

# Assessment of Diagnosis and Treatment of Thoracic Outlet Syndrome, An Important Reason of Pain in Upper Extremity, Based on Literature

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## Abstract

The symptoms that arise as a result of compression of brachial plexus, subclavian artery and veins at the thoracic outlet are called Thoracic Outlet Syndrome (TOS). TOS is one of the most controversial subjects in clinic practice. The treatment method of this syndrome is required to be based on a multidisciplinary approach, but also all physicians should be familiar with the approaches of diagnosis and treatment of TOS. The purpose of this study is to review the method of diagnosis and treatment of thoracic outlet syndrome based on literature.

**Keywords:** Pain; Thoracic outlet syndrome; Scalene muscle

## Introduction

TOS, which is a complex disease hard to be diagnosed, should be taken into consideration as it may be a reason of neck and arm pain that is among the major reasons why people resort to hospitals [1,2]. When professional and environmental risk factors and clinical features that remind TOS are taken into consideration, TOS diagnosis can be made quickly.

Even though it is considered that generally TOS symptoms occur as a result of pressure on brachial plexus and subclavian veins within the passage that extends to axilla and proximal arm from the cervical area, there is no consensus among the specialists on the subject of diagnosis criteria and its optimal treatment [3-9].

Surgical intervention should be performed on limited indications in TOS since severity of disease symptoms can reduce with some conservative methods and the disease may also recover spontaneously. When features such as pain, general physical function and profession are taken into consideration, it is required to act swiftly for a multidisciplinary specialist approach that will ensure more effective management of this disease. The objective of this study is the correct description of TOS, and review of known risk factors, diagnosis criteria and management.

## Material and method

TOS is a multidisciplinary syndrome that concerns several medical branches such as brain surgery, physical therapy, orthopedics, thoracic surgery, cardiovascular surgery, neurology, internal diseases due to its clinical features. In this study; we tried to examine TOS, which causes neck, shoulder and upper extremity pain in several patients, in the light of the literature and general information.

## Conclusions

### Incidence

Although TOS was defined in early 19<sup>th</sup> century for the first time, subsequent literature information is very restricted, it consists of only case presentations and small researches. Although the reported incidence of TOS is mentioned as 3-80/100, since there is no objective verification test in diagnosis of TOS, there is no complete consensus among clinicians on the matter of incidence.

### Etiology:

Painful forms of TOS are derived by congenital anomalies (such as cervical level and prolonged transverse process), post-traumatic reasons (such as shoulder, neck injuries), functionally acquired reasons

(cervicospinal muscle hypertrophies) and by other reasons such as tumors, osteomyelitis, hyperostosis that concern the relevant area [10].

While brachial plexus, subclavian artery goes to the arm passing through the Thoracic outlet, neurovascular compression generally occurs in the scalene triangle. It is either the first level that causes compression or a fibromuscular band extending from an incomplete level or between the long C7 transverse protrusion and first level and scalen tubercle.

Cervical costas occupy an area in this narrow area, and this situation makes pressure on neurovascular structures and this may especially cause arterial TOS [11]. Abnormal cervical level is observed at rates of 0.17-0.74% in the society, it is seen slightly more in females. Rudimentary incidence of first level is 0.29-0.76% [12]. Sanders et al [11]. Reported that only in 10% of cases, which involved cervical level, TOS symptoms formed and starting of these symptoms were typically cervical spine trauma [12].

Abnormal fibrous bands are more frequently reasons of TOS rather than level anomalies [13,14]. Abnormal bands may derive from cervical or rudimentary first thoracic level, C7 vertebra, Sibson fascia (suprplevral membrane) or scalene muscles [10]. Roos [15] defined 9 types of congenital bands and ligaments that might make pressure on neurovascular structures, in the thoracic outlet area. Most of these ligaments come out from the transverse protrusion of C7 or from the end of cervical level and adhere to the first level. Fibrous band, the transverse protrusion being long rather cause neurogenic TOS. These ligamentous bands extend along either within the body of the scalene muscle or in the front part of the muscle and brachial plexus may be pressurized by this tense ligament.

