

Observations on the Superior Thyroid Artery and its Relationship with the External Laryngeal Nerve

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Abstract

Due to the close association between the superior thyroid arteries (STA) and external laryngeal nerve (ELN) one potential complication of thyroidectomy is trauma to the ELN. The aim of the current study was to evaluate variations in the origin of the STA and its relation to the ELN in 44 hemisections from 22 Thiel embalmed cadavers (9 male, 13 female: mean age 79 years). The STA arose from the external carotid artery in 31/44 (71%) specimens, the common carotid artery in 12/44 (27%) and was absent in 1/44 (2%) specimens. The ELN crossed the STA within 10 mm superior to the superior pole of the thyroid gland in 21/44 (48%) specimens, between 10 and 15 mm superiorly in 10/44 (23%) and more than 15 mm superiorly in 7/44 (16%) in 6/44 (13%) specimens the ELN did not cross the STA. A modified classification of the relationship between the STA and ELN is proposed in which a crossing point between 10 and 15 mm superior to the superior pole of the thyroid gland is introduced.

Keywords: Superior thyroid artery; Thyroidectomy; External laryngeal nerve; Thiel-embalmed cadavers; Thyroid gland

Introduction

The superior thyroid artery usually arises as the first branch of the external carotid artery, although it can arise from the common carotid artery or its bifurcation [1-8]. As it passes inferiorly the superior thyroid artery is accompanied by the external laryngeal nerve before coursing anteromedially towards the superior pole of the thyroid gland where it divides into anterior and posterior branches which run on the respective borders of the lateral lobe as far as the isthmus before anastomosing with branches of the inferior thyroid artery. Each superior thyroid artery supplies the superior pole and anterior surface of each lateral lobe.

Arising from the vagus the superior laryngeal nerve passes deep to the common carotid artery before exiting the carotid sheath some 20 mm proximal to the carotid bifurcation [9]. It divides 3 to 20 mm from its origin into internal and external branches [10]. The ELN gives branches to the pharyngeal plexus and the superior part of inferior constrictor: it also communicates with the superior cardiac nerve and the superior cervical sympathetic ganglion deep to the common carotid artery [11]. The external laryngeal nerve (ELN) descends on superficial aspect of the larynx deep to sternothyroid giving fibers to cricothyroid [12], which maintains the vocal cords under tension during phonation [13]. In contrast the internal laryngeal nerve descends towards and pierces the thyrohyoid membrane.

Trauma to the ELN is most common during thyroid surgery, partly due to its small size and anatomical variations, as well as variations in the superior thyroid artery, including its origin. ELN variations have been classified according to its relation to the STA and inferior constrictor [14-17]. The simplest relationships are whether the ELN passes medial or lateral to the STA [17] or superficial, deep or between branches of the STA [14]. Cernea suggested a system based on the distance above the superior pole of the thyroid gland at which the ELN

crossed the STA: in type 1 the distance is 10 mm or more; in type 2a it is less than 10 mm; in type 2b the ELN crosses below the level of the superior border of the thyroid; and in type 4 (or 'Ni') the ELN cannot be located [15].

In a different approach Friedman classified the relationship of the ELN to the inferior constrictor: in type 1 it descends superficial to the inferior constrictor as far as cricothyroid; in type 2 it penetrates the lower portion of the inferior constrictor; while in type 3 it descends deep to the inferior constrictor throughout its course [16]. Friedman advocated nerve stimulation to determine whether the ELN lies deep to the inferior constrictor [16], with an absence of stimulation response implying a type 1 'at risk' nerve equivalent to types 2a and 2b [15].

The aims of the current study were to investigate:

- Variations in the origin of the STA of origin.
- The anatomical relation between the STA and ELN.

Materials and Methods

University of Dundee ethical approval has been obtained prior conducting the study. The anterolateral aspect of the neck in 22 Thiel embalmed cadavers (9 male, 13 female: mean age 79 years) were dissected and subsequently examined at Centre for Anatomy & Human Identification (CAHID) in University of Dundee. With the cadaver supine a longitudinal midline incision was made between the tip of the chin superiorly and sternal notch inferiorly. Two further incisions, one along the lower margin of the mandible and the other along the superior margin of the clavicle, were made on each side. The skin was reflected laterally, platysma sectioned at its inferior attachment and reflected superiorly following which the superficial fascia was cleaned and removed. On each side sternocleidomastoid was retracted laterally, following which the visceral, enclosing the thyroid gland and muscular parts of the deep fascia and fat were removed. Fascia and fat inferior to the posterior belly of digastric, posterior to omohyoid and anterior to sternocleidomastoid were then removed

revealing the carotid sheath, which was cut to expose its contents (common carotid artery, internal jugular vein, vagus) all of which were sectioned. The origin of the superior thyroid artery (STA) was noted, with its diameter at the origin and length from the origin to the point of branching recorded using digital vernier calipers. The internal carotid artery was reflected laterally to expose the superior laryngeal nerve, which was then carefully dissected until the external laryngeal nerve (ELN) was exposed. The relation between the STA and ELN was then examined, including the crossing point with respect to the superior pole of the thyroid gland.

