

Original Communication**CADAVERIC MEASUREMENT AND ANALYSIS OF INTERSCALENE TRIANGLE AND COSTO-CLAVICULAR SPACES IN RELATION TO THORACIC OUTLET SYNDROME****Subhramoy Chaudhury¹, Anasuya Ghosh²**¹*Department of Anatomy, Medical University of the Americas, Saint Kitts and Nevis*²*Department of Anatomy, All India Institute of Medical Sciences, Kalyani, India***ABSTRACT**

Objectives: Thoracic outlet syndrome (TOS) is an upper extremity disorder resulting from compression of brachial plexus structures and subclavian vessels within thoracic outlet region at any of the three primary sites- interscalene triangle, costoclavicular space and retro-pectoralis minor space. This study focused on detailed anatomic exploration and measurement of normal anatomic variability within interscalene triangle and costoclavicular space. **Material and Method:** We examined 49 cadavers (22 male and 27 female) and dissected both sides to explore and examine 98 dissected areas. We measured the base width, height, angle within interscalene triangle and the vertical distance within costoclavicular space. We also calculated the area of interscalene triangle. **Results:** The mean values of base width, height, interscalene angulation of interscalene triangle and height of costoclavicular space was 10.18±4.31 mm, 45.19±0.07 mm, 10.85±0.06 degrees and 10.22±0.07 mm respectively. The mean area of interscalene triangle was 214.82±5.22sqmm. **Conclusion:** We have found clinically significant differences between the interscalene and costoclavicular space vertical heights; the height of costoclavicular space was clinically significant lower than the interscalene space ($p < 0.001$). No clinical significant difference was found between male and female measurements. These ranges of dataset could be useful for planning treatment approaches in TOS.

Key words: *Interscalene triangle, costoclavicular space, thoracic outlet syndrome*

vasos subclavios dentro de la región de salida torácica en cualquiera de los tres sitios primarios: triángulo interescalénico, espacio costoclavicular y espacio menor retro-pectoral. Este estudio se centró en la exploración anatómica detallada y la medición de la variabilidad anatómica normal dentro del triángulo interescalénico y el espacio costoclavicular. **Material y método:** Examinamos 49 cadáveres (22 hombres y 27 mujeres) y diseccionamos ambos lados para explorar y examinar 98 áreas. Medimos el ancho de la base, la altura, el ángulo dentro del triángulo interescalénico y la distancia vertical dentro del espacio costoclavicular. También calculamos el área del triángulo interescalénico. **Resultados:** Los valores medios de anchura de la base, altura, angulación del triángulo interescalénico y altura del espacio costoclavicular fueron de 10,18 x 4,31 mm, 45,19 a 0,07 mm, 10,85 a 0,06 grados y 10,22 a 0,07 mm, respectivamente. El área media del triángulo interescalénico fue de 214,82 x 5,22 mm. **Conclusión:** Hemos encontrado diferencias clínicamente significativas entre las alturas verticales del espacio interescalénico y costoclavicular; la altura del espacio costoclavicular fue significativamente menor en lo clínico que el espacio interescalénico ($p < 0,001$). No se encontró ninguna diferencia clínicamente significativa entre las mediciones masculinas y femeninas. Estos rangos de conjunto de datos podrían ser útiles para planificar enfoques de tratamiento en TOS.

Palabras clave: *Triángulo interescalénico; espacio costoclavicular; síndrome de salida torácica*

RESUMEN

Objetivos: El síndrome de salida torácica (TOS) es un trastorno de las extremidades superiores resultante de la compresión de estructuras del plexo braquial y

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Received: 15 May, 2020. **Revised:** 6 June, 2020. **Accepted:** 18 June, 2020.

INTRODUCTION

Thoracic outlet syndrome (TOS) characteristically develops from abnormalities or changes that produce constriction at one or combination of three specific anatomical locations: interscalene triangle, costoclavicular space and coracopectoral tunnel. (Hooper et al., 2010; Atasoy, 1996; Demondion et al., 2006; Jordan et al., 2013). The interscalene triangle the most medial of these spaces is bordered anteriorly by the posterior edge of the anterior scalene muscle, posteriorly by the anterior portion of the middle scalene muscle, and inferiorly by the superior aspect of the first rib, between the insertion sites for the anterior and middle scalene muscles (Dahlstrom and Olinger, 2012). The anterior rami of the third, fourth, and fifth cervical spinal nerves and the superior, middle and inferior trunks of the brachial plexus and subclavian artery are located within the interscalene triangle.

