A quantitative analysis of the dimensions and content of the vertebral triangle

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Abstract

Purpose: The vertebral triangle (VT) located in the root of the neck most commonly contains the vertebral artery (VA), cervical sympathetic chain and certain roots of the brachial plexus. Although other structures have been reported, few studies have reported on the overall content of this space. Based on the current literature, there is a general paucity of anatomical information pertaining to the dimensional anatomy of the VT and specifically the structures related to it. Therefore, this study aimed to quantitatively analyze the size, position, content, and anatomical structures in relation to the vertebral triangle in a South African sample.

Methods: Forty-three VTs were dissected on bodies donated to science. Measurements taken include the dimensions of the triangle, as well as distances between prominent structures and landmarks of the VT. Observations were made on the presence/absence of the varying neurovascular structures within the VT.

Results: Mean height was 30.1 ± 1.51 mm (R) and 32.9 ± 1.78 mm (L). Mean width was 18.3 ± 0.74 mm (R) and 19.3 ± 0.98 mm (L). The C8 spinal nerve was found on average approximately halfway [16.4 ± 0.74 mm (R) and 15.9 ± 0.95 mm (L)] in the VT. The VA was present in the VT in 100% of the sample and the C7 spinal nerve and inferior sympathetic ganglia were present in more than 80% of the sample.

Conclusion: Understanding the VT and the content is of the utmost importance and of great interest to neurosurgeons, to avoid these important neurovascular structures and prevent iatrogenic complications during surgery.

Keywords: Cervical ganglia; Brachial plexus; Root of neck; Vertebral artery; Vertebral triangle

Introduction

The vertebral triangle, also known as the triangle of the vertebral artery or the scaleno-vertebral triangle, is a region found deep in the root of the neck that is of great interest to neurosurgeons, as many clinical procedures, such as cervical sympathectomies, stellate ganglion blocks, proximal brachial plexus repairs and scalenotomies, are performed there [34]. The triangle is bound laterally by anterior scalene, medially by longus colli and inferiorly by the subclavian artery. The apex of the triangle is defined as the carotid (anterior) tubercle of the sixth cervical vertebra. The vertebral artery forms the most prominent structure within the triangle, along with the cervical sympathetic chain and inferior roots of the brachial plexus. Other branches of the subclavian artery, the thyrocervical trunk and the costocervical trunk together with their branches, lie in close proximity, and may enter the triangle [34]. Additionally, the posterior wall of the triangle is made up of middle scalene and includes the cupula (superior most aspect of the cervical pleura) [29, 34].

Although the variation and course of the vertebral artery has been well established, there is a general lack of scientific literature on the actual dimensional anatomy of the vertebral triangle and the structures in relation to it and in relation to the vertebral artery itself. The anatomical literature on the origins and variation of vertebral artery in the neck dates back to as early as 1927 [17], while the dimensional anatomy of the triangle was only examined in 2005 and then again in early 2020 [27, 34]. To address the lack of pure anatomical research on the vertebral triangle, this study aimed to repeat the study conducted by Tubbs et al. [34] and quantitatively analyze the size and position of the vertebral triangle, as well as the content, variations and anatomical structures in relation to this triangle in a South African cadaver sample.

Materials and methods

Materials

Forty-three (22 left; 21 right) vertebral triangles were dissected in 26 formalin-fixed adult (> 18 years) cadavers at the Department of Anatomy, University of Pretoria (ethical clearance: UP 191/2017). The cadaver sample used in this study comprised of individuals who had donated their bodies to science via the body donor program and all research conducted conformed to the guidelines stipulated in the National Health Act, 61 of 2003. The demographics of the study population included 15 male cadavers (1 black; 14 white) and 11 white females. The mean age, weight and height for the total sample was 71.6 ± 1.98 years, 57.6 ± 2.54 kg and 168 ± 0.14 cm, respectively. Cadavers were randomly selected and body mass index (BMI), sex and population were not considered exclusion factors. Cadavers that had been previously dissected in the area of interest or had any notable surgery or pathology in the neck region were excluded. From a total of 30 cadavers available to us, 4 had to be excluded based on the above-mentioned criteria.