Results

In 31/44 (71%) specimens the STA arose as the first branch of the ECA (Figure 1A), 17 (39%) on the right and 14 (32%) on the left (Table 1): no significant difference was observed between males and females ($P>0.05$). In 12/44 (27%) specimens the STA arose from the common carotid artery (Figure 1B), 5 (11%) on the right and 7 (16%) on the left (Table 1) no significant difference was observed between males and females. In 1 (2%) female specimen the STA was absent on the left side.

	Male (n:18)		Female (n:26)		Overall (n:44)	
	Right	Left	Right	Left	Right	Left
Site of origin						
External carotid artery	6	6	11	8	17 (39%)	14 (32%)
Common carotid artery	3	3	2	4	5(11%)	7(16%)
Absent	0	0	0	1	0	1(2%)

Table 1: Site of origin of the superior thyroid artery.

In the carotid triangle the STA ascended superomedially as far as the infrahyoid muscles before descending deep to them to reach the superior pole of the thyroid gland.

The most common site of origin (41/44: 93%) was from the medial side of the vessel, with no significant difference between males and females. In 2/44 (5%) specimens the STA arose from the anteromedial side, while in 1 (2%) specimen it arose from posteromedial side (Table 2).

	Male (n:18)		Female (n:26)		Overall (n:44)	
	Right	Left	Right	Left	Right	Left
Site of origin						
Medially	8	8	13	12	21 (48%)	20 (46%)
Anteromedial	1	1	0	0	1(2%)	1(2%)
Posterior-medial	0	0	0	1	0	1(2%)

Table 2: Aspect of origin of the superior thyroid artery.

The mean diameter of the STA at its origin was 6.9 mm on both right and left sides; although the diameter was greater in males (Table 3) there was no significant different ($P>0.05$) between them or between sides. The mean length of the STA was 52.2 mm on the right and 51.2

mm on the left: there was no significant difference ($P>0.05$) between the length in males and females or between the right and left sides.

	Mean diameter (mm)		Mean length (mm)	
	Male	Female	Male	Female
Right side	7.2	6.7	50.6	53.3
Left side	7.4	6.6	53.6	50.1

Table 3: Mean diameter and length of the superior thyroid artery.

	Male		Female		Overall		Both sides
	Right	Left	Right	Left	Right	Left	
<10 mm	3	3	9	6	12 (27%)	9(21%)	21 (48%)
10-15 mm	1	3	3	3	4(9%)	6(13%)	10 (23%)
>15 mm	3	1	1	2	4(9%)	3(7%)	7(16%)
Uncrossed	2	2	0	2	2(5%)	4(9%)	6(13%)

Table 4: Relationship between the superior thyroid artery and external laryngeal nerve.

In 21/44 (48%) specimens the STA crossed the ELN within 10 mm (mean distance 5.6 mm) superior to the superior pole of the thyroid gland (Figure 1A), in 10/44 (23%) it crossed the ELN between 10-15 mm (mean distance 11.2 mm) superior to the superior pole (Figure 2) and in 7/44 (16%) it crossed the ELN more than 15 mm (mean distance 18.8 mm) superior to the superior pole (Figure 3A: Table 4). In 6/44 (13%) specimens the STA did not cross the ELN (Figure 3B) rather it ran superior and parallel to it.

