Cadaver analysis of thoracic outlet anomalies

Torasik çıkıştaki anomalilerin kadavra analizi

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Background: This study aims to determinate the rate of thoracic outlet anomalies by means of analysis of cadavers.

Methods: Supraclavicular incisions were applied by two anatomists and two thoracic surgeons in the thoracocervicoaxillary region of both extremities (n=40) in twenty cadavers (7 females, 13 males; mean age 46). The formation and type of fibrous bands, cervical ribs, C7 long transverse processes and anomalies of the clavicles, scalenus anterior and scalenus medius muscles, brachial plexus, subclavian arteries and veins were evaluated. The type and formation of fibrous bands were classified using Roos' classification.

Results: Anomalies were found in 34 (85%) of extremities. The type 3-band was most frequently (15%) observed and all of them were on the right extremity. The type 4-band was rarely seen (2.5%). Two bands (type 9 and type 11) in the same extremity were notified in one cadaver. (2.5%). The occurrence rate of cervical rib and C7 long transverse process was 10%. Some fibers of m. scalenus medius emerged from a cervical rib in one extremity (2.5%). The arteria subclavia anterior passed through the scalene muscle in three extremities (7.5%). In 10% of extremities the C5 truncus passing through the anterior scalene muscle and upper truncus of brachial plexus passing anterior scalene muscle via perforation was found in 7.5% of patients.

Conclusion: In our population, brachial plexus and subclavian artery variations are frequently observed. Therefore these types of anomalies should be taken into consideration to prevent morbidity and complications when muscle division or blockage applications are performed.

Key words: Brachial plexus; fibromuscular bands; thoracic outlet syndrome.

Amaç: Bu çalışmada kadavra analizi ile torasik outlet anomalilerinin oranını belirlemeye çalıştık.

Çalışma planı: Yirmi kadavrada (7 kadın, 13 erkek; ort. yaş 46) torakoservikoaksiller bölgede, her iki ekstremiteye (n=40) iki anatomi uzmanı ve iki göğüs cerrahı tarafından supraklaviküler kesi uygulandı. Fibröz bant formasyonu ve tipi, servikal kosta ve C7 uzun transvers çıkıntı varlığı, klavikula, skalenus anterior ve skalenus medius kası, brakiyal pleksus, subklavian arter ve subklavian ven anomalileri değerlendirildi. Fibröz bant formasyonu ve tipi Roos sınıflamasına göre adlandırıldı.

Bulgular: Otuz dört (%85) extremitede anomaliye rastlandı. Tip 3 bant en sık oranda (%15) gözlendi ve tümü sağ ekstremitede idi. Tip 4 bant ise en az oranda (%2.5) görüldü. Aynı ekstremitedeki iki bantın (tip 9 ve tip 11) varlığına ise bir kadavrada (%2.5) rastlandı. Servikal kot oluşma oranı ve C7 uzun transvers çıkıntısı %10 idi. Skalenus medius kasının bazı lifleri bir ekstremitede (%2.5) servikal kostadan başlıyordu. Anteriyor subklavyan arter üç ekstremitede (%7.5) skalen kasın içinden geçiyor idi. Yüzde on ekstremitede ise C5 trunkusun anteriyor skalen kası perfore ederek içinden geçtiği ve %7.5 oranında ise brakiyal pleksusun üst trunkusunun anteriyor skalen kası perfore ederek geçtiği gözlendi.

Sonuç: Toplumumuzda brakiyal pleksus ve subklaviyan arter varyasyonları sıklıkla gözlenmektedir. Bu nedenle kasların bölünmesi ya da blokaj uygulamaları sırasında morbidite ve komplikasyonların önlenmesi açısından bu tip anomaliler dikkate alınmalıdır.

Anahtar sözcükler: Brakiyal pleksus; fibromusküler bantlar; torasik outlet sendromu.

