REVIEW ARTICLE

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Clinical implications of variations of common carotid artery trifurcation

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Abstract

Introduction and Objective. Common carotid arteries are paired vessels supplying the head and neck, and in surgical practice their trifurcation can impact the effectiveness of various oncologic, reconstructive, and interventional procedures. Understanding anatomical variations is crucial for avoiding complications and improving procedural safety. The aim of the study was to review the literature and systematize knowledge regarding the anatomy of the common carotid a. trifurcation, with particular emphasis on its role in procedures such as carotid a. stenting, carotid endarterectomy, tumour embolization, glossectomy, thyroidectomy, and lymph node resection.

Review Methods. A literature review (including 9 original studies and 11 case reports) was conducted, considering studies on the anatomy of the common carotid a. trifurcation based on cadaveric and radiological material. Various variants of the common carotid a. trifurcation were identified, and their frequency of occurrence documented in the study.

Brief description of the state of knowledge. Based on the analyzed literature, the most frequently observed third branch of the division was the superior thyroid a. (20–76.6%). Other isolated cases included the superior laryngeal a., ascending pharyngeal a., occipital a., and lingual a.

Conclusions. Analyzing the diversity of the common carotid a. trifurcation reveals its frequent occurrence, suggesting the necessity to consider this variability in head and neck medical procedures. The most common third branch is the superior thyroid a., which holds significant importance for diagnostic and therapeutic strategies in the area of the thyroid gland. While cases of large vessels, such as the vertebral a., departing from the trifurcation are rare, their consideration is crucial in procedural planning.

Key words

carotid artery, endarterectomy, superior thyroid artery, thyroidectomy, stent

INTRODUCTION

The common carotid arteries are paired vessels that, along with the other paired vessels – vertebral arteries – constitute the main source of arterial blood supply to the head and neck. The left common carotid artery typically originates most commonly by branching off from the highest point of the aortic arch; however, rarer anatomical variations exist, such as arising from a common trunk with the right carotid artery or the right subclavian artery [1]. The right common carotid artery usually begins by branching off from the brachiocephalic trunk, but similar to the left side, other variants occur, such as direct origin from the aortic arch when the brachiocephalic trunk fails to develop [2]. Both vessels ascend steeply, entering the carotid triangle where they usually bifurcate into the internal and external carotid arteries. The bifurcation occurs at different levels: the body of the hyoid bone (40%), the upper edge of the thyroid cartilage (39%), the apex of the greater horn of the hyoid bone (15%), or lower, at the middle of the plates of the thyroid cartilage (6%). In approximately half of the population (48%), the bifurcation of the common carotid arteries is asymmetric on both sides [3]. The varied bifurcation positions stem from the variable development of the third arterial arch, giving rise to the internal carotid artery. Only later, through budding, do the common and external carotid arteries develop [4]. The distal segment of the common carotid artery is noticeably widened and has been termed the carotid sinus, which often (in 74.3% of the population) encompasses the initial part of the internal carotid artery [5]. Within the carotid triangle, the internal carotid artery laterally aligns itself behind the external carotid artery. After crossing with the stylohyoid muscle (maintaining its posterior position), it shifts medially, deep into the parapharyngeal space [6].

After the division of the common carotid artery, a crucial concern for surgeons is to differentiate between the external and internal carotid arteries. The widely accepted principle is that the external carotid artery has branches in the cervical part that the internal carotid artery lacks (applicable to over 99% of the population) [7]. The most common anomalies not adhering to this rule include the origin of the ascending pharyngeal artery or the persistent sublingual artery from the internal carotid artery (more rarely, the origin of the occipital artery, superior laryngeal artery, and sternocleidomastoid

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branches from this artery). To date, only single cases have been documented in the literature in which two arteries branched from the cervical part of the internal carotid artery, and a few cases of aplastic external carotid artery, in which all the arteries originated from the internal carotid artery [8].

