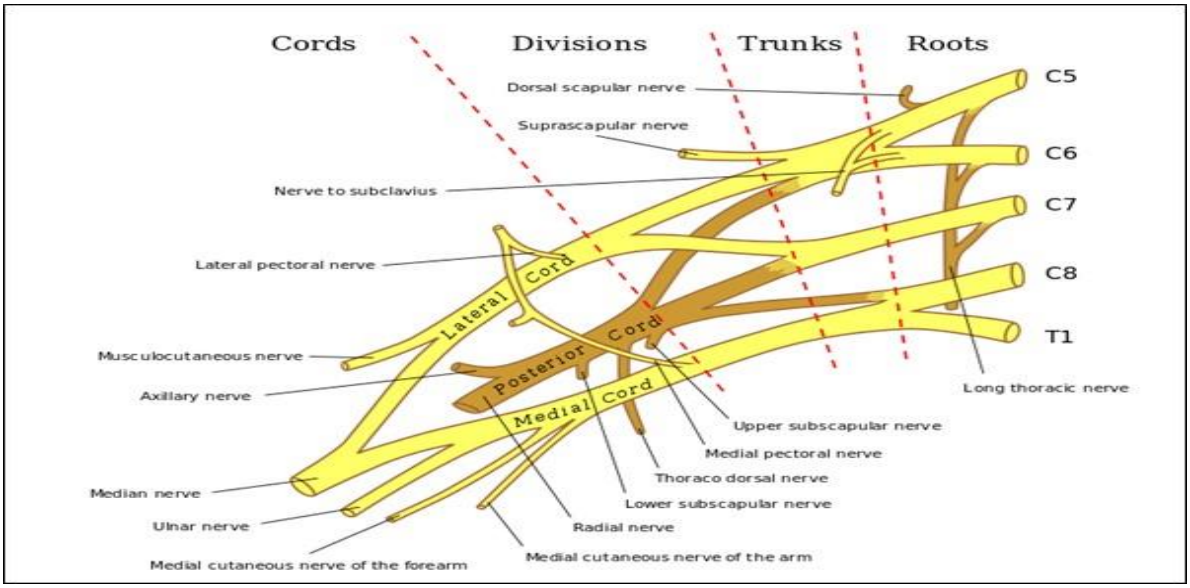

Figure 4.1: Normal brachial plexus adapted from (Emamhadi et al., 2016)

4.3 Difference in variation of right and left (laterality) brachial plexus of the study population

Table 4. 2: Frequency distribution of origin and sections of the brachial plexus

		Total Right + Left UL N=140	Percentage (%)
Roots	Normal	102	72.9
	Variant Post fixed	9	6.4
	Variant Prefixed	29	20.7
	Total	140	
Trunks	Normal	129	92.1
	Variant	11	7.9
Divisions	Normal	137	97.8
	Variant	3	2.2
Cords	Normal	136	97.1
	Variant	4	2.9

Of the total 140 upper limbs studied, the most frequent variation was at the level of the trunk (7.9%) while the least variation was at the level of division at 2.2% of upper limbs studied. (Table 4.2)

Table 4. 3: Frequency distribution of variations of terminal branches of brachial plexus

		Male	Female	Total	Percentage
		Frequency	Frequency	L+R UL	%
Auxiliary Nerve	Normal	61	57	118	84.2
	Variant	**9**	**13**	**22**	**15.8**
Radial Variation	Normal	68	65	113	95
	Variant	**2**	**5**	**7**	**5**
Ulnar Variation	Normal	61	61	121	86.4
	Variant	**9**	**9**	**18**	**13.6**
Musculocutaneous	Normal	59	55	114	81.4
Variation	**Variant**	**11**	**15**	**26**	**18.6**
Median Nerve Variation	Normal	56	63	119	85
	Variant	**14**	**7**	**21**	**15**

The variation in branching and distribution was compared against normal, the highest variation in branching was of musculocutaneous nerve with 18.6% (26) of variations whilst the lowest variation was of radial nerve at 5% of the total 140 upper limbs studied (Table 4.3).

Table 4. 4: Correlation between Laterality and variations in segments of brachial plexus

		Side			
		Left Count	Right Count	Total Count	Total Column N %
Roots Variation	Normal	54	48	102	72.9%
	Variant Post fixed	**4**	**5**	**9**	**6.4%**
	Variant Prefixed	**12**	**17**	**29**	**20.7%**
Trunks Variation	Anterior division of medial trunk connecting with medial nerve	**0**	**1**	**1**	**0.7%**
	Normal	64	67	131	93.6%
	Superior trunks pass midway via anterior scalene muscle	**6**	**2**	**8**	**5.7%**
Divisions Variation	Anterior division of medial trunk connecting with medial nerve	**2**	**1**	**3**	**2.1%**
	Normal	68	69	137	97.9%
Cords Variation	Normal	68	68	136	97.1%
	Variant	**2**	**2**	**4**	**2.9%**
	TOTAL VARIATION INCIDENCE	**14**	**11**	**25**	**17.8%**

Of the total 25 (17.8) variations in the origin and segments of brachial plexuses, the majority (14) were from the left side while only 11 (7.9%) were from the right. The highest frequency

of variation occurred at the pre-fixed root of the brachial plexus at 20.7% (29) with 12 occurring on the upper left arm and 17occuring on the right arm. The lowest occurrence of variation was at the trunk with the anterior division of the medial trunk connecting with medial nerve. This only occurred in one (0.7%) right upper limb of the total 140 specimens. (Table 4.4)

Figure 4.2: *Lateral cord formation by two cords. (Philip Omuga, 2022)*

KEY*: MN=musculocutaneous nerve, A= Cord one, B= Cord two and LC= Lateral cord.*

Table 4. 5: Test for significance between Laterality and variations in sections of brachial plexus

Pearson Chi-Square Tests		
		Side
Roots Variation	Chi-square	1.326
	df	2
	Sig.	.515a
Trunks Variation	Chi-square	3.069
	df	2
	Sig.	.216a, b
Divisions Variation	Chi-square	.341
	df	1
	Sig.	.559a
Cords Variation	Chi-square	.000
	df	1
	Sig.	1.000a

Results are based on nonempty rows and columns in each innermost sub table.

