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ANATOMIC VARIATIONS

Origin variations of the superior thyroid, lingual, and facial arteries: a computed tomography angiography study

Mario Herrera-Núñez[1] · José Luis Menchaca-Gutiérrez[2] · Ricardo Pinales-Razo[2] · Guillermo Elizondo-Riojas[2] · Alejandro Quiroga-Garza[1] · Bernardo Alfonso Fernandez-Rodarte[1] · Rodrigo Enrique Elizondo-Omaña[1] · Santos Guzmán-López[1]

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Abstract

Purpose To determine the anatomical variations and morphology of the external carotid artery (ECA) and its anterior branches.

Methods Using computed tomography angiography (CTA), the origin, internal diameter, and surface laterality emergence of the superior thyroid (STA), lingual (LA), and facial (FA) arteries were evaluated retrospectively evaluated and classified. The bifurcation level of the common carotid artery (CCA) in relation to the cervical vertebrae and disc was also determined.

Results A total of 76 CTA were included in the study. STA originated from the carotid bifurcation (CB) (type I), CCA (type II) and ECA (type III) in 20.4 (31/152), 17.1 (26/152) and 50.7% (77/152) cases, respectively. Also 10.5% (16/152) arose from a shared trunk with LA as a thyrolingual trunk (TLT) (type IVa), and absent in 1.3% (2/152). LA originated in the CB in only one case. A linguofacial trunk (LFT) was present in 14.5% (22/152). Mean diameters of STA, LA and FA were 1.70, 1.95 and 2.45 mm, respectively. Meanwhile, surface laterality were predominately from anteromedial, medial, and anterior, respectively. CB was mainly on C3 or C3–C4 (55.9% of cases).

Conclusions STA origin below the ECA is a common finding. Our population presented the highest percentage of TLT (10.5%) and high CB (9.8%) in literature. Considering these variations are important to prevent complications in neck surgical procedures.

Keywords External carotid artery · Computed tomography angiography · The superior thyroid artery · Lingual artery · Facial artery · Thyrolingual trunk · Linguofacial trunk · Morphology · Anatomy

Introduction

The external carotid artery (ECA) has three anterior branches, classically described: superior thyroid artery (STA), lingual artery (LA) and facial artery (FA). Several studies have reported variations in their origin, within the carotid triangle [11, 20, 24]. The typical STA origin from ECA has been reported with prevalence as low as 24–25% in Turkish and Spanish populations [29, 35, 40], and as high as 80.4–88.3–72% in Kenyan and Brazilian [27, 32].

Common origins have been described such as a thyrolingual trunk (TLT) [4, 16, 25], a linguofacial trunk (LFT), and a thyrolinguofacial trunk (TLFT) [23, 27]. Cappabianca et al. reported a prevalence in an Italian population of 10% of LFT, and 3.6% of TLT [4]. Natsis et al. found a higher prevalence of LFT (21%) and a similar one of TLT (3%) in Greeks [24].

There are several different classifications to describe STA origin variations. The classification proposed by Vazquez et al. is the most cited in the literature. Type I was defined when STA originated at the carotid bifurcation (CB) level, type II at the common carotid artery (CCA), type III at the ECA, and type IV when STA arose as a common trunk with 1 or more of the anterior ECA branches. The latter was then

✉ Alejandro Quiroga-Garza
dr.aquirogag@gmail.com

1 Departamento de Anatomía Humana, Facultad de Medicina, Universidad Autónoma de Nuevo León, Francisco I. Madero and Aguirre Pequeño Sin Numero, Colonia Mitras Centro Monterrey, 64460 Nuevo León, Mexico

2 University Hospital “Dr. Jose E. Gonzalez” Radiology and Diagnostic Imaging Department, Universidad Autonoma de Nuevo Leon, Nuevo León, Mexico

subdivided into IVa (TLT) and IVb (TLFT) [36]. Natsis et al. on the other hand, proposed another classification in which type I was for an independent STA which could arise from the ECA, CB, or CCA, and type II was for common trunks [24].

