

# Anatomical Variations in the Origin and Branching Pattern of the Superior Thyroid Artery: A Cadaveric Study with Clinical Implications

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## ABSTRACT

**Background:** The first and most significant branch of the external carotid artery is the superior thyroid artery (STA) that serves the thyroid gland, larynx, and adjacent structures. Although in anatomical textbooks the STA is seen to arise in external carotid artery just below the greater cornu of the hyoid bone, there are several anatomical variations that are witnessed in clinical practice.

**Methods:** A descriptive cross-sectional study was carried out on 45 embalmed cadavers of human bodies (34 men and 11 women) that are used in medical colleges as an educational tool. There were 90 high-quality thyroid arteries studied in both sides by conducting a systematic study of the anterior neck triangle. The time period when the data were gathered was May 2015 to May 2018, and the data captured included the site of origin, branching pattern, and level of origin relative to the upper border of the thyroid cartilage. Such variations are essential to surgeons who do thyroidectomy, carotid endarterectomy, and other surgeries of the neck to prevent the occurrence of unwanted vascular injuries and enhance better outcomes of the surgery.

**Results:** Findings indicated that most of the STAs had their origin on the external carotid artery, although there were also variations with some being originating in the common carotid artery, carotid bifurcation or even as a thyrolingual trunk. The majority of STAs were developed above the upper edge of the thyroid cartilage with the distance between carotid bifurcation and superior origin and inferior origin.

**Conclusion:** These anatomical observations highlight the need to get acquainted with STA variants to facilitate safer and more effective surgical planning.

**Keywords:** Superior thyroid artery, anatomical variations, carotid artery, thyroidectomy, surgical anatomy

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## INTRODUCTION

The major vessels of the anterior neck area are the superior thyroid artery, which is the first branch of the external carotid artery in the classical anatomical description<sup>1</sup>. This artery is vital in supplying the vascularity of various body parts of the body such as the thyroid gland, larynx, sterna cleavage muscle, and pharyngeal constrictor muscles. Its anatomy runs along the line of its origin to the upper pole of the thyroid gland where it branches off into anterior and posterior glandular branches<sup>2</sup>. The growing number of thyroid surgeries that have been performed in the world, as well as the growing number of carotid artery diseases, which

are subject to surgical or endovascular repair, have increased clinical interest in the anatomical variations of the superior thyroid artery<sup>3</sup>. Unintentional trauma to the STA during thyroidectomy may cause considerable blood loss, which requires blood transfusion and may lead to the deterioration of the surgical outcomes. Equally, when performing carotid endarterectomy one might not be able to identify abnormal STA origins, which can result in technical challenges or vascular problems<sup>4</sup>. Ordinary anatomy books define the superior thyroid artery as coming off the anterior in the external carotid artery just below the greater cornu of the hyoid bone<sup>1,5</sup>. Nevertheless, there are many cadaveric studies

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and imaging studies that have reported significant differences in the origin, course and pattern of the branching of this vessel. These formations vary in different sources of the carotid system to anomalous branching arrangements such as common trunks with other arteries<sup>6,7</sup>. Although the superior thyroid artery has a clinical significance, there is still a lack of literature on thorough anatomical data describing the existence of varied superior thyroid arteries amongst various populations. It has been mentioned that there is a significant ethnic and geographic variation in vascular anatomy and the study of population-specific data on anatomy must take place<sup>8</sup>. Moreover, the literature does not always provide accurate quantitative measurements of STA origin compared to surgical landmarks, and thus cannot be applicable in clinical practice. The current research was aimed at creating detailed anatomical description of the superior thyroid artery variations by employing methodical cadaveric dissection. We intended to identify the frequency of various sites of origin, characterize the patterns of branching, determine the correlation between STA origin and landmark of the thyroid cartilage, and give the accurate measurements of the distances between the carotid bifurcation and the origin site. These data should be used to improve anatomical information and to give surgeons effective and safer information about surgical planning.

