DOI: 10.7860/IJARS/2021/50019:2715

Original Article

Anatomy Section

Variations in Surgical Anatomy of Common Carotid Artery: A Cadaveric Study

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ABSTRACT

Introduction: Carotid arterial system constitutes the principal blood supply of head, neck and brain. In various physiological mechanisms and pathological processes, carotid bifurcation is an important site both anatomically and surgically. Selection of surgical techniques between carotid stenting and carotid endarterectomy requires prior knowledge of level of carotid bifurcation.

Aim: To observe the origin, level of bifurcation and geometric measurements of common carotid artery and its variations.

Materials and Methods: An observational cross-sectional study was done on 60 formalin embalmed human adult cadavers, of which 47 were male and 13 were female aged between 35-75 years, which were allotted for dissection for first year Bachelor of Medicine and Bachelor of Surgery (MBBS) students in the Department of Anatomy, Government Siddhartha Medical College, Vijayawada, NRI Medical College, Chinakakani and Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinoutapalli, India, during the academic years December 2013 to March 2018. Observations from both right and left common carotid arteries (total 120 sides) were noted. The data observed was tabulated. Statistics in terms of simple percentages were used. The mean arterial diameter±standard deviation of both right and left common carotid arteries were calculated using the Microsoft office excel sheet.

Results: In the present study, total of 120 sides of 60 origin of right common carotid artery was found normal and the origin of left common carotid artery from brachiocephalic trunk was found in 5%. Normal level of bifurcation of common carotid artery was found in 82 (68.33%) sides, high level in 26 (21.66%) sides and low level in 12 (10%) sides. The mean arterial diameter±standard deviation of lumen at the origin of right common carotid artery was 0.887±0.132 cm and left common carotid artery was 0.906±0.128 cm and for both right and left common carotid arteries was 0.896±0.129 cm.

Conclusion: Detailed study of surgical anatomy of common carotid artery is important for many surgical, radiological and clinical applications. Knowledge of its variations will help to make alterations in surgical interventions and radiological procedures.

Keywords: Carotid bifurcation, Carotid endarterectomy, External carotid artery, Internal carotid artery

INTRODUCTION

Carotid system comprises common carotid artery and its two terminal branches, the external carotid artery and the internal carotid artery. The term “carotid” is a Greek term which means heavy sleep. From ancient times compression of carotid arteries were done to induce sleep [1]. Common carotid artery, external carotid and internal carotid arteries provide major source of blood supply to the head and neck [2]. Incidence of normal origin of common carotid artery on both right and left sides was reported in between 64.9-94.3% [3,4]. Left common carotid artery may arise from brachiocephalic trunk in 7% of cases [2].

In various physiological mechanisms and pathological processes, carotid bifurcation is an important site both surgically and anatomically [1,2]. The normal level of bifurcation of common carotid artery is at the level of superior border of thyroid cartilage [1]. In the recent times, there is increased interest in the study of anatomical variations at the level of carotid bifurcation, due to evolution of intravascular treatments like embolisation and chemo-embolisation for tumours of head and neck [5]. Selection of surgical technique between carotid endarterectomy and carotid stenting requires knowledge of level of bifurcation of common carotid artery [6,7]. Injury to the cranial nerves during surgical procedures is most common in common carotid artery with high bifurcation. Most commonly injured nerves are hypoglossal and marginal mandibular, which can be injured at a rate of 5.2% [8,9].

Arterial bifurcations and bends are the sites for atherosclerotic plaque formation, which is mainly related to the accepted idea that haemodynamic forces especially wall shear stress, play an important role in development and progression of atherosclerosis [10]. Lumen geometry is an important factor which mainly determines haemodynamic forces [11-14]. During reconstructive surgeries, information on normal arterial diameters is important in relation to changes to drugs, different treatment modalities [5].

Most of the research data available are based on various imaging techniques such as computerised tomographic angiography, magnetic resonance imaging etc. Instead of extensive research, many aspects of surgical anatomy of common carotid artery especially geometric values are undetermined, which is an essential component to understand the local blood flow haemodynamics and in turn influences the development of atherosclerosis. The knowledge of carotid morphology and its geometry is the important requirement in patient selection, preoperative planning, and design of new endovascular devices for arterial reconstruction [15]. The present works adds more information to the existing data on cadaveric studies, which can be utilised in both clinical and surgical practices. The present study aims to observe the origin, level of bifurcation and geometric measurements of common carotid artery and its variations.

