

Variation in distribution of level of bifurcation of the common carotid artery among black African population in western, Kenya

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ABSTRACT

Variations in the bifurcation of the common carotid artery (CCA) are clinically important because they influence the safety and effectiveness of carotid angiography, endarterectomy, thyroid surgery, and other head and neck interventions. Several studies have shown inconsistent incidences of CCA variations, with only reports of a single case study, used non homogenous study sample or failed to correlate the variations with the populace demographic characteristics such as sex and laterality. Although such variations have been documented in different populations, there is limited anatomical data among Black Africans in Kenya. This study evaluated the anatomical variations in the bifurcation of the CCA and assessed their association among the Black African population in Western Kenya. A descriptive cross-sectional cadaveric study was conducted in the anatomy laboratories of universities in western Kenya. Seventy-two embalmed adult cadavers of Black African descent, with 57 males (114 arteries) and 15 females (30 arteries) were examined, yielding a total of 144 carotid artery specimens. Standard dissection techniques were used to expose the common carotid arteries from their origin to their terminal bifurcation. Data were analysed using IBM SPSS version 27. Frequencies and percentages were used to summarize anatomical patterns. Majority of common carotid arteries bifurcated at the superior border of the thyroid cartilage 120 (83.3%), while 18 (12.5%) bifurcated at the body of the thyroid cartilage and 6 (4.2%) at the body of the hyoid bone, representing high bifurcation. Thus significant anatomical variations exist in the bifurcation, of the common carotid artery among the Black African population in Western Kenya. The right common carotid artery presented with a higher frequency as compared to the left. These findings provide important region-specific anatomical reference data that can enhance surgical planning, improve radiological interpretation, and reduce the risk of vascular injury during head and neck procedures.

KEYWORD: Anatomical Variation, Bifurcation, Black African Population, Common Carotid Artery, Hyoid Bone, Thyroid Cartilage, Upper Border of Thyroid Cartilage

I. INTRODUCTION

The normal documented bifurcation pattern of the common carotid artery (CCA) is by bifurcation of its terminal branches into external and internal carotid artery, but due to variations in studies done two patterns have been identified i.e. bifurcation and trifurcation (Kapre et al., 2013). Studies further show high and low bifurcation, with trifurcation involving the superior thyroid artery, which ordinarily is a branch of the external carotid artery (Mina et al., 2025). As the principle vascular conduit supplying the head and neck, there was insufficient knowledge of variations in the anatomy of bifurcation of the common carotid artery especially among black African population. Therefore, knowledge of the common carotid artery bifurcation is essential for cardiovascular and respiratory homeostasis, since it forms the site of the carotid sinus and carotid body which is a key anatomical and clinical landmark. Traditionally, the CCA bifurcation is described at the level of the superior border of the thyroid cartilage, corresponding approximately to the C3–C4 vertebral level. However, numerous studies have demonstrated considerable variability in its vertical position.

Studies have shown most common site for embolism secondary to atherosclerotic plaque is at bifurcation of common carotid artery, and higher bifurcation may lead to large ischemic area thus being fatal. Studies done in Nigeria on 30 cadavers with 60 head and neck specimens, found out that (28.5%) of lesions were located at the common carotid artery bifurcation (Erete et al. 2012). This supports that plaque, which can shed of as some emboli, is often found at the carotid bifurcation, and not along the straight course of the CCA.

Variations in the level of carotid bifurcation have direct clinical implications. High bifurcation may complicate carotid endarterectomy by reducing the operative field and increasing the risk of cranial nerve injury, particularly to the hypoglossal nerve. Conversely, low bifurcation may alter surgical planes during thyroidectomy,

tracheostomy, and neck dissection. In radiologic practice, atypical bifurcation levels may affect Doppler ultrasound interpretation and catheter-based interventions.

