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Variations in external carotid artery branches and common carotid bifurcation level: a computed tomography angiography study

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Abstract

Background The common carotid bifurcation level is an important surgical landmark during head and neck surgery, especially endarterectomy, that could be omitted in patients with high bifurcation levels to reduce damage to neighboring structures like the hypoglossal nerve. Additionally, having a thorough understanding of the variations in the external carotid artery branches is crucial for head and neck cancer surgeries and thyroidectomy. However, cadavers were employed in the majority of studies on these variations. In previous research, there were significant disparities in the incidence of these variations according to gender, laterality, and ethnicity. In order to identify these changes in Egyptian patients and to compare them in terms of gender and laterality, we used computed tomographic angiography.

Methods The level of the common carotid bifurcation was assessed in a cross-sectional study utilizing computed tomographic angiography, which included 80 patients (160 carotid sides) for comparing the common carotid artery bifurcation level with the relevant vertebrae and anterior neck structures, and they were compared with regard to gender and laterality. Variations in the external carotid artery branches were also evaluated.

Results The most frequent location of the common carotid bifurcation level was between C3 and C4 (33.8%). It was 36.9% between the thyroid and the hyoid. 47.5% of patients had a high common carotid bifurcation (higher than the C3/4 level). The highest bifurcation was at C2, while the lowest was at D1. For external carotid artery branches variations, the superior thyroid artery emerged at and below the level of the common carotid bifurcation, respectively, at 19.4% and 23.7%. The facial artery had the largest diameter (2.38 ± 0.44 mm), while the ascending pharyngeal artery had the smallest (1.17 ± 0.11 mm). Seven types of trunks were found; the ascending pharyngeal artery-occipital artery trunk was the most common (25%) and was followed by the lingual artery-facial artery trunk (20%).

Conclusions Multiple anatomical variations in the external carotid artery branches and the common carotid bifurcation level were found by computed tomographic angiography. As a result, it can be utilized as a useful imaging technique to evaluate these variations before surgery.

Keywords Computed tomography angiography, Variations, Common carotid bifurcation, External carotid artery

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Background

The common carotid bifurcation (CCB) level is a significant surgical landmark for head and neck operations, and surgeons must have a thorough understanding of both its anatomy and variations. Carotid endarterectomy may not

be performed if the CCB is this high since it is close to the hypoglossal nerve and poses a high risk of damaging it [1, 2].

In earlier studies, several variants for external carotid artery (ECA) branches were discovered. In head and neck cancer procedures, plastic and vascular surgeries, and trans arterial embolization therapies, a detailed understanding of these variances helps to reduce patient morbidity and death. Anatomical variations of the superior thyroid artery (STA) are particularly important to recognize since failing to do so could result in damage to the superior laryngeal nerve, which is a catastrophic complication for head and neck surgeons performing thyroidectomies [3–5].

The prevalence of these variations differed according to laterality since the right side's CCB level was found to be higher than the left's. Additionally, there were differences in incidences between males and females [1, 6].

Although earlier research found several anatomical variances at the CCB level and in the ECA branches, the majority of those studies were still conducted on cadavers. Computed tomography angiography (CTA) was employed in fewer following research to delineate these variations [5, 7, 8].

Results from earlier studies have brought up the concern that different ethnic groups have varied incidences of these variations, and they vary greatly between populations. Compared to other populations, Asians showed higher levels of bifurcation [8, 9].

According to our knowledge, this study is the first to employ CTA to identify variations in the CCB and ECA branches in Egyptian patients, and that is what we aimed to identify. We also compared them based on gender and laterality.

Methods

At the Menofia University Diagnostic, Interventional Radiology, and Medical Imaging Department, the Computed Tomography Unit conducted a cross-sectional study. It was carried out between February 2022 and February 2023. It included 80 patients (160 carotid sides) who came to our department for preoperative evaluation for head and neck surgeries and carotid stenosis analysis in stroke patients by multidetector computed tomography (MDCT) carotid angiography.