MATERIALS AND METHODS

The present cross-sectional observational study was done on 60 formalin embalmed human adult cadavers, allotted for dissection to first year MBBS students in the Department of Anatomy Government Siddhartha Medical College, Vijayawada, NRI Medical College, Chinakakani and Dr. Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Chinoutapalli, India, during the academic years, December 2013 to March 2018.

Inclusion criteria: The cadavers were which were donated bodies procured after an informed consent according to the regulations followed by the institutions, of which 47 were male and 13 were female aged between 35-75 years.

Exclusion criteria: Cadavers with injuries in the head and neck region, or for those embalming done through common carotid artery and those which were dry, damaged by the students were excluded from this study.

Study Procedure

Routine standard dissection method for the undergraduates was followed. Dissection performed according to the standard procedures of Cunningham's manual of dissection [16]. Observations from both right and left common carotid arteries (total 120 sides) were noted. Study was conducted in NRI Medical College, chinakakani, also to reach this required sample. The observer bias is avoided by adequate training for observers in how to record findings, clearly defining the methods, tools for collecting the data. The arterial diameter of lumen of both right and left common carotid arteries at origin was noted using vernier callipers.

The parameters noted from the above study were: 1) Origin of common carotid artery; 2) Level of bifurcation of common carotid artery; 3) Diameter of lumen of common carotid artery at origin.

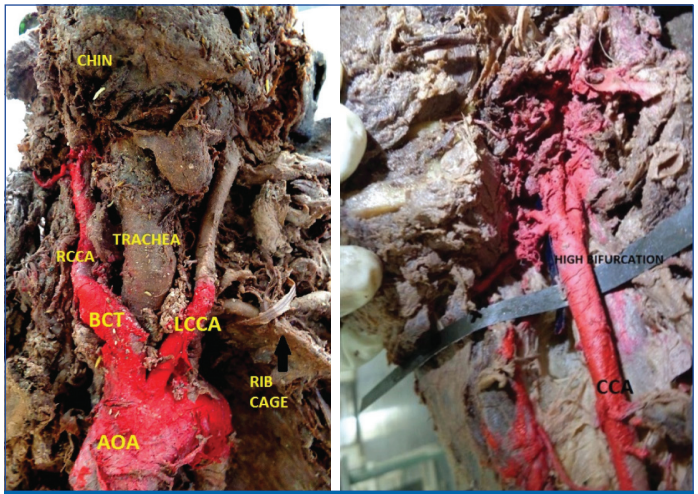
STATISTICAL ANALYSIS

The data observed was tabulated. Statistics in terms of simple percentages were used. The mean arterial diameter±standard deviation of both right and left common carotid arteries were calculated using the Microsoft office excel sheet.

RESULTS

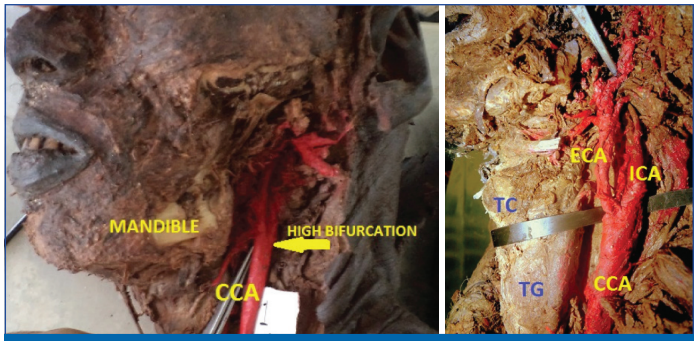
Origin of common carotid artery: In the present study, which was done among 60 right common carotid arteries and 60 left common carotid arteries (total 120 sides), origin of right common carotid artery was found normal on all sides. And the origin of left common carotid artery was found normal on 57 (95%) sides. In three sides (three male cadavers) i.e., in 5%, the left common carotid artery was found arising from brachiocephalic trunk [Table/Fig-1].

Level of bifurcation of common carotid artery: The level of bifurcation of both right and left common carotid arteries was found normal in 82 (68.33%) sides, high level of bifurcation [Table/Fig-2,3], was seen in 26 (21.66%) sides. Low level of bifurcation [Table/Fig-4], was found in 12 (10%) sides.