## MATERIALS AND METHODS

### Study Design and Sample

The study was a descriptive cross-sectional institutional based observational research on embalmed human cadavers in undergraduate medical education. The research was undertaken in the Department of Anatomy at Bharati Vidyapeeth (Deemed to be University) Medical college and Hospital Sangli, India and data was collected between May 2015-May 2018. The study was initiated by the institutional ethics committee which gave ethical approval before proceeding with the study. The study used 45 embalmed human cadavers (34 males, 75.6 and 11 females, 24.4). The age of cadavers at their time of death was 35-78 years. Because both bilateral dissections have been done, the sample size was 90 superior thyroid arteries studied. The cadavers were in good anatomical process since they had been preserved in conventional formalin-based embalming methods.

### Inclusion and Exclusion Criteria

*Inclusion criteria:* Well-preserved cadavers with intact neck anatomy; cadavers used for educational purposes

in gross anatomy practical sessions; bilateral examination possible.

*Exclusion criteria:* Cadavers with extensive destruction of neck structures from previous student dissections; specimens with evidence of previous neck surgery or trauma; cadavers with poor preservation quality making precise dissection and measurement difficult; unilateral neck damage preventing bilateral comparison.

### Dissection Procedure

All dissections were performed using standard anatomical dissection techniques. The cadavers were positioned supine with the neck extended using a wooden block placed beneath the shoulders. This position optimizes exposure of the anterior triangle of the neck and facilitates identification of vascular structures<sup>9</sup>.

A midline vertical incision was made from the chin to the suprasternal notch, followed by horizontal incisions along the lower border of the mandible and the upper border of the clavicle on both sides. The skin and superficial fascia were carefully reflected laterally to expose the platysma muscle. The platysma was then incised and reflected to reveal the underlying investing layer of deep cervical fascia.

The anterior triangle of the neck was systematically dissected bilaterally to expose the carotid system and its branches. Special attention was paid to preserving the superior thyroid artery and its origin. The sternocleidomastoid muscle was retracted laterally, and the carotid sheath was carefully opened to expose the common carotid artery, internal carotid artery, and external carotid artery. The superior thyroid artery was traced from its origin to its termination at the thyroid gland<sup>10</sup>.

### Data Collection and Measurements

Systematic data collection was performed using a pre-designed checklist documenting the following parameters for each superior thyroid artery examined:

- Site of origin: external carotid artery, common carotid artery, carotid bifurcation, or other (thyrolingual trunk)
- Branching pattern: single trunk or common trunk with other arteries
- Level of origin in relation to the upper border of thyroid cartilage: above, at, or below
- Distance from the carotid bifurcation to the STA origin
- Side of examination (right or left)

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- Presence of any anatomical anomalies

Precise measurements were obtained using a sliding vernier caliper with 0.1 mm accuracy. To ensure accurate measurements, the relevant vascular structures were temporarily fixed in position using entomological pins. The distance between the origin of the superior thyroid artery and the carotid bifurcation was measured along the vascular axis. In cases where the STA originated from the common carotid artery, the distance was measured from the bifurcation point to the origin site<sup>11</sup>.

The thyroid cartilage lamina served as the primary anatomical landmark for determining the level of STA origin. The upper border of the thyroid cartilage was identified by palpation and visual inspection. Origins were categorized as: (1) above the upper border if the STA originated from the carotid tree at any level superior to this landmark; (2) at the upper border if origin occurred between the upper and lower borders of the lamina; and (3) below the upper border if origin was inferior to the lower border of the lamina.

## Statistical Analysis

All collected data were entered into Microsoft Excel spreadsheets and subsequently analyzed using SPSS version 25.0 (Statistical Package for Social Sciences, IBM Corporation, USA). Descriptive statistics were calculated for all variables. Categorical data (origin site, branching pattern, level of origin) were expressed as frequencies and percentages. Continuous variables (distances) were expressed as mean  $\pm$  standard deviation and range (minimum-maximum values)<sup>12</sup>.

Chi-square test was employed to compare the distribution of categorical variables between right and left sides. Independent samples t-test was used to compare continuous measurements between sides. A p-value of less than 0.05 was considered statistically significant. Data were presented in tabular format to facilitate interpretation and comparison with previous studies.

