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Original Research Article

Anatomical variations of the brachiocephalic artery and their clinical relevances: A cadaveric study of Ugandan population

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A B S T R A C T

Background: The study examined variations in morphology and morphometry of the brachiocephalic artery and their clinical implications in dissected cadavers.
Materials and Methods: Fifty-eight (58) adult cadavers, 57 males and 1 female were dissected to expose the brachiocephalic artery, and the morphological and morphometric variations were recorded.
Results: Fifty-one (51) cadavers (88%) had the BCA arising directly from the aortic arch while 7 cadavers (12%) had it originating from the common trunk with the left common carotid artery. The BCA arose on the left anterolateral to the trachea in 57 cadavers (98.3%) and one cadaver (1.7%) had it arising in the midline anterior to the trachea crossed the trachea from left to right terminating posterior to the right sternoclavicular joint where it bifurcated into the right subclavian and right common carotid artery in all cadavers. The mean lengths of the torsos and Brachiocephalic arteries were 45.78±2.93cm and 4.14±0.58cm respectively and the two parameters had statistically significant positive correlation ($r=0.33$, $p<0.05$).
Conclusion: A majority of the Ugandan cadaveric population have brachiocephalic arteries with the normal origin, course, and branching patterns. The occurrence of origin variants of BCA from the common trunk and anterior midline to the trachea may be associated with tracheal compression and aortic dilation; hence should be considered as a potential risk factor for thoracic aortic aneurysm and during tracheostomy respectively.

1. Introduction

The Brachiocephalic artery (BCA) also called the innominate artery is a major artery that supplies blood to the right side of the head, neck, and upper extremities The artery expresses several anatomical variations in different individuals, most of which are associated with variations in an aortic arch branching pattern.[1] Several vascular variations have been reported in some arteries and veins of the body.[2] The most likely source of these anatomical variations occur during embryonic life and in this case, the Brachiocephalic artery lengthens and grows in diameter disproportionally.[3] According to recent studies, excessive elongation of the aortic arch causes aberrantly high riding Brachiocephalic artery.[4] The origin, branching pattern and the course of the Brachiocephalic artery in relation to the trachea and thyroid gland have profound surgical importance.[5] Life-threatening complications can

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be encountered if abnormal blood vessels get injured during surgical procedure or in the post-operative period. The aberrant Brachiocephalic artery anatomical variations have been associated with complications preceding surgical procedures to access the trachea.[6] The most clinically significant complication associated with Brachiocephalic artery variations includes fatal perioperative and post-operative hemorrhage that entails escape of blood from blood vessels as a result of injury through the vessel.[7] Hemorrhage is a feared complication of Tracheostomy and can present during Tracheostomy[8] or anytime during the following three weeks of Tracheostomy due to formation of tracheoinominate fistula as a result of friction between the Tracheostomy tube and the surface of Brachiocephalic artery.[9] The Brachiocephalic artery is anteriorly related to the trachea. Accessing the trachea during Tracheostomy involves careful deflection of, among others, the Brachiocephalic artery, a large artery in which blood flows at high pressure lying anterior to the trachea and crossing from left to right of the trachea.[10] The Brachiocephalic artery is therefore the most commonly severed vessel that makes Tracheostomy difficult and prone to life-threatening bleeding complications.[11] Existence of anatomical variations of the Brachiocephalic artery increases the risk of fatal bleeding resulting from accidental injury of the artery or its variant branches. Therefore, for successful Tracheostomy, decision and selection of the procedure, timing, and safe accessibility of the trachea are very important for surgeons and clinicians.[12] Also, cannulation of the Brachiocephalic artery should be performed with caution in cases of anatomical variations. In a case report by,[13] a patient with an aberrant right subclavian artery experienced complications during cannulation due to the unfamiliar anatomy. To avoid such complications, it is recommended to perform a thorough preoperative evaluation using imaging modalities such as computed tomography (CT) or magnetic resonance imaging (MRI) to identify any variations in the brachiocephalic artery. Because of the limited information and knowledge of the clinician about the anatomical variations of BCA in Africa based population, the current study establishes database of Brachiocephalic artery variations using Ugandan population as a case study to avoid relying on findings from other continents which might be misleading due to the presence of possible anatomical differences related to race and other demographic factors, as observed in several studies.[14,15]