Methods

Each cadaver was placed in the supine position after which the skin of the neck, superficial fascia, and platysma were removed. Sternocleidomastoid was cut at its sternoclavicular attachment and reflected supero-laterally. After the clavicles and manubrium were removed, the carotid sheath was carefully dissected and retracted laterally. The prevertebral fascia was carefully removed, and the boundaries of the vertebral triangle identified. Pins were placed at indicated landmarks (see description below), and with the use of a mechanical dial sliding caliper (with an accuracy of 0.01 mm) the distances between the pins were recorded. Measurements obtained in relation to the vertebral triangle included (Figs. 1, 2):

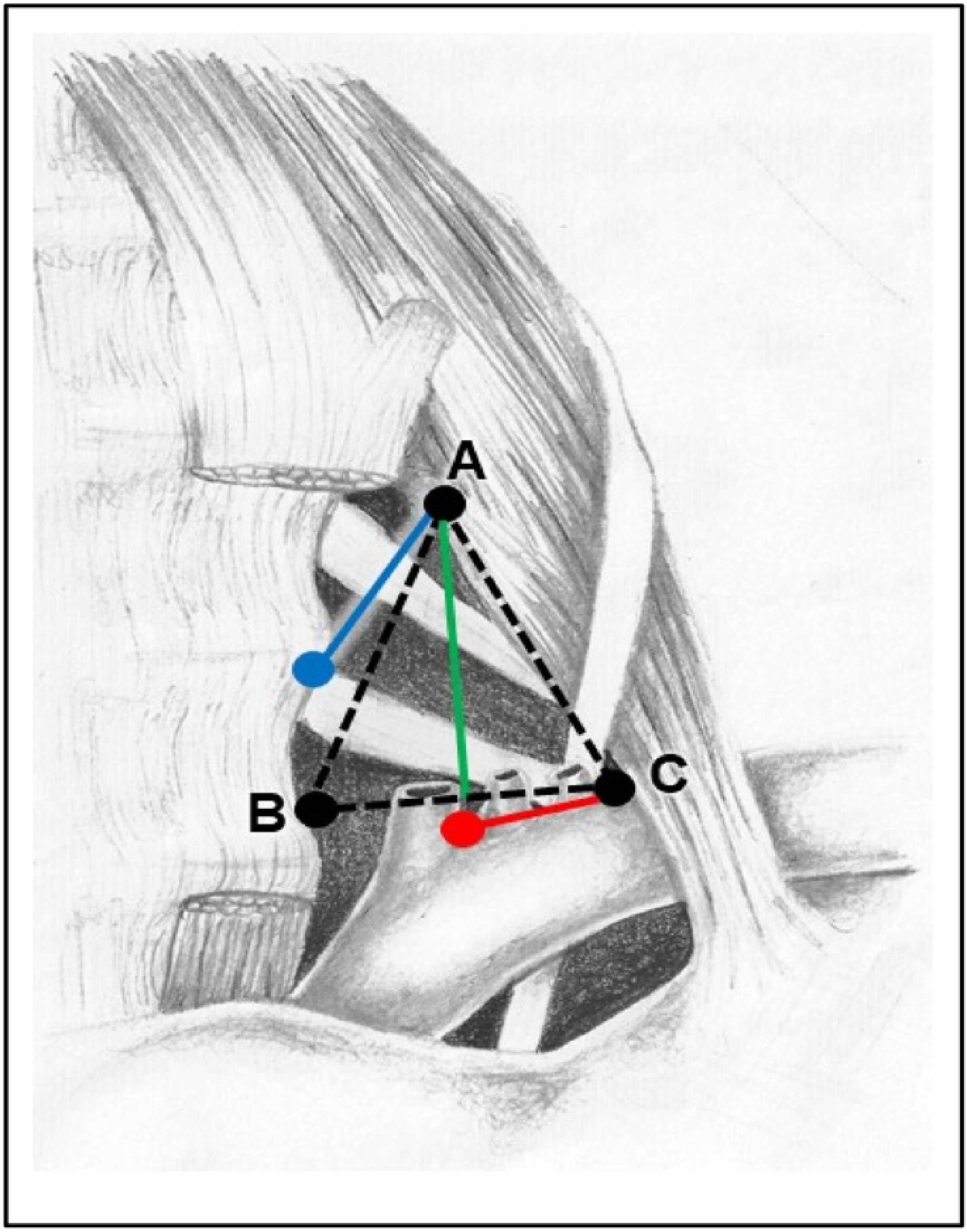

