



Variations in the origins of the thyroid arteries on CT angiography

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Abstract

Objective To investigate the anatomical variations in the origins of the thyroid arteries on CT angiography images.

Methods The presence and the origins of the superior thyroid artery, the inferior thyroid artery, and the thyroidea ima artery were retrospectively evaluated based on carotid CT angiography examinations. The bifurcation level of the common carotid artery with respect to the cervical vertebrae and disc spaces was also determined. A total of 640 patients were included in the study.

Results The right and left superior thyroid arteries arose from the external carotid artery in 413 (64.5%) and 254 (39.7%) patients, from the bifurcation of the common carotid artery in 131 (20.5%) and 148 (23.1%) patients, and from the common carotid artery in 90 (14.1%) and 226 (35.3%) patients, respectively. We could not observe the right and the left superior thyroid arteries in 6 (0.9%) and 12 (1.9%) of the patients, respectively. However, the right and left inferior thyroid arteries were not identified in 14 (2.2%) and 45 (7%) of the patients, respectively. The thyroidea ima artery was detected in 2.3% of the patients.

Conclusion The visualization of thyroid arteries on CT angiography images enables the anatomy of the arterial supply system of the thyroid gland to be explored in a noninvasive manner prior to surgery.

Keywords Thyroid artery · CT angiography · Origin variation

Introduction

The thyroid gland is a highly vascular endocrine gland that is supplied by the superior and inferior thyroid arteries. An awareness of the possible patterns for the origins, courses, and branching of the thyroid arteries is mandatory prior to surgery or interventional procedures [1, 2]. Complications

can arise when a thyroid artery has an unusual origin. The superior thyroid artery (STA) usually arises from the external carotid artery (ECA) as the first branch, and it has been mentioned that the branches of the ECA act as key landmarks in the carotid triangle for the adequate dissection of carotid arteries during carotid endarterectomy [3]. The inferior thyroid artery (ITA) is considered the principal artery of the thyroid gland and normally arises from the thyrocervical trunk [4]. Anatomical knowledge of the site at which the ITA originates is essential not only for surgery but also during the catheterization of the artery for either diagnostic or therapeutic purposes [2, 5, 6]. The thyroidea ima artery (TIA) occurs as an anatomical variant in 3–10% of the population and mainly arises from the brachiocephalic trunk [7]. The high variability of the origin and the occurrence rate of the TIA can lead to bleeding during surgery or tracheostomy [7, 8].

Identifying uncommon variations in the thyroid arteries preoperatively may help to minimize any potential complications. Although Computed tomography angiography (CTA) is a useful noninvasive multiplanar imaging modality for vascular mapping, there is not enough CTA data on the

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origin variations of the thyroid vasculature. Therefore, we aimed to investigate the origin variations of thyroid arteries via CTA examinations.

Materials and methods

Approval for the study was obtained from the ethical committee of our institute. The acquisition of informed consent was waived.

Study population

Carotid CTA examinations performed between January 2014 and December 2016 in our clinic were retrospectively evaluated. CTA examinations were mainly performed to diagnose vascular stenosis, aneurysms, and vascular malformations. Patients who were under 18 years old or had common carotid occlusions, vascular abnormalities such as carotid hypoplasia, or heavy plaque in the carotid bifurcation, as well as those who had been examined inadequately due to artifacts (such as patient movement) were excluded. Patients with a history of surgery related to the thyroid gland were also excluded. A total of 640 patients, 379 (59.2%) males and 261 (40.8%) females, were included in the study. The mean ages of the males and females were 62.4 ± 13.8 and 59.1 ± 15.7 years, respectively.

CTA imaging protocol

CTA examinations were performed with a 64-slice CT scanner (Toshiba Aquilion 64, Toshiba Medical Systems, Tokyo, Japan). Eighty milliliters of nonionic contrast medium were administered using the bolus tracking technique. Scanning was initiated when the contrast attenuation in the aortic arch reached 100 Hounsfield units with a tube voltage of 120 kVp and slice thickness of 0.5 mm. Reformulation along the coronal and sagittal plane was obtained from axial images. Scanning was performed from the ascending aorta to the vertex.