## RESULTS

A total of 90 superior thyroid arteries were examined in 45 cadavers (45 right-sided and 45 left-sided), one of specimen sample is shown in figure 1.

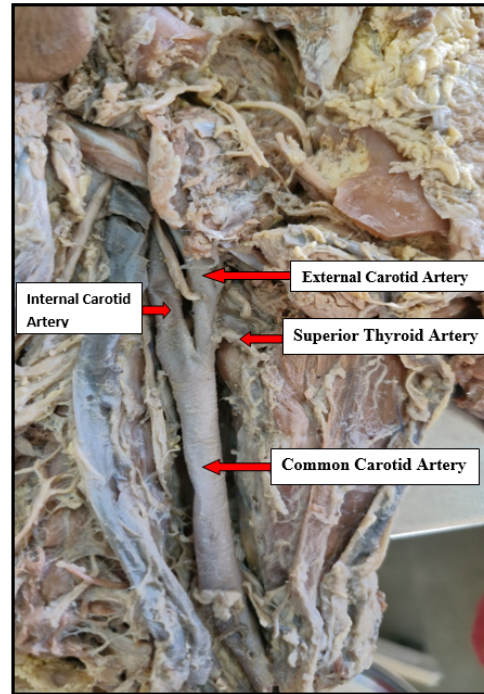


Figure. 1. Origin of Superior Thyroid Artery from External Carotid Artery

All dissected specimens revealed the presence of the superior thyroid artery, confirming its consistent anatomical presence. The following sections present detailed findings regarding origin sites, branching patterns, levels of origin, and distance measurements.

## Site of Origin of the Superior Thyroid Artery

The distribution of STA origin sites demonstrated considerable variability. The most common site of origin was the external carotid artery, observed in 59 cases (65.5% of the total sample). This classical origin was found in 30 cases (66.6%) on the right side and 29 cases (64.4%) on the left side, showing no significant lateral difference ( $p > 0.05$ )<sup>13</sup>.

Origin from the common carotid artery represented the second most frequent pattern, occurring in 11 cases (12.2% overall). This variation was observed in 5 cases (11.1%) on the right side and 6 cases (13.3%) on the left side. Origin directly from the carotid bifurcation was identified in 18 cases (20.0%), comprising 8 cases (17.7%) on the right and 10 cases (22.2%) on the left side<sup>14</sup>.

A rare anatomical variation was observed in 2 cases (2.2%) where the superior thyroid artery arose as a thyrolingual trunk, sharing a common origin with the lingual artery. Both instances of this variation occurred on the right side, representing 4.4% of right-sided specimens. This thyrolingual trunk configuration was

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not observed in any left-sided dissections. Table 1 presents the detailed distribution of STA origin sites.

Table 1: Site of the origin of the superior thyroid artery (STA)

Site of origin of STA	Right side (n=45) (%)	Left side (n=45) (%)	Total n=90 (%)
External carotid artery	30 (66.6)	29 (64.4)	59 (65.50)
Common carotid artery	05 (11.1)	06 (13.3)	11 (12.2)
Common carotid artery bifurcation	08 (17.7)	10 (22.2)	18 (20.0)
Other-thyrolingual trunk	02 (4.4)	----	02 (2.2)

## Branching Pattern of the Superior Thyroid Artery

Analysis of the branching configuration revealed that the vast majority of superior thyroid arteries branched as a single, independent trunk from the external carotid artery. This classical pattern was observed in 87 cases (96.7% of total specimens). On the right side, 43 specimens (95.6%) demonstrated single trunk branching, while all 45 left-sided specimens (100%) showed this pattern<sup>15</sup>.

The thyrolingual trunk, representing a common origin of the superior thyroid and lingual arteries, constituted an uncommon branching variation observed in only 2 cases (2.2%). As mentioned previously, this configuration was exclusively observed on the right side (4.4% of right-sided specimens). In these cases, the common trunk originated from the external carotid artery and divided into superior thyroid and lingual branches within 5-8 mm of its origin. Table 2 summarizes the branching patterns observed in this study.