The common carotid arteries, especially their bifurcations, are common sites for the deposition of atherosclerotic plaques. These plaques can significantly narrow the vessel, impairing blood perfusion to the brain, resulting in characteristic neurological symptoms such as motor and sensory disturbances on the side opposite the constriction, speech disorders if the artery on the dominant hemisphere is narrowed, or visual disturbances on the side of the constriction [9]. Atherosclerotic plaques, upon losing contact with the vascular endothelium and entering the brain, are responsible for 10–20% of ischemic strokes [10, 11]. Consequently, the common carotid arteries undergo endarterectomy and stent procedures [12], which reduce the risk of ischemic strokes from around 3.8% to over 15%, depending on the severity of carotid artery stenosis [13].

The choice of the surgical method for managing developed atherosclerotic plaques in a patient depends on various factors. Endarterectomy is preferred for patients above 70 years of age, those with kidney disease or intraplaque haemorrhage, and those who have been less adherent to medication recommendations. Stenting, on the other hand, is most commonly chosen for patients with atherosclerotic changes located high in the cervical segment of the artery, and those with concomitant heart diseases [14].

Recently, several publications have emerged regarding another anatomical variant – the trifurcation of the common carotid artery, which may pose a challenge for physicians in identifying the correct vessel. The aim of this study is to review the literature and systematize current knowledge regarding the anatomy of the trifurcation of the common carotid artery.

MATERIALS AND METHOD

The review considered 9 original studies and 11 case reports dedicated to the anatomy of the common carotid artery trifurcation. The literature search was conducted in the following databases: PubMed, Google Scholar, and Scopus. The review included studies published between 2000 – 2023. Original studies involving at least 20 samples of common carotid arteries were included in the pooled statistics (meta-analysis).

The trifurcation of the common carotid artery is asymptomatic, and this anatomical variation is usually detected during imaging studies conducted for the diagnosis of other medical conditions, surgical procedures, or sectional studies focused on this variability [15]. Various variants of the trifurcation of the common carotid artery have been described.

A significant amount of data included in this review originated from *post mortem* studies. Ogeng'o JA et al., in their *post mortem* study involving 208 left common carotid arteries in a population of black individuals in Kenya, described trifurcation in 66 cases (31.7%). In all cases, the common carotid artery bifurcated into the internal carotid artery, external carotid artery, and superior thyroid artery. Furthermore, the presence of quadrifurcation was demonstrated in 11 cases (5.4%) (with branches being the internal carotid artery, external carotid artery, superior thyroid artery, and ascending pharyngeal artery), and even pentafurcation in 3 cases (1.4%) (branching into the internal carotid artery, external carotid artery, superior thyroid artery, occipital artery, and posterior auricular artery) [16].

Lucev N et al., during their study of 40 common carotid arteries and their branches, observed the origin of the superior thyroid artery from the common carotid artery in 9 cases (22.5%), and the origin of the lingual artery in 1 case (2.5%) [17].

The origin of the occipital artery from the bifurcation of the common carotid artery was also detected in 2 out of 110 human cadavers (1.8%) [18]. In a study of 10 human cadavers (20 common carotid arteries), it was noted that in 1 case (5%), the ascending pharyngeal artery originated from the bifurcation of the common carotid artery [19]. Nansis et al., in their study of 50 human cadavers (100 common carotid arteries), detected the origin of the superior thyroid artery in 49 samples (49%) from the bifurcation of the common carotid artery. They also described a thyrodlossal trunk (1%) arising at the level of the common carotid artery bifurcation [20]. Al-Rafiah A et al., in a study of 30 human cadavers (60 common carotid arteries), found the origin of the ascending pharyngeal artery from the bifurcation of the common carotid artery in 2 cases (3.3%). The superior thyroid artery originated from the bifurcation of the common carotid artery in 46 cases (76.7%) [21]. During a study of 33 human cadavers (66 common carotid arteries), it was demonstrated that the superior thyroid artery originated from the bifurcation of the common carotid artery in 21 cases (31.81%) [23].

