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The importance of costoclavicular space on possible compression of the subclavian artery in the thoracic outlet region: a radio-anatomical study

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Abstract

OBJECTIVES: The purposes of this study were to identify possible compression points along the transit route of the subclavian artery and to provide a detailed anatomical analysis of areas that are involved in the surgical management of the thoracic outlet syndrome (TOS). The results of the current study are based on measurements from cadavers, computed tomography (CT) scans and dry adult first ribs.

METHODS: The width and length of the interscalene space and the width of the costoclavicular passage were measured on 18 cervical dissections in 9 cadavers, on 50 dry first ribs and on CT angiography sections from 15 patients whose conditions were not related to TOS.

RESULTS: The average width and length of the interscalene space in cadavers were 15.28 ± 1.94 mm and 15.98 ± 2.13 mm, respectively. The widths of the costoclavicular passage (12.42 ± 1.43 mm) were significantly narrower than the widths and lengths of the interscalene space in cadavers ($P < 0.05$). The average width and length of the interscalene space (groove for the subclavian artery) in 50 dry ribs were 15.53 ± 2.12 mm and 16.12 ± 1.95 mm, respectively. In CT images, the widths of the costoclavicular passage were also significantly narrower than those of the interscalene space ($P < 0.05$). The measurements from cadavers, dry first ribs and CT images were not significantly different ($P > 0.05$).

CONCLUSIONS: Our results showed that the costoclavicular width was the narrowest space along the passage route of the subclavian artery. When considering the surgical decompression of the subclavian artery for TOS, this narrowest area should always be kept in mind. Since measurements from CT images and cadavers were significantly similar, CT measurements may be used to evaluate the thoracic outlet region in patients with TOS.

Keywords: Thoracic outlet syndrome • Subclavian artery • Anatomy • First rib

INTRODUCTION

Thoracic outlet syndrome (TOS) is caused by compression of the neurovascular structures within the thoraco-cervico-axillary region, which is formed by the scalene muscles, the clavicle and the first rib [1]. The neurovascular structures are the brachial plexus, the subclavian vein and the subclavian artery. Compression of these structures results in different clinical types of TOS. Abnormalities of anatomical components at the thoracic outlet are common causes of TOS [2]. Arterial TOS (ATOS) is the least common manifestation of this entity and is generally associated with bone abnormalities such as cervical rib, malunion or prominent bony callus of the clavicle or the first rib, in addition to congenital narrowness of the aperture [3]. Different surgical approaches have been described for the management of TOS [4]. Cervical rib resection and scalenectomy without first rib resection are generally thought to provide adequate decompression in ATOS [5, 6]. There is however, no gold standard procedure for this complicated, multidisciplinary disorder.

We performed measurements in cadavers, computed tomography (CT) sections and dry adult first ribs to identify the possible compression points along the transit route of the subclavian artery in the thoracic outlet region and to describe the region to theorize where the subclavian artery might undergo decompression.

METHODS

The current study is based on measurements of CT sections, dry first ribs and cadavers.

Measurements in cadavers

Eighteen cervical dissections were performed in 9 formalin-fixed cadavers (5 male, 4 female; median age 64). The dimensions of the transit route of the subclavian artery (costoclavicular passage width, interscalene space width and length) in the thoracic outlet region were obtained. All cadavers had been perfused with a fixative solution containing formalin, phenol, alcohol and glycerine. None of them had a history of trauma, tumour or TOS. Each cadaver was in the supine position. Specimens were excluded from the data set if previous dissections altered the integrity of the scalene muscles or if the sterno-clavicular or acromioclavicular joint had been disrupted in any way.

Dissection was performed as follows: an incision was made along the midline from the level of the thyroid cartilage to the xiphoid process of the sternum. This incision was then diverted on both sides at the base of the neck. Skin flaps with subcutaneous fat and platysma were removed. The distal insertions of the sternocleidomastoid muscle were detached and the muscle was elevated to the hyoid level. The pectoralis major muscle was detached from the clavicle. The costoclavicular passage was measured and recorded at the level of the groove for the subclavian artery. After elevating the medial end of the clavicle, the prescalene fat and prevertebral fascia were removed to expose the interscalene triangle, and the measurements were made. All morphometric measurements were done with a digital caliper.