Fig. 1. Schematic diagram depicting the left vertebral triangle and measurements taken for each specimen. **a**–**c** Borders of vertebral triangle (black dotted line). **a** Carotid tubercle; **b** Point on lateral border of longus colli; **c** Point on medial border of anterior scalene; **b**, **c** Width of triangle; Green line: Height of triangle; Red line: Distance from vertebral artery to anterior scalene; Blue line: Distance from apex of triangle to C8 spinal nerve

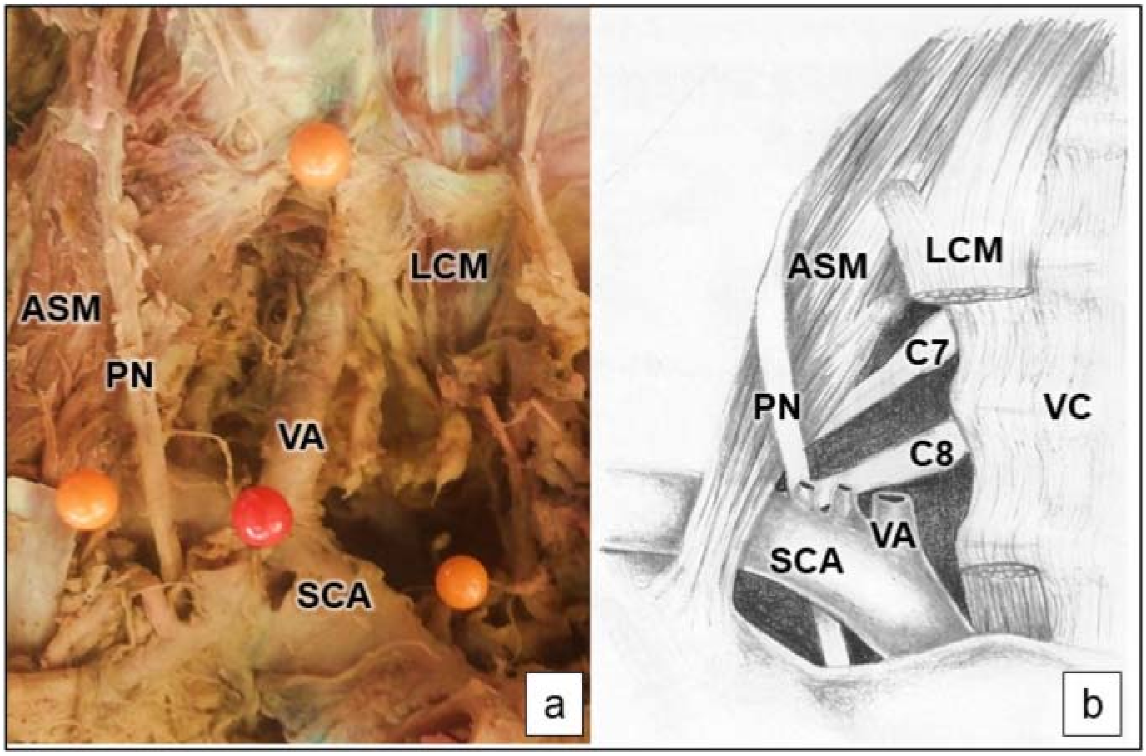

Fig. 2. a Cadaveric image depicting the right root of the neck with the three points of the vertebral triangle indicated by the orange pins. **b** Schematic diagram depicting the right vertebral triangle and its content. *ASM* anterior scalene muscle, *PN* phrenic nerve, *VA* vertebral artery, *LCM* longus colli muscle, *SCA* subclavian artery, *C7* cervical spinal nerve 7, *C8* cervical nerve C8, *VC* vertebral column