Several types of bony, fibrous and muscular abnormalities make this site susceptible to neurogenic compression (Hooper et al., 2010; Roos, 1976). The costoclavicular space, the intermediate in location of the three, is described

as the interval between the first rib and clavicle (Demondion et al., 2000). The same neural components and subclavian vessels continue to travel through the costoclavicular space en route to the upper extremity. The coracopectoral tunnel, lateral most of all is defined as the space deep to the pectoralis minor muscle and its insertion to the coracoid process. As subclavian vessels and brachial plexus traverse into the upper limb, potential exists for compression at this site. According to magnetic resonance imaging and computed tomographic studies, of the three potential locations for TOS related compression, the costoclavicular space is the most susceptible. (Jordan et al., 2013; Dahlstrom KA, 2012; Remy-jardin et al., 2000; Demondion et al., 2000). Compression or irritation of brachial nerves is referred to as true neurological TOS (nTOS) (Mackinnon and Novak, 2002; Watson et al., 2009; Urschel, 1994). Compression of the subclavian artery or vein is classified as vascular TOS (vTOS) (Watson et al., 2009). The condition is caused by the presence of a cervical rib or bony growth near a nerve root in the neck (Mackinnon and Novak, 2002; Watson et al., 2009; Archie and Rigberg, 2017).

Compression factors	Structures Compressed	Compression symptoms
1. Muscular hypertrophy (Anterior or middle scalene/ subclavius/ pectoralis minor) or abnormality (presence of scaleneus minimus/ unusual course of trunks of brachial plexus)	Nerve	Pain, paresthesia, motor weakness, Raynaud's phenomena, Horner's syndrome
2. Accessory cervical rib/ long transverse process/ fibrous band/clavicle or first rib related abnormality	Artery	Pain, ischemic or trophic changes, diminished pulse
	Vein	Edema, venous distension

Table 1- Causes and sign-symptoms of Thoracic Outlet Syndrome (TOS)

The incidence of TOS is reported to be approximately 8% of the population (Davidovic et al., 2003), is rarest in children (Cagli et al., 2006), and affects females more than males (between 4:1 and 2:1 ratios) (Gockel et al., 1994; Davidovic

et al., 2003; Demondion et al., 2003; Degeorges et al., 2004). According to Davidovic et al. (2003), 98% of all patients with TOS fall into the nTOS category and only 2% have vTOS. The majority of vTOS cases are diagnosed as arterial vTOS

(Sanders et al., 2007). Neurological TOS is typically common in young women (Van Es, 2001). Patients with diagnosed or suspected TOS may present with a wide range of upper extremity symptoms (Urschel, 2005) (Table 1) and this disorder has been regarded as a misdiagnosed, underrated and overlooked condition (Sheth and Belzberg, 2001; Watson et al., 2009).

Some researchers have reported the measurements of the base width, angle of interscalene triangle and width of costoclavicular space - though such studies are very limited in literature. The detailed description of interscalene triangle and costoclavicular space are clinically relevant as structures related to these spaces are commonly approached during surgical intervention of thoracic outlet syndrome (TOS).

Purpose of our study is to provide an elaborate anatomical description of interscalene triangle and costo-clavicular space related to clinical presentation of TOS. We focused on measurements of the height, width, angle and area of inter scalene triangle and height of costo-clavicular space, compare the values of interscalene triangle and costo-clavicular spaces in male and female cadavers to understand the

difference and get the range of values in thoracic outlet compression areas.

MATERIALS AND METHODS

The study was performed in two steps:

1. Dissection of cadavers (to expose interscalene triangle and costo-clavicular space)
2. Measurements of base, height, angulation of interscalene triangle and vertical distance of costo-clavicular space (by sliding calipers and protractor).

We examined 49 formalin fixed cadavers (male 22, female 29) without the knowledge of any medical history. All cadavers were examined for any trauma or mass lesion involving neck, clavicle or clavicular joints. As no such things were noted, all 98 sides of 49 cadavers were selected for exposure of the interscalene triangles and the costo-clavicular spaces. The initial dissection of the cadavers was done by medical students under guidance of anatomy instructors as a part of laboratory dissection in gross anatomy course.



