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Anatomical Variations of Common Carotid Artery Bifurcation: A Cadaveric Study in Hyderabad-Karnataka Region and North Konkon of Maharashtra Populations

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ABSTRACT

Right side and left side of carotid artery bifurcation (CAB) is an anatomically and surgically important landmark in variations of pathological and physiological processes. The CAB is in relations with hyoid bone and cervical vertebrae posteriorly and is highly variable across the literature. However, cadaveric dissection were employed in the majority of studies on right side and left side of CAB in terms of high and low variations according to ethnicity and genetically. The level of CAB was assessed in a cross sectional studies utilize, cadaveric dissection for 1st MBBS in department of Anatomy, which involved in 24 cadavers of both sides of CAB (18 men and 6 women., ages 45-70 years) were included during the study period. Twenty-four formalin fixed (10%) embalmed cadavers belongs to Hyderabad-Karnataka region and North of Konkan division of Maharashtra were dissected in anatomical position of CAB during the period of two years. The variations in both sides of CAB were tabulated and statistically analyzed. The CAB showed variation in right side and left side of carotid bifurcation. The normal bifurcation of the right side carotid artery found in 41.6% (C3/4 vertebrae) of the specimens, while normal bifurcation of the left side carotid artery in 50% (C3/4 vertebrae) of the dissected specimens respectively. The high CAB found in both sides at the level of angle of mandible (C2 and C3), while the lowest CAB was at the level of thyroid cartilage (C4-C5) in right side of CAB. The right CAB in majority of the cases lower than left CAB. The extent of this higher and lower variation has not been shown before in previous studies. The present study of anatomical variations of CAB will help to alterations in surgical interventions and radiological examination, Transcatheter embolization procedure while dealing with thyroidectomy and carotid aneurysm.

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Key Words
CAB, thyroid cartilage, hyoid bone, vertebrae

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INTRODUCTION

The apical border of the thyroid cartilage or the C2-C3 intervertebral disc are the typical anatomical sites where the internal as well as external carotid arteries originate at the point of division of the common carotid artery (CCA). The streamlined profile of the CAB would confer benefits to inexperienced head and neck surgeons through the provision of protection. CCA is derived from the brachiocephalic artery on its right side. Ascended from the superior media stinum of the left aortic arch is the CCA. The CCA is enclosed within the carotid sheath. It is anatomically linked to the vagus nerve and internal jugular vein through the anterior margin of the sternocleidomastoid muscle. The primary provisions of the head of the neck were supplied by the branches of the common carotid arteries. Multiple anatomic textbooks[1,2]. Define the point at which the CCA divides as the superior border of the thyroid cartilage. Limited precise information regarding the incidence of variations in the carotid artery bifurcation (CAB) has been provided in human anatomy textbooks. In the current investigation, we documented a unilateral high-level bifurcation of the right CCA. This finding enhances our comprehension of the various levels of bifurcation. An instance of the clinical application of knowledge regarding the anatomical landmarks at the point of CCA is evident in the following situations: head and neck procedures, radiological assessment to preempt vascular accidents, carotid artery catheterisation and intra-arterial delivery of chemotherapeutic agents[3]. Understanding the anatomical characteristics of the bifurcation and variations of the carotid artery is crucial in order to conduct surgical procedures that result in the least amount of perioperative and postoperative complications. An investigation carried out in India revealed that the bifurcation level of the CCA was asymmetrical in 95 cadavers, with the left side being higher in 9% of the instances[4]. Determining the height of the CCA bifurcation in relation to the cervical vertebrae was the objective of the present investigation.

Aims and Objectives: The aims were to study bifurcation of CCA variations in relations with upper border of thyroid cartilage and hyoid bone.

- To study and note down variations in the course and relations of CCA.
- To study and note down variations of facial artery.