Evaluation of thyroid arteries

The eligibility of each CTA image was determined by two experienced radiologists. Thyroid arteries were evaluated on coronal and sagittal images by the same radiologists in consensus. Both sides of the neck were studied in 640 patients. The presence and the origin sites of the superior and inferior thyroid arteries were evaluated. However, the evaluation was limited to the origin of each vessel.

We categorized the origin site of the STA into three main levels: the common carotid artery (CCA), the CCA bifurcation, and the ECA. The horizontal line crossing the CCA bifurcation was defined as the level of bifurcation, as

previously mentioned in the literature [9]. The origin of the STA was considered to be the bifurcation level if the origin site crossed this line at either the cranial or caudal boundary (Fig. 1).

The presence and the origin site of the ITA were evaluated. An analysis of whether the ITA originated from the thyrocervical trunk or as a single root from the subclavian artery was performed; if the origin of the ITA could not be detected at those sites, the vertebral artery and the CCA were also investigated.

When the TIA was present, its site of origin was recorded.

Additionally, on sagittal images, the bifurcation level of the CCA with respect to the cervical vertebrae and disc spaces was evaluated.

Statistical analysis

The relationship between the STA origin level and the CCA bifurcation level was tested using Cramér's V test. In addition, the marginal homogeneity test (the Stuart–Maxwell test) was applied to differences between the right and left measurements of the STA origin and CCA bifurcation levels. Numerical and percentage values are given below as descriptive statistics.

Results

Table 1 shows the distribution of the STA origin site. The superior thyroid artery most frequently originated from the ECA on the right (64.5%) and on the left (39.7%) sides. There was a statistically significant difference between the origin levels of the right and left STAs ($p < 0.001$). We could not observe the right STA and the left STA in 6 (0.9%) and 12 (1.9%) patients, respectively. Both STAs were absent in 2 (0.3%) patients. Additionally, in 2 patients, two STAs were detected on the right side.

In our study population, the number of right and left ITAs arising from the thyrocervical trunk were 608 (95%) and 578 (90.3%), respectively. Eighteen (2.8%) right ITAs and 13 (2%) left ITAs originated as a single root from the subclavian artery. We could not identify 14 (2.2%) right ITAs and 45 (7%) left ITAs. Both ITAs were absent in six (0.9%) patients. Four left ITAs originated from the vertebral artery.

The TIA was detected in 15 (2.3%) patients. Twelve of these arose from the brachiocephalic artery, two from the right CCA, and one from the arcus aorta. Among the patients with a TIA, we could not observe either ITA in two patients and one of the ITA in six patients. However, both ITAs and the TIA were present in seven patients.

There was no statistically significant difference between the right and left CCA bifurcation levels ($p = 0.307$). We also categorized the bifurcation levels of the left and right