There is a wide range of case reports on anatomical variations in the origin, course, and branching patterns of the BCA. The most common reported variation in the origin of the BCA is the presence of a common trunk that give rise to the BCA and left common carotid artery.[16] In some cases, the BCA may be absent, and the right subclavian artery arise directly from the aortic arch[17] reported existence of two (left and right) Brachiocephalic arteries as well as a rare anomaly in the origin of the Brachiocephalic artery from the pulmonary trunk. In terms of course, the BCA can have variations in its length and position relative to other structures. For example, the BCA can be longer or shorter than the typical length of 2-3 cm, and it can be located more anteriorly or posteriorly than usual. The BCA can also have variations in its relationship to the trachea, esophagus, and other structures in the thorax. There are also variations in the branching patterns of the BCA. The most common variation is the division of the BCA into the right subclavian artery and the right common carotid artery at the level of the sternoclavicular joint. However, the BCA can also divide at other levels, such as the thyroid cartilage or the first rib. In some cases, the BCA can have additional branches, such as the thyrocervical trunk or the vertebral artery. According to,[18] the Brachiocephalic artery may trifurcates into right common carotid artery, right subclavian artery and left common carotid artery. The thryoidea ima artery has also been observed to come off from the anterior surface of the artery in some individuals.[19]

2. Materials and Methods

A total of 58, (57 male and 1 female) formalin embalmed cadavers were used in the study. Each cadaver's torso length was measured as the distance between the spine of the seventh cervical vertebrae and the imaginary line joining the two iliac crests as depicted in Figure 1. The dissection of the thoracic region for the exposure BCA was done as outlined in Cunningham dissection handbook[20] using the primary incision line as shown in Figure 2. Following the exposure of the BCA, the length of the artery was measured from its origin until its bifurcation into RCCA and RSA as shown in Figure 3. The various anatomical variants of BCA were coded into types A, B and C.[21,22] These data were then compiled into tables to represent the quantity of variants. The proportions of variants were computed in Microsoft Excel and presented by using pie charts. Then, descriptive statistics was performed to determine the mean, highest and lowest values, standard deviation, standard error of the torso length and BCA length were determined using Microsoft Excel. The Pearson's regression analysis was performed to determine the correlations between the detected morphometric parameters i.e., torso length and Brachiocephalic artery length using Statistical Package for Social Sciences (SPSS). The Pearson's correlation coefficient (r) was utilized to evaluate the statistical relationship between the measured cadaver's torso length and BCA length while the p-value was used to determine statistical significance of the relationship.

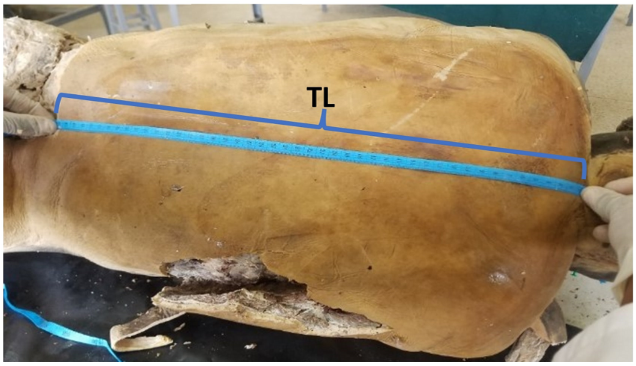

Figure 1: Measurement of cadaveric torso length (TL)

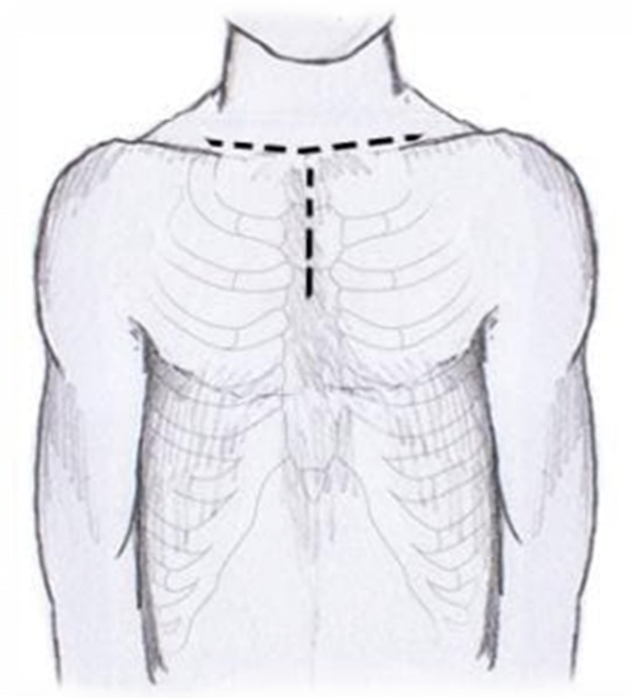

Figure 2: Primary incisions for thoracic dissection techniques represented by the dotted line