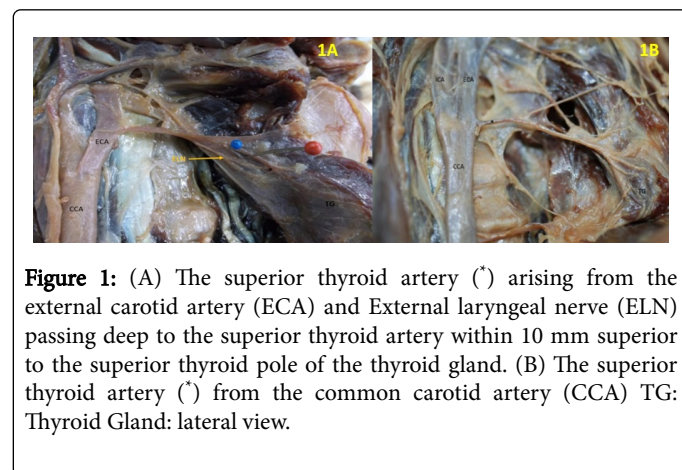


Figure 1: (A) The superior thyroid artery (*) arising from the external carotid artery (ECA) and External laryngeal nerve (ELN) passing deep to the superior thyroid artery within 10 mm superior to the superior thyroid pole of the thyroid gland. (B) The superior thyroid artery (*) from the common carotid artery (CCA) TG: Thyroid Gland: lateral view.

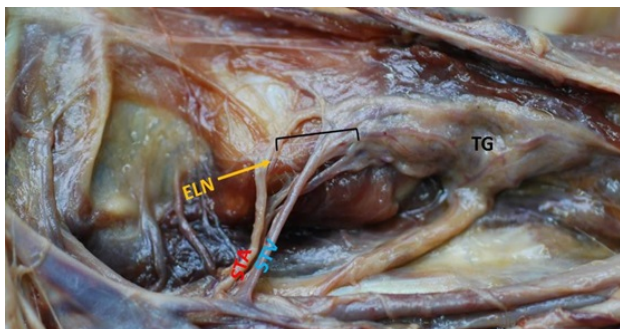


Figure 2: External laryngeal nerve (ELN) passing deep to the superior thyroid artery (STA) between 10 and 15 mm superior to the superior thyroid pole of the thyroid gland.

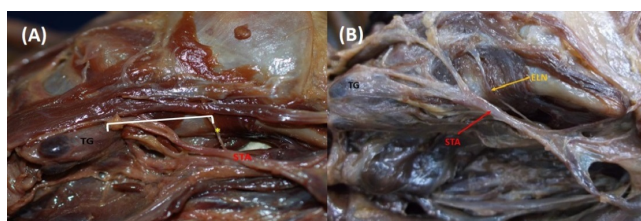


Figure 3: (A) External laryngeal nerve (ELN) passing deep to the superior thyroid artery (STA) more than 15 mm superior to the superior thyroid pole of the thyroid gland. (B) External laryngeal nerve (ELN) coursing superior and parallel to the superior thyroid artery (STA).

Discussion

The current study confirms the variable origin of the STA with it arising most commonly from the ECA (71 %) but greater than Gavrilidou [2,6,7] and Anitha [1,3] (Table 5). In contrast, Toni [18] and Lucev [4] reported the most common origin as being from the CCA, while in Vasquez [8] the most common origin was from the common carotid bifurcation (Table 5). These differences may be due to the ethnicity of the populations studied as Toni [18] reported that in Caucasians the majority of STAs arise from the ECA, while in an East Asian population the majority arose from the CCA group, but are probably a reflection of the variability of origin. There are also case reports in which the superior thyroid artery was absent bilaterally [19] or on one side only [20]. In these cases the respective lobes of the gland were supplied by the inferior thyroid artery. A single case of an absent STA on one side was observed in the current study in which case the lobe was entirely supplied by the inferior thyroid artery. In support of this, Jianu [21] observed bilateral and unilateral anastomoses between the thyroid arteries, as well as one case of an anastomosis between the lingual and STA via their suprahyoid and cricothyroid branches respectively. Benchimol-Barbosa [22] had earlier reported a case of bilateral occlusion of the CCA, which was compensated for by the vertebral basilar system and a dilated STA.

	Number of specimens	ECA	CC A	CC B	Other
Anitha [1]	-	30	21	49	
Chandrakala and Swapnali [2]	55	72	20	9	
Gavrilidou [3]	64	53	28	19	
Lucey [4]	40	30	47.5	22.5	
Ongeti and Ogeng'o [6]	46	80	13		7 (LFT)
Patel [7]	50	77		23	
Vasquez [8]	300	23	28	49	
Current study (2016)	44	71	23		6 (absent)

Table 5: Superior thyroid arteries arising from the external carotid artery (ECA), common carotid artery (CCA), common carotid bifurcation (CCB) and linguofacial trunk (LFT), expressed as percentages, as reported in previous studies and the current study.

In the present study the majority (93%) of STAs originated from the medial side of its origin artery, with no significant difference between males and females or between the right and left sides.