The study excluded patients with a history of prior neck surgery, known renal impairment, known contrast allergies, and pregnant women. All patients received thorough explanations of the procedures before providing their informed consent. This study was accepted by the Menofia Faculty of Medicine Ethical Committee for Human Research Approval.

A 128-slice CT scanner (General Electric, Revolution EVO, USA) was used to obtain the images. A power injector was used to administer 70 ml of iodinated contrast medium in adults, followed by 30 ml of saline at a rate of 5 mL/s for each of them after an 18G or 20G needle was placed in the antecubital vein. In children, the dose of contrast was 2 mL/kg. Using the Smart Prep software, the bolus tracking was done while monitoring the opacification of the aortic arch.

The scanning parameters were 120 kV, 130 mAs, 0.625 mm slice thickness, 0.65 s rotation time, and 0.984 pitch. By using automatic exposure control, these parameters were adjusted according to patient size. Images were produced on medical workstations (AW Volume Share 7) using maximum intensity projection and multiplanar reformation.

The horizontal position of the CCB on each side was compared to the following vertebral levels: C2, C2/3, C3, C3/4, C4, C4/5, or at a lower level. It was also measured in relation to the following anterior structures: above the mandibular angle, mandibular angle level, between the hyoid bone and the mandibular angle, the hyoid, between the thyroid cartilage and the hyoid, superior border of the thyroid cartilage, mid aspect of the thyroid cartilage, lower border of the thyroid cartilage, or below this level.

External carotid artery branches, namely the superior thyroid artery (STA), lingual artery (LA), facial artery (FA), ascending pharyngeal artery (APA), occipital artery (OA), and posterior auricular artery (PAA) on both sides, were investigated. The following items were assessed:

- Origin of STA, whether as a trunk or a separate branch (above, at, or below the CCB horizontal level)
- Diameter and distance of the STA origin from the CCB horizontal level
- Other arteries' origins (trunk or a separate branch), diameters, and distances of origin from the CCB horizontal level
- Common trunk incidence, diameter, and distance of origin from the CCB horizontal level

Statistical analysis

Data were collected, tabulated, and statistically analyzed using Statistical Package for the Social Sciences (SPSS) version 26 (SPSS Inc, released 2018. IBM SPSS Statistics for Windows, version 26.0, Armonk, NY: IBM Corp.). Quantitative data were expressed as mean (\bar{x}), standard deviation (SD), and range (minimum–maximum), whereas qualitative data were expressed as number (N) and percentage (%). The Chi-square test was used to evaluate analytical statistics. Results from significant tests

were presented as two-tailed probabilities. The significance of the obtained results was judged at 5%.

Results

A total of 160 carotid sides from 80 patients (51 men and 29 women; ages 2–64; mean, 40 years) were included during the study period.

Regarding the vertebral level, the most frequent CCB level was found at C3/C4 in 33.8%, followed by C3 in 30.6%. On the right side, it was at C3/4 (38.8%), then C3 (26.3%). On the left, it was at C3 (35%) and C3/4 (28.7%), respectively (Table 1; Fig. 1). However, there was no statistically significant difference in laterality.

It was at the level between the thyroid and hyoid (36.9%), followed by the hyoid (33.2%), compared to

anterior relations. It was between the thyroid and hyoid on the right side (35%), and then the hyoid (33.8%). It was between the thyroid and hyoid on the left side (38.8%), then at the hyoid (32.5%), according to Table 1’s findings.

In (45%), the CCB level was symmetrical. It was 30% higher on the left than on the right.

Regarding gender, In males, it was at C3/C4 in (31.4%), followed by C3 in (29.4%). While in females, it was at C3/C4 (37.9%), followed by C3 (32.8%), and this revealed statistical significance (p 0.023). Compared to anterior relations in males, it was at the hyoid (35.3%), followed by the level between the thyroid and hyoid (34.3%). In females, it was between the thyroid and hyoid (41.4%), followed by the hyoid (29.3%) (Table 1).