Figure 1- Measurement points of costo-clavicular space . PT- vertical distance of costo-clavicular space. R1- 1st rib, R2- second rib, SV- subclavian vein, SA- subclavian artery, BP- brachial plexus

All the cadavers were in supine position. In most of the cadavers, the skin was removed from the face, anterior and posterior triangle areas; dissection was extended and the subcutaneous fat and platysma were removed to fully expose the structures of posterior triangle and neighboring thoracic outlet region. The distal insertions of the sternocleidomastoid muscle were detached, pre-scalene fat and prevertebral fascia, lymph-nodes were removed and the anterior and middle scalene muscles were exposed clearly. The clavicle was fully exposed and the part of the first rib beneath the clavicle was cleaned too.

The walls and contents of interscalene triangle were cleaned and examined. The course of brachial plexus and subclavian artery within scalene triangle, costo-clavicular passage and beyond the first rib were noted. No fibrous bands or cervical ribs were noted.

First, the vertical distance of costo-clavicular space was measured between the adjacent points of clavicle and first rib at the level of groove for subclavian artery (Figure 1). The caliper's jaws were placed on the inferior limit of the clavicle and anterior border of the first rib to measure the vertical distance.

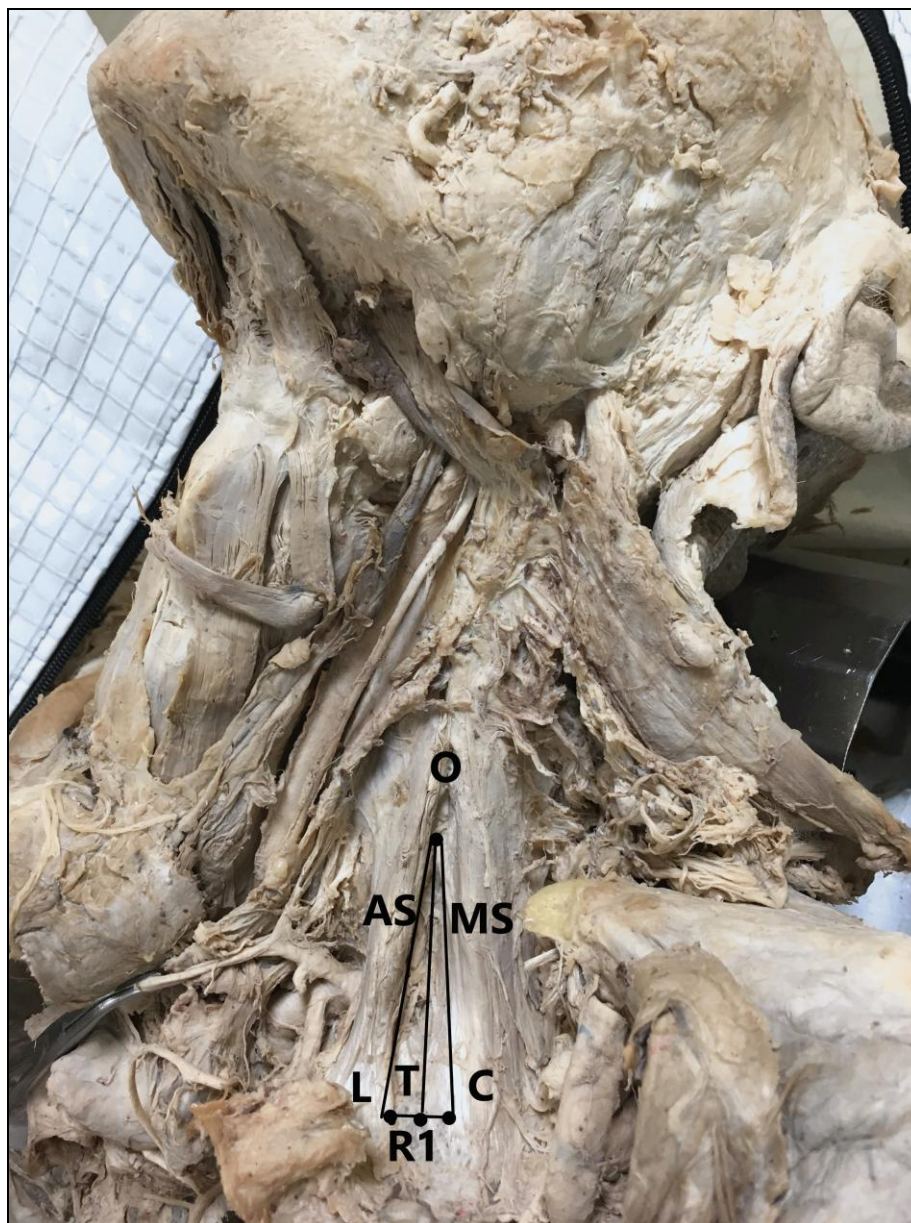


Figure 2- Measurement points for interscalene triangle. LC- base-width, T- midpoint of LC, OT- height, LOC- interscalene angle. AS- anterior scalene, MS- middle scalene, SA- subclavian artery, R1- 1st rib.

Then the medial end of the clavicle was elevated and cut to expose the insertions of anterior and middle scalene muscles at first rib. The part of the brachial plexus within the inter-scalene triangle was cut to expose the borders of the muscles and the angulation between them clearly. Then following measurements of inter-scalene triangle were taken - the base width (between the anterior edge of the middle scalene and the posterior edge of the anterior scalene, right at the insertion onto the first rib), the interscalene angle and height (midpoint of the base to the point of convergence of adjacent muscle borders) (Figure 2).

The interscalene angle was measured with a protractor. The vertex of the angle was placed at the point from where the edges of anterior and middle scalene muscles visibly diverged downwards. The two arms of the protractor were placed on the adjacent edges of anterior and middle scalene muscles as they descend to their insertion points bordering the inter-scalene triangle. All the linear distances were measure by caliper in millimeters. All the values were tabulated in Microsoft Excel software (2010) and were calculated. The area of triangle was calculated by utilizing the mathematical formula [area of triangle = $\frac{1}{2}$ (base x height)].