Measurements of dry first ribs

Fifty dry adult first ribs (25 right and 25 left first ribs) were examined to determine the dimensions (width and length) of the groove for the subclavian artery (interscalene space). To the best of our knowledge, none of the cadavers whose ribs were taken had a clinical history of TOS.

Radiological measurements

To determine the dimensions of the subclavian artery transit route in living individuals, we also made measurements from carotid artery CT angiography studies in 15 patients who had diagnoses other than TOS. This study was approved by the Ufuk University Hospital ethics review board, Ankara/Turkey, as part of the clinical vascular database. All CT angiography studies were performed with a 16-detector row CT scanner (GE Lightspeed 16, General Electric Health Systems, Milwaukee, WI, USA) with injection of 100 ml of nonionic contrast medium (Omnipaque 300/100 Mallinckrodt) via the right antecubital vein with the help of an automatic power injection pump (Medtronic, Minneapolis, MN, USA). The patients were in supine and anatomical positions. At least 20 ml saline was used to push the rest of the contrast medium inside the catheter through the veins. Sections were started at the skull base and ended at the level of the aortic arch with 1.25 mm slice thickness and 0.8 pitch factors. Images of all studies were collected from a picture archiving and communication system (PACS, Clearcanvas, Synaptive Medical, Toronto, ON, Canada) and uploaded into another workstation (Sun Workstation 4.6, Sun Microsystem Inc. Santa Clara, CA, USA). Multiplanar reconstructions with oblique planes were designed manually to identify the length and width of the interscalene space and the width of the costoclavicular space.

All measurements in the cadavers and in the dry first ribs were made by 2 anatomists and 1 thoracic surgeon. The linear distances were measured using a digital caliper. The measurements of the CT section were made by a radiologist on 3 different dates. Interclass correlation coefficients were calculated to assess the repeatability of the intra- and interobserver measurements. The differences between the groups were analysed with the independent sample *t*-test for continuous variables. A P-value <0.05 was considered statistically significant.

RESULTS

Cadavers

The median age of the cadavers was 64 years, and the male/female ratio was 5/4. In the cadavers, the mean measurements of the width and length of the interscalene space (Figs 1A and B and 2) were 15.28 ± 1.94 mm and 15.98 ± 2.13 mm, respectively. The mean width of the costoclavicular passage (12.42 ± 1.43 mm) (Fig. 3) was significantly lower than the width and length of the interscalene space in the cadavers ($P < 0.05$) (Table 1).

Dry first ribs

The mean measurements of the width and length of the interscalene space (groove for subclavian artery) in the ribs (Fig. 4) were 15.53 ± 2.12 mm and 16.12 ± 1.95 mm, respectively (Table 1). Additionally, when we compared the width of the costoclavicular passage (12.42 ± 1.43 mm) measured from the cadaver with the width and length of the interscalene space measured from the dry adult first ribs, we found that the costoclavicular passage was significantly narrower than the width and length of the interscalene space measured from the dry adult first ribs ($P < 0.05$).

Computed tomographic sections

The median age of the patients whose CT angiography images were used was 69 years and the male/female ratio was 9/6. The mean width of the costoclavicular space (Fig. 5), measured from the CT angiography studies, was 13.78 ± 2.60 mm, whereas the mean lengths (Fig. 5) and widths (Fig. 6) of the interscalene space were 16.20 ± 1.80 mm and 16.40 ± 2.10 mm, respectively (Table 1). In the CT images the widths of the costoclavicular passage were significantly narrower than the widths and lengths of the interscalene space ($P < 0.05$) (Table 1). There was no statistically significant difference between the measurements from the cadavers and those from the CT images for the width and length of the interscalene space and for the width of the costoclavicular passage (P 0.05).