MATERIALS AND METHODS

A cross-sectional study design was employed to evaluate the carotid artery bifurcation (CAB) in 24 (48 sides) formalin-preserved head and neck specimens using the detailed dissection technique. The research was conducted at the department of anatomy, BRIMS, Bidar. The Department of Anatomy, BRIMS Bidar, Karnataka, India, dissected twenty-four formalin-fixed (10%) unclaimed embalmed cadavers in order to perform bilateral neck dissection of the carotid triangle. The bifurcation of the CCA was meticulously traced and observed for any deviations in the facial artery's branching pattern over a two-year duration at the Bidar Institute of Medical Sciences, Bidar, as well as Department of Anatomy. The research encompassed a period of two years, beginning in March 2021 and concluding in August 2023.

Age and Sample Size: 24 cadavers, 6 women and 18 men, arranged in carotid triangles with 48 sides.

Age: 45-70 years.

Study Design: Observational based descriptive Study.

Study Method: A 15mm scalpel was employed to perform sharp dissection, which involved the removal of the platysma muscle as well as the detachment of the sternocleidomastoid muscle from its origin. In order to expose the right and left sides of the carotid triangle and to delineate the CCA bifurcation in the neck region, the carotid sheath of the deep cervical fascia was severed. Appropriately, these unclaimed or donated cadavers were delivered to the Department of Anatomy at the Bidar Institute of Medical Sciences (BRIMS), Bidder, India. At first, the remains are embalmed and subsequently utilised by 1st MBBS students. From 24 cadaveric images, the luminal diameter and length of CCA were determined and analysed. The data underwent statistical analysis.

Dissection Procedure of CCA: The dissections were conducted in adherence to the guidelines provided in volume 3 of Cunningham's Manual of Practical Anatomy. Marking the following points within the CCA on its right side.

- At sterno clavicular joint.
- In proximity to the posterior border of the thyroid cartilage, at its uppermost boundary, sternocelidomastoid muscle.

Connects these two points along the sternocleidomatoid muscle's anterior border.

Dissection Procedure of CCA: Marking the following points on the left side of CCA.

- At the centre of manubrium sterni.

- At sterno clavicular joint.
- At the level of upper border of thyroid cartilage behind the anterior border of sternocleidomatoid muscle.

Connects these three sites along the sternocleidomatoid muscle's anterior border. The Institutional Ethics Committee (IEC) authorised the current investigation under reference number 229/BRIMS/IEC/2023., dated 10/10/2023. The examined sample can therefore be considered representative of the population residing in the Hyderabad-Karnataka region of the North Konkan division of Maharashtra state, Karnataka, India.

Inclusion Criteria:

- Subjects were cadavers of males and females.
- Adults male and female cadavers (37-70 years).

Exclusion criteria:

- Subjects of cadavers in case of decomposition and pathogenic state.
- Embalmed cadavers via carotid artery.
- Dry cadavers.

Each specimen was photographed and the corresponding data was entered into a table on the left side. The results were presented using figures and tables, as well as the analysis was conducted manually.

RESULTS AND DISCUSSIONS

Bifurcation of Right Carotid Artery: An elevation in the bifurcation level of the right CCA at the superior border of the thyroid cartilage (C3-C4 vertebrae) was identified in 41.6% (10/24) of the cases. At the laryngeal prominence (C4 vertebrae), the conventional bifurcation of the right CCAwas observed in 29.1% (7/24) of the cases. The bifurcation of the right CCA was found to be minimal at the thyroid cartilage level (C4-C5) in four instances (16.6%). Conversely, the bifurcation at the C3-C4 level was the most pronounced (41.6%). The right side of the neck of CCAB demonstrated a comparable dissection at the C3-C4 level in 41.6% of cases, whereas a moderate dissection was observed at the C4-C5 vertebrae in 12.5% of cases. The maximal bifurcation of the right CCA (41.6%) was observed at the C3-C4 vertebral level, as indicated in (Table 1). As shown in (Table 1), the C4-C5 vertebral level (12.5%) contained the lowest bifurcation of the right CCA. The degree of bifurcation between the right as well as left common carotid arteries was observed to differ significantly from one another in 90% of the instances. A statistically insignificant difference in the degree of bifurcation between the right as well as left common carotid arteries was not observed in 10% of the cases when compares were made between adjacent cases.