There was no statistically significant difference in variations between the left and the right upper limbs in all the segments of the brachial plexus. (Table 4.5)

Table 4. 6: Correlation between Laterality and terminal branches of the brachial plexus

		Side			
		Left Count	Right Count	Total Count	Total Column N %
Axillary Variation	Normal	62	56	118	84.3%
	Variant	**8**	**14**	**22**	**15.7%**
Radial Variation	Normal	68	65	133	95.0%
	Variant	**2**	**5**	**7**	**5.0%**
Ulnar Variation	Normal	64	58	122	87.1%
	Variant	**6**	**12**	**18**	**12.9%**
Musculocutaneous Variation	Normal	63	51	114	81.4%
	Variant	**7**	**19**	**26**	**18.6%**
Median Nerve Variation	Normal	60	59	119	85.0%
	Variant	**10**	**11**	**21**	**15.0%**
TOTAL VARIATION INCIDENCE		**33**	**61**	**94**	**67%**

In the current study, the right upper limbs had the highest incidence of variations in the branching patterns of brachial plexus at 43% (61) whilst the left had a variation incidence of only 23.5% (33). The highest frequency of variation was of musculocutaneous nerve (18.6%) with 19 (13.6%) variations occurring on the right side whilst only 7 (5%) variations occurred on the left side. Variation in origin of radial nerve had the lowest frequency with only 2 (1.42%) on the left side and 5 (3.5%) incidences on the right side. (Table 4.6)

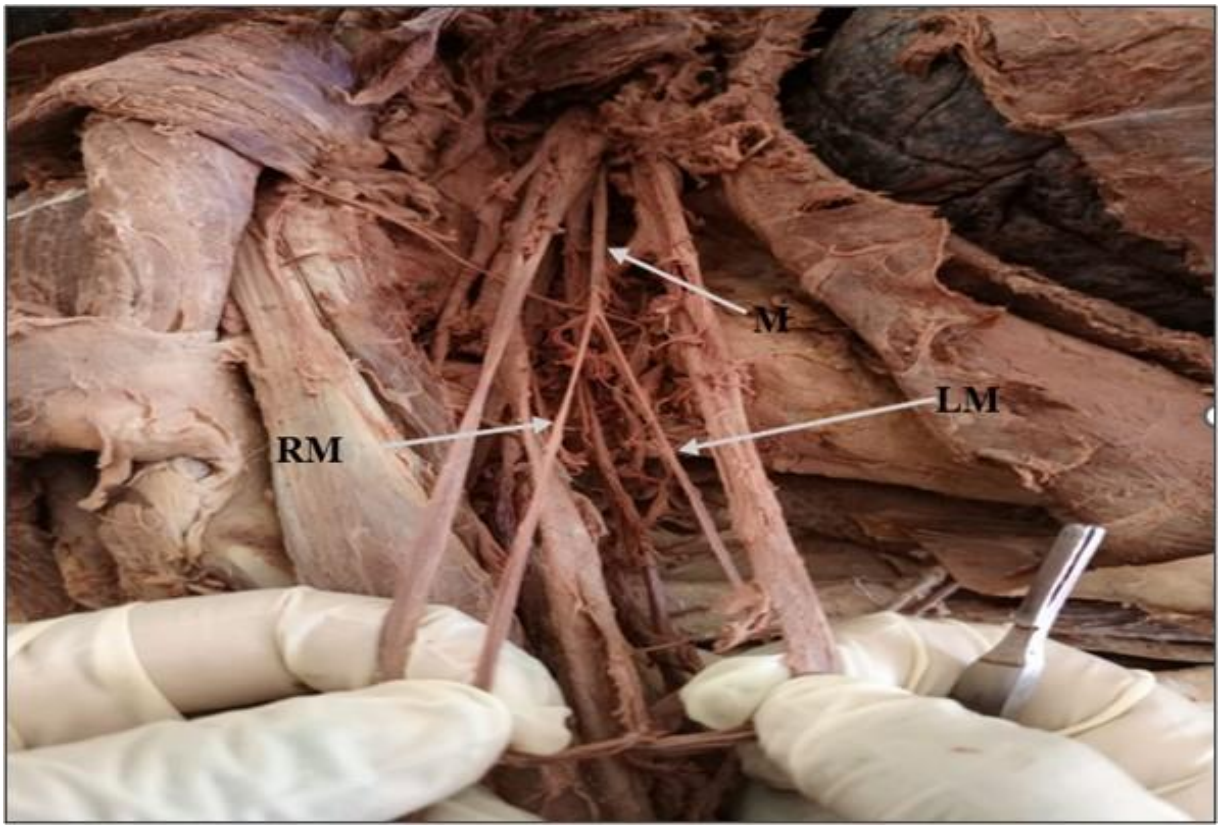

Figure 4. 3: Variation of musculocutaneous nerve in branching pattern in relation to the coracobrachialis muscle (Philip Omuga, 2022).

***KEY**:M=musculocutaneous nerve, RM= right branch of musculocutaneous nerve and LM= left branch of musculocutaneous nerve.*

Table 4. 7: Test for significance between Laterality and variations in branching of brachial plexus

Pearson Chi-Square Tests		
		Side
Axillary Variation	Chi-square	1.941
	df	1
	Sig.	.164
Radial Variation	Chi-square	1.353
	df	1
	Sig.	.245
Ulnar Variation	Chi-square	2.295
	df	1
	Sig.	.130
Musculocutaneous Variation	Chi-square	6.802
	df	1
	Sig.	.009*
Median Nerve Variation	Chi-square	.056
	df	1
	Sig.	.813

Results are based on nonempty rows and columns in each innermost suitable.

***. The Chi-square statistic is significant at the .05 level.**

There was a statistically significant difference (p=0.009) between the right and the left upper limb in the branching of musculocutaneous nerve. There was no statistically significant difference in variations between the left and the right upper limbs in the remaining terminal branches of the brachial plexus.

Figure 4.4 Median nerve formation by as single root while musculocutaneous nerve gives a communicating branch to median nerve (Philip Omuga, 2022).

KEY*: M=Musculocutaneous nerve, MN= Median nerve and CM= Communicating branch of musculocutaneous joining the median nerve.*

4.4 cross tabulation of gender and variations in brachial plexus of the study population

Table 4. 8: Correlation between gender and segments of the brachial plexus

		Gender			
		Female	Male	Total	
		Count	Count	Count	Column Valid N %
Roots Variation	Normal	54	48	102	72.9%
	Variant Post fixed	**3**	**6**	**9**	**6.4%**
	Variant Prefixed	13	16	29	20.7%
Trunks Variation	Anterior division of medial trunk connecting with medial nerve	**0**	**1**	**1**	**0.7%**
	Normal	67	64	131	93.6%
	Superior trunk pass midway via anterior scalene muscle	**3**	**5**	**8**	**5.7%**
Divisions Variation	Anterior division of medial trunk connecting with medial nerve	**2**	**1**	**3**	**2.1%**
	Normal	68	69	137	97.9%
Cords Variation	Normal	69	67	136	97.1%
	Variant	**1**	**3**	**4**	**2.9%**
	TOTAL VARIATION INCIDENCE	**9**	**16**	**25**	**17.8%**

Of the total 140 upper limbs studied, males had the highest frequency of variations in the segments of brachial plexuses examined at 16% (11) whilst females had only 6.5% (9) cases. The most common variation was post-fixed brachial roots at 6.4%, with highest occurrence in males with 9 incidences (Table 4.8)

Figure 4.5 Pre-fixed variation of brachial plexus (Philip Omuga, 2022).