1. The width of the triangle: measured from the point at which the medial border of the anterior scalene and the subclavian artery intersect, to a point on the longus colli that was defined as a horizontal line from the medial border of the anterior scalene—this was considered to be the base of the vertebral triangle.
2. The height of the triangle: measured from the apex of the triangle, which was defined as the carotid tubercle on the sixth cervical vertebra, to a point that corresponds with the midpoint on the base of the vertebral triangle.
3. The distance from the vertebral artery to the anterior scalene: measured from the vertebral artery point of origin from the subclavian artery to the closest point of the anterior scalene.
4. The distance of the root of the C8 spinal nerve to the apex of the triangle: measured from the superior border of the C8 nerve to the apex. This measurement was taken after the anterior scalene was reflected and the vertebral artery had been removed. Care was taken not to disturb the pin that marked the apex of the triangle.

In addition to these measurements, observations were made on the presence, or absence of the following structures within the vertebral triangle (Fig. 2):

- The middle and inferior sympathetic ganglia
- The phrenic nerve
- The C7 spinal nerve; and

- Any additional neurovascular structures of importance that were encountered within the vertebral triangle.

Statistical analyses

All data were captured in a Microsoft Excel Worksheet (Office 365) and imported in the statistical analysis program Past3 (version 3.1.8) [15], where it was analyzed. Descriptive statistics included the mean, standard error, and standard deviation, and 95% confidence interval. Additionally, the prevalence for the discrete data was established. Comparisons between left and right were made using a two independent sample *t* test, where $p < 0.05$ indicated a statistically significant difference. The association between collected measurements (dependent variables) and age, height, and weight (independent variables) were tested using a Pearson's correlation test. A high (strong) correlation between the dependent and independent variables was considered if the *r* value was between ± 0.75–1.0, moderate correlation if the *r* value was between ± 0.5–0.74, and a poor correlation if the *r* value < ± 0.5. To test the association of the categorical data, a Chi-square test of independence was conducted. If the *p* value was less than or equal to 0.05, then a relationship exists between the observations on the right and left side of the specimen.

Results

Descriptive statistics and the results from the t test are displayed in Table 1. The mean height of the vertebral triangle was found to be 30.1 ± 1.51 mm (R) and 32.9 ± 1.78 mm (L). The mean width was found to be 18.3 ± 0.74 mm (R) and 19.3 ± 0.98 mm (L). The position of the superior aspect of the C8 spinal nerve root was found to be approximately 16.4 ± 0.74 mm (R) and 15.9 ± 0.95 mm (L) inferior to the apex. Such can be considered to be located approximately at the halfway zone within the triangle. Finally, the mean distance from the vertebral artery to the anterior scalene was found to be 10.1 ± 1.00 mm (R) and 15.4 ± 2.02 mm (L). No significant difference between the left and right sides with regard to the height and width of the triangle, as well as the closest distance between the C8 spinal nerve to the apex of the triangle was found. However, a significant difference ($p < 0.05$) between the distance from the origin of the vertebral artery to the anterior scalene was noted between the right and left vertebral triangle ($p = 0.0243$).