[Table/Fig-1]: Origin of left common carotid artery from brachiocephalic trunk; **[Table/Fig-2]:** High bifurcation of common carotid artery. (Images from left to right)
AOA: Arch of aorta; BCT: Brachiocephalic trunk; LCCA: Left common carotid artery; RCCA: Right common carotid artery; CCA: Common carotid artery

Diameter of lumen of common carotid artery at origin: The mean arterial diameter of lumen at the origin of right common carotid artery, it was 0.887±0.132 cm and that of left common carotid artery was 0.906±0.128 cm. For both right and left common carotid arteries, it was found to be 0.896±0.129 cm.



[Table/Fig-3]: High bifurcation of common carotid artery; **[Table/Fig-4]:** Low bifurcation of common carotid artery. (Images from left to right)
CCA: Common carotid artery; ECA: External carotid artery; ICA: Internal carotid artery; TC: Thyroid cartilage; TG: Thyroid gland

DISCUSSION

In the present study, origin of right common carotid artery was found normal on all 60 sides. Origin of left common carotid artery was normal in 57 (95%) sides, and in three sides (5%) in three male cadavers, it was found arising from brachiocephalic trunk. According to the literature, the normal branching pattern of arch of aorta was found with an incidence of 64.9-94.3% [3,4]. Left common carotid artery may arise from brachiocephalic trunk in 7% of cases [2].

The most common variation of origin of left common carotid artery from brachiocephalic trunk, as common trunk also called bovine arch is found with an incidence of 10-22%. However, the word bovine arch, is a misnomer, because the arch of aorta of cattle has only one branch, that branches into right subclavian artery, and a common trunk for common carotid arteries and left subclavian artery [17]. The [Table/Fig-5] shows incidence of origin of left common carotid artery from brachiocephalic trunk in different populations [18-28]. The variation of origin of left common carotid artery from brachiocephalic trunk in the present study observed as 5%, which was not comparable with the normal incidence (10-22%) reported by Layton KF et al., in the literature [17]. The present findings are nearly in concordance with the studies done by Satyapal KS et al., i.e., 3.4% and Moskowitz WB and Topaz O i.e. 3.2% [18,19].

S. No.	Author and year of study	Population studied	Sample size n	Percentage (%)
1.	Satyapal KS et al., 2003 [18]	South African	320	3.4%
2.	Moskowitz WB and Topaz O, 2003 [19]	American	1480	3.2%
3.	Makhanya NZ et al., 2004 [20]	South African	60	28.3%
4.	Gupta M and Sodhi L, 2005 [21]	Indian	100	12%
5.	Natsis KI et al., 2009 [22]	Greek	633	15%
6.	Ogengo JA et al., 2010 [23]	Kenyan	113	25.7%
7.	Bhattarai C and Poudel PP, 2010 [24]	Nepalese	85	12.9%
8.	Pasaoglu L et al., 2014 [25]	Turkey	881	7.2%
9.	Shakthi KR and Ramasamy C, 2019 [26]	Indian	50	12%
10.	Keet K et al., 2019 [27]	South Africa	733	23.7%
11.	Naik SK, 2020 [28]	Indian	50	20%
12.	Present study	Indian	60	5%

[Table/Fig-5]: Incidence of origin of left common carotid artery from brachiocephalic trunk in different populations [18-28].

In the present study, the normal level of bifurcation of common carotid artery was found in 68.33%, high level is seen in 21.66% and low level in 10% of sides. Comparison of levels of bifurcation of common carotid artery in different studies shown in [Table/Fig-6] [8,29-37].

The high bifurcation levels of common carotid artery in present study were 21.66%, which is nearly comparable with Deepa D et al., which was 25% [37]. The low bifurcation levels of present study were 10%, which is not comparable with any of the studies

S. No.	Author and year of study	Sample size	Normal level bifurcation	High level bifurcation	Low level bifurcation
1.	Anu VR et al., 2007 [29]	190	89%	10%	1%
2.	Sanjeev IK et al., 2010 [30]	74	56.76%	16.22%	27.62%
3.	Al-rafiah A et al., 2011 [31]	60	48.3%	46.6%	3%
4.	Ambali M and Jadhav S, 2012 [32]	200	57%	42%	1%
5.	Radha K, 2014 [33]	80	83.75%	11.25%	5%
6.	Vatsala AR et al., 2014 [34]	80	32.45%	63.8%	3.75%
7.	Woldeyes DH, 2014 [35]	26	53.84%	46.16%	-
8.	McNamara JR et al., 2015 [8]	76	16.4%	79.3%	4.3%
9.	Mompeo B and Bajo E, 2015 [36]	38	63.15%	36.85%	-
10.	Deepa D et al., 2018 [37]	80	75%	25%	-
11.	Present study	120	68.33%	21.66%	10%

[Table/Fig-6]: Comparison of levels of bifurcation of common carotid artery in different studies [8,29-37].

mentioned. The differences in the results seen between the present study and other studies may be due to difference in sample size and location of study.