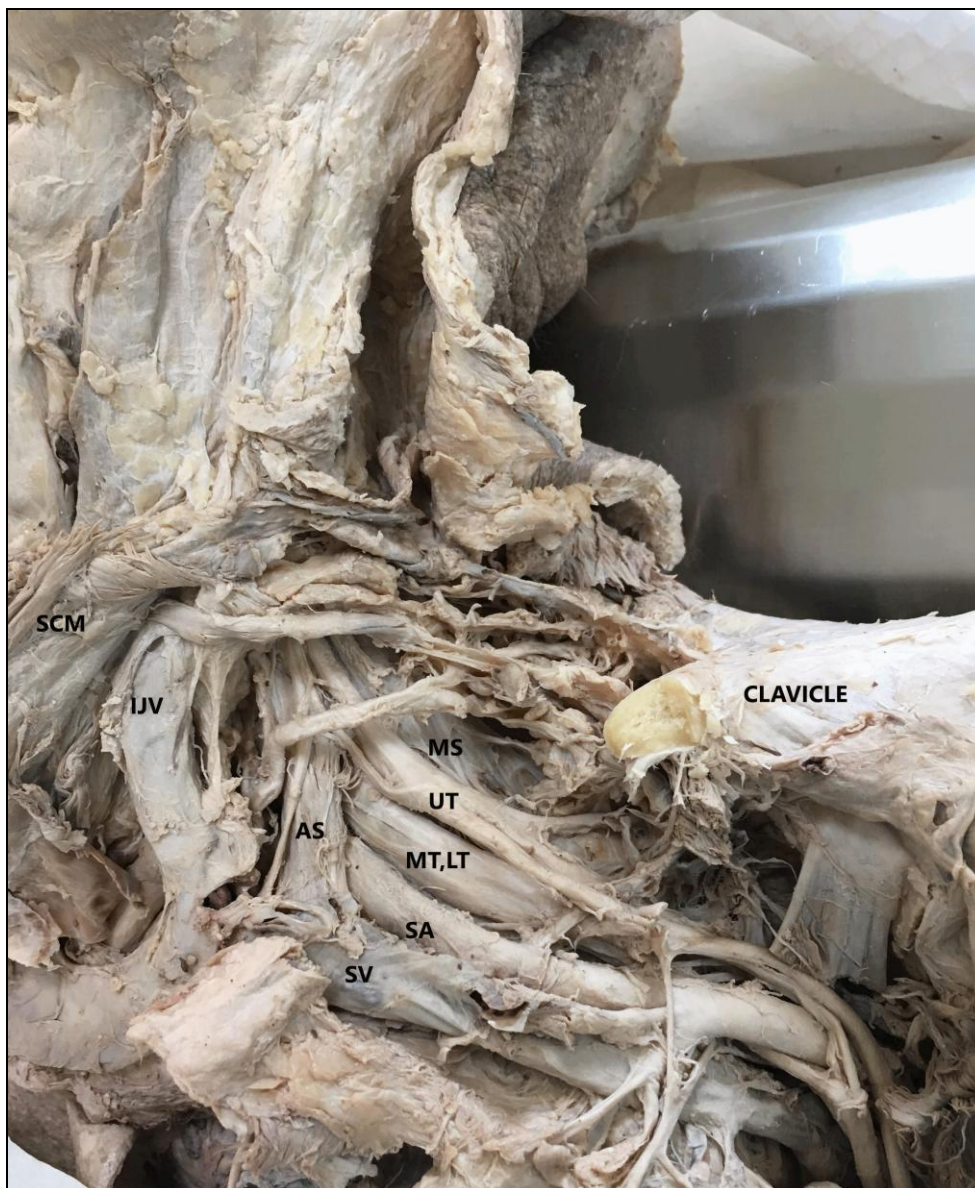


Figure 3- Structures of neck in relation to interscalene triangle. SCM- sternocleidomastoid, AS- anterior scalene, MS- middle scalene, SA- subclavian artery, BP- brachial plexus, UT- upper trunk, MT, LT- middle trunk and lower trunk wrapped in common sheath, SV- Subclavian vein, IJV- Internal jugular vein

RESULTS

In the interscalene triangle subclavian artery always passed through the lower part of this space. The brachial plexus upper (C5–C6) and middle (C7) trunks passed through the upper part of this space. The lower (C8–T1) trunk crossed the inferior part of the interscalene triangle posterior to the subclavian artery. The subclavian vein ran between the clavicles anteriorly and the anterior scalene muscle posteriorly (Figure 3).

In the costoclavicular space, the axillary vein was anterior to the axillary artery. The nerve cords course just above and posterior to the axillary artery. (The lateral nerve cord was the most anterior cord. The posterior nerve cord was above the lateral and medial nerve cords.)

Lateral to costoclavicular space in the coracopectoral tunnel the cords divides into several branches. We noted that the scalene muscles

inserted at first rib adjacent to each other. All of the insertions were tendinous.