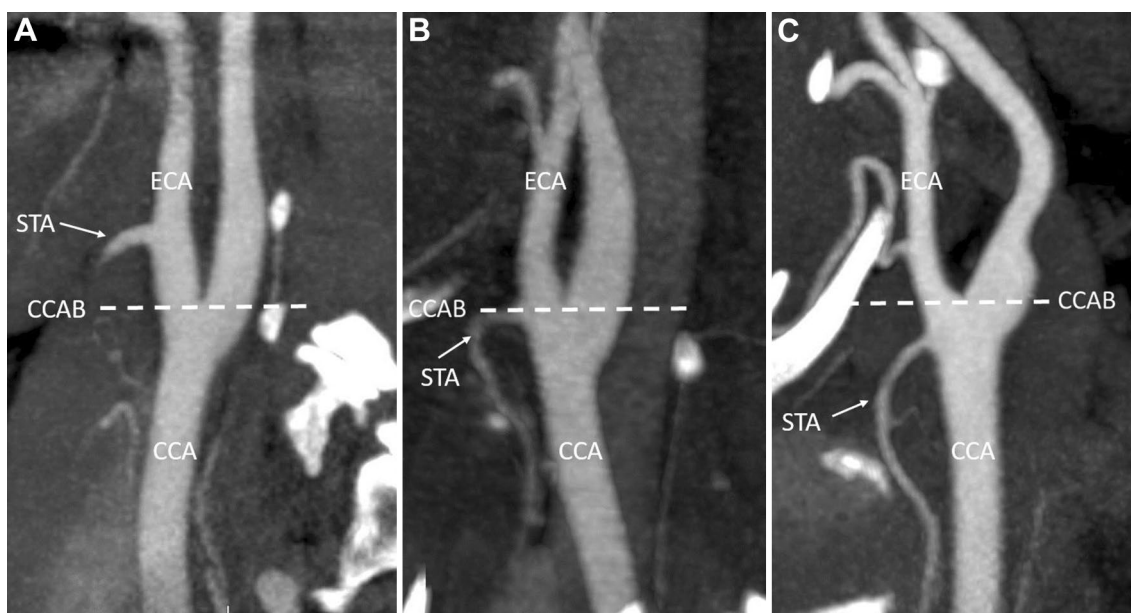


Fig. 1a–c Sagittal oblique maximum-intensity-projection CT angiography images showing the variations in the origin of the STA. The horizontal line is the level of CCA bifurcation. **a** The STA originates from the ECA. **b** The STA arises from the CCA bifurcation. **c** The

STA arises from the CCA (STA superior thyroid artery, ECA external carotid artery, CCA common carotid artery, CCAB common carotid artery bifurcation)

Table 1 Distribution of the superior thyroid arteries with respect to the site of origin

	Absent	ECA	CCA bifurcation	CCA
RSTA, <i>n</i> (%)	6 (0.9)	413 (64.5)	131 (20.5)	90 (14.1)
LSTA, <i>n</i> (%)	12 (1.9)	254 (39.7)	148 (23.1)	226 (35.3)

n Number of patients, ECA external carotid artery, ICA internal carotid artery, CCA common carotid artery, RSTA right superior thyroid artery, LSTA left superior thyroid artery

CCAs with respect to the cervical vertebrae and disc spaces as level 1 (C2 and C2–3), level 2 (C3, C3–4, C4, C4–5), or level 3 (C5, C5–6, C6, C6–7), and attempted to correlate this level with the origin site of the STA on the carotid arteries (Tables 2 and 3). The correlation was found to be statistically significant ($p < 0.001$). In the majority of the patients, the bifurcation level of the CCA was 2. The percentage of patients in which the STA originated from the ECA was significantly higher for the patients with left CCA bifurcation at level 3 than for those with left CCA bifurcation at level 2 or

1 ($p < 0.001$). The same was true of the patients with right CCA bifurcation at level 3 ($p = 0.7386$). Additionally, the percentage of patients in which the STA originated from the CCA was significantly higher for the patients with left CCA bifurcation at level 1 than for those with left CCA bifurcation at level 2 or 3 ($p = 0.0017$).

Discussion

The anatomical variations of the thyroid arteries are well defined in the literature due to various studies. Various techniques, such as cadaveric dissections, radiography of cadavers, and angiography, have been used to study these variations [10]. However, in our daily practice, CTA has become an indispensable noninvasive examination method for studying blood vessels that can show vascular lumina, vascular walls, and perivascular structures [11]. Therefore, in contrast to the rest of the literature in this field, we investigated the visibility and origin site variations of the thyroid

Table 2 The bifurcation levels of the common carotid arteries with respect to the cervical vertebrae and disc spaces

	C2	C2–3	C3	C3–4	C4	C4–5	C5	C5–6	C6	C6–7
RCCA, <i>n</i> (%)	6 (0.9)	25 (3.9)	175 (27.3)	131 (20.5)	185 (28.9)	62 (9.7)	47 (7.3)	6 (0.9)	2 (0.3)	1 (0.2)
LCCA, <i>n</i> (%)	7 (1.1)	25 (3.9)	186 (29.1)	126 (19.7)	185 (28.9)	57 (8.9)	43 (6.7)	7 (1.1)	4 (0.6)	0 (0)

n Number of patients, RCCA right common carotid artery, LCCA left common carotid artery