These branches have also been subject to anatomical studies in cadaveric specimens [9, 11, 20, 21, 24, 27–29, 31, 32, 35, 37]. Imaging studies such as the computed tomography angiography (CTA) with 3D reconstruction, is considered a high sensitivity head and neck study for the assessment of vascular structures [1, 4, 14, 33]. It allows better circulatory anatomic visualization, thus improving head and neck surgery planning or minimally invasive procedures (i.e. laparoscopic thyroidectomy, embolizations, selective chemoembolization, endarterectomy, fasciocutaneous flaps of face and neck, etc.) [3, 9, 10, 22, 28, 33, 36, 38]. Anatomical variations also need to be considered to avoid complications such as perforation and rupture that may cause hemorrhage, and the treatment of these [12, 26, 39].

There is a high prevalence of variants of the anterior ECA branch origin, with variability between populations [24, 27, 35]. However, data from Latino populations is limited [11, 32]. It is important to consider these during head and neck surgical procedures [10, 13, 15, 31]. The objective of our study was to determine the variations and morphometries of these branches.

Materials and methods

An observational, retrospective, transversal and descriptive study was performed. Imaging studies (CTAs) were obtained from the database of the Radiology and Image Department of the University Hospital “Dr. José Eleuterio González”. CTA examinations were performed with a 64-slices CTA scanner (General Electric CT99 Light Speed VCT, Software 2978195VCT). CTA parameters were: rotation 0.4 s helicoidal acquisition, 20 mm detector covering, 120 kV, 400+, 0.625 mm width slices, 0.53:1 mm/rot Pitch and 22 to 23 cm FOV.

A total of 152 ECA were included from 76 patients, of which 66% (50/76) were men and 34% (26/76) women, with a mean age of 58.7 ± 16.4 years (18–90 years). CTAs from adult patients (>18 years), without gender distinction, with adequate artery visualization were included. Those with a history of neck surgeries, structural alterations, great tumors, artifacts or cervical trauma were excluded. Those with low image quality or unidentifiable arteries were eliminated. The sample size was previously calculated based on the variability reported in the literature and a confidence of 95%. This resulted in a sample size of 114 carotid arteries however, it was decided to expand the sample size to 152.

Two observers reviewed and analyzed the image studies. Origin related to the carotid bifurcation and vertebral level, internal diameter, and surface laterality emergence of each anterior ECA branches (STA, LA, and FA) were recorded on a database. STA origin was classified according to Vazquez et al. 2009 classification (Fig. 1). CB origin was determined when the vessel’s emergence was in contact with a perpendicular line traced in the division of the CCA. The length was measured when a trunk between two (TLT, LFT) or more arteries was found (TLFT).

Statistical analysis was performed by 20.0 version SPSS computational program for Windows XP. Central tendency tests (average, standard deviation, frequency) were performed to analyze data. Chi-square non-parametric tests were made to assess significant differences between groups according to gender. *p* value equal to or lower than 0.05 was considered statistically significant.

This study was previously reviewed and approved by the University’s ethics and research committees under the registration number AH17-0001.

Results

STA had a typical origin in 50.7% (77/152) of the cases, originating as an only branch from the ECA, with another 37.5% (57/152) originating at a lower level (CB or CCA) (Fig. 1). The remaining 10.5% (16/152) of STAs originated from a common trunk (Table 1) with 1.3% (2/152) absent. Overall, including trunks, only 55.9% (85/152) originated from the ECA, 24.3% (37/152) from the CB, and 18.4% (28/152) from the CCA. STA originated directly from the carotidal system as an individual artery in 88.2% (134/152) of the cases. Only in one case, was the LA originating from the CB.

The origin of the STA from the carotid artery, concerning laterality, had a statistically significant difference (*p* 0.037), as well as in relation to gender (*p* 0.013) (Table 1).

The FA had the largest mean internal diameter and was the furthest from the CB with 2.45 ± 0.46 mm and 20.89 ± 7.66 mm, respectively. STA had a mean distance of 6.7 mm cephalic to the CB when originating from the ECA, and 7.5 mm caudally when originating from the CCA (Table 2).

The most common emerging surfaces were anterior and anteromedial for the STA and FA, while the LA was most prevalent on the anteromedial and medial surfaces. Only 2.6% (4/152) of LA and 2.0% (3/152) of FA originated from a posterior surface (Table 3).