The average distance of base of interscalene of triangle was 10.18mm (\pm 4.31mm), the average height of the triangles was 45.19 mm (\pm 0.07mm) and average area was 214.82sq.mm (\pm 5.22). We measured male and female cadaveric measurements and right versus left sided measurements (Tables 2 and 3). The average distance of costo-clavicular space was 10.22 (\pm 0.07) mm.

The mean area of interscalene triangle in male cadavers was 216.63mm² where in case of female the average area was 212.64mm². The difference between the areas of interscalene triangle in male and female cadavers was not statistically significant ($p>0.05$). The mean measurement of the angle between anterior and middle scalene muscles in male and female cadavers was 10.86 and 10.85 degrees respectively.

Measurements	Right side			Left side		
	Mean	SD	Range	Mean	SD	Range
Scalene triangle						
Base width (mm)	10.22	4.80	4-22	10.18	4.61	2-21
Height (mm)	45.22	6.60	35-60	45.27	5.99	35-58
Angle (degrees)	10.79	1.90	4-15	10.93	1.78	5-15
Area (sq.mm)	211.95	75.98	120-385	80.94	221.31	58-368
Costo-clavicular space distance (mm)	10.13	2.74	6-15	10.31	3.09	5-17

Table 2- Measurements in male cadavers

Measurements	Right side			Left side		
	Mean	SD	Range	Mean	SD	Range
Scalene triangle						
Base width (mm)	10.14	4.26	1-21	10.18	3.94	2-20
Height (mm)	45.14	6.26	34-55	45.11	5.18	35-50
Angle (degrees)	10.81	1.81	3-15	10.88	1.59	5-14
Area (sq. mm)	209.48	70.52	55-357	74.18	216.55	50-350
Costo-clavicular space distance (mm)	10.22	1.70	7-14	10.22	2.69	7-18