KEY: A= joining spinal axon and C= cervical root origin

.

Figure 4.6 Post-fixed variation of brachial plexus where T1 has 2 spinal axons(Philip - Omuga, 2022).
KEY: T1a=1st spinal axon and T1b=2nd spinal axon.

Table 4. 9: Test for significance between gender and segments of the brachial plexus

Pearson Chi-Square Tests		
		Gender
Roots Variation	Chi-square	1.663
	df	2
	Sig.	.435
Trunks Variation	Chi-square	1.569
	df	2
	Sig.	.456[a]
Divisions Variation	Chi-square	.341
	df	1
	Sig.	.559
Cords Variation	Chi-square	1.029
	df	1
	Sig.	.310[a]

Results are based on nonempty rows and columns in each innermost sub table.

There was no statistically significant difference between gender and variations in the segments of the brachial plexus in all the sections. (Table 4.9)

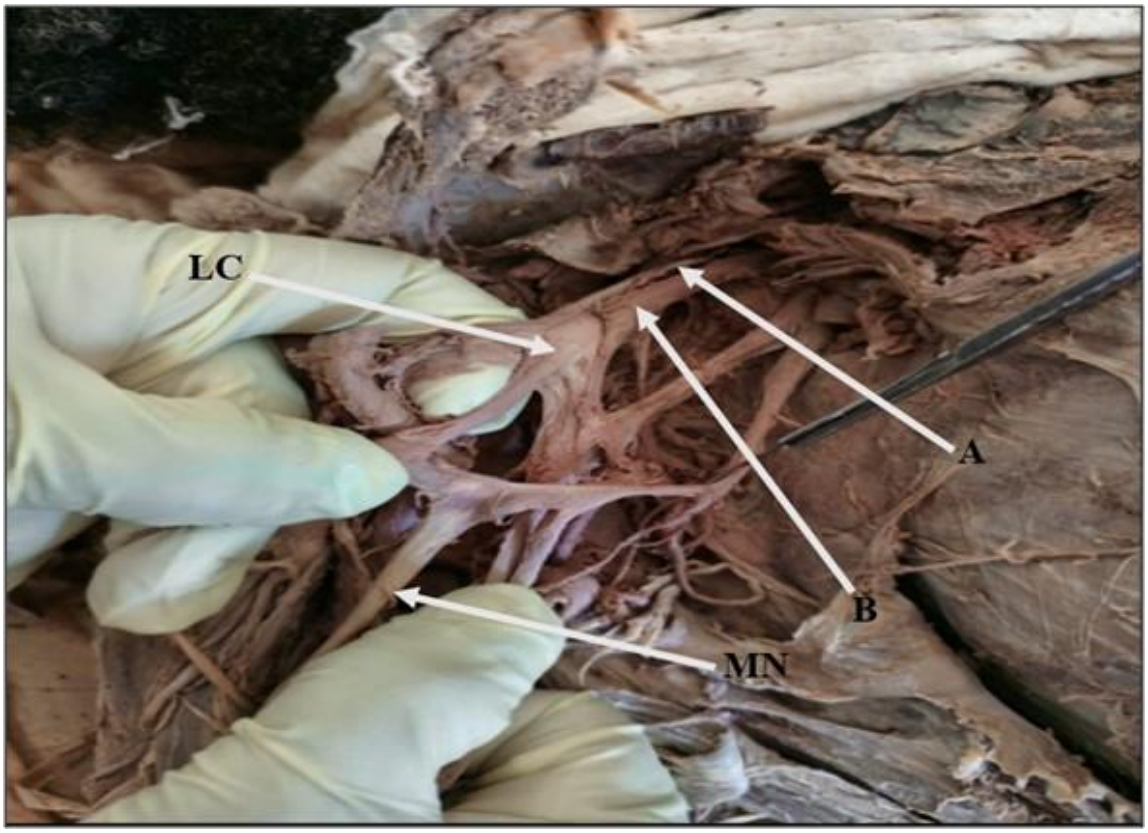

Figure 4.7 Lateral cord formation by two cords (Philip Omuga, 2022).

KEY: MN=musculocutaneous nerve, A= Cord one, B= Cord two and LC= Lateral cord.

Table 4. 10: Correlation between Gender and terminal branches of the brachial plexus

		Gender			
		Female	Male	Total	
		Count	Count	Count	Column Valid N %
Axillary Variation	Normal	57	61	118	84.3%
	Variant	**13**	**9**	**22**	**15.7%**
Radial Variation	Normal	65	68	133	95.0%
	Variant	**5**	**2**	**7**	**5.0%**
Ulnar Variation	Normal	61	61	122	87.1%
	Variant	**9**	**9**	**18**	**12.9%**
Musculocutaneous Variation	Normal	55	59	114	81.4%
	Variant	**15**	**11**	**26**	**18.6%**
Median Nerve Variation	Normal	63	56	119	85.0%
TOTAL INCIDENCE OF VARIATION	Variant	**7**	**14**	**21**	**15.0%**
	TOTAL	**53**	**45**	**94**	**67%**

Out of the total 140 limbs examined, females had the highest number of variations of the terminal branches of the brachial plexus at 37.8% followed by males at 32%. The total variations of the branches of brachial plexus were 67% (94) of the total upper limbs. (Table 4.10)

Table 4. 11: Test for significance between gender and Branching of the brachial plexus.

Pearson Chi-Square Tests

		Gender
Axillary Variation	Chi-square	.863
	df	1
	Sig.	.353
Radial Variation	Chi-square	1.353
	df	1
	Sig.	.245a
Ulnar Variation	Chi-square	.000
	df	1
	Sig.	1.000
Musculocutaneous Variation	Chi-square	.756
	df	1
	Sig.	.385
Median Nerve Variation	Chi-square	6.745
	df	1
	Sig.	.008

Results are based on nonempty rows and columns in each innermost sub table.

a. More than 20% of cells in this sub table have expected cell counts less than 5. Chi-square results may be invalid.

There was a statistically significant difference (p=0.008) in the variation of distribution of median nerve in relation to the sexes. Other variations had no significant differences. (Table 4.11).