Despite extensive documentation of carotid bifurcation variability in European, Asian, and North American populations, African data remain comparatively scarce. Available studies suggest that Black African populations may exhibit distinctive vascular patterns, emphasizing the need for region-specific anatomical evidence. This study therefore aims to provide detailed cadaveric data on variations in the bifurcation level of the CCA among a Black African population in Western Kenya, contributing to the anatomical literature and informing clinical practice.

I.I Research Objectives

- To determine the anatomical levels of bifurcation of the common carotid artery among the Black African population in Western Kenya.
- To establish the frequency and distribution patterns of high, normal, and low bifurcation of the common carotid artery within the study population.
- To assess the anatomical relationship between the level of bifurcation of the common carotid artery and adjacent cervical vertebral and neck landmarks among the Black African population in Western Kenya.

II. METHODOLOGY

This was a descriptive cross-sectional observational study in select anatomy laboratories within western Kenya. A nonprobability consecutive sampling method was employed through which 72 cadavers, with 144 total left and right sample number, from a pool of 96 cadavers were obtained. Whereby, right and left carotid arteries obtained from the same cadaver were not considered statistically independent observation. Only cadavers with intact head and necks were included in the study therefore, a total 57 males and 15 females were finally picked, though sex based analysis was not conducted in the current study. Cadavers with deformities on the head and neck were excluded from the study. Each cadaver was placed in the supine position with the neck extended. A midline skin incision was made from the chin to the sternum, and bilateral incisions extended laterally along the clavicle. The skin, superficial fascia, and platysma were carefully reflected to expose the carotid triangle. The common carotid artery was identified and traced to its origin from the arch of the aorta or brachiocephalic trunk. A data entry form was used to capture characteristics such as sex, laterality (right or left) and observe possible variations on each side of the CCAs. The variant origins were observed and recorded as follows: I. Arterial variation is observed when an artery originate on another position other than the traditional one. The presence of arterial variation from the upper border of the thyroid cartilage were noted II. The high bifurcation was observed above the upper border of the thyroid cartilage, while low origin is noted below the hyoid bone III. Unusual trifurcation was also noted. Using toothed forceps and hook retractor was used to identify the position of the bifurcation of CCA. The artery was identified and marked, extending from the exact point of formation to point of termination; a low bifurcation was recorded if the CCA terminated after reaching the carotid fossa. Descriptive data was analysed and presented in frequencies and percentiles.

II.I Ethical Consideration

Ethical approval was obtained from the relevant institutional ethics committees. The process of acquiring and disposing of the cadavers was done as per the current Anatomy Act Chapter 249 edition of 2012. The proposal was approved by school of graduate studies ref number MSC/SM/00008/022, bioethics was approved ref number UEAB/ISERC/05/08/2025, and licensed by NACOSTI ref no NACOSTI/P/25/4180375.

III. FINDINGS & DISCUSSION

III.I Findings

The level of bifurcation was assessed in 144 common carotid artery specimens obtained from 72 embalmed adult cadavers, with each cadaver contributing both right and left arteries. The bifurcation level was determined in relation to established anatomical landmarks, including the superior border of thyroid cartilage, body of thyroid cartilage and hyoid bone.

Table 1

Distribution of the Level of Bifurcation of the Common Carotid Artery among Black African Population in Western Kenya

Level of bifurcation	Frequency	Percentage (%)
Normal bifurcation: Superior border of thyroid cartilage (C3–C4)	120	83.3
Low bifurcation variant: Body of thyroid cartilage (C4–C5)	18	12.5
High bifurcation variant: Hyoid bone (C3)	6	4.2
Total	144	100

Table 1 shows descriptive statistics such as frequency distribution and percentages, were used to evaluate variations in the bifurcation of both the right and left common carotid arteries, at the normal superior border of thyroid cartilage (C3-C4 are corresponding cervical vertebral level) and higher or lower variant at (C3) and (C4-C5) Superior border of thyroid cartilage, which is regarded as typical anatomical level, showed bifurcation in 120 cases (83.3%) of 144 specimens analyzed. On the other hand, variation in bifurcation was seen in 24 cases (16.7%) either at body of thyroid cartilage or hyoid bone.