TLT was found in 10.5% (16/152), emerging 8 from ECA and 6 from CB (Fig. 2) (Table 1). LA originated with FA, forming a LFT in 14.5% (22/152) (Fig. 3) (Table 1). The mean length of TLT was 6.60 mm and an

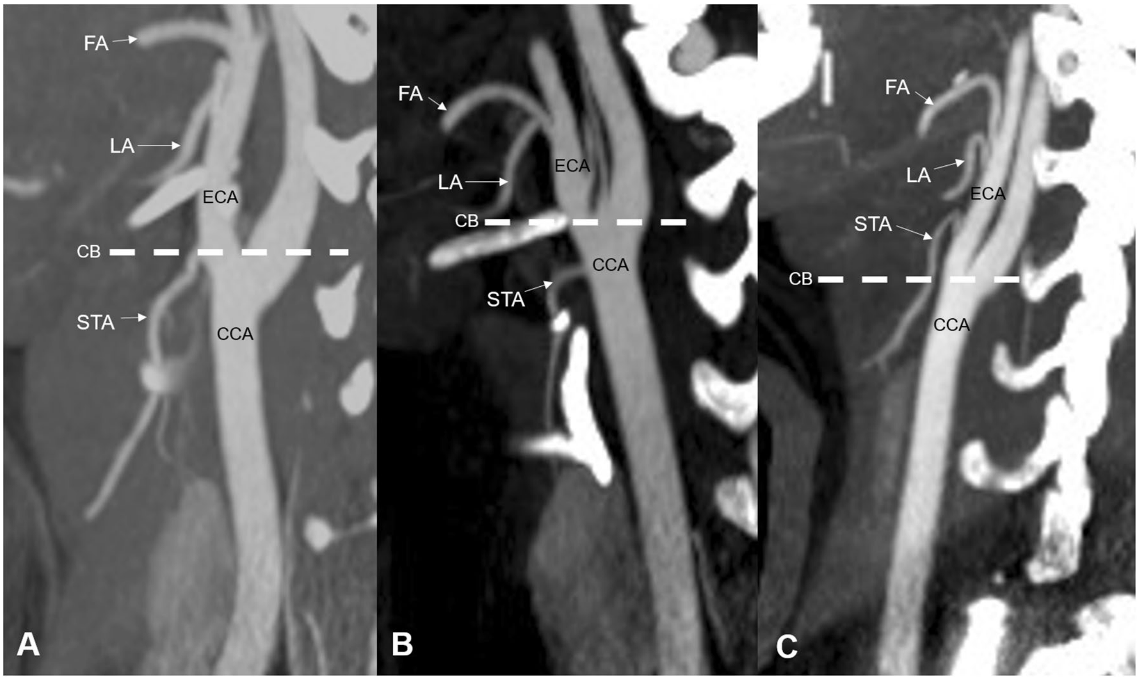

Fig. 1 Origins of superior thyroid artery. Sagittal oblique maximum-intensity-projection CT angiography images showing the variations in the origin of the STA. The horizontal line is the level of CB. **a** Type I (STA originates at the same level as the CB). **b** Type II (STA originates from the CCA). **c** Type III (STA originates from the ECA). *STA* superior thyroid artery, *LA* lingual artery, *FA* facial artery, *ECA* external carotid artery, *CCA* common carotid artery, *CB* carotid bifurcation

Table 1 Superior thyroid artery origin comparison by laterality and gender

STA origin	Right *n* (%) (*n* = 76)		Left *n* (%) (*n* = 76)		Men *n* (%) (*n* = 100)	Women *n* (%) (*n* = 52)
	Type I–III	Type IVa	Type I–III	Type IVa		
CB	18 23.7)		19 (25.0)		28 (28.0)	9 (17.3)
	15 (19.7)	3 (3.9)	16 (21.0)	3 (3.9)		
CCA	8 (10.5)		20 (26.3)		12 (12.0)	16 (30.8)
	7 (9.2)	1 (1.3)	19 (25.0)	1 (1.3)		
ECA	48 (63.2%)		37 (48.7)		59 (59.0)	26 (50)
	43 (56.6)	5 (6.6)	34 (44.7)	3 (3.9)		
Absent	2 (2.6)		0		1 (1.0)	1 (1.9)

Type I superior thyroid artery origin from carotid bifurcation, *Type II* superior thyroid artery origin from common carotid artery, *Type III* superior thyroid artery origin from external carotid artery, *Type IVa* thyrolingual trunk, *ECA* external carotid artery, *CB* carotid bifurcation, *CCA* common carotid artery, *n* sample, % percentage

internal diameter of 2.97 mm. For LFT, the mean length was 9.23 mm and an internal diameter of 3.10 mm. TLFT were not identified emerging from ECA nor CB in this sample population.