Table 1 The CCB horizontal level compared to vertebral level and anterior structures

	Right side (n = 80)	Left side (n = 80)	Both sides (n = 160)	Male (n = 102)	Female (n = 58)
	n (%)	n (%)	n (%)	n (%)	n (%)
Level of Vertebra					
C2	1 (1.2)	1 (1.2)	2 (1.2)	0 (0)	2 (3.4)
C2/C3	12 (15)	13 (16.4)	25 (15.7)	13 (12.7)	12 (20.7)
C3	21 (26.3)	28 (35)	49 (30.6)	30 (29.4)	19 (32.8)
C3/C4	31 (38.8)	23 (28.7)	54 (33.8)	32 (31.4)	22 (37.9)
C4	9 (11.3)	10 (12.5)	19 (11.9)	17 (16.7)	2 (3.4)
C4/C5	5 (6.2)	4 (5)	9 (5.6)	8 (7.8)	1 (1.7)
Lower level	1 (1.2)	1 (1.2)	2 (1.2)	2 (2)	0 (0)
Anterior structures					
Hyoid-mandible	10 (12.5)	10 (12.5)	20 (12.5)	14 (13.7)	6 (10.3)
Hyoid	27 (33.8)	26 (32.5)	53 (33.2)	36 (35.3)	17 (29.3)
Thyroid-hyoid	28 (35)	31 (38.8)	59 (36.9)	35 (34.3)	24 (41.4)
Superior thyroid	12 (15)	12 (15)	24 (15)	13 (12.7)	11 (19)
Mid-thyroid	2 (2.5)	0 (0)	2 (1.2)	2 (2)	0 (0)
Lower level	1 (1.2)	1 (1.2)	2 (1.2)	2 (2)	0 (0)

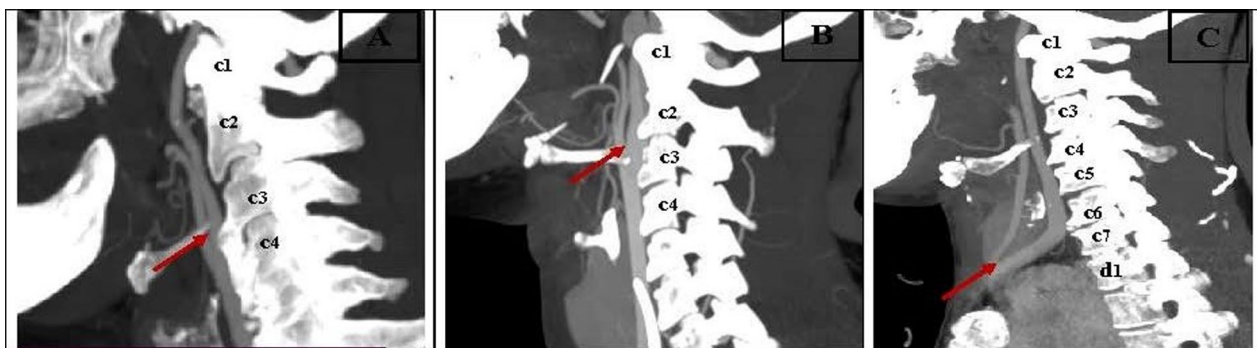


Fig. 1 Level of the CCB: Images with a sagittal maximum intensity projection display changes in CCB level. **A** Arrow points to the level of CCB at C3/4. **B** The CCB’s level is higher at C2/3 (arrow) and corresponds to the level of the hyoid bone. **C** At a very low level (C7/D1), the level of CCB is found (arrow)

The lowest bifurcation was detected at C7/D1 on the right and D1 on the left, while the highest bifurcation on both sides was at C2 (Fig. 1).

About 47.5% of patients had CCB levels higher than C3/4. Regarding gender, it was higher than the C3/4 level in 56.9% of females compared to 42.1% of males (Table 1).