There was no statistical significance between the measurements (width/length of the interscalene space) of the right and left sides of the cadavers, ribs or tomographic sections. Additionally, there was no statistically significant difference between the anatomical measurements obtained from the male and female cadavers and those from the CT sections. The interobserver measurements for cadavers and dry ribs and the intraobserver measurements for CT sections were all well correlated (Table 2).

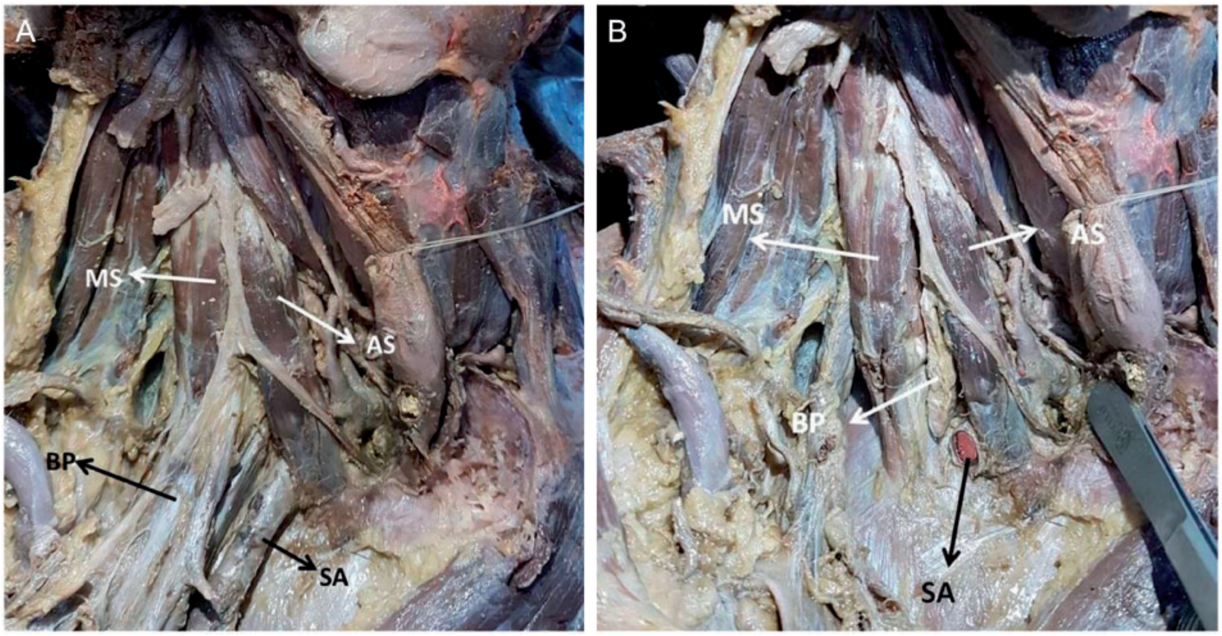

Figure 1: (**A**) Right cervical dissection in a cadaver: right interscalene triangle; right clavicle was removed. (**B**) BP and SA were removed. AS: anterior scalene muscle; BP: brachial plexus; MS: middle scalene muscle; SA: subclavian artery.