CB was most frequent in C3/C4 level with 29.6% (45/152), with overall, 79.6% (121/152) of CB occurring at the levels of C3, C3/C4 and C4 (Table 4).

Discussion

The STA is the most variable anterior branch of the ECA and is of great importance during the planning of any neck surgery, such as thyroidectomy, cricothyroidotomy, tracheostomy, laryngectomy, super-selective intra-arterial

Table 2 Mean internal diameter and distance between each artery origin and CB

Arteries	Internal diameter	Distance to CB	
STA	1.70 ± 0.46	Type I	0.0
		Type II	7.5 ± 4.19
		Type III	6.7 ± 2.50
LA	1.95 ± 0.57	15.89 ± 7.17	
FA	2.45 ± 0.66	20.89 ± 7.66	

All values expressed as mean ± SD (mm)

STA superior thyroid artery, *LA* lingual artery, *FA* facial artery, *Type I* superior thyroid artery origin from carotid bifurcation, *Type II* superior thyroid artery origin from common carotid artery, *Type III* superior thyroid artery origin from external carotid artery

chemotherapy, endarterectomy, and minimally invasive procedures of the neck due to the risk of damage [1, 3, 4, 10, 12, 14, 15, 22, 26, 28, 33, 36, 38, 39]. Imaging studies do not classically report vascular variations; therefore, the surgeon should keep in mind the high anatomical variability of these to prevent complications, such as perforation and rupture [3, 5, 10, 12, 15, 26, 39]. Most STA studies have been performed in cadavers and few with image studies (Table 5).

STA origin has been a controversial topic. Embryologic studies confirm an origin from the CB and CCA, forming from them third aortic arch, while ECA derives from the first and a contribution of the second. Consequently, STA classification can be divided into two categories: one from CB and CCA and the other from just ECA [21, 24, 35].

Classically CCA has no collateral branches [2, 22]. STA origin incidence from the CCA have been reported from 3 to 45% [1, 4, 6, 8, 21, 24, 29, 32, 35, 37]. We observed an overall incidence of 17.1% (26/152), with a significantly higher prevalence in women (30.8% 16/52) than in men (12.0% 12/100) (p 0.013). At a CB level, prevalence ranges between 2 and 49%[4, 18, 19, 21, 24, 27, 35, 40]. We report a 20.4% (31/152) prevalence as an individual branch.

The common trunk of the anterior branches of the ECA variates. The TLT is composed of an artery or common trunk that after a short distance, branches the STA and LA. The trunk can originate from the ECA, CB or CCA. The latter is the least frequent [16, 25]. Past studies have reported a low incidence of TLT ranging from 0 to 3.5% [24, 25, 27, 31, 35]. In this study we found a high TLT prevalence in 10.5% (16/152) of the cases, including a bilateral case from CB, the highest reported in the literature, except for Won et al. [37], who reported a prevalence of 16.7% in 15 cadavers, without differentiating between TLT and TLFT.

The lingual and facial arteries have also been reported absent (agenesis) from the carotid artery, or as ectopic branches, such as an intra-parotid origin [15, 17, 19, 29, 31, 34]. An origin as a common trunk, such as the LFT have been reported between 7.5 and 31% [9, 21, 24,, 31, 40]. We report a 14.5% (22/152) prevalence, similar to that of a Turkish (7.5%) [29] and Italian (10%) [4] populations. TLFT are rare, most studies reporting below 1% [4, 11, 21, 23, 24, 31, 35], except for Ongeti et al. [27], who reported a 6.5% prevalence in a Kenyan study. We found no cases in our study.

STA was absent in 1.3% (2/152) cases, both on the right side. Therefore, 74 right and 76 left STA were analyzed. Laterality was significant, as 39 out of 65 (60%) samples with an abnormal origin (CB or CCA) were left-sided ($p = 0.037$); these results coincide with previous authors that attribute left preference due to the aortic arch evolutionary and anatomic asymmetry, as well as to the thyroid embryonic gen [21, 24, 35, 40].