Table 3- Measurements in female cadavers

DISCUSSION

We have examined and presented a set of measurements related to interscalene triangle

and costoclavicular spaces in cadavers. These areas are regarded as two primary sites of compression of neural and vascular structures giving rise to thoracic outlet syndrome (Watson et

al., 2009; Dahlstrom and Olinger, 2012). Compression may happen due to alteration of size and shape of thoracic outlet (Watson et al., 2009) due to poor posture. Other causes could be presence of a cervical rib, abnormalities related to first rib or clavicle, muscular hypertrophy, trauma related damage and muscle spasm or bony growth around the nerve roots at neck (Levin and Rigby, 2018; Watson et al., 2009). We did not find any cervical rib, fibrous band, bony growth or other structural abnormality in any of the cadavers.

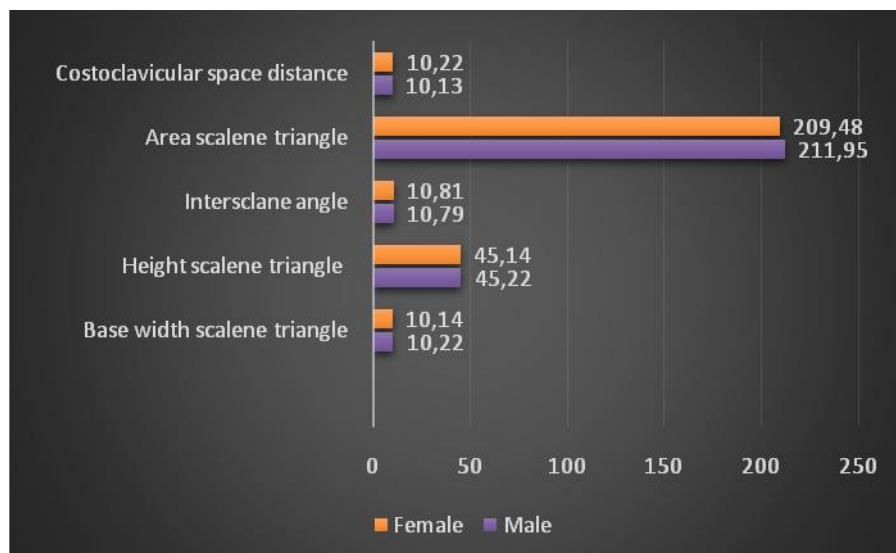
In our study, the mean base width of interscalene triangle was 10.18 mm (range 1-22 mm). Savgaonkar et al (2006) reported the mean measurement as 9 mm (range 0-25mm). The mean value of same measurement by Dahlstrom and Olinger (2012) was 10.7mm (range 0-21mm), by Kaplan et al (2018) was 15.28 mm. The difference in values of different studies proves the variability in the region of interscalene triangle.

We measured the height of interscalene triangle and calculated the area as well. The mean height in current study was 45.19 mm and mean area within interscalene triangle was 214.82sq.mm. No previous studies reported any measurements regarding the height and area of interscalene triangle. The area or more accurately the volume of interscalene triangle can give us some idea

about chances of compression if it could be calculated in living and in symptomatic versus non symptomatic patients. The average measurement of interscalene angle was 10.85 degrees (in our study), 11.4 degrees (Dahlstrom and Olinger, 2012) and 27.06 degrees (Demondion et al., 2006). The cadaveric studies having similar findings and the MRI based study reporting relatively different finding- shows the difference between manual cadaveric measurements versus radiological dynamic measurements. Though Kaplan et al (2018) reported no difference between tomographic and cadaveric measurements in thoracic outlet region.

Our study found the mean vertical distance of costoclavicular space as 10.22mm (range 5-18 mm) where as in previous studies the reported mean was 13.5mm (range 6-30.9mm) (Dahlstrom and Olinger, 2012) and 12.42±1.43mm (Kaplan et al., 2018). The difference again could be due to possible variability in the costoclavicular space.

Though clinically TOS is more commonly seen in female (Van Es, 2001) we could not find any clinically significant variation in measurements between male and female cadavers and between right versus left sides (Graphic 1 and 2) like the study by Dahlstrom and Olinger (2012).