Table 1. Summary of t test (left vs. right) and measurements (in mm) within the vertebral triangle

	Right (*n* = 21)			Left (*n* = 22)			95% CI	*p* value
	Mean	SE	SD	Mean	SE	SD		
Height of triangle	30.08	1.51	6.91	32.90	1.78	8.36	29.17–33.84	0.2358
Width of triangle	18.33	0.74	3.40	19.25	0.98	4.60	17.58–19.94	0.4580
C8 to apex	16.37	0.74	3.37	15.92	0.95	4.45	14.97–17.29	0.7177
Vertebral artery to anterior scalene	10.07	1.00	4.57	15.41	2.02	9.45	10.22–14.87	0.0243*

SE Standard error, *SD* Standard deviation, *95% CI* Confidence interval of 95%

*Statistically significant difference if $p < 0.05$

Poor correlations (*r* value < ± 0.5) between the dependent (triangle height, triangle width, C8 nerve to apex of triangle and distance between the vertebral artery and anterior scalene muscle) and independent variables (height, weight and age of cadaver) were noted (Table 2).

The age of individuals was significantly associated ($p < 0.05$) with the height of the vertebral triangle and the distance from the C8 spinal nerve to the apex of the triangle. The height of the individuals was significantly associated ($p < 0.05$) with the height and width of the vertebral triangle.

Table 2. Results from the Pearson's correlation test between dependent and independent variables

	$n = 43$		1	2	3	4	5	6	7
1	Age of individuals	*r*							
		p							
2	Height of individuals	*r*	−0.26						
		p	(0.0890)						
3	Weight of individuals	*r*	−0.16	0.41					
		p	(0.3194)	(0.0065)*					
4	Height of VT	*r*	−0.41	0.39	0.19				
		p	(0.0068)*	(0.0096)*	(0.2189)				
5	Width of VT	*r*	−0.03	0.30	0.15	0.36			
		p	(0.8285)	(0.0474)*	(0.3367)	(0.0187)*			
6	C8 spinal nerve to apex	*r*	−0.38	0.25	0.24	0.36	0.29		
		p	(0.0122)*	(0.1052)	(0.1219)	(0.0176)*	(0.0618)		
7	VA to anterior scalene	*r*	0.07	−0.05	0.10	0.32	0.15	0.09	
		p	(0.6640)	(0.7297)	(0.5350)	(0.0347)*	(0.3405)	(0.5534)	

VT vertebral triangle, *VA* vertebral artery, *r* Pearson's correlation coefficient, *p p* value (two-tailed)

*Statistically significant difference if $p < 0.05$; 1. Age of individual; 2. Height of individual; 3. Weight of individual; 4. Height of vertebral triangle; 5. Width of vertebral triangle; 6. C8 spinal nerve to the apex of the triangle; 7. Vertebral artery to anterior scalene

Table 3. Summary of the prevalence of anatomical structures found within the 43 vertebral triangles observed

	R	L	Total	%
Anatomical structure				
Phrenic nerve	5	4	9	20.93
Middle cervical ganglion	4	10	14	32.56
Inferior cervical ganglion	18	18	36	83.72
C7 spinal nerve	19	16	35	81.40
Other structures				
Thyrocervical trunk only	8	9	17	39.53
Costocervical trunk only	0	2	2	4.65
Both trunks	6	1	7	16.28
Inferior thyroid artery only	6	6	12	27.91
Inferior thyroid artery and ascending cervical artery	1	3	4	9.30
Inferior thyroid artery, ascending cervical artery and costocervical trunk	0	1	1	2.33

R prevalence within the right vertebral triangle, *L* prevalence within the left vertebral triangle, *%* percentage of observed structures within the vertebral triangles of the 43 individuals

The most common structures, other than the vertebral artery, found in the vertebral triangle for this sample (Table 3) were the inferior cervical ganglion (83.7%) and the C7 spinal nerve (81.4%). The most common arterial vessel, other than the vertebral artery, present in the 55.8% of the sample was the thyrocervical trunk. Other structures that showed moderate prevalence in the vertebral triangle included the inferior thyroid artery (39.5%), the middle cervical ganglion (32.6%) and the phrenic nerve (20.9%). Association of the categorical data between left and right side was tested using a Chi-square test of independence (Table 4). The degrees of freedom for the Chi-square test analysis was 9, with a Chi-square value of 10.509 and a *p* value of 0.3108.