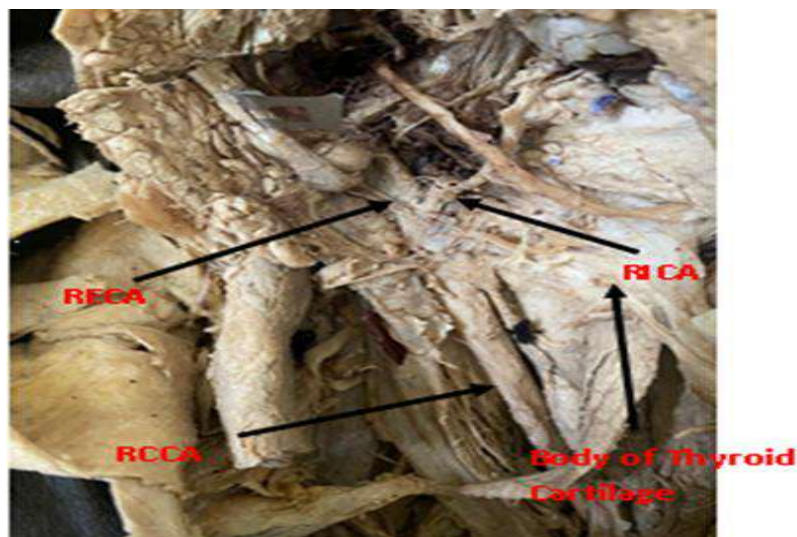


Plate 1

Dissection and illustration of the right-sided normal bifurcation of common carotid Artery at the superior body of Thyroid Cartilage at the neck, with the two terminal branches right external carotid artery supplying the head and neck with its branches, and right internal carotid artery supplying the brain with its branches

KEY: RECA: Right External Carotid Artery, RICA: Right Internal Carotid Artery, RCCA: Right Common Carotid Artery.

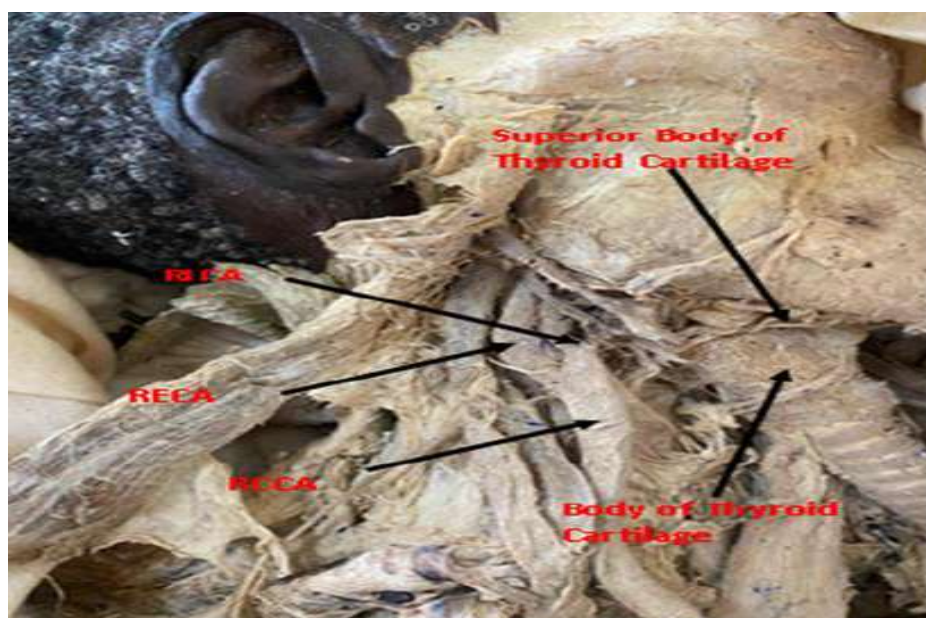


Plate 2

Dissection and illustration of the right-sided variation bifurcation of common carotid Artery below upper border of thyroid cartilage at the neck, with the two terminal branches right external carotid artery supplying the head and neck with its branches, and right internal carotid artery supplying the brain with its branches

KEY: RECA: Right External Carotid Artery, RICA: Right Internal Carotid Artery, RCCA: Right Common Carotid Artery.