Figure 3: Proportion of variation in the origin of BCA in 58 cadavers in Uganda

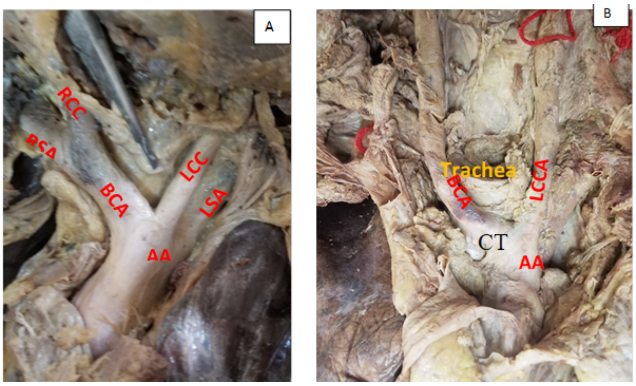

Figure 4: The origin of BCA. Photograph A is the normal origin of BCA from aortic arch (AA) as seen in 51 cadavers and photograph B is the variant of BCA from common trunk (CT) as seen in 7 cadavers; showing the right common carotid artery (RCC), right subclavian artery (RSA), arch of aorta (AA), left subclavian artery (LSA), and left common carotid artery (LCCA)

3. Results

3.1. Variation in the origin and Branching pattern of BCA

The study identified two categories of origin of the BCA in the cadaveric population (Type A and Type B). Type A is a normal occurrence with a direct origin of BCA from the arch of aorta and Type B being the common variant from the short common trunk from which the BCA and the left common carotid artery arise as shown in Figure 4 A and B. Of the 58 dissected cadaveric sample, type A was found in 51 cadavers (88%) while 7 cadavers (12%) had type B (Figure 5).

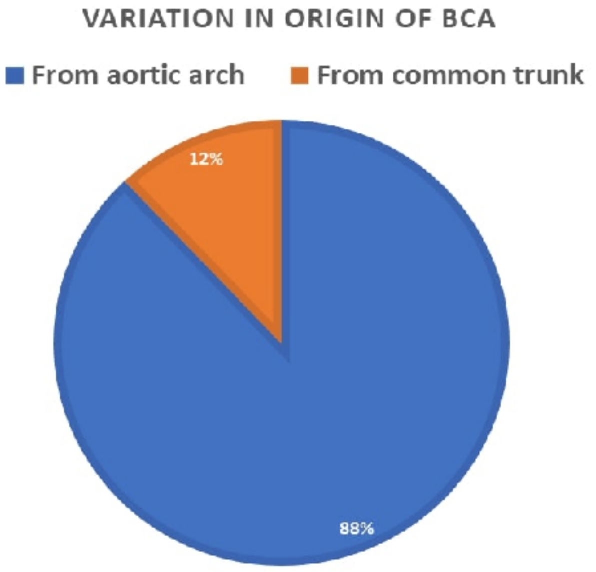

Figure 5: Proportion of variation in the origin of BCA in 58 cadavers in the Ugandan population

In relation to the trachea, two patterns of origin of Brachiocephalic artery were observed, type A being left anterolateral to the trachea and the second is anterior (in the midline) to the trachea. The BCA arose on the left anterolateral to the trachea in 57 cadavers (98.3%) and one cadaver (1.7%) had the artery arising in the midline anterior to the trachea. In all 58 dissected cadavers, the BCA ascended from its origin crossing to the right of the trachea to end posterior to the right sternoclavicular joint where it divides into its terminal branches.

The two-terminal branched Brachiocephalic artery was identified in all dissected sample cadavers. At the level of posterior surface of the right sternoclavicular joint, the BCA terminated by giving rise to the right subclavian artery (RSA) laterally and the right common carotid artery (RCCA) medial to it. Along its course, the BCA contains no any collateral branches.

3.2. *Morphometric dimensions of cadavers and Brachiocephalic artery*

Descriptive statistics of torso length and Brachiocephalic artery length. The mean torso length of cadavers was found to be 45.78±2.93cm the minimum of which was 40cm and maximum length was 51cm. The mean length of Brachiocephalic artery was found to be 4.14±0.58cm of which the minimum length was 3cm and the maximum length was 5cm. This information is summarized in Table 1.

In order to establish the relationship between cadaver's torso length and the length of BCA, a regression analysis was performed. The linear regression analysis revealed a significant positive correlation between torso length and BCA length ($r = 0.33$, $p < 0.05$) as shown in Table 2.