Table 4. Chi-square test of independence for the categorical data (Observations of structures found within the triangle)

	A	B	C	D	E	F	G	H	I	J	Total
Observed											
R	5	4	18	19	8	6	1	6	0	0	67
L	4	10	18	16	9	1	3	6	2	1	70
	9	14	36	35	17	7	4	12	2	1	137
	A	B	C	D	E	F	G	H	I	J	Total
Expected											
R	4.40	6.85	17.61	17.12	8.31	3.42	1.96	5.87	0.98	0.49	67
L	4.60	7.15	18.39	17.88	8.69	3.58	2.04	6.13	1.02	0.51	70
	9	14	36	35	17	7	4	12	2	1	137
Chi-square test analysis											
Rows, columns		2,10		Degrees of freedom			9				
Chi-square test		10.509		*p* value			0.3108				

A Phrenic nerve, *B* Middle cervical ganglion, *C* Inferior cervical ganglion, *D* C7 spinal nerve, *E* Thyrocervical trunk only, *F* Thyrocervical and costocervical trunks, *G* Inferior thyroid artery and ascending cervical artery, *H* Inferior thyroid artery only, *I* Costocervical trunk only, *J* Inferior thyroid artery, ascending cervical artery and costocervical trunk

Discussion

The results of this study demonstrate that the vertebral artery (100%), the C8 spinal nerve root of brachial plexus (100%), the inferior cervical ganglion (83.7%) and the C7 spinal nerve root (81.4%) are the most commonly found structures in the vertebral triangle. What makes the results very interesting in this study was that both the inferior cervical ganglion and the C7 spinal nerve were only present in 7.5% and 5% of the sample investigated by Tubbs et al. [34], respectively, indicating a much higher incidence of these structures in this study population. This may have some clinical implications as the surgical procedures involving the cervical sympathetic ganglia include cervical sympathectomies, for conditions such as hyperhidrosis, and stellate ganglion blocks for conditions such as chronic regional pain. The low percentage observed (32.6%) of the middle cervical ganglion within the vertebral triangle could be explained by the variability of its location on the cervical sympathetic trunk. Civelek et al. [6], found that the ganglion was found at the C6 vertebral level in 33% of their sample, 26% at the C5 level and 13% at the C7 vertebral level. In 26% of the sample, it was not seen at these levels. The *p* value ($p = 0.3108$) for the Chi-square test was not significant, and thus indicates that there is no relationship between the left and right vertebral triangles regarding all the observed data present within the triangle.

Another study that examined the vertebral triangle, investigated by Singal et al. [27], found that the stellate ganglion was never found in the lateral or upper third of the triangle. Thus, if the ganglion is found within the triangle, it is always inferomedial. They further studied the relationship of the ganglion to other structures in the vertebral triangle and found that the mean distance of the stellate ganglion to the phrenic nerve, the anterior scalene and the origin of the vertebral artery was 12.6 ± 4.5 mm, 12.26 ± 4 mm and 2.3 ± 1.3 mm, respectively. This new insight shows the close relationship of the structures within the triangle and the need for caution during clinical procedures. Due to the fact that the inferior cervical sympathetic ganglion is present within the triangle in more than 80% of the specimens, it is evident that surgeons need to pay close attention to the ganglion when working within or near the triangle to avoid damage to the chain which may result in fallouts, such as Horner's syndrome [8, 33].