Thoracic outlet syndrome (TOS) is characterized by compression on the subclavian vessels and brachial plexus at the superior aperture of the chest. The diagnosis or treatment of the thoracic outlet syndrome is complicated.[1] Factors which cause pressure on the thoracic outlet include bony tissue and soft tissue

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related anomalies. Bone anomalies include cervical rib, abnormal first rib and long C7 cervical transverse processes while soft tissue factors are ligaments, fibrous bands and scalene muscle anomalies resulting in symptoms due to compression.[2-4]

Functional symptoms become apparent when these anomalies are demonstrated in operation with various combinations. If myofascial anomalies impinge on soft and sensitive nerves of the plexus, nerve compression causes pain and gradual progression to compression neuropathy. Abnormal anatomic structures create the basic problem of mechanical compression or irritation of the sensitive cervical nerves. Since appropriate dissection of the anomalies are required for sustained relief[5] it is helpful to know compressing structures. The thoracic outlet region is rich in anatomical variations making proper characterization of this region necessary. Special attention was given to Roos' classification of abnormal anatomy in the upper thorax.[6]

There is more need for cadaver studies for characterization of these anomalies. The aim of our study is to determine the rate of anomalies in the thoracocervicoaxillary region in cadavers.

MATERIALS AND METHODS

Subjects

Cadavers were provided by Ankara University School of Medicine, Department of Anatomy. Observations were noted without any medical history. The thoracic outlets of 20 cadavers (7 females, 13 males; mean age 46) were dissected by two anatomists and two thoracic surgeons. Supraclavicular incisions were performed on both extremities (n=40).

Dissection technique

The Platysma, sternocleidomastoideus (SCM), omohyoid and scalene muscles were dissected with subcutaneous fat tissue after supraclavicular incisions. Clavicula was evaluated with respect to any structural anomaly. The presence of cervical ribs was noted. Sternocleidomastoid muscles were cut. The scalenus anterior and scalenus medius muscles were palpated and described with macroscopic observation. The brachial plexus (BP) was reached between the scalene muscles using blunt dissection. Relationships of the subclavian artery and subclavian vein between muscles were determined. Anomalies of the first rib were evaluated. Dissection was extended to the neck through the posterior triangle thoracic outlet and adjacent structures. Absence of C7 long transverse process formation was documented. Presence or absence of compression on the brachial plexus was recorded, including origin from an anterior or posterior site, level of plexus involved (T1, C8-T1, C7-C8-T1 or more distal) and the cause (muscle anomaly or band anomaly).

Demographic data; age and laterality of anomalies were also noted. The formation and type of fibrous bands were evaluated via Roos' classification (Table 1).[6]

RESULTS

Fibromuscular bands

The type 3 band was most frequently observed and all of them were on the right extremity (15%, n=6/40). The type 4 band was the rarest anomaly (2.5%, n=1/40). The other bands (types 12, 9, 2, 11 and 1) were found in rates of 10%, 10%, 7.5%, 5% and 5% respectively. The formation of two band-anomalies (type 9 and type 11) was found in only one extremity (2.5%; Table 2).

The anomalies had no statistically significant difference with respect to extremities and sex (p=0.48, p=0.33).

Brachial plexus

It was observed that the C5 trunk passed through the anterior scalen muscle (ASM) in 10% of extremities by perforation and the upper truncus of the BP passed through the ASM by perforation in 7.5% of dissections.

Scalene muscle anomaly

Some fibers of m. scalenus medius emerged from a cervical rib in one extremity (2.5%).

Subclavian artery and vein

In three extremities (7.5%) the arteria subclavia anterior passed through scalene muscle (Fig. 1).

Bone anomalies

Cervical ribs and cervical long transverse processes each of these occurred in 10%. Clavicula and first rib anomalies were not observed. Anomalies are summarized in table 3 with the exception of fibromuscular bands.

DISCUSSION

In our anatomical study the existence of a cervical rib was demonstrated in 10%. A cervical rib was present at a rate of 63.8% in our surgical series, which consisted of 206 cases.[1] Cervical ribs are encountered at a rate of 7.5 to 9% in surgical cases. Cervical ribs may occur in 0.5% of the general population and may be symptomatic in 10 percent of people.[5,7-9] Our surgical and cadaver series may suggest higher rates of anomalies and variations than those of other series in our population. This situation may reflect ethnic differences. However, no discussions on thoracic outlet susceptibility to genetic variation between populations could be found in the English literature. If cervical ribs are present, the pleural dome ascends higher in the neck so it becomes more superficial. Such