Ribiero RA et al., studied on 46 heads of male embalmed cadavers [38]. In 2006 and reported the mean arterial diameter±standard deviation of lumen diameter at origin of right common carotid artery was 0.91±0.02 cm and that of left common carotid artery was 0.94±0.02 cm.

According to Jaroslaw K et al., in 2006 reported that an angiographic study done on 500 consecutive patients age 52±15 years, in which 61% were women, measured the lumen diameter of 15 to 20 mm below the common carotid artery bifurcation and reported the mean±standard deviation of common carotid artery in women was 6.1±0.80 mm and that of men was 6.52±0.98 mm [39].

A study done on 37 adult cadavers by Keet K et al., in 2019, reported the mean arterial diameter±standard deviation of left common carotid artery in males 7.9±1.0 mm and in females 7.6±0.9 mm [27]. A study reported in 2020 by Naik SK et al., shows the geometric values of left common carotid artery as 8.27±0.89 mm [28]. The findings of the present study are nearly correlating with the findings of Naik SK and Ribiero RA et al., studies [28,38].

Embryological basis: The possible developmental aspect of two branch pattern of arch of aorta is, initially aortic sac divides into right and left limbs. The left limb of aortic sac becomes part of the arch, which lies between brachiocephalic trunk and left common carotid artery. If there is failure in the division of aortic sac, then left common carotid artery directly gets connected to the aortic sac, giving rise to a common trunk of brachiocephalic trunk and left common carotid artery [40,41]. In the present study, it was observed in 5% of cases. Embryological origin of carotid system is not completely clarified. Common carotid artery, internal carotid artery and carotid bifurcation develop from 3rd aortic arch, while external carotid artery develop from 2nd aortic arch. From this point of view, the internal carotid artery should be considered continuation of common carotid artery, while the external carotid artery, its branch [42]. Many unknown developmental mechanisms such as duplication and regression of primitive vessels results in large number of variations in the carotid system [5].

The possible embroyological explanation for high bifurcation of common carotid artery is origin of external carotid artery from top of 3rd aortic arch or directly from dorsal aorta and origin of internal carotid artery from 2nd aortic arch concomitant with external carotid artery formation from small canals [43-45].

Low bifurcation of common carotid artery is rare with an incidence of 3.75-7.5%. A proposed embryologic explanation for low bifurcation of common carotid artery is origin of External carotid artery, from low in aortic arch. Rarely, a double communication between external carotid artery and internal carotid artery, propose persistence of both 2nd and 3rd aortic arches [43,44].

Limitation(s)

Sample consisting of unequal number of males and females, so the comparison of differences in prevalence between sexes could not be done. Sample size is limited to generalise the present data to a population.

CONCLUSION(S)

In all the cases, origin of right common carotid artery was found normal. Origin of left common carotid artery arising from brachiocephalic trunk was seen in 5% cases. Detailed knowledge of surgical anatomy of common carotid artery and its variations will help to make alterations in surgical interventions and radiological procedures like selection between carotid endarterectomy and carotid stenting. Morphometric study of common carotid artery helps to understand pathogenesis of atheromatous diseases. Knowledge of carotid morphology and its geometry is the important requirement in patient selection, preoperative planning, and design of new endovascular devices for arterial reconstruction. Further research needs to be done on large number of specimens so that generalisations for the population are appropriate.

Acknowledgement

I sincerely thank my family members and colleagues for their valuable suggestions and support while preparing this article.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 24, 2021
- Manual Googling: Jul 29, 2021
- iThenticate Software: Aug 13, 2021 (19%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Apr 22, 2021**
Date of Peer Review: **Jun 12, 2021**
Date of Acceptance: **Aug 02, 2021**
Date of Publishing: **Oct 01, 2021**