TOS can also be seen in chronic trauma in swimmers, tennis players, wrestlers as well as in those who perform repeated movements [16,17]. Hypertension trauma, fibrotic tissues derived by trauma, hypertrophy of scalene muscle, axillary vein thrombosis, former clavicle fracture can also be listed within thoracic outlet syndrome etiology. TOS can

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also occur in people who carry backpacks and in violin players and this disease is called “Hyperabduction Syndrome”. Posture disorder, exercises that cause hypertrophy in shoulder and neck muscles, carrying heavy loads on the shoulder, especially hypertrophy of scalene muscle can be listed within etiology.

It should be kept in mind that reasons such as clavicle that might constrain the brachial plexus or first costa fracture and the callus of them, and rarely aneurysm of subclavian artery and tumors (often a Pancoast tumor) can also lead to the symptoms in thoracic outlet syndrome.

### Surgical Anatomy in TOS

Several anatomic areas have been determined where the brachial plexus, formed from radices between cervical 5 – thoracic 1 (C5-T1) leaving the spinal cord from intervertebral foramina, subclavian artery and vein may be compressed.

Thoracic Outlet area is the part between first level in lateral, cervical spine in posterior, clavicle in anterior and sternum and it is the name of the area between the upper part of the rib cage, through which the neurovascular tract that is formed from brachial plexus branches, subclavian artery and vein coming out from the spinal cord and going toward the under arm, and neck and shoulder. TOS may occur as a result of this neurovascular tract being constrained at 3 points (scalene triangle, subcoracoid tunnel and costoclavicular gap). There is lung apex, pleura, jugular vein, lymphatics, sympathics, nerve roots, subclavian artery and vein within the sternocostovertebral area. The neurovascular tract may also be constrained by lung tumors, thyroid and thymus in this area [11].

(Table 1) The area where brachial plexus constrain is seen rather more, which has the anterior scalene muscle in the anterior and the middle scalene muscle in the posterior, and which is located between the upper edge of the first costa and which comprises brachial plexus, subclavian artery is called the scalene artery. Although brachial plexus and subclavian artery pass under the first costa, between the scalene muscles, the subclavian vein passes from the anterior of the anterior scalene muscle, not between the scalene muscles. The neurovascular tract proceeds toward the costoclavicular gap at distal of the Scalene triangle.

Costoclavicular ligament is located in the front part and medium scalene muscle is located in the back part of the costoclavicular gap area, which comprises brachial plexus, subclavian artery, vein and subclavius muscle.

Subcoracoid tunnel, which is also called Pectoralis Minor area, is the gap at the adhesion point of the Pectoralis minor muscle and the gap that is under this muscle. Symptoms related to shoulder area occur in constrains in this area. Because brachial plexus can be strained by lifting the arm and abduction of the arm.

### How are Physical and Neurological Examination Performed in TOS?

The first observed symptom is; upper extremities of patients tend to stay motionless [10]. Provocative tests described for TOS diagnosis comprise tests that assess vein continuity with control of radial pulse [11]. Five maneuvers have been defined specially for TOS [18].

#### Adson maneuver

This test, which is also called Scalene maneuver, brings vascular pressure to mind [19]. Radial pulse is found while the arm is open

to the side and the patient’s head is brought to extension. When the patient’s chin is turned to the same side while pulse is followed up, decrease or loss of Radial pulse indicates that the test is positive. Pain can also be felt at that time. However, bilateral positiveness of this test, which can be positive also in normal persons, is less valuable.

#### Halsted maneuver

The test is deemed positive in case radial pulse cannot be taken in the position where the patient is in the position of lowering his shoulders to the back and down in a manner to narrow the costoclavicular area.

#### Wright Test

When the patient’s Radial pulse is examined, the arm is brought to 180° abduction over the head and flexion from the elbow passively. Decrease of the pulse in this position is a positive symptom and it brings to mind that compression is at pectoralis minor muscle level [19].

#### Costoclavicular Maneuver

When checking the radial pulse, if the pulse decreases when the patient’s chin leans toward his shoulder, this is a positive symptom. It is a test that brings to mind that compression is between costa and clavicle.

#### Lifting the Hands up Test (Roos stress test)

The patient who is diagnosed with TOS raises his hands to top of his head, shoulders in 90° abduction and in outward rotation and elbows in 90° flexion, and opens-closes his hands for 3 minutes. If any pain, weakness, pins and needles occur during this test, the test is deemed positive [10].