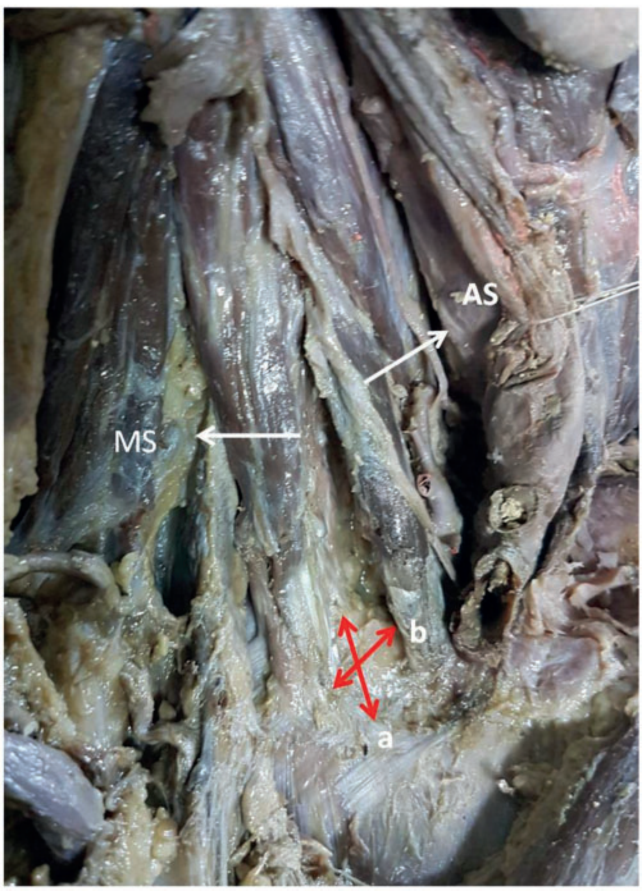

Figure 2: Measurement of the width and length of the interscalene space. a: interscalene space length; AS: anterior scalene muscle; b: interscalene space width; MS: middle scalene muscle.

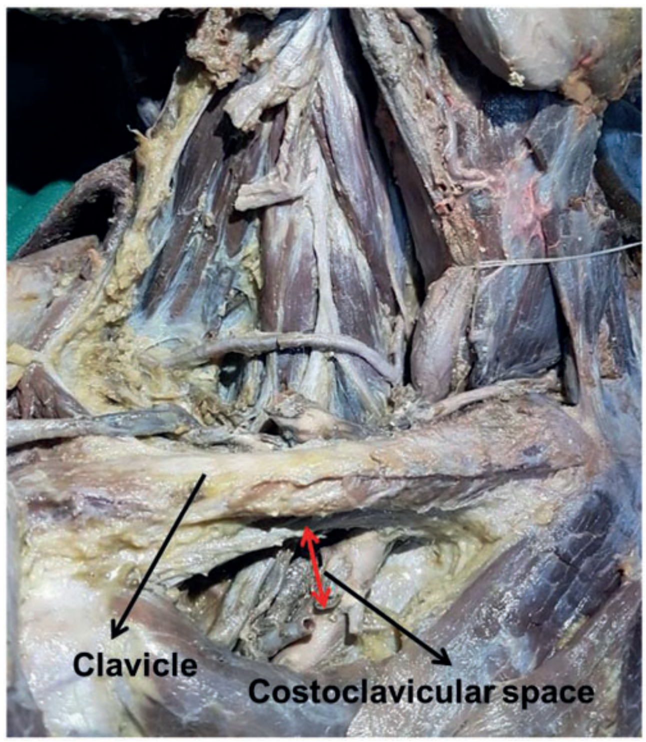

Figure 3: Measurement of the costoclavicular space.

DISCUSSION

ATOS is caused by compression of the subclavian artery within the thoracocervical region leading to the development of occlusion or aneurysms. The interscalene triangle and costoclavicular

Table 1: The measurements of the transit route of the subclavian artery

	Interscalene space (mm)		Costoclavicular passage	
	Length, mean ± SD	Width, mean ± SD	Width (mm), mean ± SD	*P*-value
Cadaver (*n* = 18)	15.98 ± 2.13	15.28 ± 1.94	12.42 ± 1.43	0.05[a]
Dry ribs (*n* = 50)	16.12 ± 1.95	15.53 ± 2.12		
CT section (*n* = 30)	16.20 ± 1.80	16.40 ± 2.10	13.78 ± 2.60	0.05[a]

[a]The costoclavicular space was found to be significantly narrower than the length and width of the interscalene space.

CT: Computed tomography; SD: standard deviation.