Figure 4. 8 Median nerve formation by as single root while musculocutaneous nerve gives a communicating branch to median nerve (Philip Omuga, 2022).
KEY*:M=Musculocutaneous nerve, MN= Median nerve and CM= Communicating branch of musculocutaneous joining the median nerve.*

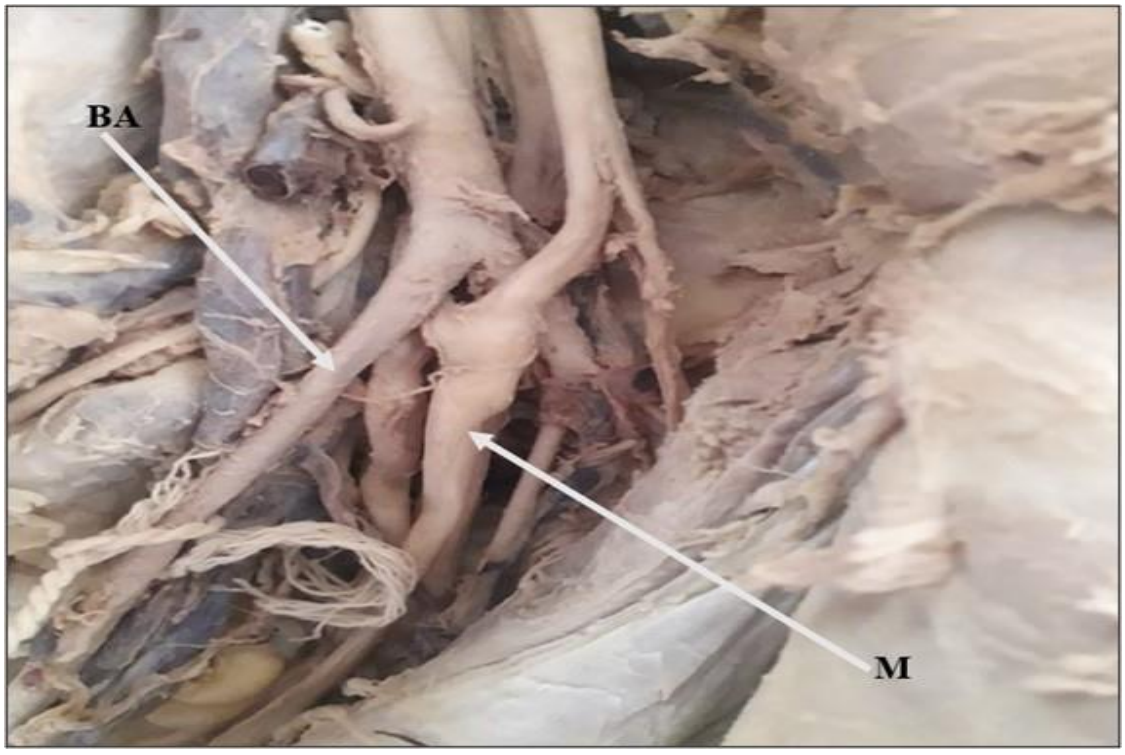

Figure 4. 9 Brachial artery passing superiorly and superficial to the median nerve (Philip Omuga, 2022).

KEY*:M=Musculocutaneous nerve and BA= Brachial artery.*

4.5 anatomical variations in the origin, course, and the distribution of the main terminal branches of brachial plexus.

Levene's test for equality of variances was used to determine if the variances of the terminal branching patterns are equal and to assess the strength of relationship of variations from normal. The F value and its associated p-value are reported. If the p-value is less than .05, then the assumption of equal variances is violated and the "equal variances were not assumed" row is used. The 95% confidence interval of the difference between the means was reported. The mean difference, standard error difference, and lower, and upper limits of the confidence interval are provided.

Table 4. 12: Independent Samples Test (Right Terminals of Brachial Plexus)

		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	Df	One-Sided p	Two-Sided p	Mean Difference	SED	Lower	Upper
Axillary Nerve	EVA	.196	.659	-1.860	68	.034	.067	-.0886	.0476	-.1836	.0064
	EVA			-1.860	67.374	.034	.067	-.0886	.0476	-.1836	.0065
Radial Nerve	EVA	.161	.689	.575	68	.284	.567	.0343	.0597	-.0847	.1533
	EVA			.575	67.978	.284	.567	.0343	.0597	-.0847	.1533
Ulnar Nerve	EVA	1.952	.167	-1.300	68	.099	.198	-.5429	.4175	-1.3760	.2902
	EVA			-1.300	64.425	.099	.198	-.5429	.4175	-1.3768	.2911
Musculocutaneous Nerve	EVA	.965	.329	-1.422	68	.080	.160	-.3429	.2411	-.8241	.1383
	EVA			-1.422	67.270	.080	.160	-.3429	.2411	-.8242	.1384
Median Nerve	EVA	2.720	.104	.558	68	.289	.579	.2743	.4916	-.7067	1.2553
	EVA			.558	64.163	.289	.579	.2743	.4916	-.7078	1.2563

Key: EVA=Equal variance assumed; SED=Std. Error Difference

From the above table, there was no statistically significant variation observed in all the branching patterns of the brachial plexus, even though the variations were reported, Levene's test does not show any strong variation from the normal anatomical standards. (Table 4.12).

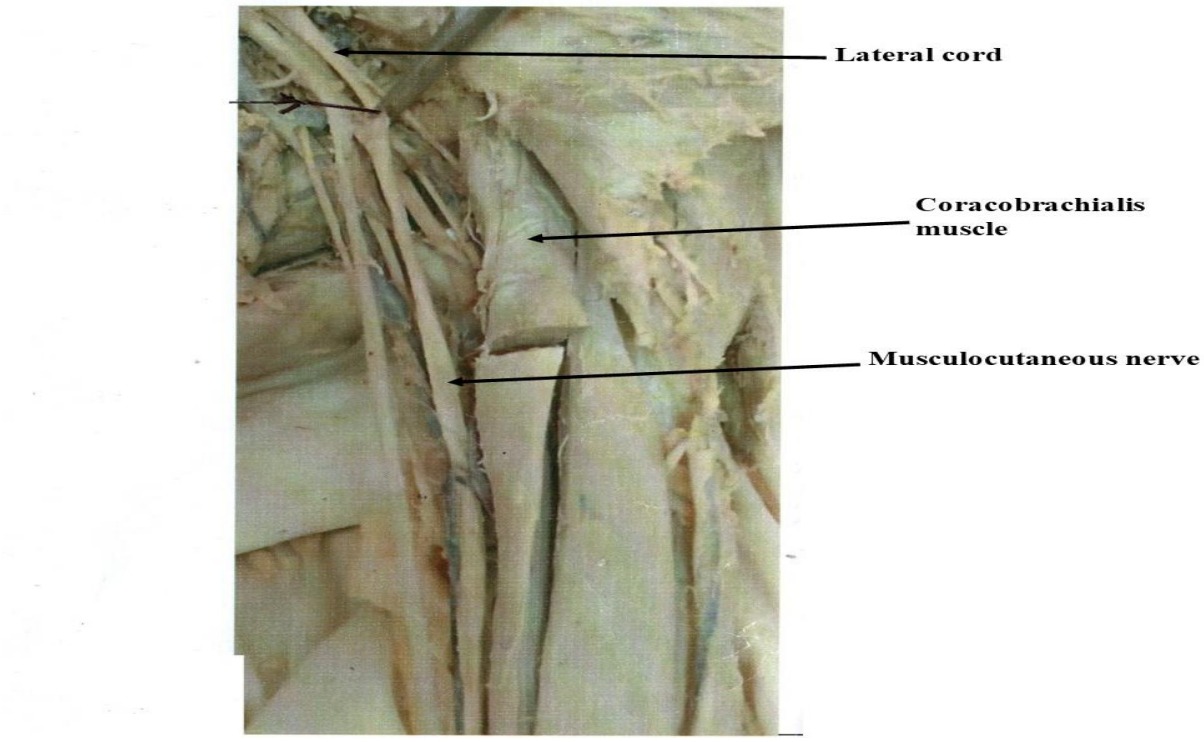

Figure 4. 11 **Musculocutaneous not piercing coracobrachialis muscle** ***(Philip Omuga, 2022).***