STA arises above the CCB level in 55%, from the CCB level in 19.4%, below the CCB level (from CCA) in 23.7%, or as a trunk in 1.9%. It had a 1.83 ± 0.36 mm diameter. When it arose above the CCB level, the distance from CCB was 6.20 ± 9.02 mm; when it arose below the CCB level, it was 5.03 ± 2.60 mm (Table 2; Fig. 2).

Other branches (LA, FA, APA, OA, and PAA): In (84.4%) and (15.6%), LA emerged as a separate branch and a trunk, respectively. FA originated as a separate branch in 86.3% of cases and as a trunk in 13.7%. In 82.5% and 17.5%, APA emerged as a separate branch and trunk, respectively. OA emerged as a separate branch in 73.1% of cases and as a trunk in 26.9%. In 88.7% and 11.3%, respectively, PAA emerged as a separate branch and a trunk (Table 3).

While the FA distance from the CCB level was 21.72 ± 12.19 mm, the LA distance was 15.18 ± 11.09 mm. The APA, OA, and PAA distances were respectively 16.97 ± 12.13 mm, 20.79 ± 15.18 mm,

Table 2 STA origin, diameter and distance from the CCB horizontal level

	Right side (n=80) n (%)	Left side (n=80) n (%)	Both sides (n= 160) n (%)
Origin			
At CCB horizontal level	18 (22.5)	13 (16.3)	31 (19.4)
Above CCB horizontal level	46 (57.5)	42 (52.5)	88 (55)
Below CCB horizontal level	13 (16.2)	25 (31.2)	38 (23.7)
Trunk	3 (3.8)	0 (0)	3 (1.9)
Diameter (mm)			
Mean \pm SD (range)	1.83 ± 0.36 (1.1–2.9)	1.83 ± 0.37 (1.1–2.8)	1.83 ± 0.36 (1.1–2.9)
Distance above CCB (mm)			
Mean \pm SD (range)	6.52 ± 7.31 (1–48)	5.86 ± 10.68 (1–69)	6.20 ± 9.02 (1–69)
Distance below CCB (mm)			
Mean \pm SD (range)	4.53 ± 2.05 (1.0–8.2)	5.29 ± 2.85 (1.5–14.3)	5.03 ± 2.60 (1.0–14.3)