CB is usually described at the same level as the superior border of the thyroid cartilage (C3–C4 vertebral level) [13, 15, 22, 37]. Zümre et al. studied 40 fetuses and reported CCA bifurcation from C3, C4, and C5 in 55, 35, and 10%, respectively from the right sides; while from C3 and C4 in 60 and 40%, respectively from left sides [40]. Similarly, Klosek et al. reported CB with 2.7% in C2/C3, 10.4% in C3, 20.9% in C3/C4, 30.2% in C4, 16.3% in C4/C5 and 8.1% in evel C5 [13]. This study found the most frequent CB was localized at the intervertebral disk of C3/C4 with 29.6% (45/152), with 79.6% (121/152) between the vertebral bodies C3 and C4. However, 9.8% (15/152) had a high bifurcation (above vertebral body C3) and 10.5 (16/152) a low bifurcation (below vertebral body C4). High bifurcation is rare [7, 13]. This presentation should

Table 3 Emergence surface of the external carotid artery's anterior branches

Emergences surfaces	STA *n* (%) (*n* 152)	LA *n* (%) (*n* 152)	FA *n* (%) (*n* 152)
Anterior	61 (40.1)	18 (11.8)	71 (46.7)
Anteromedial	63 (41.4)	47 (30.9)	53 (34.9)
Anterolateral	2 (1.3)	2 (1.3)	4 (2.6)
Lateral	0 (0)	0 (0)	2 (1.3)
Medial	24 (15.8)	81 (53.3)	19 (12.5)
Posterior, posteromedial, posterolateral	0 (0)	4 (2.6)	3 (2.0)