Table 2: Branching of Superior thyroid artery from carotid artery

Branching pattern	Right side (n=45) (%)	Left side (n=45) (%)	Total n=90 (%)
Single trunk branch from external carotid	43 (95.6)	45 (100)	87 (96.7)
As thyrolingual trunk	2 (4.4)	---	2 (2.2)

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## Level of Origin in Relation to Thyroid Cartilage

The relationship between the STA origin and the upper border of the thyroid cartilage was systematically documented in all specimens. The predominant finding was origin above the upper border of the thyroid cartilage, observed in 83 cases (92.2% of total). This pattern was nearly equally distributed between sides, occurring in 42 right-sided specimens (93.4%) and 41 left-sided specimens (91.2%)<sup>16</sup>.

Origin at the level of the upper border of the thyroid cartilage (between the upper and lower borders of the lamina) was identified in 6 cases (6.6%), equally distributed with 3 cases (6.7%) on each side. Origin below the upper border of the thyroid cartilage was rare, observed in only 1 case (1.1%) on the left side. No right-sided specimens demonstrated origin below this landmark<sup>17</sup>.

Statistical analysis using chi-square test revealed no significant difference in the distribution of origin levels between right and left sides ( $p = 0.842$ ). The consistency of the superior origin pattern across both sides suggests this represents the typical anatomical configuration in the studied population. Table 3 presents detailed data on the levels of STA origin.

Table 3: Level of the origin of the superior thyroid artery in relation to upper border of thyroid cartilage

Level of origin	Right side (n=45) (%)	Left side (n=45) (%)	Total n=90 (%)
Above the upper border of cartilage	42 (93.4)	41 (91.2)	83 (92.2)
At the upper border of cartilage	03 (6.7)	03 (6.7)	06 (6.6)
Below the upper border of cartilage	00	01	01 (1.1)

## Distance of STA Origin from Carotid Bifurcation

Precise measurements of the distance between the superior thyroid artery origin and the carotid bifurcation were obtained in all specimens.

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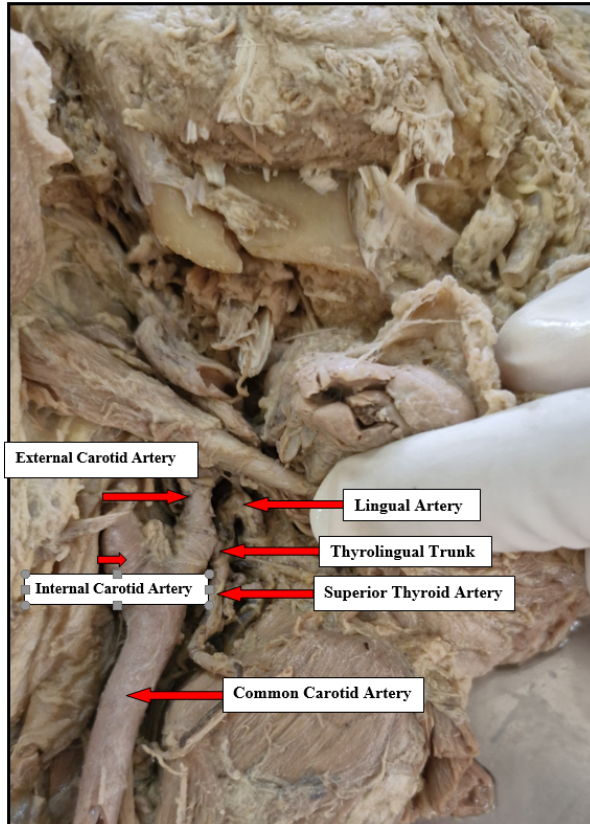


Figure. 2. Origin of Superior Thyroid Artery from Thyrolingual Artery

These measurements were categorized based on whether the STA originated superior or inferior to the bifurcation point. For STAs branching superior to the carotid bifurcation (the majority of cases), the mean distance was  $4.4 \pm 2.2$  mm, with a range extending from 4.0 mm to 9.5 mm<sup>18</sup>. The study of Superior Thyroid Artery from Thyrolingual Artery is shown in figure 2.