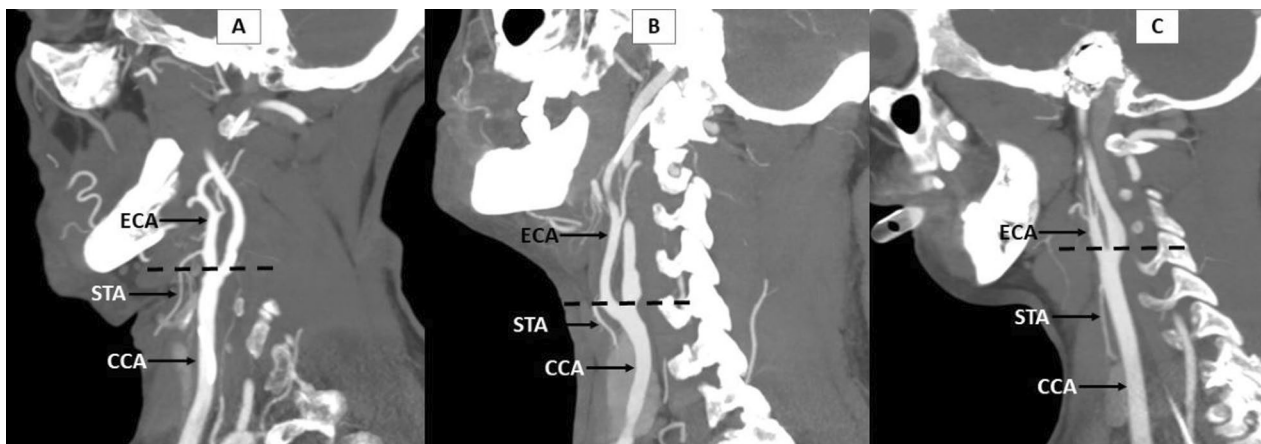


Fig. 2 Origin of STA: Images of the sagittal maximum intensity projection demonstrate changes in the origin of the STA in relation to the CCB's horizontal level. On the CCB horizontal level, a horizontal line is drawn. **A** STA emerges from ECA above the CCB's horizontal level. **B** STA arises at the CCB's horizontal level. **C** STA arises from CCA below the horizontal level of CCB. Superior thyroid artery (STA), common carotid bifurcation (CCB), external carotid artery (ECA), and common carotid artery (CCA)

Table 3 Origin, diameter, and distance of other ECA branches (LA, FA, APA, OA and PAA) from the CCB horizontal level

	LA	FA	APA	OA	PAA
Origin type: n (%) (n = 160)					
Trunk	25 (15.6)	22 (13.7)	28 (17.5)	43 (26.9)	18 (11.3)
Separate	135 (84.4)	138 (86.3)	132 (82.5)	117 (73.1)	142 (88.7)
Diameter (mm)					
Mean \pm SD (range)	2.11 \pm 0.41 (1.4–3)	2.38 \pm 0.44 (1.4–3.4)	1.17 \pm 0.11 (0.8–1.5)	2.17 \pm 0.38 (1.3–3)	1.71 \pm 0.28 (1.0–2.4)
Distance (mm)					
Mean \pm SD (range)	15.18 \pm 11.09 (1.0–99)	21.72 \pm 12.19 (2.0–109)	16.97 \pm 12.13 (3.0–100)	20.79 \pm 15.18 (3.8–111)	33.53 \pm 14.92 (5.3–119)

and 33.53 ± 14.92 mm. The diameters for APA (1.17 ± 0.11 mm) and FA (2.38 ± 0.44 mm) were the smallest and largest, respectively. PAA had a diameter of 1.71 ± 0.28 mm, LA had a diameter of 2.11 ± 0.41 mm, and OA had a diameter of 2.17 ± 0.38 mm (Table 3).

There are seven different varieties of trunks. The least frequent trunks were the APA-OA-PAA trunk, the APA-PAA trunk, and the LA-FA-APA trunk, with 1.3% for each. The most frequent trunk was the APA-OA trunk (25%), followed by the LA-FA trunk (20%) (Fig. 3). The diameters of these trunks and the distance of their origin from CCB were discussed in Table 4.

In one patient, the APA and OA had an anomalous origin from the ICA (Fig. 4).

Discussion

Appropriate knowledge of anatomical variations in the CCB level and ECA branches is essential for head and neck surgeries. The risk of hypoglossal nerve injury increases when the CCB level is high during endarterectomy [1, 8].

It is less likely that the superior laryngeal nerve will be damaged during thyroidectomy if STA anatomical variations are sufficiently understood [10].

Based on CTA's ability to define vascular anatomy, we aimed to use it to detect these variations. Still, cadavers were employed in the majority of studies on these variations.

In our study, C3/4 (33.8%) was the vertebral level where CCB levels are most frequently found.

Similar results to ours were found in two studies on Asian populations, with CCB levels at C3/4 in 56% and 32% [8, 11]. Additionally, research in Mexico found that 30% of the population had the same vertebral level [12].

Two studies on the Turkish population produced results that were different from ours, with the most frequent location being at the C4 vertebral level in 33% and 29% of cases, respectively [9, 13].

When the carotid bifurcation was higher than C3/4, it was considered to be high. 47.5% of the patients in our research of the Egyptian population showed high carotid bifurcation. Our study's incidence is higher than that of previous studies done in Thailand, Turkey, and Mexico.