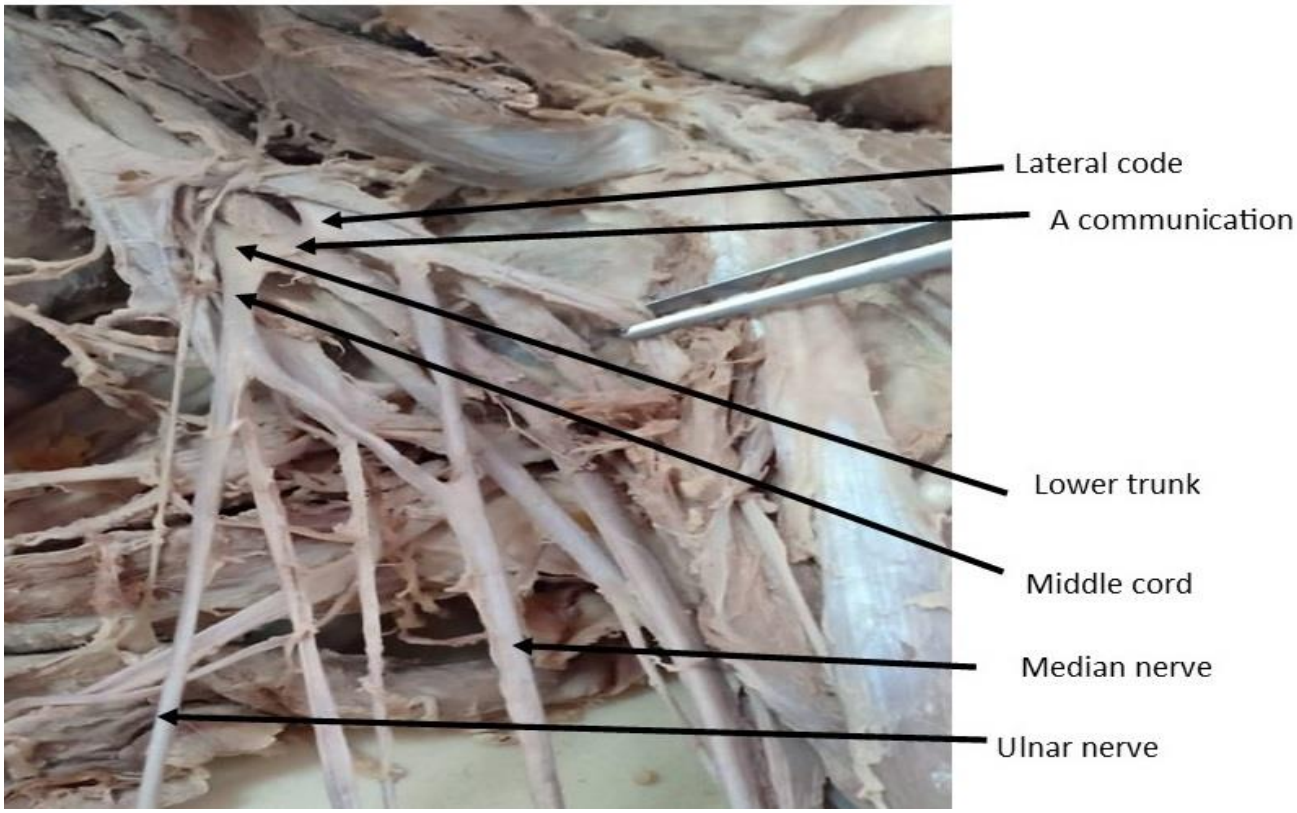

Figure 4. 12 **Communication between lower trunk and lateral code (*Philip Omuga, 2022*).**

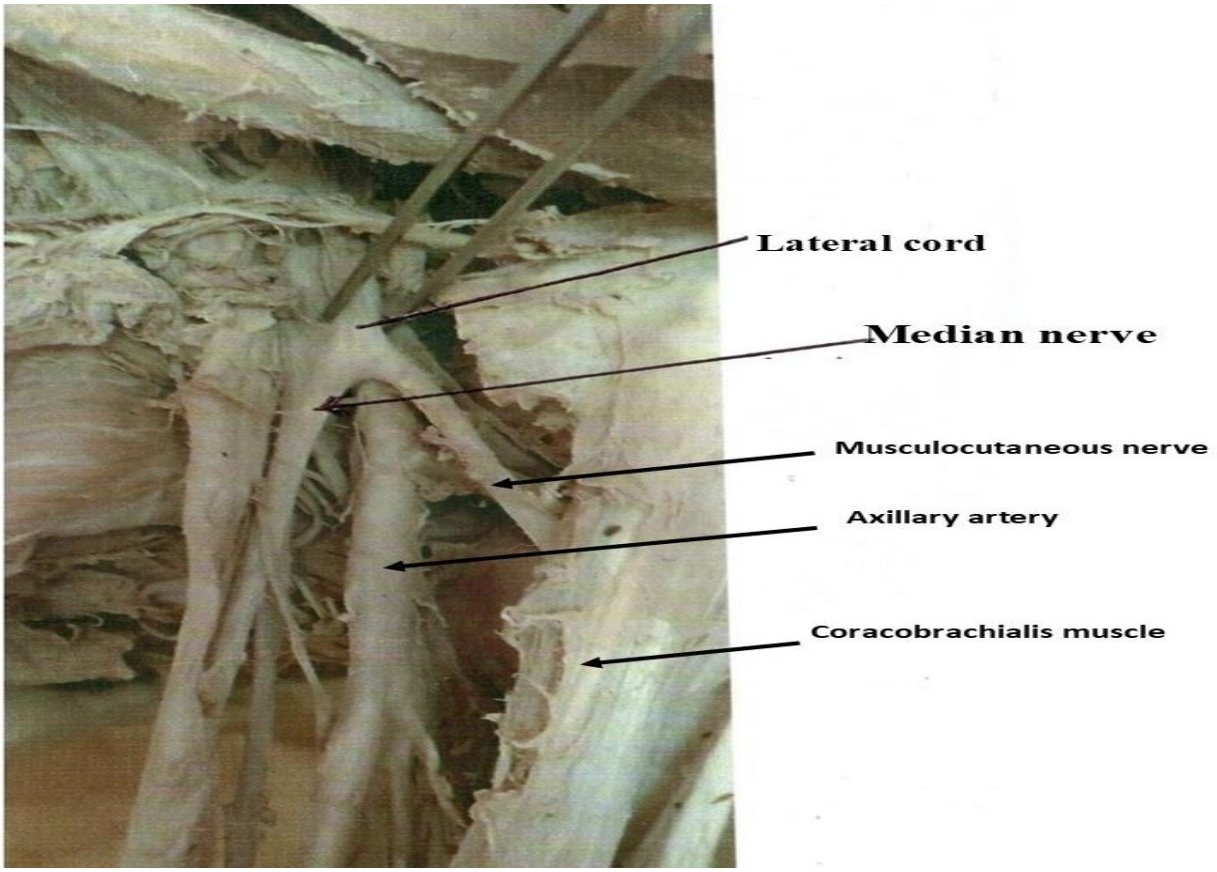

Figure 4. 13: Median nerve established from one lateral cord *(Philip Omuga, 2022).*