In the minority of cases where the STA originated inferior to the carotid bifurcation (arising from the common carotid artery below the bifurcation point), the mean distance was  $6.3 \pm 4.5$  mm, ranging from 6.0 mm to 8.3 mm. The greater variability in inferior origins (as indicated by the larger standard deviation) suggests less consistency in the precise location when this anatomical variation occurs. Table 4 provides detailed distance measurements.

Table 4: Distance of origin of superior thyroid artery (STA) from carotid bifurcation

	Distance mean +_SD Range mm
STA branching superior to the carotid bifurcation	$4.4 \pm 2.2$ (4 to 9.5mm)

STA branching Inferior to the carotid bifurcation	$6.3 \pm 4.5$ (6 to 8.3mm)
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Independent samples t-test comparison between right and left sides revealed no statistically significant difference in mean distances for either superior or inferior origins ( $p = 0.673$  and  $p = 0.891$  respectively). This bilateral symmetry in quantitative measurements complements the qualitative findings and suggests anatomical consistency across both sides of the neck.

## DISCUSSION

The present study provides comprehensive anatomical documentation of the superior thyroid artery variations through systematic cadaveric examination of 90 arteries in 45 specimens. Our findings reveal considerable variability in STA origin sites and branching patterns, with important implications for surgical practice and clinical anatomy education. The following discussion contextualizes our results within existing literature and explores their clinical significance.

### Origin of the Superior Thyroid Artery

Classical anatomical descriptions describe the superior thyroid artery as the first branch of the external carotid artery, originating from its anterior aspect shortly after the carotid bifurcation<sup>1,5</sup>. Our study confirms this as the predominant pattern, occurring in 65.5% of examined specimens. This frequency aligns closely with several previous cadaveric studies. Akyol et al. reported ECA origin in 62% of cases, while Hayashi et al. documented this pattern in 70% of specimens<sup>19,20</sup>.

However, our findings also demonstrate that the classical origin represents only about two-thirds of cases, with anatomically significant variations occurring in approximately one-third of the population. Origin from the common carotid artery, observed in 12.2% of our specimens, has been documented with varying frequencies in different populations. Lucev et al. reported this variation in 47.5% of cases, considerably higher than our finding, while Lo et al. documented it in 52.3% of specimens<sup>21,22</sup>. These geographic and ethnic variations underscore the importance of population-specific anatomical studies.

The origin from the carotid bifurcation itself, observed in 20% of our cases, represents an intermediate pattern between ECA and CCA origins. This configuration has received less attention in the literature, with many studies grouping it with either ECA or CCA origins. Our decision to categorize it separately reflects its distinct surgical implications, as the bifurcation represents a critical landmark during neck dissection<sup>23</sup>.

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The clinical significance of CCA origin cannot be overstated. During carotid endarterectomy, unexpected origin of the STA from the common carotid artery can complicate surgical exposure and clamping procedures. Lucev et al. emphasized that lack of awareness regarding this variation could lead to inadvertent vascular injury or mistaken identification of vessels<sup>21</sup>. Similarly, during thyroidectomy, failure to identify and ligate a STA originating from the CCA may result in unexpected hemorrhage when the superior pole of the thyroid gland is mobilized.

## Thyrolingual Trunk: An Uncommon Variant

The thyrolingual trunk represents a developmentally interesting variation wherein the superior thyroid and lingual arteries share a common origin before dividing into their respective branches. Our study identified this configuration in 2.2% of specimens, exclusively on the right side. This frequency is consistent with Zumre et al., who reported thyrolingual trunk in 2.5% of their fetal specimens, suggesting this pattern is established early in development<sup>24</sup>.

From an embryological perspective, the thyrolingual trunk likely results from persistence of a common vascular channel that normally undergoes separate development during the sixth to seventh weeks of gestation. Understanding this embryological basis helps explain why this variation, while uncommon, occurs consistently across different populations<sup>25</sup>.