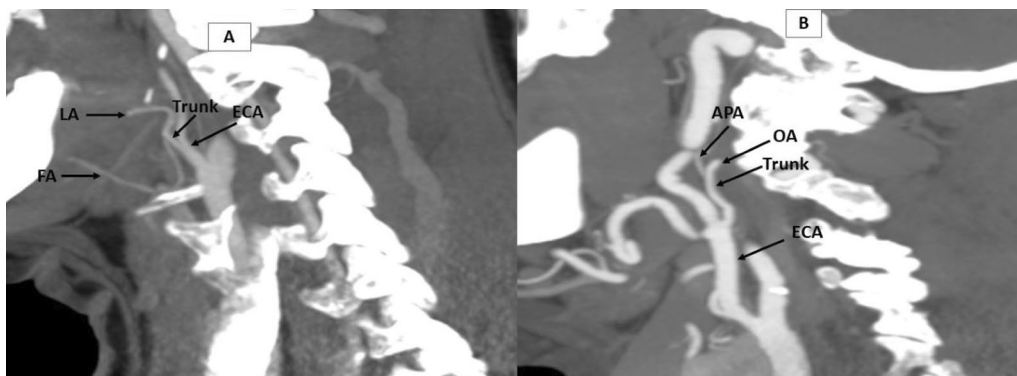


Fig. 3 Common trunks of ECA branches: Common trunks have emerged from the ECA in sagittal maximum intensity projection images. **A** The origin of both LA and FA can be traced to a common trunk that emerges from ECA. **B** The origin of both APA and OA can be traced to a common trunk that emerges from ECA. External carotid artery (ECA), lingual artery (LA), facial artery (FA), ascending pharyngeal artery (APA), and occipital artery (OA)

Table 4 Common trunks of ECA branches: incidence, diameter and distance from the CCB horizontal level

	APA-OA	LA-FA	OA-PAA	STA-LA	APA-OA-PAA	APA-PAA	LA-FA-APA
Incidence n (%) (n=80):							
Absent	60 (75)	64 (80)	67 (83.7)	77 (96.3)	79(98.7)	79 (98.7)	79 (98.7)
Right	6 (7.5)	4 (5)	5 (6.3)	3 (3.7)	1 (1.3)	1 (1.3)	0 (0)
Left	9 (11.2)	7 (8.7)	4 (5)	0 (0)	0 (0)	0 (0)	1 (1.3)
Bilateral	5 (6.3)	5 (6.3)	4 (5)	0 (0)	0 (0)	0 (0)	0 (0)
Diameter(mm):							
Mean ±SD (range)	2.35 ±0.37 (1.8–3)	2.28 ±0.41 (1.8–3)	2.23 ±0.29 (1.7–2.6)	2.23 ±0.42 (1.9–2.7)	2.2	1.2	1.9
Distance(mm):							
Mean ±SD (range)	14.77 ±10.19 (3.8–41)	13.71 ±6.41 (5.0–26)	30.24 ±17.63 (6.3–57.5)	4.23 ±3.79 (0–7.3)	30	13	9.6

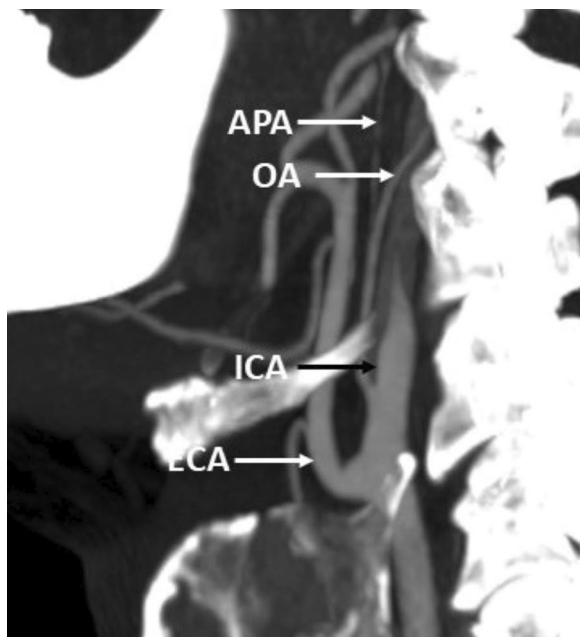


Fig. 4 Anomalous origin of ECA branches: the sagittal maximum intensity projection image reveals that APA and OA had an anomalous origin from ICA. External carotid artery (ECA), ascending pharyngeal artery (APA), occipital artery (OA), and internal carotid artery (ICA)