CHAPTER FIVE

DISCUSSION

5.1 Introduction

The results of this study were critically synthesized and correlated with available literature to comprehend and answer the problem posed in current project. This chapter comprehensively discusses the findings of this study in line with the three objectives presented. Possible reasons have been presented where results of the present do not concur with the works of other researchers.

5.2 Demographic characteristics of the study sample

In this Study the ratio of male to female in the study was equal, a total of 70 study subjects were examined each with both the upper right and left limbs totaling to 140. The standard textbook anatomy of the brachial plexus as 5 roots emanating from the C5-T1 spinal nerves, 3 trunks (upper, middle, and lower trunk), 6 divisions (3 anterior and 3 posterior divisions), 3 cords (lateral, posterior and medial cord) and 5 branches (musculocutaneous, axillary, radial, median and ulnar) Gilcrease-Garcia *et al*., (2020). The current study found that the variations at the root of brachial plexus was 27.1% (38), on the trunks 7.9% (11), at the divisions 2.2% (3) and on the cords 2.9% (4). The highest variation was at the pre-fixed root while the least was at the division.

A study done by Mohammadreza Emamhadi *et al.* (2016) to evaluate the cords, trunks and terminal nerves of the brachial plexus of 32 cadavers which included 21 males and 11females in Iran where all study subjects were from one province found 9.4% of the brachial plexus to be pre-fixed while 3.1% to be post- fixed. Among those with pre-fixed brachial plexus, 5 were males and one was a female while those with pre-fixed were young male study subjects. The number of pre-fixed and post fixed brachial plexus in the previous study was lower than the

present study which could be attributed to the number of study specimen and the geographical region that the study specimen came from.

On further studies, the previous study noted that the male gender was more at risk of injuries and damage to the brachial plexus because of the nature of their work therefore during corrective surgery and physiotherapy these variations can cause confusion leading to further damage and injury of the brachial plexus by the surgeon.

Similarly, the current study had more males with variations in the pre-fixed and post fixed brachial plexus while females had more variations on the terminal branches. Other factors that influence variation in the brachial plexus were highlighted by Gilcrease-Garcia *et al.* (2020) in their study and these included genetics, geographical location and gender noting that the factors could have a positive or negative impact on the health of an individual depending on the extent of the variation, the cause and the area innervated by the affected nerve.

Another study by Claassen, Schmitt, Wree, and Schulze (2016) observed 45 cadavers, 40 males and 5 females from the same locality and found 4 with anomalies of a single cord originating from the six divisions with normal roots, trunks, division and branches. Although this was a unique finding probably attributed to the geographical location and ethnicity of the study population, he noted that it occurred more commonly to male gender. This was dangerous since any damage to the single cord which originated from the 6 divisions could render all the branches functionless leading to loss of function on the upper limbs.

Although Edengenet Guday, Asegedech Bekele, and Abebe Muche (2017) is in agreement with the previous study by Claassen *et al.* (2016), he highlights the significance of the single cord in relation to the position where it lies as deeply and safe as compared to the other 3 cords that are superficial and easily prone to injury. He however observes that 2 cords are better than 1 or the 3 normal cords because of their ability to share functions. Although the present study

had equal ratio in gender of the study subject, most of the variations were found in male study subjects probably due to genetics and the nature of work that they do.

Another study found that among the Spanish population established that on 27 study subjects of different gender and color found 24% pre-fixed brachial plexus among them 2 males and 11female (5 white and 8 black) and 3 post fixed brachial plexus all from white male cadavers. The study specimen with pre-fixed brachial plexus was higher in the previous study than the current study while the post- fixed was higher in the present study than the previous study. Although the previous study attributed the variations to factors like gender race and geographical location, the present study noted that some of these variations could have occurred later in life as a result of trauma or disease process as a mechanism for the body to attain its normal functioning hence with the current occurrence of diseases like cancer, HIV and other non-communicable diseases like hypertension, diabetes mellitus and the continuous exposure to accidents and trauma, the occurrence of these variations is expected.

While other studies observed 9% variations, which was nearly identical to the present study's 7.9% variations in the trunk, the present study discovered 7.9% variations in the trunk.

In the previous study, 2 anterior divisions joined to give rise to the anterior superior trunk while both posterior divisions joined to give rise to the posterior superior trunk, both nerves later joined to form the superior trunk. Furthermore, they found a rare occurrence where the middle trunk received communication from C8 and another branch from the inferior trunk. Although the previous findings were almost similar with the present study, in the present study the divisions of the middle and the superior trunk led to the formation of the posterior cord while the lateral cord was formed by the anterior divisions of the superior and the inferior trunks. The medial cord in 2 study subjects was formed by the anterior division of the inferior and middle cord. The present and the previous studies found the posterior cord originating from the

posterior division of superior and middle trunks although the prevalence of the previous study was higher at 9% while the present study had 3 incidences.

In the present study, among the variations at the terminal branches, the musculocutaneous nerve had the highest variation at 18.6% (26) while the least was the radial nerve at 5% (7) Mohammadreza Emamhadi *et al.* (2016**)** recorded 3 variations in the ulnar nerve and noted that ideally the ulnar nerve originates from the medial cord, but in their study, it received a communicating branch from the lateral cord while the median nerve received communication from the posterior cord yet it was supposed to receive communication from the lateral and medial cord. In the present study, variation of the ulnar and the median nerve was higher than the previous study because the communications received by this branch were from the posterior, lateral and medial cords combined thus increasing the number of variations.

Although this may be confusing to the surgeon during treatment of neck surgeries, the communications received from other variant branches may as well have a saving effect to the parts innervated.