STA superior thyroid artery, *LA* lingual artery, *FA* facial artery

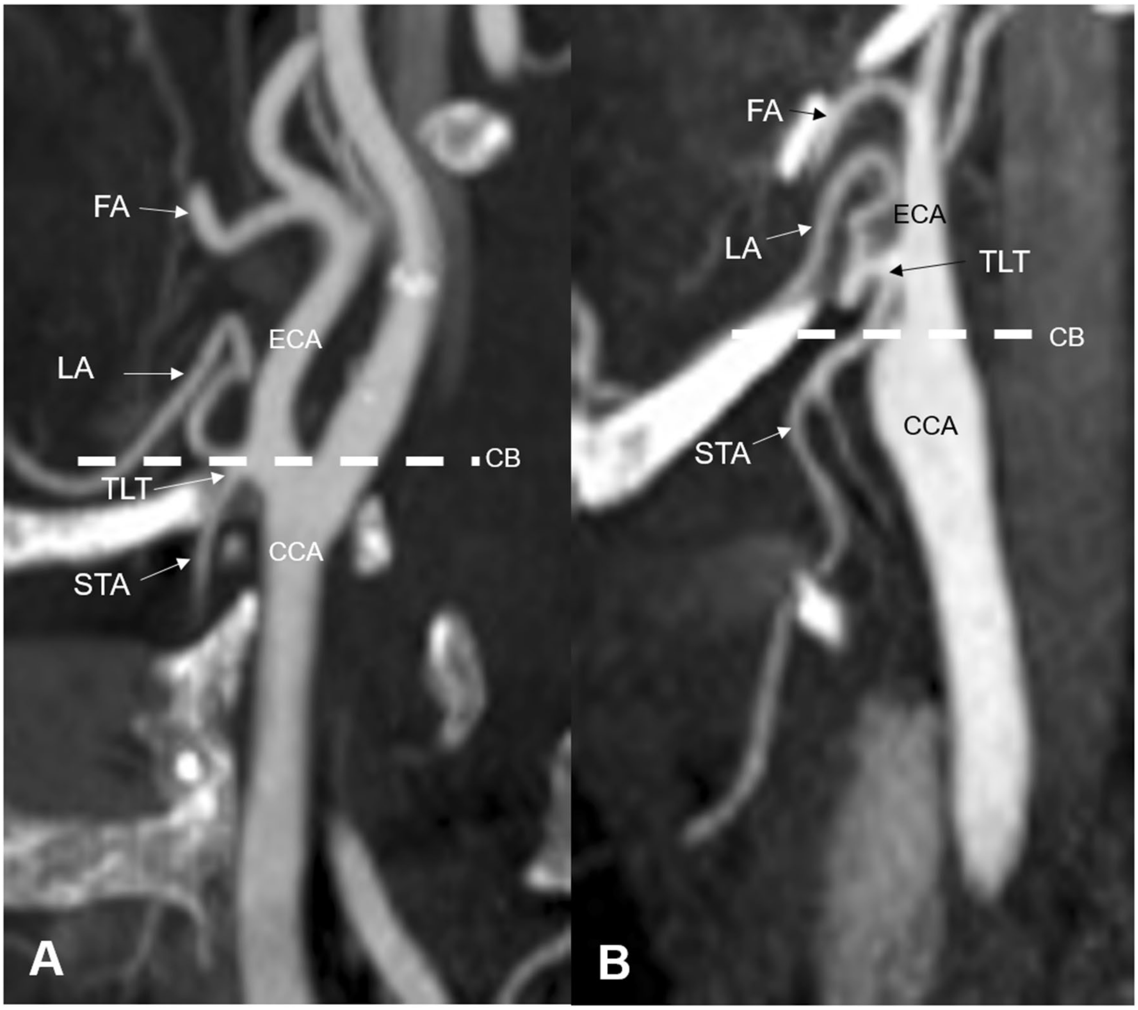

Fig. 2 Origins of the thyrolingual trunk (Type IVa). Sagittal oblique maximum-intensity-projection CT angiography images showing the variations in the origin of the TLT. The horizontal line is the level of CB. **a** TLT originating at the same level of the CB and branching into LA and STA. **b** TLT originating from the ECA before branching into LA and STA. *TLT* thyrolingual trunk, *STA* superior thyroid artery, *LA* lingual artery, *FA* facial artery, *ECA* external carotid artery, *CCA* common carotid artery, *CB* carotid bifurcation

warn a possible lesion to the hypoglossal nerve, a nerve that passes with the carotid artery and the jugular vein in the carotid sheath, as well as other risks during surgical procedures, such as minimally invasive surgery, catheterization, endarterectomy, fasciocutaneous flaps, etc [5, 7, 9, 10, 13, 15, 17, 19, 22, 29, 37].

Variations in the vascular anatomy have been correlated with a higher prevalence of complications. These should be considered during surgical procedures (conventional and minimally invasive) as they may be damaged or occluded due to their abnormal origin. They are also important during the treatment of complications such as unexpected hemorrhages. Common trunks should also be kept in mind during chemoembolization as treatment for malignancies, due to the shared origin and extensive blood supply [3, 9, 10, 12, 13, 15, 19, 20, 22, 23, 26, 29, 32–34, 40].

Narayanan et al. proposes that altered blood flow due to a high CB could originate a disproportionated growth and thus changes in ECA branches' origins [23]. In our study, there was no statistical relationship between a high CB and a higher incidence of STA from CB or CCA ($p = 0.308$).

Our study has several limitations. Although the sample was obtained from a large reference center of the northeastern part of Mexico, its results cannot be generalized, due to ethnical differences between the regions of the country. Measurements were performed by two observers. However, kappa coefficient for interobserver reliability was not performed. Strengths of this study include the calculation of a sample population, to validate results. Few studies include as many parameters in their analysis (STA origin, laterality, and gender correlation, morphometry of all anterior branches, the prevalence of individual branches and common trunks,