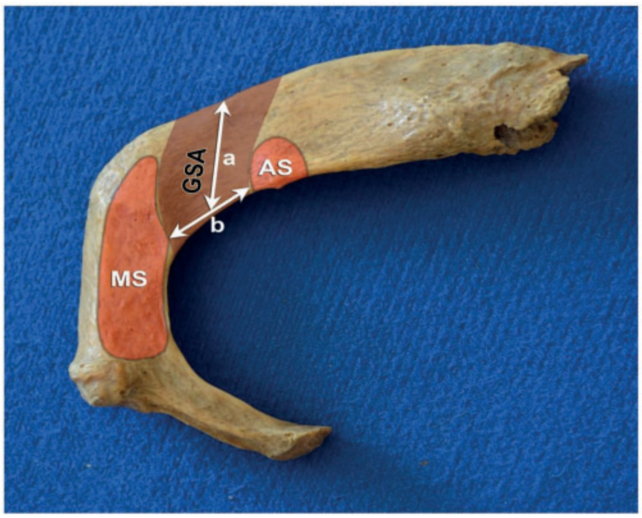

Figure 4: Photograph showing the upper part of the dry adult first rib and measurements of the grove for the subclavian artery. a: interscalene space length; AS: anterior scalene muscle; b: interscalene space width; GSA: groove for subclavian artery; MS: middle scalene muscle.

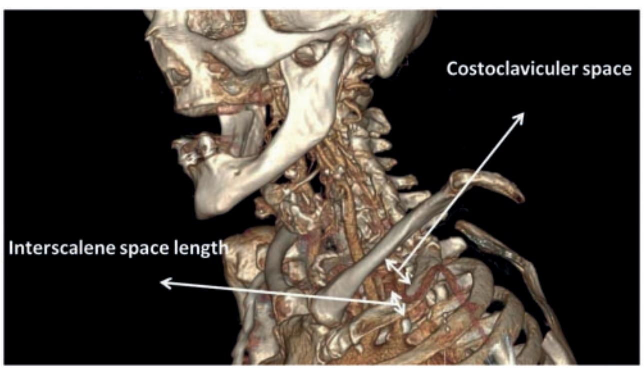

Figure 5: Computed tomography angiography showing the interscalene space length and costoclavicular space width.

space are known as the most frequent sites of neurovascular entrapment [7]. ATOS is the least common form of TOS but has some of the most serious symptoms and complications. Most of these patients are found to have underlying bony abnormalities such as cervical rib, abnormal first rib, large C-7 transverse process or abnormal clavicle. There are many published reports

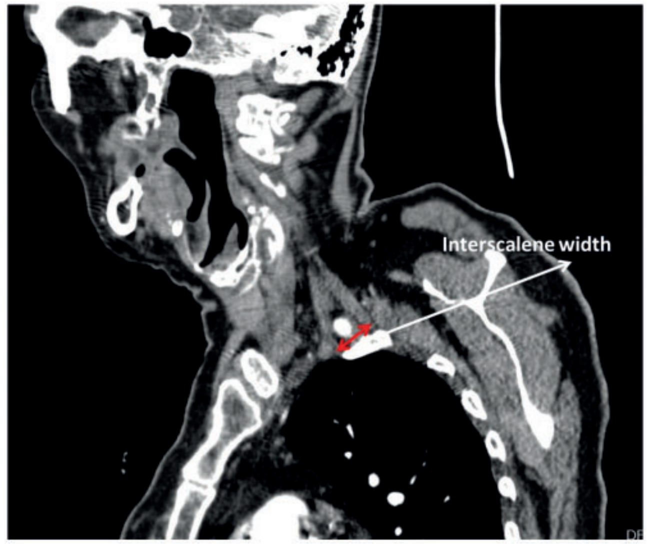

Figure 6: Computed tomography angiography showing the interscalene space width.

describing treatment strategies and different surgical approaches to relieve the symptoms of TOS. Surgeons choose one over another depending on the anatomical abnormality causing the compression. Most of these published reports came from large referral centres as a single-centre experience, and most of them had a small number of cases, especially for vascular TOS [8–15]. Surgical decompression of the subclavian artery in the reported studies generally included cervical rib excision if present or scalenectomy with or without first rib resection through a supraclavicular approach. When adequate decompression was provided by cervical rib resection and scalenectomy, first rib resection was not considered [5–16]. Additionally, some authors believed that microsurgical decompression of TOS without removal of the first rib using a supraclavicular approach was an effective treatment method for complete relief from the symptoms of TOS [14–16].