In case of diseases, injury or tumor of specific regions affecting the functioning of nerves innervating the regions, there can be an alternate pathway for nerve transmission which will help to prevent further injury and loss of function in the affected areas. Similarly, (Benes, Kachlik, Belbl, Whitley, *et al.*, 2021) in their study which was to determine the relationship between the terminal branches of the brachial plexus and the functioning of the arm that was done on 48 Turkish cadavers noted a lot of variations in the branches which could cause confusion to the health care providers and surgeons during assessment of nerve injuries like carpal tunnel syndrome, cubital tunnel syndrome and leprosy neuropathy However, they also noted that these variations in connections may also be good because they may provide sensory or motor innervation when an alternate nerve has trauma or defect and cannot function. They advised that since the variants had both positive and negative implications, it was important to

identify the type of variant that an individual had so that management could be established early enough.

Another study on 39 previously dissected cadavers among them 20 females and 19 males observed variations in the musculocutaneous branch where it was formed by the medial and the lateral cords and even changed its course of movement to innervate additional muscles of the anterior forearm apart from the coracobrachialis, biceps and the brachialis. The same case applies to the present study where the musculocutaneous nerve had the highest variation which could be attributed to receiving branches from the posterior and medial cord. This could affect the conduction of plexus blockade as a component of anesthesia in the upper arm.

Patel, N. T., & Smith, H. F. (2023) studies on 306 cadavers observed how variations in the brachial plexus could facilitate the deterioration of the functioning of the axillary artery. The previous study found variations in 12 study subjects whose axillary nerves merged from the lateral and medial cord and ran anteromedial towards the axillary artery which brought intertwining of the artery and nerve therefore compromising the activity of the axillary artery, brachial artery, and the other blood vessels adjacent to them. In the present study, 22 axillary nerves had variations which was higher than the previous study. These variations included originating from lateral and medial cord, or both combined which could highly interfere with the distribution of the axillary artery. This could seriously affect the functioning of the upper limb due to numbness and reduced circulatory flow.

Other variations on the branches of the brachial plexus were observed by Edengenet Guday *et al.* (2017) where radial nerve received communication from the inferior trunk in 7% of the cases, the ulnar nerve had communication with the lateral cord in 30% of the cases while the median nerved originated from the 2 lateral roots and the medial root in 52% of the cases . This variation from the previous studies were higher than the present study and this could be attributed to the gender and geographical location.

5.3 Difference in variation of right and left brachial plexus of the study population.

The current study noted that a total 25 (17.8%) variations in the origin and segments of brachial plexuses, the majority (14) were from the left side while only 11 (7.9%) were from the right... This observation is similar to the reports Vanaclocha *et al.* (2015) who established that variations of the supraclavicular side of the brachial plexus were more on the left side as compared to the right side. This also concurs with reports of Mohammadreza Emamhadi *et al.* (2016) noted that Iranian cadavers had suprascapular nerve which emerges from the supraclavicular zone was more on the left side than right side. This type of variation, therefore, establishes a comprehensive understanding by surgeons and neurosurgeons when conducting surgical procedures following injury or carcinomas of the brachial plexus.

It was observed that the highest frequency of variation occurred at the pre-fixed root of the brachial plexus at 20.7% with 12 variations occurring on the left upper limb and 17 occurring at the right upper limb**.** These findings differ to what Chaudhary, Singla, Kalsey, and Arora (2012) found. In their study most of the variations were post fixed in females than males while assessing the conjunction or co-incidence of a four trunked brachial plexus and a post- fixed brachial plexus.

However, the findings in the present study are contrary to the reports of Kirik, Mut, Daneyemez, and Secer (2017) in Turkey who found out that half of the brachial plexus were found to be pre-fixed, while 15% were post- fixed while studying the anatomical variations of the brachial plexus in fetal cadavers. These anatomical variations noted may lead to deviations from the expected dermatological distribution and contribute to the differences in the motor innervation of muscles of the upper limb. This can further contribute to pathological changes on the upper limbs, might produce conditions that are clinically attributable to abnormal relations between the brachial plexus and ribs and altered surgical approaches of brachial plexus.

In the current study, the right upper limbs had the highest incidence of variations in the branching patterns of brachial plexus at 43% (61) whilst the left had a variation incidence of only 23.5% (33). This is in agreement with observations of Uysal, Seker, Karabulut, Buyukmumcu, and Ziylan (2015) which found out that most of the brachial plexus variations were from right (19.5%), (12%) and left (10.5%), (11.5%) among female and male respectively while assessing the brachial plexus variations in human fetuses. This study therefore postulates that although the variations are more on the right side than left side, this might not interfere much with the surgical procedures as this laterality could possibly not interfere with the formation of cords, trunks and branches. This might also not affect the divisions of the trunks as they form anterior and posterior parts and consequently form the terminal branches. Studies of da Costa *et al.* (2019) while assessing the emergence of upper and lower trunk noted that the upper trunk variation of brachial plexus were of the right part of male adult cadavers.

It was observed that the highest frequency of variation was of musculocutaneous nerve (18.6%) with 19 (13.6%) variations occurring on the right side whilst only 7 (5%) variations occurred on the left side. These results are similar to the reports of Bhattarai and Poudel (2019) in Nepal who established a 6.25% of variation of musculocutaneous nerve which was unilaterally of the right side while assessing the unusual variation in musculocutaneous nerve.

Here musculocutaneous nerve variation of right side pierced the coracobrachialis muscles to run downwards between short head biceps brachii and medial intermuscular septa to join the median nerve on the medial side of the arm. In the current study, musculocutaneous nerve branched into 2 where the right branch pierced coracobrachialis muscle while the left remained afloat. In the musculocutaneous nerve gives a branch that communicates with median nerve which is an anomaly. In rare cases of variation, musculocutaneous nerve does not pierce coracobrachialis muscle however it can be observed joining the median nerve at the arm Nasrabadi *et al.* (2017**).** These types of variations might provide important knowledge in

understanding the peripheral nerve distribution as this remains the leading cause of pain and dysfunctional injuries around the shoulder joint. On the other hand, median and musculocutaneous nerve variations can be noted during the embryonic life and this may be due to several factors influencing mechanism of forelimb muscle development. During the development of brachial plexus, as the axonal spinal fibers grow distally into the limb buds to give a dorsal and ventral division, the later will give rise to median and ulnar nerve whereby musculocutaneous nerve later develops from the median nerve. Therefore, any developmental abnormalities might lead to significant variation (Nasrabadi *et al.*, 2017; Schoenwolf, Bleyl, Brauer, & Francis-West, 2020).

In the current study, it was observed that there was a statistically significant difference ($p=0.008$) in the variation of distribution of median nerve in relation to the sexes. This is in agreement with the observations in India where it was established that median nerve variation prevalence was 12.8% and 13.2%, 10.7% among male and females respectively. These changes are variant in terms of origin, location and course in relation to axillary artery. This study therefore postulates that this kind of variation are more prone during radial neck dissection and axilla surgical procedures. Formation of median nerve occur lateral to axillary artery in axilla, which is normal anatomy, however, median nerve can be associated with variations in the abnormal communication with nerves like musculocutaneous and ulnar nerves or even splitting and penetrating vessels.