In a study by Vázquez T et al., involving 207 common carotid arteries, 102 cases (49%) of the origin of the superior thyroid artery from the bifurcation of the common carotid artery were identified. The origin of the superior laryngeal artery from the bifurcation of the common carotid artery was also observed in 6 out of 142 cases (4%) [22].

Also included in this review is a study based on radiological material. In Gupta et al.'s study, 25 head and neck angiograms were evaluated. The origin of the superior thyroid artery from the common carotid artery bifurcation was found in 5 cases (20%) [24].

Changes in the bifurcation of the common carotid artery have also been detected during surgical procedures. It was observed that the third branch, branching-off from the bifurcation of the common carotid artery (in addition to the internal carotid artery and external carotid artery), may be the facial artery [25], occipital artery [26, 27], vertebral artery [28], or ascending pharyngeal artery [29]. The thyroglossal trunk [30], thyro-glosso-facial trunk [31, 32], and thyro-glosso-facial-occipital trunk [33, 34] have also been described as the third branch of the common carotid artery. A case of pentafurcation of the common carotid artery into the internal carotid artery, external carotid artery, occipital artery, ascending pharyngeal artery, and lingual-facial trunk, has been reported [35].

In summary, it can be noted that the most common third end branch of the common carotid artery is a vessel properly originating from the external carotid artery. Collective data from studies on larger groups describing the frequency of occurrence of different forms of the third branch are presented in Table 1.

Table 1. Frequency of common carotid artery trifurcation variants [16–24]

		The third branch of trifurcation of the common carotid artery					
Author	No. of samples tested	Superior thyroid a.	Superior laryngeal a.	Ascending pharyngeal a.	Occipital a.	Lingual a.	Thyroglossal trunk
Ogeng'o JA	208	66 (31.7%)	-	-	-	-	-
Lucev N	40	9 (22.5%)	-	-	-	1 (2.5%)	-
Marques	110	Not investigated	Not investigated	Not investigated	2 (1.8%)	Not investigated	Not investigated
Cavalcanti DD	20	Not investigated	Not investigated	1 (5%)	Not investigated	Not investigated	Not investigated
Natsis K	100	49 (49%)	Not investigated	Not investigated	Not investigated	Not investigated	1 (1%)
Al-Rafiah A	60	46 (76.7%)	Not investigated	2 (3.3%)	Not investigated	Not investigated	Not investigated
Vázquez T	207	102 (49%)	Not investigated	Not investigated	Not investigated	Not investigated	Not investigated
	142	Nie badano	6 (4%)	Not investigated	Not investigated	Not investigated	Not investigated
Joshi A	66	21 (31.81%)	Not investigated	Not investigated	Not investigated	Not investigated	Not investigated
Gupta P	25	5 (20%)	Not investigated	Not investigated	Not investigated	Not investigated	Not investigated
Total number	978	298/706 (42.21%)	6/390 (1.53%)	3/328 (0.91%)	2/358 (0.56%)	1/248 (0.4%)	1/348 (0.29%)

DISCUSSION

The trifurcation of the common carotid artery, involving the internal carotid artery, external carotid artery, and potentially additional arterial branches, significantly influences vascular procedures, especially in the field of head and neck surgery. Variations in the construction of carotid arteries pose challenges during procedures, introducing variability in vascular access, identification, and the procedures themselves. These changes can have significant implications in oncological, reconstructive, and interventional surgery.

A typical endovascular procedure performed on common carotid arteries is the stenting of carotid artery stenosis. In situations where the stenosis mainly affects the internal carotid artery and placing the stent before the bifurcation of the common carotid artery, would not sufficiently improve blood flow, and it becomes necessary to place the stent directly in the internal carotid artery. Trifurcation can significantly hinder the surgeon in placing the catheter with the stent in the appropriate vessel, thereby potentially prolonging the procedure [36].