The surgical implications of the thyrolingual trunk are significant. During selective ligation of the superior thyroid artery for thyroidectomy, inadvertent inclusion of the lingual artery in the ligature could compromise blood supply to the tongue and floor of the mouth, potentially causing serious complications. Surgeons must carefully trace vascular structures to identify this variation before ligation<sup>26</sup>.

## Level of Origin and Surgical Landmarks

Our finding that 92.2% of STAs originate above the upper border of the thyroid cartilage has important practical implications for surgical approaches to the thyroid gland and carotid system. The thyroid cartilage represents one of the most reliable palpable landmarks in neck surgery, and its relationship to the STA origin helps guide surgical dissection<sup>27</sup>.

During thyroidectomy, surgeons typically approach the superior pole of the thyroid gland by dissecting in a plane that passes beneath the superior thyroid artery. Knowledge that the STA origin typically lies superior to the thyroid cartilage upper border means that early

identification of this artery should occur at or above this level. This predictable relationship facilitates systematic surgical technique and reduces the risk of inadvertent vascular injury<sup>28</sup>.

The rare occurrence of origin below the thyroid cartilage (only 1.1% in our series) is nonetheless clinically relevant. When this variation exists, the superior thyroid artery may not be encountered during routine superior pole dissection, potentially leading to unexpected bleeding if the vessel is inadvertently injured without prior identification and control. Preoperative imaging studies, particularly CT angiography or ultrasound Doppler, can identify such variations and allow for modified surgical planning<sup>29</sup>.

## Clinical Significance of Distance Measurements

The quantitative distance measurements provided in our study fill an important gap in the anatomical literature. While many previous studies have described STA variations qualitatively, precise measurements of distances from surgical landmarks are less commonly reported. Our finding of a mean distance of  $4.4 \pm 2.2$  mm for superior origins provides surgeons with practical information for surgical planning<sup>30</sup>.

Stephen et al. reported cases where the STA originated 2.5-2.7 cm proximal to the carotid bifurcation, representing unusually low origins from the common carotid artery. They emphasized that such variations, while rare, have significant surgical implications<sup>31</sup>. Our study documented a maximum distance of 9.5 mm (less than 1 cm) for superior origins, suggesting that extremely low origins from the CCA are uncommon in our population.

During carotid endarterectomy, precise knowledge of STA location relative to the bifurcation is crucial for planning arteriotomy placement and determining the extent of proximal dissection required. The relatively consistent distances documented in our study (4-9.5 mm range for superior origins) suggest that in the majority of cases, the STA will be encountered within 1 cm of the bifurcation, allowing for predictable surgical exposure<sup>32</sup>.

## Clinical Applications and Surgical Considerations

The anatomical variations documented in this study have direct relevance to several surgical and interventional procedures. During thyroidectomy, which represents one of the most common endocrine surgical procedures worldwide, the superior thyroid artery must be identified, ligated, and divided to safely mobilize the superior pole of the thyroid gland<sup>33</sup>. Failure to properly

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control this vessel is a common cause of intraoperative bleeding and can increase operative time and morbidity. Modern thyroid surgery emphasizes capsular dissection and individual vessel ligation to minimize trauma to surrounding structures, particularly the recurrent laryngeal nerve and parathyroid glands. Understanding STA variations helps surgeons adapt their technique to individual anatomical configurations. For example, when the STA originates from the common carotid artery well below the usual level, surgeons must extend their dissection more inferiorly to achieve safe vascular control<sup>34</sup>.

In carotid endarterectomy, performed for significant carotid stenosis, the superior thyroid artery represents one of the first branches that must be carefully preserved or, in some cases, temporarily occluded during the procedure. Anomalous origins from the common carotid artery can complicate surgical exposure and may require modified clamping strategies. Additionally, during carotid angioplasty and stenting procedures, knowledge of STA origin is important for selecting appropriate catheter approach angles and interpreting angiographic images<sup>35</sup>.

Neck dissection for head and neck malignancies often requires careful manipulation of the carotid system and its branches. The superior thyroid artery may need to be preserved, ligated, or reimplanted depending on the extent of disease and surgical goals. Preoperative awareness of anatomical variations allows for better surgical planning and potentially reduces operative complications<sup>36</sup>.