Table 3 Comparison of the origin site of the STA on the carotid arteries to the bifurcation level of CCA with respect to the cervical vertebrae/disc spaces

	Origin site of STA			<i>p</i>
	ECA	CCA bifurcation	CCA	
RCCA, <i>n</i> (%)				
Level 1	17 (56.7)	3 (10)	10 (33.3)	< 0.001
Level 2	347 (63.3)	124 (22.6)	77 (14.1)	
Level 3	49 (87.5)	4 (7.1)	3 (5.4)	
LCCA, <i>n</i> (%)				
Level 1	6 (20)	5 (16.7)	19 (63.3)	< 0.001
Level 2	212 (38.9)	137 (25.1)	196 (36)	
Level 3	36 (67.9)	6 (11.3)	11 (20.8)	

n Number of patients, *ECA* external carotid artery, *RCCA* right common carotid artery, *LCCA* left common carotid artery, *STA* superior thyroid artery

arteries using a cross-sectional imaging modality that is widely used before surgical and interventional procedures.

According to classical anatomy, the STA is a branch of the external carotid artery [12]. However, the variability in the origin site of the STA from the carotid arteries has been evaluated in various studies, and it is reported that the STA can also originate from the CCA or the CCA bifurcation. Different classifications have been used to evaluate the origin of the STA, including whether it is distinct or whether the STA originates from the same trunk as the facial and lingual arteries. Vázquez et al. [13] defined four major types of STA origin. The first three were those from the ECA, the CCA bifurcation, and the CCA. In the fourth type, the STA originated from the same trunk as other branches of the carotid arterial tree. Natsis et al. [14] proposed a classification system with two main types of branching patterns. In type I, no trunks were present; in type II, there was always a trunk. Anagnostopoulou and Mavridis [9] revealed a classification with three types in which a STA originating from a common trunk was classified as a subgroup originating from the ECA. Whether the superior thyroid artery originates as an individual root or as part of a common trunk is an important distinction in these classifications. However, the STA is commonly considered to originate from either the ECA or the CCA bifurcation or the CCA. We did not evaluate whether the STA was a distinct branch in our study; we only evaluated the origin site of the STA or the origin site of the common trunk of the STA.

The question of whether the STA originates more frequently from the ECA, the CCA bifurcation, or the CCA is a controversial issue in the literature [14]. Toni et al. [15], in a meta-analysis of STA variations, classified STA origins into three major groups, and reported that the STA more frequently originated from the ECA on the right side and from the CCA on the left side in both Caucasoids and

East Asians. A substantial asymmetry between the two sides of the neck in terms of the origin site of the STA has been demonstrated in East Asians. Lučev et al. [16] reported that the STA arose more often from the CCA than from the ECA and the CCA bifurcation. Vázquez et al. [13] dissected 330 embalmed human heminecks and reported that the most frequent site of STA origin was the carotid bifurcation (49%). Natsis et al. [14] reported that the STA originated from the external carotid artery in 39% and at the level of the carotid bifurcation or the common carotid artery in 61% of cases. In our study, the STA more frequently originated from the ECA on both the right (64.5%) and left (39.7%) sides. However, on the left side, the percentage of STAs originating from the CCA (35.3%) was close to the percentage of STAs originating from the ECA.

The inferior thyroid artery appears to be more variable than the STA (Fig. 2) [17]. An absent ITA, an accessory/double artery, and an origin that is not sited on the thyrocervical trunk are the major variations described in the literature. An earlier report revealed that about 15% of all ITAs arise from the subclavian artery [18]. Inferior thyroid arteries originating from the vertebral artery, the internal thoracic artery, and the common carotid artery have also been reported [2, 4, 19]. In a study reported by Roshan et al. [17], ITAs were found in both the right and left sides of all 50 cases dissected. On the left side, the ITA originated from the thyrocervical trunk in all cases. On the right side, the ITA originated from the thyrocervical trunk in 48 patients (96%) and from the subclavian artery in 2 patients (4%). In our study population, the percentage of ITAs arising from the subclavian artery was 4.8%, and the percentage arising from the vertebral artery was 0.6%.