4. Discussion

The Brachiocephalic artery is the first branch of the aortic arch (from right to left). BCA exhibits some anatomical variations in origin, course and branching most of which are associated with variation in the pattern of aortic arch branching. The current study reveals that the normal origin of the Brachiocephalic artery from the aortic arch exists in 82% of Ugandan population. These finding corresponds to a study on branching pattern of aortic arch that reported that normal Brachiocephalic artery origin (from aortic arch) existing in 77.3% of Indian population.[16] The prevalent variant of Brachiocephalic artery in terms of where the artery takes its origin was found in 12% of dissected cadavers and was associated with aortic arch branching variant called the "bovine aortic arch". In this case, the aortic arch contains only two branches in which the Brachiocephalic artery (BCA) originate from a common trunk with the left common carotid artery (LCCA). The findings of this study are in accordance with a study of[23] using computed tomography (CT) scan which reported that bovine aortic arch exists in about 11-27% of the adult population in the United Kingdom. Also, a study by using computed tomography (CT) scan revealed a 15-35% prevalence of bovine arch in the United States population.[24] However; the prevalence of this variant in the current study is relatively less than (14.66%) that was reported in Indian population.[16] The current study disagrees with that of[18] which generalized that blacks have a higher prevalence of bovine aortic arch variant than whites. The low prevalence of variation reported in this study can be attributed by environmental factor like altitude and temperature variability. Uganda is located 1100 metres high above the sea level and experience annual temperature of around 22.8°C, with monthly temperatures ranging between 21.7°C in July and 23.9°C in February. indicated that exposure to extreme environmental temperature This temperature is greater than 16°C and less than 31.9°C, that were reported to induce abnormal organogenesis.[25] Low occurrence of anatomical variations in the Ugandan population in the current study may be due to low particulate matter exposure which has been reported to selectively impairs organogenesis (26). Maternal exposure to air pollution influences endothelial function which would alter maternal–placental oxygen and nutrient exchanges and thus affecting vasculogenesis.[26] According to" Uganda Air Quality Index (AQI) and Air Pollution Information, (2019)", the air in Uganda registers low yearly average quantities of particulate matter ($PM_{2.5}$=29.1 μg/m^3) compared to other countries. This average concentration of particulate matters is lower than 35.4 μg/m^3 which has been reported to be associated with cardiovascular defects.[27]

Table 1: Descriptive analysis of the morphometric dimensions of the cadavers and Brachiocephalic artery in the Ugandan population. n = 58

Morphometric parameters	N	Minimum	Maximum	Mean	Std. Deviation
Torso length(cm)	58	40.00	51.00	45.78	2.92
BCA length(cm)	58	3.00	5.00	4.14	0.58
Valid N (listwise)	58				

Table 2: Regression analysis for Torso length (cm) and BCA length(cm)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	1.13	1.14		0.99	0.33	-1.16	3.43
Torso length	0.06	0.02	0.33	2.63	0.01	0.02	0.12

The current study revealed that, the normal trajectory course of BCA exists in 98.3% of the population in which the artery runs from its normal origin (arch of aorta) left anterolateral to the trachea then ascend upward crossing the trachea from left to right terminating posterior to the right sternoclavicular joint where it bifurcates into its terminal branches. However, in one cadaver 1.7%, the BCA originated anterior to the trachea in the midline and then crossed the trachea to its right side to the point of normal bifurcation and it is related to demographic factors like sex and gender since the variant was observed in a female cadaver and all dissected cadavers were adults. This finding is supported by a study which reported that the origin of Brachiocephalic artery to the left of the trachea is a common occurrence and with age the origin tends to shift rightward.[28] It was stated by[29] that the dynamics of aortic growth throughout life are greater in women than in men thus the occurrence of this variation in only one cadaver may be due to the fact that only one female cadaver was involved in the study. In all dissected cadavers, the BCA began below the second tracheal ring thus there was no finding of high riding Brachiocephalic artery. Some studies have reported cases of Brachiocephalic artery located above the second tracheal ring and sometimes abnormally high riding the fourth and fifth rings of the trachea[30] suggested that the best incision site for Tracheostomy is between 3^{rd} and 4^{th} rings of the trachea. Therefore, high localization of Brachiocephalic artery along the course of the trachea increases the risk of possible injury to the vessel in Tracheostomy.[10] The classical two branching pattern of the BCA was found in all 58 dissected cadavers (100%) with right common carotid artery and right subclavian artery terminating at the posterior surface of the right sternoclavicular joint and there was no any collateral branch along the projection of BCA and thus there was no observed branching variant. Contrary to these findings, some cases have reported existence of thyroidea ima artery originating as a collateral branch from the anterior surface of Brachiocephalic artery.[19]