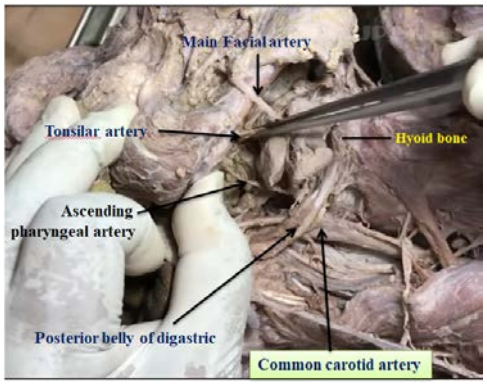

Fig. 1: Dissected Specimen on Right Side Showing High Bifurcation of Carotid Artery at the Level of Hyoid Bone and Upper Border of Thyroid Cartilage According to C3 Vertebrae

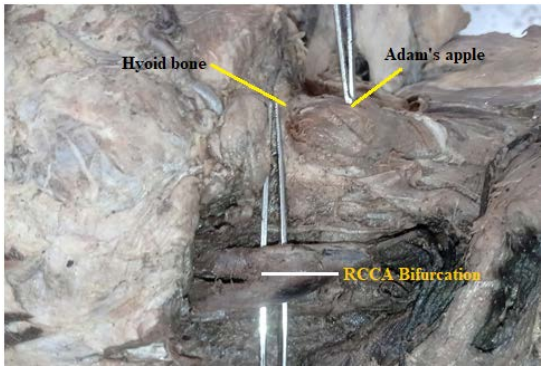

Fig. 2: Dissected Specimen on Right Side Carotid Artery Bifurcation Showing at the Level of Hyoid Bone According to C3 Vertebrae

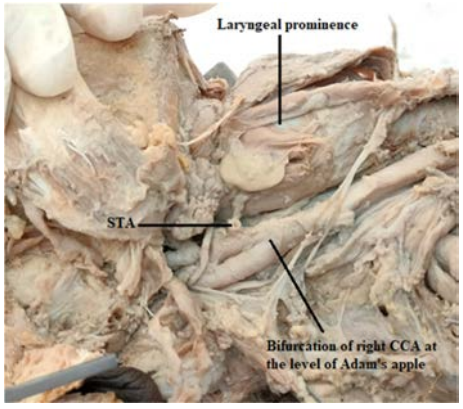

Fig. 3: Dissected Specimen on Right Side Showing Standard Bifurcation of Carotid Artery at the Level of Adam's Apple According to C4 Vertebrae

Bifurcation of Left Carotid Artery: The traditional division of the left carotid artery occurs in 50% (12/24) of the instances, specifically at the juncture of the

superior horn of thyroid cartilage as well as the thyroid membrane (C3-C4 vertebrae). At this juncture, the CCA ascends to its greatest degree. In 8.3% of the cases, the dissection at the level of Adam's apple (C4 vertebrae) on the left side of the CCA bifurcation was observed to be low. The angle of the mandible (C2 vertebrae) was identified as the location where the origin of the left CCA bifurcation was elevated in 16.6% (4/24) of the cases. A quarter of the cases (6/24) exhibited the origin of the left CC. Bifurcation at the greater cornu of the hyoid bone, which corresponds to vertebrae C2-C3. The data presented in (Table 2) indicates that 50% of the bifurcation of the left CCA took place at the C3 vertebral level. The bifurcation of the left CCA at the C4 vertebral level constituted the lowest 8.3%, as indicated in (Table 2). A 90% confidence level was established for the statistical significance of side-by-side variations in the bifurcation of the right as well as left common carotid arteries. No difference was found to be statistically significant. observed between pairs of items. In contrast, 4.1% of the right as well as left common carotid arteries bifurcated at the hyoid bone (C3 level posteriorly) and 4% at the angle of the mandible (C2 level posteriorly).