The thyroidea ima artery is a rare anomalous artery supplying the thyroid gland [20]. It ascends in front of the trachea and also supplies the parathyroid glands and trachea [7]. This artery is normally found in the fetus and occurs subsequently as a persistent embryonic artery [7, 20]. Though rare, the course of the thyroidea ima artery in the superior mediastinum and lower neck is hazardous and may cause complications during surgery of the thyroid and parathyroid glands, the trachea, and the mediastinum [8, 20]. Most commonly, the TIA arises from the brachiocephalic artery, the aortic arch, or the CCA. In the present study, we found that the TIA arose from the aortic arch, the brachiocephalic trunk, or the CCA, as mentioned in the literature (Fig. 3) [21]. It may also originate from the subclavian artery, the cardiophrenic artery, the thyrocervical trunk, or the internal mammary artery [7]. It has been mentioned that, in some cases, the TIA replaces the ITA and becomes one of the principal arteries supplying the gland [7, 8, 22]. Krudy et al. [23] reported that if routine angiography is negative and the inferior thyroid arteries are small or absent, a TIA

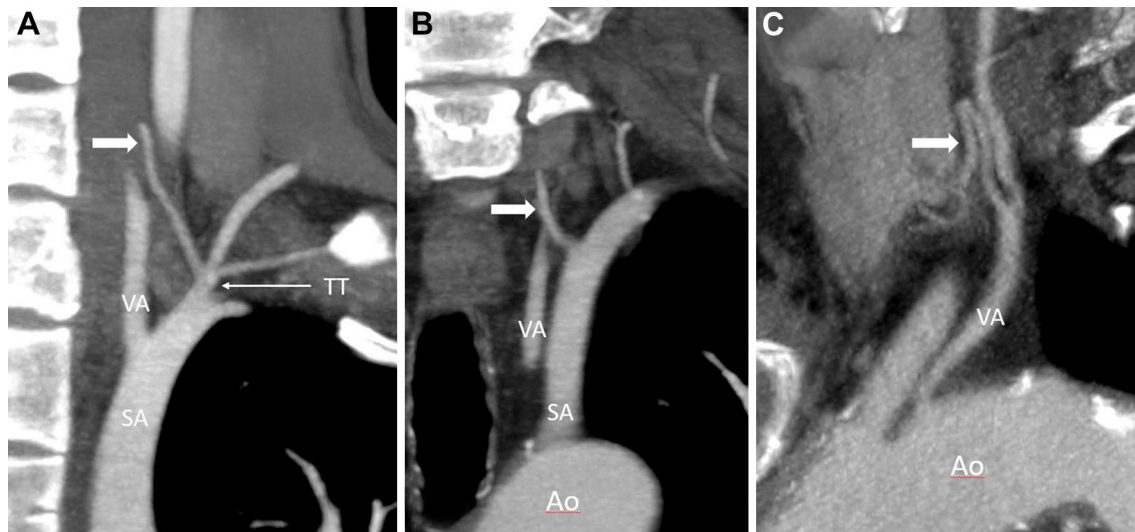


Fig. 2a–c Maximum-intensity-projection CT angiography images show different sites of origin of the inferior thyroid artery (ITA). **a** The ITA arises from the thyrocervical trunk (*arrow*). **b** The ITA originates from the subclavian artery (*arrow*). **c** The ITA arises from the

vertebral artery (*arrow*). Note the vertebral artery arising from the aortic arch (*Ao* aortic arch, *SA* subclavian artery, *VA* vertebral artery, *TT* thyrocervical trunk)