This study also reports that, the mean torso length of cadavers was 45.78±2.93cm. The minimum length was 40cm and maximum length was 51cm. The observed mean torso length in the current study is relatively higher than the previously reported value of 45.16 ± 2.88cm possibly because morphometry of cadaver increases slightly from the measurement taken two hours post-mortem.[31] The mean distance from the point of origin of BCA to the point of its bifurcation was 4.14±0.58cm of which the minimum length was 3cm and the maximum length was 5cm. This finding is in accordance to the recent study conducted in Greece that reported the length of BCA to range from 1.7-6.0cm.[32] This study found a statistically significant positive correlation between cadaveric torso length and BCA length ($r=0.33$, $p<0.05$) which implies that individuals with longer torsos may have longer BCA. Although the use of torso length to estimate other anthropometric dimensions like height was reported to be unreliable due to weak relationship, the current study reveals a strong reliability of torso length in estimating the length of the Brachiocephalic artery. This information can be useful in clinical settings, such as pre-operative planning for cardiac surgeries or angiographic procedures such as catheterization of Brachiocephalic artery during cerebral angiography as well as cannulation of brachiocephalic artery as a way to attain circulatory arrest[33] reported that BCA cannulation is preferred over axillary and brachial artery cannulation to achieve cardiopulmonary bypass and to provide antegrade cerebral perfusion for treatment of patients with lesions of the ascending aorta because it does not require additional incision i.e., only one cannula is used and provides more centralized blood flow.

Anatomical variations of the BCA are of paramount clinical significance since they constitute major risk-factors of accidental haemorrhage when performing Tracheotomy, surgeries of the thyroid and parathyroid glands, in the tumor excision of the neck and invasive radiology.[8] Brachiocephalic artery injury is the primary cause of fatal haemorrhage in tracheostomized patients due to establishment of a tracheo-vascular fistula and this arterial bleeding accounts for 59.3% of the cases.[34] Although, the prevalence of anatomical variations of the BCA reported in this study is low, their presence provides an insight on occurrence of BCA variants in a sample representative of African population (Ugandan population) of which the surgeons should pay attention when performing surgeries of the thoracic cavity and anterior of the neck. Despite the low prevalence, the existence of BCA from a common trunk (bovine aortic arch) variant may clinically be associated with aortic dilation and it should be considered as a potential risk factor for thoracic aortic aneurysm.[35] Bovine aortic arch can also associate with tracheal compression by the aberrant Brachiocephalic artery.[36]

5. Conclusion

The anatomical analysis of the Brachiocephalic artery reveals that the majority of the Ugandan population depicts the usual normal categories of the origin, course, and branching pattern. However, low prevalent variants were found to exist in which the Brachiocephalic artery originated from the common trunk with the left common carotid artery and that of the BCA arising from the aortic arch in the midline anterior to the trachea. Nevertheless, surgeons should pay attention when performing surgeries of the thoracic cavity and anterior of the neck like Tracheostomy. Occurrence of the origin variant of the BCA from the common trunk may be associated with tracheal compression and aortic dilation and it should be considered as a potential risk factor for thoracic aortic aneurysm. Also, the observed origin of the BCA in the midline anterior to the trachea can increase the chances of accidental to the artery during Tracheostomy and should be taken into consideration during pre-operative planning for Tracheostomy. Also, the occurrence of origin variants of the BCA from the common trunk and anterior midline to the trachea may be associated with tracheal compression and aortic dilation; hence should be considered as a potential risk factor for thoracic the aortic aneurysm. Furthermore, the correlation between torso length and Brachiocephalic artery length was statistically significant, and thus the present study suggests a simple and non-invasive method of estimating the length of the Brachiocephalic artery using the torso length. BCA length is an important parameter for consideration during cannulation and catheterization of the Brachiocephalic artery.

6. Authors' Contributions

Andrew Emmanuel Tito, Kebe Edet Obeten, Victor Archibong, and Ibe Michael Usman, participated in the conceptualization and designing of the study; Ibe Michael Usman, Ekom Monday Etukudo, Mario E Fernandez, and Joseph Atupele Mwabaleke participated in the statistical analysis and interpretation; Andrew Emmanuel Tito, Kebe Edet Obeten and Victor Archibong, drafted the manuscript; Andrew Emmanuel Tito, Kebe Edet Obeten, Victor Archibong, Ibe Michael Usman, Ekom Monday Etukudo, Mario E Fernandez, and Joseph Atupele Mwabaleke carried out the critical review of the manuscript prior to submission. All authors read and approved the final manuscript.

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8. Conflict of Interest

The authors declare no conflicts of Interest.

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