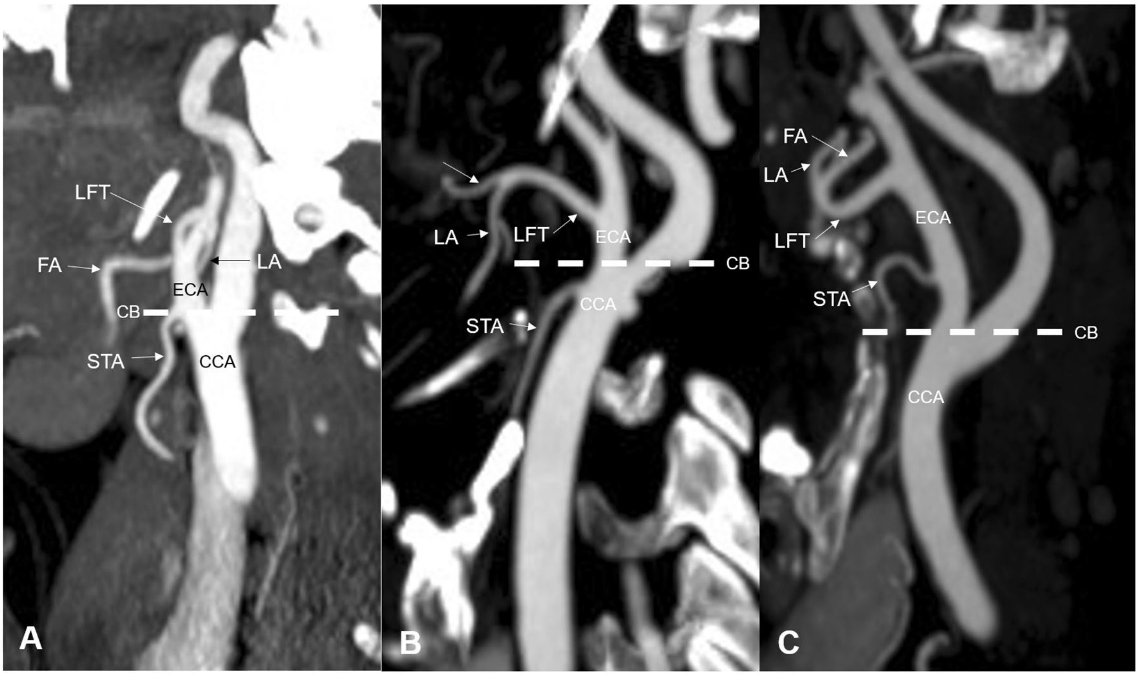

Fig. 3 Linguofacial trunk origin classification. Sagittal oblique maximum-intensity-projection CT angiography images showing the variations of the LFT according to the Natsis et al. classification, in which the LFT originates from the ECA, and the STA originates in different levels. **a** LFT-$_{CB}$ (LA and FA as common trunk from the ECA, and the STA as separate branch emerging from CB). **b** LFT-$_{CCA}$ (LA and FA as common trunk emerging from the ECA, and the STA as separate branch emerging from CCA). **c** LFT-$_{ECA}$ (LA and FA as common trunk emerging from the ECA, and the STA as a separate branch emerging from ECA). *LFT* linguofacial trunk, *STA* superior thyroid artery, *LA* lingual artery, *FA* facial artery, *ECA* external carotid artery, *CCA* common carotid artery, *CB* carotid bifurcation

Table 4 Vertebral level of carotid bifurcation

Vertebral level	Men ($n=100$)		Women ($n=52$)		Total
	Right ($n=50$)	Left ($n=50$)	Right ($n=26$)	Left ($n=26$)	n (%)
C2	1 (2%)	1 (2%)	1 (3.8%)	1 (3.8%)	4 (2.6)
C2–C3	1 (2%)	2 (4%)	3 (11.5%)	5 (19.2%)	11 (7.2)
C3	13 (26%)	12 (24%)	9 (34.6%)	6 (23.0%)	40 (26.3)
C3–C4	16 (32%)	16 (32%)	7 (26.9%)	6 (23.0%)	45 (29.6)
C4	13 (26%)	14 (28%)	4 (15.3%)	5 (19.2%)	36 (23.7)
C4–C5	6 (12%)	4 (8%)	2 (7.6%)	2 (7.6%)	14 (9.2)
C5	0 (0%)	1 (2%)	0 (0%)	1 (3.8%)	2 (1.3)

Values expressed as sample size and percentage: n (%)

surface of emergence, and vertebral level of bifurcation stratified by gender and laterality). A simple review was performed to compare results amongst populations and studies.

Conclusion

The STA originated from the ECA (Type III) as an independent artery, as described in the literature, in only half of the cases (50.7%, 77/152). A high incidence of variability was shown, with 37.5% (57/152) emerging from the CB (type I) or CCA (type II), and the remaining 11.8% originating from a common trunk (Type IVa, 16/152) or absent (2/152).

Our population presented a high percentage of TLT (10.5%, (16/152)), the highest in literature according to our knowledge. The percentage of TLFT (Type IVb) was null, similar to the low prevalence of other authors. STA origin variations were significantly different in gender (p 0.013), with more men having an origin at the CB (28.0 [28/100) vs 17.3% [9/52]), and more women at the CCA (30.8 [16/51] vs 12.0% [12/100]). CCA origin was also statistically (p 0.037) more common on the left side than the right (26.3 [20/76] vs 10.5% [8/76]).