Table 1. Congenital bands and ligaments described by Roos

Type 1	A band from the anterior tip of an incomplete cervical rib to the middle of the first thoracic rib inserts into the upper rib surface posterior to the scalene tubercle.
Type 2	A band arising from an elongated C7 transverse process attaches to the first rib just behind the scalene tubercle in the same place as a type 1 band.
Type 3	A band both originating from and inserting into the first rib arises posteriorly, near the neck of the rib, and inserts more anteriorly, just behind the scalene tubercle.
Type 4	A band originating along with the middle scalene muscle from a transverse process run along the anterior edge of the middle scalene muscle and inserting with it into the first rib. The lower nerves of the plexus may lie against it.
Type 5	The scalene minimus muscle is the 5th type of band. It arises with the lower fibers of the anterior scalene muscle and runs parallel to it but passes deep into it, behind the subclavian artery but in front of the plexus, to insert into the first rib. Normally, the entire anterior scalene muscle passes anterior to the artery. Any fibers that pass anterior to the plexus but posterior to the artery belong the scalene minimus muscle.
Type 6	When the scalene minimus muscle inserts into Sibson's fascia over the cupola of the pleura and lung instead of into the 1st rib, it is labelled separately to distinguish its point of insertion.
Type 7	A fibrous cord running along the anterior surface of the anterior scalene muscle down to the first rib attaches to the costochondral junction or sternum. In this position, the band lies immediately behind the subclavian vein and can be the cause of partial venous obstruction.
Type 8	A band arising from the middle scalene muscle runs under the subclavian artery and vein to attach to the costochondral junction.
Type 9	A web of muscle and fascia filling the inside posterior curve of the first rib forms the 9th type of band.
Type 10	Some of the anterior scalene muscle fibers form a band that connects to the perinerium of the brachial bundle.
Type 11	A band formed by fibers existing between the anterior and middle scalene muscles passes between nerve roots.
Type 12	The upper part of an anomalous anterior scalene muscle passes behind the C5 and C6 roots.
Type 13	Fused scalene muscles form a band, and the brachial nerve roots pass through the muscle like arrows.
Type 14	Fibrous bands passing vertically in front of the nerve roots behind the anterior scalene muscle form the 14th type of band.

displacement could explain the compression of the subclavian artery and brachial plexus when a load is carried on the shoulders.[10] The brachial plexus is usually formed between the 4th and 8th cervical nerves when a complete cervical rib is found. The first thoracic ventral ramus may also continue to join the plexus but it must ascend a considerable distance to do so. The inferior trunk of the brachial plexus must take the most acute course of the plexus relative to the cervical rib, predisposing it to compression and traumatic neuritis.[9]

Table 2. Fibromuscular band types in 40 cervical dissection

	Present series*		Roos**	
	n	%	n	%
Normal	6	15	39	67
Total anomalies	34	85	19	–
Type 3	6	15	10	17
Type 12	4	10	–	–
Type 9	4	10	–	–
Type 2	3	7.5	10	14
Type 1	2	5	7	2
Type 11	2	5	–	–
Type 4	1	2.5	1	2

*: Data presents 40 cervical dissection in 20 cadavers; **: Data presents 58 cervical dissection in 29 cadavers.

It was reported that the frequency of fibrous bands was 98% in surgical series, but it was 33% in cadaver series. In our study fibrous bands were found in 55% of the subjects. The frequency of type 3 bands was 15% but it was 17% in Roos series.[6] In our study two band-anomalies (type 9 and type 12 band anomalies together) were found in 10% of the subjects. Type 9

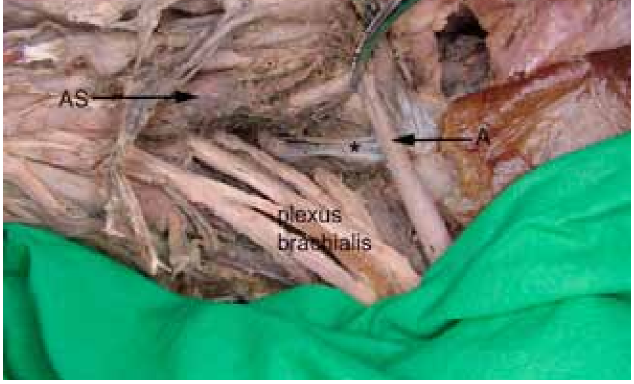

Fig. 1. A lateral view of the right side of the neck region depicting an anomalous right subclavian artery piercing through the scalenus anterior muscle. BP: Brachial plexus; A; Subclavian arteria; AS: Scalenus anterior; *: Fibromuscular band type 3.