(31%, 33%, and 36%, respectively) [8, 12, 13]. The disparity in incidence between studies confirms the racial differences in CCB levels between populations.

Our study revealed that the lowest CCB was at D1. The lowest levels were found at C5 and C5-6 by Shen et al. and Jitpun et al. [6, 8]. They are explained by these populations' varied ethnic backgrounds.

Comparing vertebral levels with bifurcation levels, we found statistical differences between males and females. This matched what Demirtas et al. and Shen et al.

reported on the statistical significance [6, 9]. Sasikumar et al. found no statistical significance for this finding [14].

The anatomical variations of STA include its origin at or below the CCB level. We found these variations in 43.1% (19.4% from the CCB level + 23.7% below it).

Charles et al. reported a 57% occurrence of this STA origin variation, while Saha et al. and Sreedharan et al. reported incidences of 19% and 12%, respectively, which were lower than our findings [10, 15, 16]. These earlier studies were based on cadavers, which may account for the difference in incidence reported by them in comparison to our study.

In our investigation, FA had the largest diameter while APA had the smallest; Devadas et al. and Herrera et al. also found this [5, 12].

In our analysis, we identified seven distinct types of trunks. The most frequent trunks were APA-OA trunks (occurring 25% of the time), followed by LA-FA trunks (20%). Jitpun and Demirtas et al. reported LA-FA trunk close to our findings in 29% and 23%, respectively, based on CTA studies [8, 9].

The LA-FA trunk was only found in 1.7% of cadavers in research by Saha et al. In cadavers, Devadas et al. observed no posterior branching trunks as APA-OA [5, 16]. The lower detection rate of cadaveric-based studies as compared to CTA, which has a higher capacity to delineate the vascular anatomy, explains these lower incidence rates.

We identified a trunk from the left internal carotid artery (ICA) in one individual as an abnormal origin for OA and APA. Similar results to ours were reported in three patients by a case-report CTA study [17].

The use of several imaging modalities in earlier studies, including cadaveric dissection, digital subtraction angiography, magnetic resonance angiography, and CTA, causes inaccuracy when comparing studies. This was the first limitation of our study. Additionally, our study was

conducted on an Egyptian population, which may had ethnographic variation. The second limitation was that, in order to find more variations and their precise occurrence, a larger sample size would also be necessary.

Conclusions

Multiple anatomical variations in the CCB level were found using CTA. Additionally, it detected variations in the origin and diameter of the ECA branches. Consequently, it can be a useful imaging modality for their evaluation before surgery.

Abbreviations

CCB	Common carotid bifurcation
ECA	External carotid artery
STA	Superior thyroid artery
CTA	Computed tomographic angiography
MDCT	Multidetector computed tomography
LA	Lingual artery
FA	Facial artery
APA	Ascending pharyngeal artery
OA	Occipital artery
PAA	Posterior auricular artery
ICA	Internal carotid artery

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Author contributions

TF, MS, AG and MM contributed equally to study design, data collection, analysis, and interpretation of results. All authors read and approved the final manuscript.

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Availability of data and materials

Data will be available upon request via contacting the corresponding author.

Declarations

Ethics approval and consent to participate

All study procedures were conducted in accordance with the declaration of Helsinki and were approved by the Ethical Committee of the Menofia faculty of medicine. All data were extracted after taking consent from patients involved in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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