The mean length of the STA in the present study on the right and left sides (52.2 mm and 51.5 mm respectively) is significantly shorter than what Rimi [23] (25 mm right, 26 mm left) and Anitha [1] (23 mm right, 28 mm left) were reported. In the present study no significant difference in vessels length between males and females or between the right and left sides ($P > 0.05$) was observed. The mean diameter on both sides in the present study was 6.9 mm, more than double that reported by Rimi [23] in which STA diameter ranged between 2.7 and 3.1 mm. These differences in length and diameter could be due to the method of fixation used, as in formalin fixation arteries tend to shorten and become rigid. The present study was undertaken on Thiel embalmed cadavers in whom the vessels maintain their flexibility and life-like quality. Furthermore, the points at which measurements were taken as well as the accuracy of the measurements could be additional factors contributing to the differences.

With respect to the superior pole of the thyroid gland, the present study observed that in 48% of specimens the STAs crossed the ELN within 10 mm, corresponding to type 2a [15,24] and type 2 [25]. No difference between males and females, age or side was observed in the relationship between the STA and ELN. In the present study and that of Aina and Hisham [24] the majority of STAs crossed the ELN within 10 mm (Table 6) of the superior pole of the thyroid gland, while Cernea [15], Kierner [25] and Pradeep [26] report the majority of STAs crossed the ELN more than 10 mm from the superior thyroid pole (Table 6). This difference could be due to racial factors, as Cernea [15] studied non-white Mexicans, Aina and Hisham [24] studied Chinese, Malays and Indians, while in Pradeep [26] undertook surgery on Indians.

In 14% of specimens in the present study the STA did not cross the ELN, being similar to Kierner [25] but greater than Cernea [15]; however both Cernea [15] and Kierner [25] classified an unidentifiable ELN as type 4. The ELN coursing superior and parallel to the STA has not been previously reported. To add to the confusion, Botelho [27] reported type 1 in their classification as an unidentified ELN.

Study	Specimens	Type 1	Type 2/2a	Type 3/2b	Type 4/Ni
Cernea [15]	30	60%	17%	20%	3%
Aina and Hisham [24]	202	17%	56%	27%	-
Kierner [25]	52	42%	30%	14%	14%
Pradeep [26]	404	71%	12%	7%	4%
Present study	44	38%	48%	-	14%

Table 6: Incidence of the relationship between the superior thyroid artery and the external laryngeal nerve in previous studies compared with the present study.

Considering the observations of the present study, as well as taking into account previous classifications, four types of relationship between the STA and ELN are proposed. In type 1 the STA crosses the ELN more than 15 mm superior to the superior pole of the thyroid gland; in type 2 the STA crosses the ELN between 10 and 15 mm of the superior

pole; in type 3 the STA crosses the ELN within 10 mm of the superior pole; and in type 4 in which the STA does not cross the ELN. There are two reasons why this new classification should be adopted. Firstly, having a type greater than 10 mm from the superior pole of the thyroid gland is relatively vague from which to determine the exact crossing point; adding a 10 to 15mm category will improve the accuracy of identifying the crossing point during surgery. Secondly, in 23% of specimens in the current study the STA crossed the ELN between 10 and 15 mm of the superior pole, being the second most common.

Due to the relationship between the ELN and the STA the ELN is at risk of injury during thyroidectomy, with different relationships having different risk rates. Based on the distance between the ELN and superior pole of the thyroid gland the risk rate is approximately 20%, with the most at risk site being close to the superior pole [28]. Types 2 and 2a therefore have the greatest risk and type 1 the least [24,29]. Surgeons need be aware of the different classifications of the STA and ELN during thyroidectomy (Table 7), as trauma to the ELN results in voice changes ranging from huskiness to loss of the ability to produce high-pitch sounds. This can have a major impact on those who use their voices professionally.

	Lennquist [4]	Block [14]	Friedman [16]
Criteria	ELN passing medial or lateral to the STA	ELN passing superficial or deep to the STA	Relation of the ELN to the inferior constrictor muscles
Types	1&2	A,B,C&D	1,2&3

Table 7: Anatomical classifications of the relationship between the superior thyroid artery and the external laryngeal nerve.

Conclusion

The relationship between the STA and ELN varies significantly. While a number of classification systems have been put forward, there should nevertheless be a full visual assessment and, where possible, palpation of the ELN before undertaking any procedure that involves the STA/ELN relationships. The intimate relationship between the STA and ELN confirms the importance of (a) Understanding variations in the relationship and anatomical variations between the nerve and artery and (b) The advantages and disadvantages of different surgical approaches with respect to variations in the STA/ELN relationship.

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Contribution

Dissection, design, analysis and interpretation of data were done by REA, AA and RWS. Drafting and critical revision were done by RA and RWS. The project was supervised by RWS.

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