Table 5 Superior thyroid artery origin literature review (trunks)

Study	Method	*n* (heminecks)	Type I (%)	Type II (%)	Type III (%)	Type IVa (%)	Type IVb (%)	LFT	STA mean diameter (mm)
Itezerote et al. (Brazil, 1999) [11]	Cadaveric	110	15.4	16.4	67.3	–	0.9	–	–
Shintani et al. (Japan, 1999) [31]	Cadaveric	58	100[a]			3.5	0	31.0	1.5
Zümre et al. (Turkey, 2005) [40]	Cadaveric (fetus)	40	75	5	25	2.5	2.5	20	–
Hayashi et al. (Japan, 2005) [9]	Cadaveric	98 (M 50, F 48)	30[b]		70	1	–	18	–
Terayamna et al. (Japan, 2006) [33]	Angio	96	44	9	46	–	–	–	–
Ozgur et al. (Turkey, 2008) [29]	Cadaveric	40 (M 34, F 6)	40	35	25	2.5	–	7.5	3.5 ± 1.2[e]
Vázquez et al. (UK, 2009) [35]	Cadaveric	207 (M 95, F 112)	49	27)	24	0.6	0.3	–	2.6 ± 1.2[e]
Natsis et al. (Greek, 2011) [24]	Cadaveric	100 (M 88, F 12)	49	12	39	3	0	21	–
Ongeti et al. (Kenya, 2011) [27]	Cadaveric	46 (M 36, F 10)	2.2	10.9	80.4	0	6.5	–	–
Cappabianca et al. (Italy, 2012) [4]	CT and MR	165	42	11	–	3	1	10	
Mata et al. (Brazil, 2012) [21]	Cadaveric	36	45.3	3.5	51.2	2.8	0	19.9	–
Acar et al. (Turkey, 2013) [1]	CTA	200 (M 100, F 100)	31	18	51	2	–	–	–
Gupta et al. (India, 2014) [8]	Angio	25	20	4	72[c]	–	–	–	–
Manjunath et al. (India, 2016) [20]	Cadaveric	30	23.33	16.66	60	–	–	–	–
Won et al. (Korea, 2016) [37]	Cadaveric	30 (M 20, F 10)	40	40	20	16.7		–	–
Esen et al. (Turkey, 2018) [6]	CTA	1280 (M 758, F 522)	21.8	24.7	52.1[d]	–	–	–	–
Sreedharan et al. (Brasil, 2018) [32]	Cadaveric	60	8.33	3.33	88.33	–	–	–	–
Herrera-Núñez et al. (Mexico, 2020)	CTA	152 (M 100, F 52)	20.4	17.1	50.7	10.5	0	14.5	1.70 ± 0.46

CTA computed tomography angiography, *MRA* magnetic resonance angiography; *Angio* angiography, *CT* computed tomography, *MR* magnetic resonance, *n* sample size, *Type I* superior thyroid artery origin from carotid bifurcation, *Type II* superior thyroid artery origin from common carotid artery, *Type III* superior thyroid artery origin from external carotid artery, *Type IVa* thyrolingual trunk, *Type IVb* thyrolinguofacial trunk, *LFT* linguofacial trunk, – data not reported

[a]Differences in STA origins were not reported

[b]Authors combined CB and CCA results

[c]Remaining 4 originated from internal carotid artery

[d]Remaining 1.4 STA were absent

[e]Outer diameter

We propose considering a high prevalence of anatomical variations in our population, in regards to the anterior branches of the ECA, to prevent complications in surgical procedures (i.e. conventional open neck surgery of the thyroid, trachea, larynx and adjacent structures, minimally invasive procedures with implementation of laparoscopy, endoscopy and robotic surgery of the neck, as well as embolization, and selective chemoembolization, treating complications such as hemorrhages, etc.) of our population.

Author contributions MH-N: Idea development, Protocol/project development, Submission to Committees, Data collection and management, Data analysis, Manuscript writing, manuscript editing. JLM-G: Protocol/project development, Data collection and management, Data analysis, Manuscript writing. RP-R: Protocol/project development, Data collection and management, Data analysis, Manuscript writing. GE-R: Protocol/project development, Submission to Committees, Data analysis, manuscript editing. AQ-G: Idea development, Protocol/project development, Submission to Committees, Data collection and management, Data analysis, Manuscript writing, manuscript editing. BAF-R: Idea development, Protocol/project development, Data analysis, Manuscript writing. REE-O: Idea development, Protocol/project development, Data analysis, Manuscript editing. SG-L: Idea development, Protocol/project development, Data analysis, Manuscript editing.

Compliance with ethical standards

Conflict of interest This study was not funded by any academic or industry resources. Therefore, authors declare the absence of conflict of interest.

Ethical approval This study was submitted and approved by the local research committee.

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