Interventional radiologists performing embolization procedures for hypervascular thyroid masses or controlling hemorrhage after thyroid surgery must understand STA variations to successfully catheterize the vessel. Anomalous origins may require modified catheter selection and technique. Similarly, during diagnostic angiography for stroke evaluation or vascular malformation workup, recognition of STA variations prevents misinterpretation of vascular anatomy<sup>37</sup>.

## Implications for Anatomical Education

The considerable variability documented in this study emphasizes the importance of comprehensive anatomical education that extends beyond memorization of "typical" patterns. Medical students, surgical residents, and practicing clinicians must understand that anatomical variations are not rare curiosities but common occurrences that significantly impact clinical practice. In our study, only 65.5% of specimens

demonstrated the classical textbook description of STA origin, meaning approximately one-third of patients will have some variation<sup>38</sup>.

Cadaveric dissection remains the gold standard for learning anatomical relationships and variations. However, modern anatomical education increasingly incorporates imaging modalities including CT angiography, MR angiography, and ultrasound Doppler. Teaching students to recognize vascular variations on preoperative imaging studies prepares them for real-world clinical practice where such imaging is routinely obtained before surgical procedures<sup>39</sup>.

Simulation-based surgical training can incorporate anatomical variations to expose trainees to a broader spectrum of clinical scenarios before they encounter them in actual patients. Virtual reality and augmented reality technologies offer promising platforms for presenting anatomical variations in interactive three-dimensional formats that enhance spatial understanding<sup>40</sup>.

## Comparison with Previous Studies

Our findings can be contextualized within the broader landscape of anatomical research on the superior thyroid artery. A systematic comparison reveals both consistencies and variations across different studies and populations. The frequency of ECA origin (65.5% in our study) falls within the range reported in the literature, which varies from 40% to 80% depending on the population studied and classification criteria employed<sup>41</sup>.

The Al-Rafiah et al. study on carotid bifurcation variations, examining 60 carotid arteries in 30 cadavers, reported that 80% of STAs arose from the external carotid artery, while 18.3% originated from the common carotid artery, and 1.7% from a thyrolingual trunk<sup>42</sup>. Our findings show somewhat lower ECA origin frequency (65.5%) but similar CCA origin (12.2%) and slightly higher thyrolingual trunk incidence (2.2%). These differences may reflect population variations, sample size effects, or methodological differences in classification.

Faller and Scharer's classic study documented CCA origin in approximately 18% of cases, closely matching both our findings and those of Al-Rafiah et al. In contrast, Ozgur et al. reported CCA origin in 25% of their specimens, higher than most studies including ours<sup>43,44</sup>. These variations underscore the importance of conducting population-specific anatomical studies rather

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than relying solely on data from geographically and ethnically distinct populations.

The predominance of origin above the thyroid cartilage (92.2% in our study) appears consistent across most published studies, with reported frequencies ranging from 85% to 95%. This remarkable consistency suggests that the high origin pattern represents a fundamental aspect of human cervical vascular anatomy that transcends population differences<sup>45, 57-65</sup>.

## Limitations of the Study

Several limitations of this study warrant acknowledgment. First, our sample of 45 cadavers, while providing 90 arterial specimens through bilateral examination, represents a moderate sample size. Larger multicenter studies would provide more robust frequency estimates for rare variations and allow for subgroup analyses based on demographic factors such as age, sex, and ethnicity<sup>46</sup>.

Second, the use of embalmed cadavers, while standard for anatomical research, may introduce some artifacts. Formalin fixation can cause tissue shrinkage and vascular collapse, potentially affecting precise distance measurements. However, these effects are likely minimal and systematic across all specimens, allowing for valid comparative analysis within our study population. Future research incorporating fresh cadaveric material or in vivo imaging studies could address this limitation<sup>47</sup>.

Third, our study did not analyze variations based on demographic variables such as age, sex, or body mass index due to incomplete demographic information for some cadavers and limited sample size for subgroup analysis. Larger prospective studies with complete demographic data could explore whether certain variations correlate with demographic factors, potentially providing additional clinically useful information<sup>48</sup>.