Mingoli *et al.* [17] showed that recurrence of TOS symptoms requiring reoperation was frequently due to an incomplete resection of the first rib. They described a series of patients in whom a long posterior first rib stump, shown on routine follow-up chest radiographs, was identified as the cause of recurrent symptoms in 20 (80%) of 25 patients with fair or poor surgical results [17]. Similarly, Ambrad-Chalela *et al.* [18] reported that incomplete excision of the first rib and surrounding structures was a common cause for TOS recurrence. Apparently partial rib resection or sparing the first rib is one of the major causes of recurrence of this syndrome.

Variations in the scalene muscles affect the size of the interscalene triangle and the base of the triangle (interscalene width), and the changes in the size of this area contribute to the spectrum of symptoms and signs of TOS [19, 20]. Early studies found that the width of the interscalene space ranged from 1 to 22 mm with an average width of 11 mm [21]. Savgaonkar *et al.* [22] reported an interscalene width with a range of 0–25 mm and an average width of 9 mm. In our study, the average width of the interscalene space was 15.28 ± 1.94 (range 3–23 mm) mm in cadavers and 15.53 ± 2.12 (range 4–26 mm) mm in dry adult ribs.

Tightness in the costoclavicular space is the second potential cause of the symptoms observed in the TOS. The characteristics of

Table 2: The values of the interclass correlation coefficients of the measurements from the cadavers, the dry ribs and the computed tomographic sections

	ICC for cadavers (95% CI)	ICC for dry ribs (95% CI)	ICC for CT sections (95% CI)
Interscalene space (mm)			
Length	0.95 (0.78–0.97)	0.97 (0.94–0.99)	0.99 (0.97–0.99)
Width	0.93 (0.79–0.97)	0.96 (082–0.98)	0.98 (0.97–0.99)
Costoclavicular space (mm)			
Width	0.94 (0.78–0.98)		0.97 (0.96–0.99)

CI: confidence interval; CT: computed tomography; ICC: interclass correlation coefficients.

this area have been studied in cadavers before. Dahlstrom *et al.* [23] found that the average distance for the costoclavicular space was 13.5 mm with a range of 6–30.9 mm in cadavers. In our study, the average measured costoclavicular space in the cadavers was 12.42 ± 1.43 mm, which was the narrowest space among the measurements. This finding is consistent with those of previous authors who stated that the costoclavicular space was the main site of arterial compression in the thoracic outlet region [24, 25].

We found no difference between the measurements from preserved cadaveric specimens and those from the tomographic sections. All measurements taken from the cadavers and from the tomographic sections were static measurements in the supine and anatomical positions. We believe that the measurements from the tomographic sections could be used in the assessment of the thoracic outlet region for TOS.

In evaluating these results, there are some limitations. First, the study group for cadaveric measurements was small. A larger series is needed to obtain the normal ranges for the anatomical measurements. Second, we had no measurements from patients with TOS. An idea for a different project would be to evaluate the morphometric measurements of patients with TOS.

This study showed that the costoclavicular width was the narrowest space along the route of the subclavian artery. Therefore, we believe that eliminating this narrowest space should be an indispensable part of the decompression of the subclavian artery in patients with TOS. Furthermore, we found no difference between the tomographic and cadaveric measurements of the thoracic outlet region. Tomographic measurements could be used in the diagnosis of TOS.

Conflict of interest: none declared.

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