In addition to the above-mentioned procedures, injury to the roots and trunks of the brachial plexus, caused by high speed motor-vehicle accidents, is a common occurrence. Due to the high speed of the accidents, patients can experience either caudal traction of the shoulder and arm, which often affects the roots of C5–C6, lateral traction affecting the root of C7 or cranial traction affecting the roots of C8–T1. Depending on the severity of the injury to the brachial plexus, as well as the pain that is experienced, surgical intervention may be required with the most common approach being from an anterior aspect [25, 28]. Should the injury be in the supraclavicular region and concern the roots of the plexus (C7 and C8), the vertebral triangle will usually be encountered. Thus, the same measure of precaution should be taken when working with the roots of the cervical spinal nerves. The C7 spinal nerve contributes to most of the branches of the brachial plexus, any damage to the root may result in serious motor and sensory fall-out to the upper limbs [29].

Another cautionary neurological note regarding the vertebral triangle, is that the phrenic nerve was observed within the triangle in 20.9% of the current sample and, although this is not exceptionally high, it may be of clinical relevance, as damage to the nerve may have detrimental effects with regard to respiration due to its innervation of the diaphragm. What also highlights the mention of the phrenic nerve prevalence is that in the Tubbs et al. [34] study, the phrenic nerve was only noted in 12.5% of the study sample, which is considerably less than the current study population. On occasion (incidence not reported) the phrenic nerve was found within the triangles reported by Singal et al. [27]. The course of the phrenic nerve in the neck has been described as originating from the cervical plexus in the posterior triangle of the neck, descends and runs obliquely across the anterior scalene muscle and finally, runs anterior to the subclavian artery before entering the thorax [14, 20]. However, other studies suggest that the phrenic nerve descends vertically across the anterior scalene muscle [4, 10, 13, 29]. This variability in the course of the phrenic nerve in relation to the anterior scalene muscle may attribute to the low incidence observed of the nerve within the vertebral triangle. Thus, the urge of surgeons to identify these structures preoperatively may help prevent postoperative complications.

To compare this study with the combined left and right sides presented by Tubbs et al. [34] and Singal et al. [27], the nominal data that showed no significant difference between the right and left vertebral triangles was combined (Table 5) for comparison with the previously mentioned studies. No significant difference between the left and right sides with regard to the height and width of the triangle, as well as the closest distance between the C8 spinal nerve to the apex of the triangle was found and, therefore, combined. However, a significant difference ($p < 0.05$) between the distance from the origin of the vertebral artery to the anterior scalene was noted and, therefore, the data could not be grouped together and are summarized separately within Table 5. With regard to the dimensions of the vertebral triangle, the current study and the study by Tubbs et al. [34], show similar dimensions for the height (current study: 31.5 mm; Tubbs et al. [34]: 32 mm) but somewhat different dimensions for the width/base (current study 18.8 mm; Tubbs et al. [34]: 13 mm). Singal et al. [27], investigated 30 vertebral triangles and found the height and width of the triangle to be 21.7 ± 5.1 mm and 19.4 ± 4.4 mm, respectively. In comparison to their study, the dimensions of the height differ from Tubbs et al. [34], and the current study. These differences could be attributed to possible population differences or possible measurement discrepancy since it is unclear exactly which measurement points or landmarks were used in the Tubbs et al. [34] study with regard to the width/base length. The position of the C8 spinal root of the brachial plexus also differed significantly in its position and relation to the apex of the vertebral triangle in the current study and the Tubbs et al. [34] study. In the current study, the C8 root was positioned approximately halfway between the base and the apex (16.1 mm from apex), while in Tubbs et al. [34], it was positioned higher, around 12 mm inferior to the apex.

Table 5. Combined statistics (left and right) for comparative purposes between the current study and other studies

	n	Mean	SE	SD	95% CI	*p* value
Height of triangle	43	31.52	1.18	7.73	29.21–33.83	0.2358
Width of triangle	43	18.80	0.62	4.04	17.59–20.01	0.4580
C8 to apex	43	16.14	0.60	3.92	14.96–17.31	0.7177
Vertebral artery to anterior scalene: right	21	10.07	1.00	4.57	8.11–12.02	0.0243*
Vertebral artery to anterior scalene: left	22	15.41	2.02	9.45	11.46–19.36	