Another procedure complicated by trifurcation is the embolization or chemoembolization of head and neck tumours. Interventional chemotherapy with embolization is used as adjuvant or palliative treatment, and although it may not significantly increase the local drug concentration in tumours or reduce side effects, it can block arterial blood flow, promote necrosis and tumour shrinkage, and improve the effectiveness of treatment, thereby significantly improving patient prognosis [37]. Proper identification of the vessel undergoing this procedure is essential. Otherwise, it may result in the administration of embolic or chemotherapeutic agents to the wrong vessel, leading to damage to a properly functioning organ, such as a stroke [38].

Another example of a procedure where the trifurcation of the carotid artery can significantly complicate its execution (due to difficulties in identifying the appropriate vessel) is glossectomy or haemiglossectomy. This surgical procedure involves removal of the tongue or part of it (followed by reconstruction of the excised portion), typically in cases of squamous cell carcinoma of the tongue (constituting 95% of tumours in this organ [39]), macroglossia, or obstructive sleep apnea [40]. During this procedure, it is necessary to ligate the lingual artery supplying the tongue. This vessel may originate from the trifurcation of the common carotid artery, which is crucial information for the performing surgeon [41].

Trifurcation can also complicate thyroidectomy, often performed in cases of thyroid cancer. The intervention involves removal of the entire or part of the thyroid gland. The thyroid is vascularized by paired arteries: the inferior and superior thyroid arteries, which must be properly ligated during surgery. The superior thyroid artery may originate from the trifurcation of the common carotid artery. Ligating the wrong vessel can result in profuse bleeding within the gland and serious complications [42].

The removal of metastatic lymph nodes in the neck may require ligating the facial artery. Its origin, along with the internal and external carotid arteries at the bifurcation of the common carotid artery, can cause difficulties in locating and ligating it in the right place [43].

One useful diagnostic tool is Doppler ultrasound of the carotid arteries, a non-invasive, effective, and cheap method of imaging larger vessels in the neck. During the procedure, vascular anomalies, including the trifurcation of the common carotid artery, can be visualized [44].

Among various imaging diagnostic techniques, computed tomography angiography provides the most accurate, multiplanar, three-dimensional image of the vascular tree (an example is presented in Figure 1). The study allows observation of artery geometry, branching points, length, width, and helps determine the topographic course of vessels. The accuracy of the examination significantly minimizes the risk of overlooking additional structures [45, 46].

CONCLUSIONS

Analysis of the diversity of the trifurcation of the common carotid artery indicates its relatively frequent occurrence, emphasizing the need to consider this variability during medical procedures in the area of the head and neck. The third branch, branching-off from the bifurcation of the common carotid artery, is most often an artery that properly originates from the external carotid artery. Most commonly, this is the superior thyroid artery, which can significantly influence diagnostic and therapeutic strategies within the thyroid gland. It is worth noting that descriptions of cases

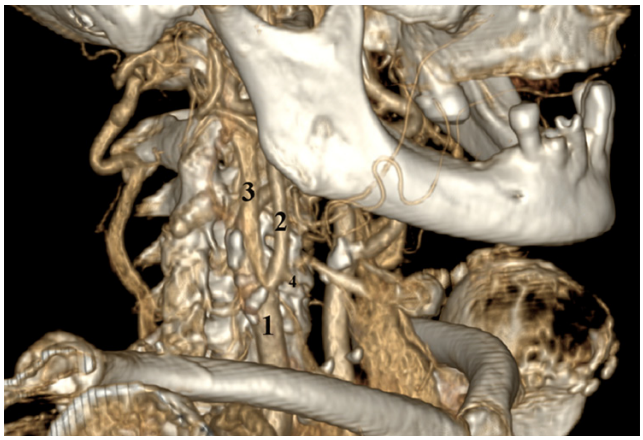

Figure 1. Normal anatomy of the right common carotid artery. 1) Common carotid artery, 2) external carotid artery, 3) internal carotid artery, 4) superior thyroid artery (3D reconstruction of the angio-CT scan)

involving the departure of large vessels, such as the vertebral artery, are rather rare.