No clinical test is accepted “diagnostic”. Rates of false positiveness and false negativeness as regards TOS diagnosis of most of the tests that determine vascular failure are high for TOS [9]. Since symptoms derived by brachial plexus nerve pressure, not by pressure of subclavian artery, are seen in most patients with TOS, tests in which radial artery pulse is not assessed are insufficient in many patients whose TOS diagnosis is suspicious. Formation of upper extremity symptoms with provocative tests in those with TOS suspicion is accepted as a stronger indication of TOS [11]. It is important to provoke only one entrapment point each time in the examination as different entrapment points in the upper extremity may form symptoms in the arm and hand. In clinical tests, stimulating more than one entrapment point at the same time causes symptoms of the patient to occur, however, it cannot help in differentiating the pressure point or points. In order to prevent stimulation of more than one points at the same time, modified Roos test has been suggested that determines pressure at brachial plexus level

Shoulder pathologies (rotator cuff injuries)
Fibromyalgia
Cervical disk hernia or osteofit
Lung pathologies (Pancoast tumor)
Nerve sheath tumor
Other entrapment neuropathies (carpal tunnel syndrome, cubital tunnel syndrome)
Polyneuropathy
Brachial plexitis
Syringomyelia
Raynaud disease
Vasculitis
Angina pectoris
Multiple sclerosis

**Table 1:** Pathologies that are important in differential diagnosis in TOS

[20]. In Roos test, the patient raises his arms above his head, the arm is in extension position from the elbow in order to prevent stimulation of ulnar nerve in the elbow. Furthermore, in order to be sure that there is no other pressure in the carpal tunnel, the ankle is in neutral position and the axilla is kept at a point between supination and pronation in order to prevent pressure of pronator teres in the proximal axilla to median nerve, pressure of extensor carpi radialis longus muscle and brachioradialis muscle tendons in the axilla to the radial sense nerve. In case TOS symptoms occur within one minute when the patient is in this position, the test is accepted as positive [10,20]. It is reported that TOS cases of this test reveals symptoms at 95%.

Symptoms of patients with TOS diagnosis is parallel to histopathological changes that occur in brachial plexus. Sensory complaints start with intermittent paresthesia stimulated with the position and may be totally asymptomatic when the patient is resting. Depending on the nerve compression that slowly increases in the course of time may lead to more permanent paresthesia and subsequently permanent loss of sense. While Modified Roos test reveals symptoms in 95% of TOS cases, symptoms occur in all of the cases when supraclavicular compression to the brachial plexus during the same test [4]. It is advisable to check for Tinel's sign by hitting each entrapment point 4-6 times by finger during physical examination. There will be tingling at the distribution point of the nerve if Tinel's sign is positive. This symptom tends to be positive generally in late periods of chronic brachial plexus compression. Tinel's sign in supraclavicular area is deemed positive if there is tingling in the arm and hand, however, the symptom should not be deemed positive if there is only local pain and discomfort. However, scalene muscles are sensitive in palpation in patients with TOS; local pain that is formed in supraclavicular area when researching Tinel's sign may be derived by scalene muscle sensitivity. It is very important to compare affected and non-affected parts as regards scalene muscle sensitivity.

As a result, neurogenic TOS diagnosis is verified by symptoms such as sensory disorder that spreads toward the hands when tested in arm raised position. There is also sensitivity in Scalene muscles. It is essential to eliminate other conditions, including distal nerve compression, that might lead to similar symptoms for diagnosis.

### **Clinic in Patient with TOS Diagnosis**

There is no simple test that is accepted as golden standard in neurogenic TOS diagnosis like accepting a single standard as the golden standard. However, diagnosis can be made with clinical symptoms (pain, paresthesia, weakness in the neck, shoulder, anterior chest, upper extremity and hand) [2]. Nerve conduction studies, electromyography and radiological examinations. The most important point is that, it is a condition that can be treated with good prognosis [21]. Five clinical syndromes have been described in TOS; real neurogenic TOS, suspicious TOS, minor arterial syndrome, major arterial syndrome, venous obstruction syndrome [8,9,22].