SE Standard error, *SD* Standard deviation, *95% CI* Confidence interval of 95%

*Statistically significant difference

When looking at the distance from the origin of the vertebral artery to the anterior scalene muscle, it was found to be significantly different when comparing left and right sides ($p = 0.0243$). This can be attributed to the more inferiorly placed subclavian artery origin on the left-hand side compared to the right, and thus a more inferiorly placed vertebral artery origin. This lower position then creates a much greater distance between the origin of vertebral artery to the anterior scalene on the left side. The range reported by Tubbs et al. [34] for the same measurement was 5.0–8.0 mm in comparison to a range of 2.8–20.9 mm on the right and 5.8–50.6 mm on the left in this study.

Regarding the vasculature in the vertebral triangle, the inferior thyroid artery was observed in 39.5% of the sample population, which is considered relatively high and, therefore, worth noting. Tubbs et al. [34], although noting the presence of the inferior thyroid artery, did not quantitatively report on its occurrence. In a book chapter about the anatomy of the vertebral artery, Campero et al. [2] found that the inferior thyroid artery crossed anterior to the vertebral artery within the vertebral triangle. Additionally, the stellate ganglion was found medial or anteromedial to the vertebral artery, at the first costovertebral junction. Though this is not necessarily within the triangle, the close relationship between these structures is still noteworthy. In a case study by Chaudhary et al. [5], it was found that the vertebral artery coursed through the stellate ganglion on both sides of the specimen. The vertebral artery in this case would be susceptible to damage in the case of a stellate ganglion block. These various relationships between the vertebral artery and the sympathetic chain should always be taken into consideration before performing anterior cervical spine surgery or nerve blocks in or near the vertebral triangle. Furthermore, traction during the anterolateral surgery of cervical spine injuries has a greater risk of injury to the sympathetic chain [21, 32].

The vertebral arteries commonly originate from the left and right subclavian arteries; however, variations do exist. These variations usually occur unilaterally; however, some cases have reported bilateral variations. Previously reported variations of the origin of the right vertebral artery include arising from the brachiocephalic trunk or right common carotid artery [9, 11, 12, 17]. The presence of two right vertebral arteries have also been described. In these cases, either both the arteries originated from the right subclavian artery or one artery originated from the subclavian artery and the other from the brachiocephalic trunk [3, 16, 18, 23, 31]. Two of the most common variations with regard to the origin of the left vertebral artery is directly from the arch of the aorta, between the left common carotid and the left subclavian arteries, and in this study, three cadavers showed this variation. The second common variation is the left vertebral artery arising from a common trunk formed by the common carotid and vertebral arteries or subclavian and vertebral arteries [1, 3, 11, 12, 17,18,19, 22, 26, 35]. In the case where the presence of two left vertebral arteries were observed, it was found that one originated from the aortic arch and the other from the left subclavian artery [7, 16, 17, 24, 30]. In this study, one cadaver had the vertebral artery with two origins from the subclavian artery.

Conclusion

It is evident that the vertebral triangle is filled with many vital neurovascular structures and knowledge of the exact locations and possible variations are important to help avoid iatrogenic injury to these structures. The main structures of the vertebral triangle are the vertebral artery, the inferior cervical sympathetic ganglia and the C7 and C8 spinal nerves. The measurements and observations reported in this study and that by Tubbs et al. [34] and Singal et al. [27], highlight possible population specific variation that is present in this region. The results of these three studies could, however, be used to provide clinicians with the proper anatomical knowledge of the dimensions and content of the vertebral triangle—which in turn should translate to improved surgical competence and confidence when performing surgical procedures in the area of the vertebral triangle.

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Contributions

SG: protocol development, data collection, data analysis, manuscript writing. LP: project co-supervisor, manuscript editing. NK: project co-supervisor, manuscript editing, data analysis. AvS: project supervisor, project development, manuscript editing.

Conflict of interest

The above-mentioned authors certify that there are no financial gains or associations that may pose a conflict of interest in connection to this article.

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