Plate 3

Dissection and illustration of the right-sided variation bifurcation of common carotid Artery at the superior body of Thyroid Cartilage at the neck, with three terminal branches right external carotid artery supplying the head and neck with its branches and a subsequent addition, and right internal carotid artery supplying the brain with its branches

KEY: RECA: Right External Carotid Artery, RICA: Right Internal Carotid Artery and RCCA: Right Common Carotid Artery.



Plate 4 *Dissection and illustration of the left-sided variation bifurcation of common carotid Artery above the superior body of Thyroid Cartilage at the neck, with no terminal branches of either right external carotid artery supplying the head and neck with its branches, and right internal carotid artery supplying the brain with its branches.*

KEY: LCCA: left Common Carotid Artery

IV. DISCUSSION

The superior border of thyroid cartilage(C3-C4) is regarded as typical anatomical level of bifurcation of CCA, it showed bifurcation in 120 cases (83.3%) of the 144 specimens analyzed. On the other hand, aberrant bifurcation was seen in either at body of thyroid cartilage 18 cases (12.5%), or hyoid bone 6 cases (4.2%) (Table 4.2). These results show that whereas most people follow the normal anatomical pattern, a significant minority (about one in six people) exhibit diversity in degree of bifurcation. This current study establishes two major bifurcations, i.e. higher level at C3 at the hyoid bone and lower level at C4-C5 body of thyroid cartilage, with normal level bifurcation at C3-C4. This concurs with Anangwe et al., (2008) study conducted at the University of Nairobi in anatomy department on 80 carotid vessels to determine level of bifurcation of common carotid artery: It was observed that 63.8% bifurcations

were normal at C3-C4, 28.7% were high at C3 while 7.5% were low at C4-5. It was further observed that there was no statistically significant variation of level of bifurcation from normal C3-C4 level.

In conjunction with other literatures, similar variations have been reported previously, for example in studies done by (Gwunireama et al., 2023) in departments of Anatomy of the University of Port Harcourt and Bayelsa State Medical University, both located in South-Southern Nigeria. Results showed that the most frequent findings were in 21 cases (84%), of carotid bifurcation (CB) at the level of upper border of thyroid cartilage (normal C3-C4), and in 4 cases (16%) it was above the upper border of thyroid cartilage (high C3). This is in correlation with the current study showing a massive correlation of normal level of bifurcation at the level of upper border of thyroid cartilage. This variation can be due to similarity in black African race where studies show that similar race or shared ancestry influences anatomical variations primarily through population-specific genetic patterns, environmental adaptations and historical gene flow (Xu et al., 2023). This is further emphasized in (Zuin et al., 2023) where CB was seen at the level of intervertebral disc of C3 - C4, also known as big cornu of the hyoid bone or the upper border of the thyroid cartilage.

Cases of higher C3 and lower C4-C5 carotid bifurcations, above and below upper border of thyroid cartilage respectively, have been reported. A case report by Szymanska et al. (2020) showed a rare case of higher right carotid artery trifurcation assessed by computer tomography angiography (CTA). The trifurcation was into internal carotid artery and two branches of external carotid artery, this analogous variation was also not noted in the current study, this may be attributed to unknown congenital vascular anomalies. In another study by Borges et al. (2021) identified intraoperatively during a neck dissection for a cancerous malignancy, trifurcation with additional arterial trunk which concurs with the current study of left higher bifurcation with an addition arterial trunk. However, Shreevastava et al. (2022) study of morphometric characteristic of the common carotid artery bifurcation on 40 cadaveric fetuses were studied, with the CCA bifurcation at C3, C4, and C5 levels in 55%, 35%, and 10%, respectively, on the right side; while 60% at C3 and 40% at C4 vertebral level on the left side. Showing right carotid artery higher level of bifurcation with addition arterial trunk differing to the current study.