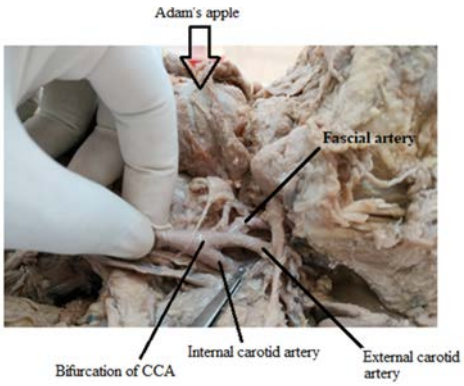

Fig. 4: Dissected Specimen on Left Carotid Artery Bifurcation Showing at the Level of Adam's Apple According to C4 Intervertebral Disk

Fig. 5: Dissected Specimen on Left Carotid Artery Bifurcation Showing at the Level of Body of Hyoid Bone According to C3 Vertebrae in (table 3).

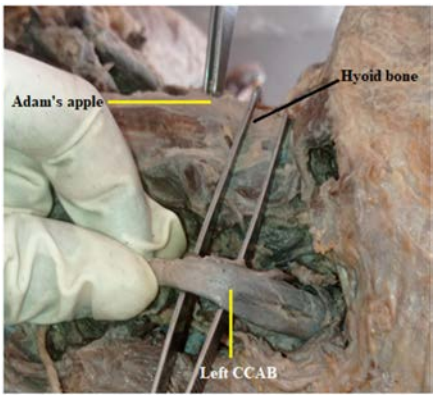

Fig. 6: Dissected Specimen on Left Carotid Artery Bifurcation Showing at the Level of Body of Hyoid Bone According to C3 Vertebrae in table no. 3

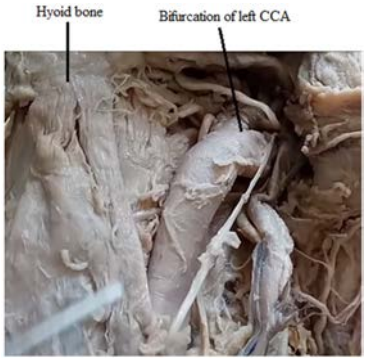

Fig. 7: Dissected Specimen on Left Carotid Artery Bifurcation Showing Below the Level of Body of Hyoid Bone According to C3-C4 Vertebrae

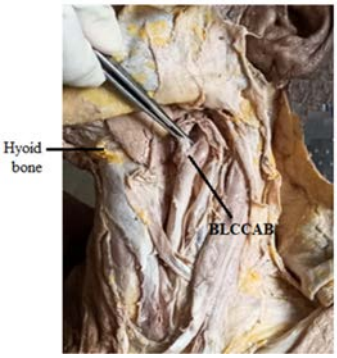

Fig. 8: Dissected Specimen on Left Carotid Artery Bifurcation Showing at the Level of Body of Hyoid Bone According to C3 Vertebrae

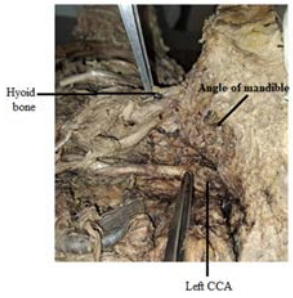

Fig. 9: Dissected Specimen on Right and Left Sides of Carotid Arteries Bifurcation Showing in Higher Level at Angle of Mandible with C2 Vertebrae

Table 1: Frequency of the Right Side of CCA Bifurcation Level

Right side of CCA bifurcation	Level of bifurcation	Numbers	Percentage
1 cadaveric study of CCA	C2 vertebrae at the level of angle of mandible	1	4.1%
3 cadaveric study of CCA	C3 vertebrae at the level of hyoid bone	3	12.5%
10 cadaveric study of CCA	C3-C4 vertebrae at the level of thyroid membrane and superior horn of thyroid cartilage	10	41.6%
7 cadaveric study of CCA	C4 vertebrae at the level of laryngeal prominance	7	29.1%
4 cadaveric study of CCA	C4-C5 vertebrae between thyroid cartilage and cricoid cartilage	3	12.5%

Table 2: Frequency of the Left Side of Carotid Artery Bifurcation Level

Left side of CCA bifurcation	Level of bifurcation	Numbers	Percentage
4 cadaveric study of CCA	C2 at the level of angle of mandible	4	16.6%
6 cadaveric study of CCA	C2-C3 vertebrae at just above the greater cornu of hyoid bone	6	25%
12 cadaveric study of CCA	C3-C4 vertebrae at the level of thyroid membrane and superior horn of thyroid cartilage	12	50%
2 cadaveric study of CCA	C4 vertebrae just above the level of Adam's apple	2	8.3%