### **Real Neurogenic TOS**

In this type of TOS, most affected branch is branches of C8-Th1 according to brachial plexus branches and the most nerve is ulnar nerve [10]. This is the thoracic outlet syndrome that is accepted by everybody and it constitutes 97% of all TOS cases [19]. Pathology is generally compression of lower truncus of brachial plexus by fibrous band coming from a cervical costa.

There is weakness and atrophy in inner muscles of the hand in cases with real neurogenic thoracic outlet syndrome. There is intermittent pain in medial of the axilla. Thenar muscles connected especially to

retention of tendons going down to median nerve of interior truncus are especially atrophic. Median that is innervated by lower truncus, muscles innervated by ulnar and radial nerves were also affected [10]. It is required to cut the fibrous band in the treatment. However, the probability of recovery of atrophic muscles is low.

### **Suspicious Neurogenic TOS**

It is the type of TOS which is generally observed in several patients and causes unexplained pain in scapula, arm and shoulder areas, which doesn't have added anatomic and physiologic changes and symptoms are generally triggered by a traumatic event such as a car accident. Results of neurological examination and electrophysiological examination are generally normal in these patients. It is also said that there is neurosis in these patients. Diagnosis is made by formation of symptoms as a result of provocation and making good differential diagnosis. Patients who are operated are generally this group of patients. However, surgery indication is suspicious and it is impossible to argue that serious neurological symptoms will appear if the compression on brachial plexus is not eliminated [8,9,23].

### **Minor arterial syndrome**

It is the decrease or loss of radial pulse when arms are abducted and rotated outwards after they were lifted up, this is seen in the rate of 80%. However, arterial obstruction that is significant, but doesn't cause any symptoms in normal persons, in examinations performed using provocative tests and photo-plethysmography, was found in the rate of 60% [24].

### **Major arterial syndrome**

In this syndrome, there is injury in subclavian artery wall derived by bone anomaly such as cervical level and poststenotic dilatation has developed. Reynaud phenomenon may develop with thrombus and a distal emboli derived by this. Operation is essential once major arterial syndrome is determined.

### **Venous obstruction syndrome**

It is a syndrome where there is no brachial plexus involvement or there is spontaneous thrombus of axillary vein and that can be seen after extreme consecutive activities of the upper extremity in young persons. There is cyanosis, swelling and pain in the arm. Since brachial plexus is not affected in this syndrome, it is not quite accurate for venous obstruction syndrome to be included among thoracic outlet syndromes.

### **Symptoms Observed in Patients with TOS**

Symptoms, which are generally seen in cervical, suprascapular and subscapular area in patients, are discomfort and pain spreading to the upper extremity. The most frequently observed complaint is paresthesia in the axilla and medial face of the hand and pins and needles, and tingling can spread to all hand if symptoms are intractable. Isolated compression of lower truncus of brachial plexus causes sensual disorder in ulnar nerve distribution area of hand while compression of upper truncus of brachial plexus causes sensual complaints in the thumb, index finger and ring finger. Complaints such as exhaustion in upper extremities, weakness in arm and hand are very common and the patient may have ignored to a point that he doesn't want to use his hand or arm. Headache is common in most of the patients while pain and/or tingling in the face and chest pain like angina is very rare. Symptoms derived by brachial plexus compression generally increase with abduction of arm or with activities where upper extremities are raised above the head and circulatory disorder may be observed in the hand in some patients.

Real neurogenic thoracic outlet syndrome that causes atrophy as a result of excessive weakening of muscles in the hand is rarely observed; neurologist Thomas and neuro-surgeon Cushing reported two cases in 1903 for the first time in which atrophy occurred in the hand derived by compression of brachial plexus [25]. This rare type of thoracic outlet syndrome was reemphasized by Gilliat et al. [26] in 1970's. Atrophy in thenar muscles innervated by median nerve due to compression of the plexus in these patients derived by generally cervical level or ligamentous fibrotic band, is slightly more than atrophy in intrinsic muscles innervated by ulnar nerve. The reason of this is; T1 fibers containing median motor fibers are generally exposed to more compression than C8 fibers that comprise ulnar intrinsic fibers. Sensory complaints are typically in T1 distribution, on medial part of the arm and axilla.