A study by Ib and Elghazaly (2022) in eastern India showed the commonest level of carotid bifurcation was at the level of upper border of TC. They also showed a few incidences of lower bifurcation at C4-C5. Lower bifurcation may refer to the thoracic bifurcation of the CCA which occurs in very rare cases such as vascular anomalies. However other studies in India also showed, bifurcation was found at the level of the superior border of TC at C3-C4 (Manisha et al., 2019). This variation can be due to genetic factors, developmental variations, or even environmental influences (Manokaran et al., 2025). In contrast with the current study, an angiographic report by Gharahi et al. (2016), reported that the left carotid bifurcation was higher than the right in 50% of the cases and the right bifurcation was higher than the left in 22% of the cases. A study by Liu et al. (2024), reported similar findings, noting that out of 181 specimens, 130 (71.9%) had intra-plaque hemorrhage at higher bifurcation levels which complicate carotid surgery in carotid plaque and increase the risk of injury to the hypoglossal nerve, which crosses near carotid bifurcation.

Besides simple bifurcation as reported in this study, authors have reported other forms of branching patterns such as: trifurcation, quadrifurcation and even penta-furcation of carotid termination, often involving branches of external carotid artery, ascending pharyngeal, occipital, posterior auricular or lingual branches (Manokaran et al., 2025). These complex variations are clinically important in surgical procedures such as: carotid endarterectomy, tumor embolization, thyroidectomy and glossectomy. Consequently, ligation of a variant branches at the point of bifurcation is seen to compromise regional perfusion and increase hemorrhage risk (Biskupski et al., 2024). In the present study, cadavers were of black African descent, so the level of bifurcation of CCA was expected to be at C3-C4, similar to that of other African descent as reported by other authors. However, variations occurred at level of C4-C5, which is lower than usual black Africans' Pattern. Thus, filling the knowledge gap of lower bifurcations in black African descent.

V. CONCLUSION & RECOMMENDATIONS

V.I Conclusion

The superior border of thyroid cartilage was identified as most common level of bifurcation of common carotid artery, representing typical anatomical pattern. Nevertheless, a proportion of arteries bifurcated at body of thyroid cartilage and at body of hyoid bone, indicating presence of both intermediate and high bifurcation patterns. These findings demonstrate that level of carotid bifurcation is variable in this population and should not be assumed to occur uniformly at the classical anatomical landmark.

V.II Recommendation

This study therefore recommends that; A high bifurcation at the hyoid bone level (C3) leads to increased risk of hypoglossal nerve injury, during carotid endarterectomy. While lower bifurcation at the thyroid cartilage level (C4) which denoted the cavernous segmented, increases the risk of procedural aneurysm during endovascular coiling, this is

noted to be the most common procedural complication, accounting for 2/3 of endovascular complications (Turfe et al., 2015).

Preoperative imaging techniques such as Doppler ultrasonography, CT angiography, and MR angiography should be routinely considered before cervical surgical procedures to accurately identify variations in carotid bifurcation patterns. Anatomical variations of the common carotid artery should be emphasized in undergraduate and postgraduate medical anatomy training to improve the clinical competence of healthcare professionals dealing with head and neck anatomy. Further multicentre cadaveric and radiological studies involving larger sample sizes and diverse African populations should be conducted to establish the prevalence, patterns, and clinical significance of carotid artery bifurcation variations within the African population. Additional studies should investigate the association between carotid bifurcation variations and demographic factors such as sex, age, ethnicity, and laterality to enhance understanding of population-specific vascular anatomy and its clinical implications.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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