Table 3: Frequency of Level of Bifurcation of Right Side and Left Side of Common Carotid Arteries

Both sides of carotid artery bifurcation	Level of bifurcation	No. of specimens	Numbers	Percentage
1 cadaveric study of CCA	C2 at the level of angle of mandible	48	1	4.1%
1 cadaveric study of CCA	C3 vertebrae at the level of hyoid bone	48	1	4.1%

Table 4: Percentages of Various Levels of Right Side and Left Side of Common Carotid Arteries in Carotid Triangle Region

Levels of bifurcation of right CCA	Percentage	Levels of bifurcation of left CCA	Percentage
C2- Angle of mandible	4.1%	C2- Angle of mandible	16.6%
C3- Hyoid bone	12.5%	C2-C3- between angle of mandible and greater cornu of hyoid bone	25%
C3-C4- Superior border of thyroid cartilage	41.6%	C3-C4 vertebrae at the level of thyroid membrane and superior horn of thyroid cartilage	50%
C4- Adam's apple	29.1%	C4- Adam's apple	8.3%
C4-C5- Thyroid cartilage and cricoid cartilage	12.5%	C4-C5- Thyroid cartilage and cricoid cartilage	Nil

Table 5: Comparison of Present Study Findings of Carotid Artery Bifurcation with Previous Studies in Indian Population

Sl. No.	Authors	Sample size	Standard level of CAB	High level of CAB	Low level of CAB
1.	Sanjeev I K et al. 2010	74	56.7%	16.2%	27.6%
2.	Ambali M and Jadhav S., 2012	200	57%	42%	1%
3.	Radha K, 2014	80	83.7%	11.2%	5%
4.	Vatsala AR et al. 2014	80	32.4%	63.8%	3.75%
5.	Deepa D et al. 2018	80	75%	25%	-
6.	Pushyami Peruri et al.	120	68.3%	21.66	10%
7.	Present study- Right CAB	24	41.6%	16.6%	41.6%
	Present study- Left CAB	24	50%	41.6%	8.3%

The present inquiry noted that the right CCA originated normally on ten sides., cadaveric dissection, on the other hand, unveiled a low level on ten sides and a high level on four. Similarly, it was noted that the bifurcation of the left carotid artery exhibited normal characteristics on fourteen sides., ten sides displayed a high level of bifurcation, whereas no low level was detected. Assessing and analyzing the morphometry as well as degrees of CCA bifurcation of the common carotid arteries was the purpose of this research. The variability of CAB bifurcation in dissected cadevers can be attributed to a multitude of factors, including genetic, environmental and developmental influences[5]. The CAB's height is typically measured in relation to cartilaginous or osseous structures of the neck, namely the hyoid bone (HB) and cervical vertebrae (CV) anteriorly and posteriorly, respectively, whereas the majority of head and neck operations are conducted with the head in extension. In addition, the cervical vertebrae are inaccessible and the head is extended during the majority of carotid head and neck procedures. The majority of anatomical textbooks define the CAB position as the superior border of the thyroid cartilage or the C3/4 intervertebral disc. Golth as well as Von Poisel were the ones who identified 67%. CCA may bifurcate at an abnormally high or low level, with the prevalence of high bifurcations being greater. Attenuation of the bifurcation may occur at an altitude ranging from the lower border of thyroid cartilage to the hyoid bone. The clinical implications of these variations encompass surgical methodologies pertaining to the region of the head and neck[6]. Our results indicate that anatomical variation at the carotid bifurcation extends beyond distinctions between the high and low CAB. Furthermore, the diameter and area ratios of the CCA vary substantially among and even within individuals. Normal levels of right CAB were observed in 41.6% of the cases, while high levels were detected in 16.6% of the cases., low bifurcated levels were observed in 41.6% of the cases. The left CAB was found to be normal in 50% of the cases, high in 41.6% of the cases and low bifurcated in 8.3% of the cases. The prevalence of right CAB was found to be 46.1% at levels C3-C4, C2-C4. The percentage of variations was 4.1%, C3-12.5%, C4-29.1% and C4-C5%, respectively, according to cadaveric investigations. In a similar fashion, the left CAB was detected at the level of C3-C4 in 50% of the cases, C2-C3 in 16.6% and C4 in 8.3%. The current investigation unveiled that there are distinctions between the right and left sides in terms of CAB. In 25% of the cases, The left carotid bifurcation was observed to be higher than the right CAB, with both sides of the equal bifurcation being present in 8.2% of the cases. The prevalence of right CAB was