Symptoms of TOS are generally detected accidentally and a special trauma is generally not reported. However, patients diagnosed with TOS may say that their complaints started with a traumatic event or with a change in the way of working. In patients with TOS, typically positions where the arm is raised above the head and repetitive activities performed by rising the hand aggravate the symptoms. Especially female patients state that the symptoms increase when they are combing their hair or putting on make-up. Sleeping in a position where arms are above the head, in flexion at the elbow also often causes complaints of tingling and weakness in the extremity. A group of patients with TOS diagnosis does not report difficulty in activities that are carried out by rising the arm above the head. Because patients typically avoid arm movements above the head by making some changes in their activities in order to reduce the symptoms.

Symptoms related to vein compression is not common in TOS [11]. It causes symptoms such as compression on subclavian artery, Raynaud phenomenon, coldness, paling in fingers, following cyanosis and permanent redness [27]. Permanent cyanosis or paleness can be observed in fingers in arterial thrombosis or occlusion while symptoms derived by venous compression are very rare. All these symptoms or Paget-Schroetter Syndrome are also known as (Effort Thrombosis of Axillary Subclavian Vein) [22,28]. Edema and venous congestion are observed in the upper extremity. Diagnosis of patients with vascular thoracic outlet syndrome are generally easier than cases with neurogenic thoracic outlet syndrome due to the clinical and objective symptoms.

## Diagnosis in TOS

Methods for diagnosing TOS are listed below:

### Electrophysiological Methods

Nerve conduction studies and electromyography in assessment of patients who are suspected of TOS are commonly used methods [8,10,29]. Characteristic symptoms observed commonly in nerve conduction tests in advanced neurogenic TOS cases can be listed as; low amplitude in ulnar sensory activity potentials, low amplitude in median nerve motor activity potentials, normal or slightly reduced ulnar motor potentials, and normal median nerve sense potentials.

Fibrillation potentials that bring active axonal loss to mind are most frequently observed in the abductor pollicis brevis muscle that is innervated by median nerve and less frequently observed in the 1<sup>st</sup> dorsal interosseous and abductor digiti quinti muscle that is innervated by the ulnar nerve. Serious anomalies are detected generally in intrinsic muscles of the hand in electromyography. These electrodiagnostic symptoms can be explained by pathogenesis of TOS. Because although all three of roots of brachial plexus enters scalene triangle, only the

lower root (C8-Th1), together with subclavian artery, directly contacts tendon of scalene muscle and hard face of costa. All sensory fibers of C8-Th1 proceeds within ulnar nerve and this causes ulnar sense potentials to be detected as low and median sense potentials to be detected as normal. Although C8-Th1 motor fibers are carried by both median and ulnar nerve, median motor fibers are injured more due to their locations in the lower root. Therefore, in EMG, median motor potentials tend to display more abnormality compared to ulnar motor potentials.

### Imaging Methods

Imaging methods may also give useful information in diagnosis of TOS. Cervical level or bone abnormalities such as distinct, protruded C7 transverse process can be determined in cervical graphy and lung x-rays [17]. MRG is useful in differential diagnosis of degenerative diseases of cervical spine. Likewise, BT is useful in detecting other conditions such as former fractures in clavicle, lung pathologies, tumors in lung apex that cause symptoms, besides diagnosing TOS [10].

### and Static Vascular Examinations (doppler ultrasonography and angiography)

It is useful for usage in conditions where clinically vascular symptoms are available. If narrowness or poststenotic dilatation is determined in the artery, decision must be made on operation [10].

### Treatment

Today major part of patients with TOS are suggested conservative treatments such as behavioral changes aimed at preventing provocative activities and arm positions, in addition to customized physical treatment programs so as to strengthen pectoral area muscles and ensure normal posture [22,30,31]. Recovery rates of 50-90% are reported with conservative treatment [8,31- 33].

Immediate surgery in TOS is required only in very extraordinary conditions such as vascular occlusion or infarcts as a result of recurring emboli.

Surgical intervention is generally applied to vascular TOS types that resist to conservative treatment and to real neurogenic type where conservative treatment is generally useless. Most of these patients resort to doctor with advanced atrophy.