The following anatomical variations were observed in the reports of (Budhiraja, Rastogi, & Asthana, 2017; Samarawickrama, 2017) in Brazil where in 22.4% of upper limbs 3 roots took part in formation of median nerve, 6.12% medial to axillary artery and 1.53% anterior to axillary artery. In the current study, it was observed that median nerve was formed by a single root rather which is abnormal rather than the normal two roots. It was also observed that the

brachial artery was superficial to the median nerve which is abnormal as compared to normal anatomy brachial artery courses below the median nerve.

5.4 Variation between gender and segments of the brachial plexus

The current study findings recorded more variation in male (16%) as compared to female (6.5%) in 141 cadavers where this variation was mainly at a post fixed brachial root. This current study findings were in tandem with Lalloo and Gupta (2021) who also recorded significance variation in male as compared to female. However, Other literatures (Dixit, 2019; Graham, 2019) differed with the current study findings by recording a significance ($p \leq 0.005$) variation in female as compared to male with the most varying pattern being at the anterior belly of the scalene muscle and subclavian artery at 48%. This becomes a reason why surgeons injure the brachial plexus at the neck and axilla region during a procedure.

Each part of the segment was observed in 140 cadavers and the study findings recorded no statistically significant difference between gender and variations in the segments of the brachial plexus in all the sections. Other literatures disagreed with the current study findings by recording a significance difference in the length of medial and lateral cords between male and females. Lalloo and Gupta (2021) recorded significance ($p \leq 0.05$) difference between the size of the radial, musculocutaneous and the ulnar nerve in male as compared to female. The current study findings agreed with normal standard text book anatomy that shows no variation in gender in terms of the segmentation of the brachial plexus.

5.5 Variation in branching of the brachial plexus in male compared to female.

Terminal branches of the brachial plexus includes the musculocutaneous, ulnar, axillary, median and the radial nerve. Literature has shown that this varies from one gender to another in terms of the origin of the terminal branch, size, volume, length and other many ways. This current study finding demonstrated high number of variations in female (37.8%) as compared to male (32%) and this was in total variations 67% variation observed in 140 limbs. Median

nerve demonstrated a significance ($p \leq 0.008$) in variation in both sexes. This current study finding concurred with Mohammadreza Emamhadi *et al.* (2016) who recorded (33%) variation in median nerve and 53.12% medial antebrachial cutaneous nerve in both sexes. Other researchers (Benes, Kachlik, Belbl, Kunc, *et al.*, 2021; El-Boghdadly, Brull, Sehmbi, & Abdallah, 2017) disagreed with the current study findings by demonstrating a higher number of variations in male as compared to female and the origin of the upper subscapular nerve recorded a significance variation.

5.6 General terminal branching of the brachial plexus

In the general study population, the study findings recorded no statistical significance in variation of the axillary, ulnar, musculocutaneous, medial and the radial nerve. The current study findings differed with Sumit Sinha, Khani, Mansoori, and Midha (2016) in lran who recorded a significance variation of the terminal branches of the brachial plexus. Other authors Demis and Bekele (2017) From Ethiopia also collaborated with the current study findings by recording no statistically significant variation in terminal branching of the brachial plexus in male and females. However, it recorded variations mostly of the median, musculocutaneous, and axillary nerve respectively.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

There are multiple variations in the brachial plexus which need to be continuously observed. Musculocutaneous nerve variations are more common with most of the variations occurring on the right-side affecting females. There were gender variations in the distribution of the brachial plexus in the study population more of it being on the median nerve.

6.2 Recommendations

1. Gender related variations are present in the brachial plexus among the Western Kenya population which call for specialised management.
2. Training of surgeons and anesthesiologist early enough on the variations of brachial plexus to avoid further injuries and damages.
3. Gender specific variations to be considered for further studies to ensure that diseases and abnormalities associated to a specific gender are managed early enough.

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APPENDICES

APPENDIX I: DATA COLLECTION TOOL

Code of cadaver _____

University code _____-

Laboratory location code____

Tool number----------

1. Demographic factors

Sex: ☐ Male ☐ Female

2. Side: ☐ Right ☐ Left

3. Brachial Plexus

Table A. Sections of Brachial Plexus

Nerves	**Origin**	**Normal**	**Variant**	**Length in (cm)**
Roots				
Trunks				
Divisions				
Cords				

Table B. Main Terminal Branches of Brachial Plexus

Nerve	Origin	Normal	Variant	Length in (cm)
Axillary				
Radial				
Ulnar				
Musculocutaneous				
Median				

APPENDIX II:NACOSTI LICENCE

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **450349**

Date of Issue: **08/December/2022**

RESEARCH LICENSE

This is to Certify that Dr.. PHILIP CHARLES ALINYO OMUGA 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: ANATOMICAL VARIATIONS IN MORPHOLOGY OF THE BRACHIAL PLEXUS AMONG BLACK AFRICAN POPULATION; A CADAVERIC STUDY IN WESTERN KENYA. for the period ending : 08/December/2023.

License No: **NACOSTI/P/22/21874**

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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.
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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 III: ETHICAL APPROVAL LETTER

MASENO UNIVERSITY SCIENTIFIC AND ETHICS REVIEW COMMITTEE

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

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

REF: MSU/DRPI/MUSERC/01141/22 **Date**: 3rd November, 2022

TO: Philip Charles Alinyo Omuga
MSC/ SM/ 00043/020
Department of Human Anatomy
School of Medicine, Maseno University
P. O. Box, Private Bag, Maseno, Kenya

Dear Sir,

RE: Anatomical Variations in Morphology of the Brachial Plexus 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/01141/22.The approval period is 3rd November, 2022 – 2nd November, 2023.

This approval is subject to compliance with the following requirements;

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

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

Yours sincerely

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

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE 03 NOV 2022

APPENDIX IV: ETHICAL APPROVAL LETTER

UZIMA UNIVERSITY
SCHOOL OF MEDICINE
DEPARTMENT OF ANATOMY

11th December 2022

TO: Phillip Charles Omuga
Department of Human Anatomy,
PO BOX 3275-40100,
Maseno University,

Dear Phillip

SUBJECT: **APPROVAL TO COLLECT CADAVERIC DATA**

Your request to collect data on "**Variations in the morphology of brachial plexus among black African population; A cadaveric study in Western Kenya**'. Has been approved

You are therefore requested to comply with all ethical commitments and legal processes during data collection.

Also furnish us with a copy of your dissertation on completion.

Sincerely

T. Juma
Department of Human Anatomy

APPENDIX V: ETHICAL 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: 14th November 2022

TO: Phillip Charles Omuga
Department of Human Anatomy,
PO BOX 3275-40100,
Maseno University,

Dear Phillip

SUBJECT: APPROVAL TO COLLECT CADAVERIC DATA

We have considered and noted your application received on 8th November 2022. We are glad to inform you that your request to collect data in this facility has been approved in bid of completing your MSc studies "**Variations in the morphology of brachial plexus 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