found to be 46.1% at levels C3-C4, C2-C4. The percentage of variations was 4.1%, C3-12.5%, C4-29.1% and C4-C5%, respectively, according to cadaveric investigations. In a similar fashion, the left CAB was detected at the level of C3-C4 in 50% of the cases, C2-C3 in 16.6% and C4 in 8.3%. The current investigation unveiled that there are distinctions between the right and left sides in terms of CAB. In 25% of the cases, 8.2% of the cases exhibited the presence of both sides of the equal bifurcation, with the left CAB being higher in elevation than the right CAB. Elevated levels of CAB bifurcation are associated with a greater propensity for embolus formation in the CCA compared to the external carotid artery, both of which are potentially fatal[7]. The risk of intra-articular screw impingement on a high common carotid increases during procedures involving cervical vertebrae[8-12].

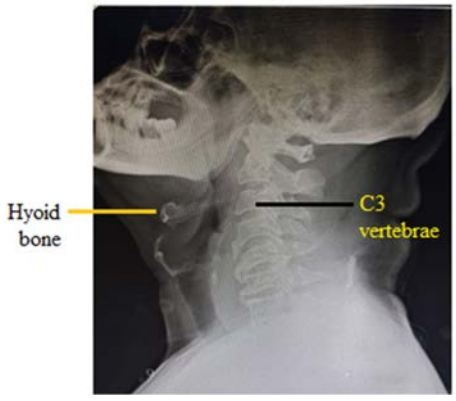

Fig. 10: Digital Radiograph of Cervical Vertebrae (Lateral View). Hyoid Bone Compared with Cervical Vertebral Level to Evaluate the CCA Bifurcation

The observed data was documented using the data collection form. The precision, accuracy and consistency of the data pertaining to the level of bifurcation of the cervical collarbone (CCA) were verified prior to its analysis using a radiological digital image (see Fig. 10). The data were subsequently partitioned along sides in order to depict their distribution on the left and right. The results were presented using figures and tables and the analysis was conducted manually.

CONCLUSION

Left and right bifurcations in the cadaveric investigation exhibited substantial interindividual variation. The prevalence of bifurcation at a higher level in the left carotid artery was greater in comparison to that of the right carotid artery. The higher CCA bifurcation at the angle of mandible (C2) level should alert radiologists and surgeons to the closer proximity and increased vulnerability of the hypoglossal nerve. In most instances, the right CAB is lower than the left CAB. Prior research has not previously addressed the magnitude of this upper and lower variation. While performing thyroidectomy and managing carotid aneurysms, head and neck surgeons, radiologists and transcatheter embolisation procedures will find the current study of CAB anatomical variations beneficial. Additional research must be conducted on a substantial sample size of cadavers in order to enhance the accuracy of generalisations to the population.

Conflicts of Interest: The Authors have declared that no conflicts of interest.

Sources of Fund: None.

Human Ethics: Consent was obtained and granted permission by the Institutional Ethics Committee (IEC), Bidar Institute of Medical Sciences, Bidar, Karnataka Issued approval no. 229/BRIMS/IEC/2023., Dt. 10/10/2023 by prime investigator of Dr. Asma Begum, P.G Student, Dept. of Anatomy.

Author Contributions:

- **Dr. Asma Begum:** Dissection, execution of the research and interpretation of results.
- **Dr. Roshan Z. Maniyar:** Image acquisition, Data analysis and scientific writing of research.
- **Dr. K. Vrushali:** Scientific guidelines, proof reading and Plagiarism of the article.
- **Dr. Sandeep S. Deshmukh:** Ethical approval.

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