An alternative division of the common carotid artery usually goes unnoticed for a long time and is recognized accidentally during surgical procedures or intraoperative examinations. There are situations where trifurcation is discovered during routine examinations or autopsies (the *post mortem* presentation of the anatomical structure of arterial vessels in the neck region corresponds to what is depicted in Figure 2). Early recognition facilitates the performance of the afore-mentioned vascular procedures, increases the chances of success, and reduces time and complications. Specialists should be aware of the possibility and frequency of various forms of variability in the origin and course of major arterial branches in the head and neck.

Available diagnostic tools, such as Doppler ultrasound and computed tomography of blood vessels, despite their general availability, remain fundamental in imaging the vessels of the head and neck, allowing for the identification of anatomical diversities.

However, it is important to note that this study has certain limitations related to the small number of analyzed scientific articles. Therefore, further, more extensive research is necessary for a more comprehensive understanding of the prevalence of trifurcation of the common carotid artery, and better identification of potential clinical consequences associated with this phenomenon.

DISCLOSURES

All authors have read and agreed with the published version of the manuscript, and declare that they have no conflict of interest. No external funding was received to perform this review. Permission was obtained to use photographs of anatomical material from the Department of Normal, Clinical, and Imaging Anatomy at the Medical University in Lublin, Poland. Permission was also obtained to use images from the computer tomography study conducted at the Department of Medical Radiology I, Medical University in Lublin, Poland

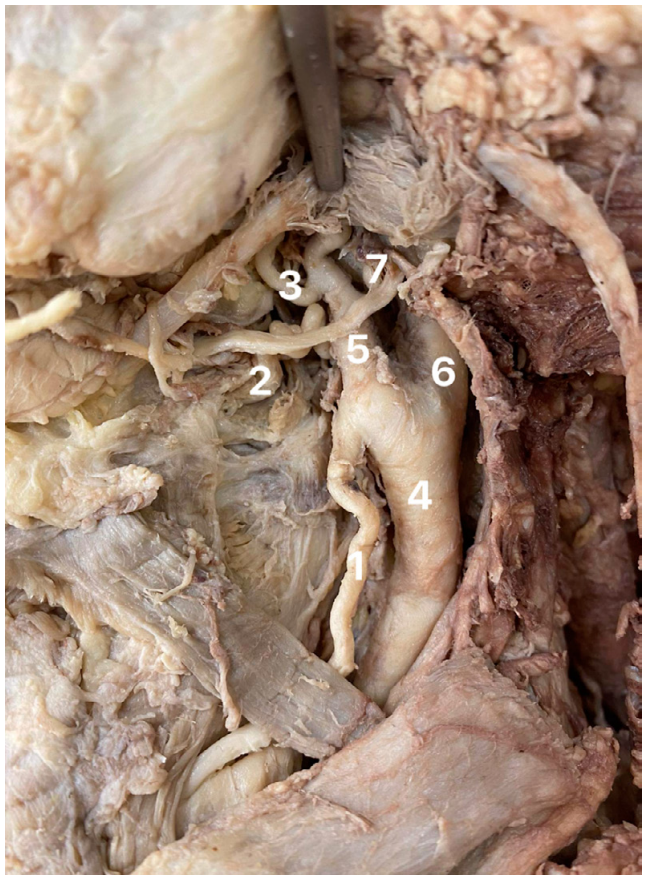

Figure 2. Trifurcation of the left common carotid artery. 1) Superior thyroid artery, 2) lingual artery, 3) facial artery, 4) common carotid artery, 5) external carotid artery, 6) internal carotid artery, 7) occipital artery (dissection material from the Department of Normal, Clinical and Imaging Anatomy, Medical University, Lublin, Poland)

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