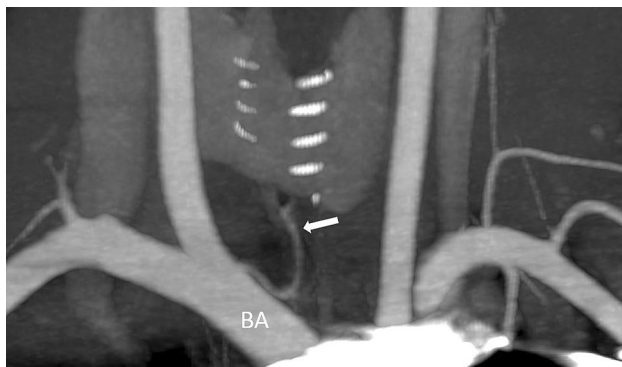


Fig. 3 Coronal maximum-intensity-projection CT image shows the thyroidea ima artery (*arrow*) arising from the brachiocephalic artery (*BA* brachiocephalic artery)

should be detected. Nevertheless, in the present study, both ITAs were also present in 46% of the patients with a TIA.

Lo et al. [24] found that the origin site of the STA appeared to be related to the level of the CCA bifurcation. We also investigated the relationship between the origin site of the STA and the bifurcation level of the CCA, which was determined with respect to the cervical vertebrae. We found that when the CCA had a relatively low bifurcation, the STA tended to originate from the ECA, although there was not a statistically significant correlation for the right side. When the CCA had a high bifurcation, the STA on the left side tended to originate from the CCA in our study population.

As mentioned before, as well as cadaveric dissections, conventional or digital subtraction angiography has been used to evaluate thyroid artery variations. However, the

results obtained from conventional angiography were found to be poorly consistent with the STA distribution indicated by dissection [15]. Additionally, in STA evaluations using conventional angiography, STAs originating from the CCA are only rarely or are never detected [15]. In Caucasoids, nonselective thyroid angiography has been shown to be as effective as dissection at detecting both the presence and the origin of the ITA [10]. It has been reported that ITA visualization is less affected by the angiographic procedure [10].

CCTA of the head and neck has become the primary imaging modality for evaluating vascular lesions [25]. To the best of our knowledge, the visualization of thyroid arteries by CCTA has not been evaluated in the literature. However, Wilson et al. [26] reported the utility of CCTA for the pre-operative evaluation of STA perforators. Perivenous beam-hardening streak artifacts and venous reflux that obscure evaluations of the arterial system may be important limitations of CCTA in the neck region [27, 28]. As expected, ITA seems to be particularly affected by this issue due to its anatomical location. Although in some cases it was not possible to visualize all of the segments and branches of the ITA because of artifacts, we were able to evaluate the origin site of this thyroid artery using multiplanar imaging and appropriate windowing.

In two different meta-analyses reported by Toni et al. [10, 12], ITAs were found to be statistically less likely to be present than STAs in all human groups, and the presence of superior thyroid vessels was found to be more likely than the presence of inferior thyroid vessels in Caucasian and Asian subjects. The inferior thyroid artery was found to be absent in 5% of the cases in a study that was performed with 55

adult human cadavers and 25 fetuses [29]. The left ITA was reported to be absent in 1–6% of the cases in another study [30]. In the present study, we did not observe the STA and the ITA in one or both sides in 2.5 and 8.2% of the patients, respectively.

Our study has some limitations. The retrospective design of our study is an important limitation. The present study did not examine variations in the courses and branching patterns of the thyroid arteries. Additionally, we did not have a gold standard with which to compare our results. Hypoplastic arteries may have been invisible on the CTA images, meaning that they may have been missed due to the lack of a gold standard imaging technique. Further prospective comparative analyses are needed to determine the effectiveness of CTA for the evaluation of thyroid arteries.

Conclusion

A knowledge of the detailed anatomy of the thyroid arteries is crucial to the optimal management of patients during surgical procedures in the neck region. However, most patients are evaluated with cross-sectional imaging modalities before surgery. Computed tomography angiography could be an important imaging modality in this context due to its non-invasive nature.

Compliance with ethical standards

Conflict of interest The authors declare that they have nothing to disclose.

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