Table 3. Anatomical variations in cadaveric dissections

	Frequency		Bilateral		Right		Left	
	n	%	n	%	n	%	n	%
Cervical rib	4	10	–	–	4	10	–	–
Long C7 transverse process	4	10	1	2.5	2	5	1	2.5
C5 only pierce AS	4	10	–	–	3	7.5	1	2.5
C5 and C6 pierce AS together	3	7.5	–	–	2	5	1	2.5
Arteria subclavia pierce AS	3	7.5	–	–	3	7.5	–	–
MS slip inserts on cervical rib	1	2.5	–	–	–	–	1	2.5

AS: Scalenus anterior; Anatomic variations in the thoracic outlet in adults (n: No. of the extremities)

and type 10 anomalies were found in 1%, although a type 12 band was not observed in 98 cadavers.[10] High rates of type 9 and type 12 bands compared with other studies may be due to the small cadaver sample. The type 3, 1, 6 and 7 fibrous bands were observed most frequently in studies. Most of these series were surgical series.[5,11] Thoracic outlet syndrome development is less than 1% in people who have these bands. In our series types 3, 2, 9 and 12 band anomalies were observed with decreasing frequency, unlike Roos series where types 3, 5, 6 and 1 were observed in that order.[6] It is thought that the existence of bands and a combination of repetitive predisposing factors could induce TOS development more effectively than the type of fibrous bands do. The addition of factors such as micro traumas, muscle hypertrophies, inflammatory reactions onto these morphological variations can result in TOS formation.[12]

In our study, it was observed that the C5 trunk passed through the ASM in 10% of extremities and the upper trunk of the BP passed through the ASM in 7.5%. In a study by Harry et al.[13] the root of C5 passed through the ASM in 13% of a 51 cadavers. It was observed that the roots of C5 and C6 passed in front of the ASM in one case in Roos series.[5] In an analysis of 93 cadavers by Natsis et al.[14] a variation in which the C5 trunk did not perforate the ASM although it passed anterior to the trunk in 3.2% of cadavers, and a variation in which the upper truncus of the BP passed the ASM was recorded. In many studies anomalies related to the root of C5 are generally reported as root fibers of C5 passing in front of the ASM.

Anomalies observed in people such as friction around scalene muscles or neck movements which can induce symptoms may be related to UT involvement of the BP. It was shown that if a nerve is compressed over a long period, vascular support of the BP roots in the endoneurium and mesoneurium could be damaged.[15] Roos et al.[5] reported that the upper plexus type of TOS occurs due to anatomical variations in the relation between the roots of the BP and the scalene muscles. Anomalies of the brachial plexus mentioned in our study also predispose to development of upper brachial plexus type neurogenic disorders in housewives, hairdressers, teachers and people who work with computers.

Arterial thoracic outlet anomalies were generally characterized on the right extremity in our study. These anomalies may involve the subclavian artery passing posterior to the esophagus, between esophagus and trachea.[16-18] In our study the arteria subclavia passed through scalene muscle in three extremities (7.5%). One of the factors which causes thoracic outlet syndrome is the compression of subclavian artery caused by hypertrophic muscle with fibrotic bands. In these types of anomalies, there are no symptoms observed in neutral position of the anterior scalene muscle, although pain can occur with pressure on the artery and complaints of arm weakness can be observed.

In our cadaver population, the frequent occurrence of brachial plexus and arterial anomalies suggests that we should be careful when exploration of penetrating trauma of the neck is performed for diagnosis and treatment of TOS. The route of the subclavian artery through the ASM by perforation is important particularly with respect to exploration of vascular structures during TOS surgery. The types of anomalies should be kept in mind in order to prevent morbidity and complications when muscles are divided.

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