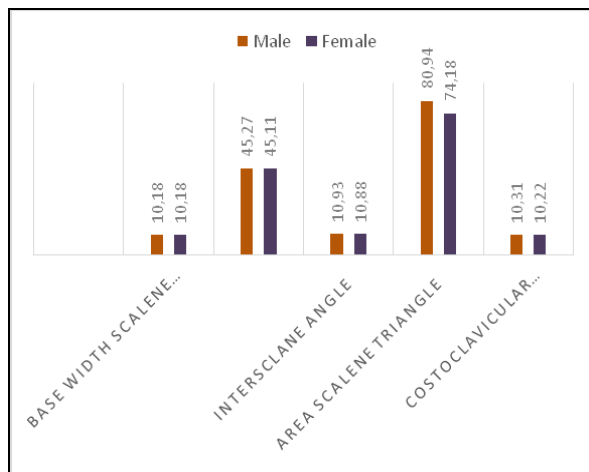
Graphic 1- Comparison of values between male and female cadavers on right side

The present study focused on the morphometry of scalene triangle and costoclavicular spaces however study by Natsis et al (2006) revealed the relationship of the scalene muscle with the upper trunk of brachial plexus. They found 12.9% cases of variations where either the upper trunk or C6 root pierced the scaleneus anterior muscle which could predispose to the pathology of TOS.

In another study, Natsis et al. (2013) observed the presence of scaleneus minimus muscle in 4.11% cases of cadavers and mentioned it as another predisposing factor for TOS. We also found the presence of scaleneus minimus muscle in some of our dissected cadavers.

Current study found the height of costoclavicular space was clinically significantly lesser in

comparison to height of interscalene triangle ($p < 0.001$). Our finding that costoclavicular space was much narrower than the interscalene area was supported by a previous study (Kaplan et al., 2018).



Graphic 2- Comparison of values between male and female cadavers on left side

TOS has been regarded as a complicated, controversial and challenging upper extremity disorder without any standardized classification or management protocol (Jordan et al., 2013; Jam B, 2017). Diagnosis is usually done by detailed history and clinical examination of symptomatic patients (Watson et al., 2009) electrophysiological study (Urschel 2005; Savgaonkar et al., 2006) and standard imaging techniques (Redenbach and Nelems, 1998; Demondion et al., 2006; Levine and Rigby, 2018) help planning the treatment modalities. Treatment could be conservative including proper postural instruction, muscle stretching and strengthening by active neck exercise, heat message etc. (Urschel, 2005; Demondion et al, 2006; Dahlstrom and Olinger, 2012; Levine and Rigby, 2018). The patients with progressive symptoms or serious complications are particularly treated with surgical approaches (Kaplan et al., 2018; Urschel, 2005; Savgaonkar et al., 2006, Watson et al., 2009).

The present study has calculated the area of interscalene triangle and provided a range within interscalene space. As the structural compression by bony or soft tissue anomaly are not always related to severity of symptoms in some variants of TOS (Watson et al., 2009), the anatomic variability in thoracic outlet region (Levine and Rigby, 2018) reflected as wide range of measurements could be the cause of symptoms.

The main limitation was relatively small sample size and being not able to know any history related to TOS in any of the cadavers. If these measurements could be done in symptomatic patients and could be compared with population with same age and sex without any upper extremity symptoms - that information could be more useful in diagnosis and management of TOS.

This study presents the detailed anatomic description and a set of measurements of the interscalene triangle and costoclavicular space as they are the two primary sites of compression of neurovascular structures and relevant areas for planning the management approaches in patients with TOS. We did not find any clinically significant difference in measurements between male and female cadavers. We did not find any cervical ribs or fibrous bands in any of the cadavers. Our study reported clinically significant difference between the height of inter-scalene triangle versus costoclavicular height and it was significantly low in costoclavicular space.

Conflict of Interest

No conflict of interest was present

Funding

None

Ethical approval

Approved by institutional Ethics committee

Informed consent

Not applicable

Contributions:

SC: Research idea, planning, data acquisition, drafting manuscript. AG: Research plan, data acquisition, drafting manuscript, revision of final manuscript

ACKNOWLEDGEMENT

The authors like to express their sincere gratitude towards those who donated their bodies for the sake of medical science and education; without their generosity and kindness this work could not have been done.

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