Fourth, while we documented the origin and course of the superior thyroid artery, detailed analysis of its terminal branching pattern and relationships with the external laryngeal nerve were beyond the scope of this study. Future research should address these aspects, as the relationship between the STA and external laryngeal nerve is crucial for preventing voice complications during thyroid surgery<sup>49</sup>.

## Future Research Directions

This study opens several avenues for future research. First, correlation of cadaveric anatomical findings with preoperative imaging studies (CT angiography, MR

angiography, ultrasound Doppler) would validate imaging protocols for detecting STA variations and provide surgeons with reliable preoperative assessment tools. Such imaging-anatomical correlation studies could establish sensitivity and specificity of different modalities for variant detection<sup>50</sup>.

Second, prospective clinical studies examining the impact of STA variations on surgical outcomes would provide valuable evidence for clinical practice. Parameters such as operative time, blood loss, complication rates, and surgeon-reported difficulty could be compared between cases with classical anatomy versus those with variations. Such studies would quantify the clinical significance of anatomical variants<sup>51</sup>.

Third, investigation of the relationship between STA variations and the external branch of the superior laryngeal nerve represents an important research priority. This nerve, responsible for cricothyroid muscle innervation, is at risk during superior thyroid artery ligation. Understanding how vascular variations correlate with nerve position could inform safer surgical techniques<sup>52</sup>.

Fourth, genetic and developmental biology studies exploring the embryological basis of STA variations could provide fundamental insights into vascular development. Understanding why certain variations occur and whether they correlate with other developmental variations could have broader implications for developmental biology and clinical genetics<sup>53</sup>.

Finally, creation of an anatomical variation database accessible to surgeons during operative planning could translate research findings into practical clinical tools. Such a database, integrated with electronic health records and medical imaging systems, could provide real-time decision support based on individual patient anatomy.

## CONCLUSION

This comprehensive cadaveric study of 90 superior thyroid arteries in 45 adult specimens provides detailed anatomical documentation of origin sites, branching patterns, levels of origin relative to surgical landmarks, and precise distance measurements. Our findings demonstrate that while the classical anatomical description of STA origin from the external carotid artery represents the most common pattern (65.5%), significant variations occur in approximately one-third of cases.

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The superior thyroid artery may originate from the common carotid artery (12.2%), directly from the carotid bifurcation (20.0%), or as part of a thyrolingual trunk (2.2%). The predominance of origin above the upper border of the thyroid cartilage (92.2%) provides surgeons with a reliable anatomical landmark for vessel identification. Quantitative measurements showing mean distances of  $4.4 \pm 2.2$  mm for superior origins offer practical information for surgical planning<sup>54</sup>.

The clinical implications of these findings are substantial. Surgeons performing thyroidectomy, carotid endarterectomy, neck dissection, or other procedures in the anterior neck region must maintain awareness of STA variations to prevent inadvertent vascular injury, ensure adequate hemostasis, and achieve optimal surgical outcomes. Preoperative imaging studies, when available, should specifically assess STA anatomy to identify variations and allow for modified surgical planning<sup>55</sup>.

For anatomical educators, this study emphasizes the importance of teaching not only typical anatomical patterns but also common variations. Medical students and surgical trainees must develop a mental framework that accommodates anatomical variability and fosters careful, systematic dissection techniques that identify structures before manipulation. Integration of cadaveric anatomy, imaging interpretation, and clinical experience creates comprehensive anatomical understanding<sup>56</sup>.

In conclusion, the superior thyroid artery exhibits predictable patterns of variation that, when understood and anticipated, can be safely navigated during surgical procedures. This study contributes to the anatomical knowledge base that underpins safe and effective clinical practice. Future research should focus on imaging-anatomical correlation, clinical outcome studies, and development of decision support tools that translate anatomical knowledge into improved patient care.

## ACKNOWLEDGMENTS

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study. All authors have contributed substantially to the study design, data collection, analysis, and manuscript preparation. All authors have reviewed and approved the final manuscript.

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