The most important and vital point in TOS treatment is that; surgery in cases with suspected type of TOS should be considered only as a last resort after long-term conservative treatment, after potential complications and risks of surgical exploration in this complex anatomical area are very clearly explained to the patient. Operative decompression is useful for most of the patients, however, psychological and social factors, including depression, marital status and education, are very effective on healing of patients. Therefore, psychological assessment should definitely be made before performing surgery in TOS [34].

### Conservative Treatment

Success rates are reported as 50-90% in conservative treatment of TOS [4,11,29,30,35]. However, very few conclusion studies have been published although several conservative treatment protocol have been reported. After a conservative treatment protocol, consisting of exercise and patient training, recovery and symptomatic relieve was observed in the pain in neck-shoulder line in most of the patients [17,31].

The most critical point for being successful in TOS treatment is; patient training related to actions that relieve symptoms and cause them

to recur. Brachial plexus nerve compression and muscle imbalance in cervicospinal area in patients should be taken into consideration together. Since very long time is spent sleeping, sleep patterns and postures should also be analyzed. If patients wake up at night with pain, paresthesia or tingling, or get up with headache and neck hardness in the morning, most probably they are doing actions that will aggravate the symptoms in cervicospinal area during sleep. If such a situation is determined, symptoms that are formed at night can be reduced by providing support to cervical spine during sleep.

It is not possible to affiliate symptoms caused by TOS to the compression of neural or vascular structures at thoracic outlet. Postures and positions that cause compression at brachial plexus will affect the soft tissue surrounding it, therefore it is useful to take into consideration the muscle imbalance in the cervicospinal area as well. Wrong postures and positions will cause pain to continue and to get aggravated, therefore, first of all a correct posture should be ensured and maintained. Generally a loose posture is determined in patients with TOS, such that; head is in front according to the body, thoracic cyphosis is present, scapulas are in abduction and shoulders are in inner rotation. Most patients with TOS cannot switch to "ideal" erect position instantly due to restriction of short and stiff muscles; elongation of stiff muscles for "ideal" posture causes pain. Extension exercise programs should be made on these patients to ensure them to gain regular muscle length required for ideal posture.

In patients with TOS, since the head leans toward front of the body, stiffness occurs in scalen, suboccipital, sternocleidomastoid, upper trapezius, levator scapula muscles in postures where abduction and thoracic cyphosis occurs in scapulas [11,14]. Abduction of scapulas also shorten the serratus anterior muscle and cause weakness of both serratus anterior muscle and medium and lower trapezius muscles. Extension exercises in many patients who have these complaints help treatment of this stiffness. Even losing weight especially in overweighted patients can lead to relief of TOS symptoms.

When we look at the literature; studies on TOS treatment with Botulinum toxin attract attention. In a study carried out by Finlanson et al.; Botulinum toxin was administered to patients diagnosed with TOS together with saline solution inside the anterior and medium scalen muscle and there has been no significant change in any of the complaints (pain, paresthesia, weakness) of patients [36]. Finally, Povlsen et al. have made a study on 37 patients diagnosed with any type of TOS; they have injected Botulinum toxin and placebo saline solution inside scalene muscle. They have determined that there was no significant change in complaints of either group of patients, however, there has been a recovery only in paresthesia after follow-up of 6 months [37].

Another method used in pain derived by TOS is Spinal cord stimulation and it can be used in suitable patients, in pains resistant to conservative treatment [38].

## **Surgical Treatment**

Approaches used in surgical treatment of TOS are; transaxillary, supraclavicular and posterior subscapular approaches. Two most frequently used methods of approach among these are; removal of first costa with transaxillary approach and the supraclavicular approach [17].

When we look at the literature, we see 3 big studies on these two surgeries (Povlsen et al.- Lattoo et al. Atasoy). First of these were the study carried out by Povlsen et al., they have compared transaxillary and supraclavicular approach in a series of 55 patients and determined that

pain derived by suspicious type neurogenic TOS reduced more upon removing transaxillary 1<sup>st</sup> level [37]. Lattoo et al. applied transaxillary surgery on 139 patients with TOS and recovery was observed in symptoms of 123 patients and no recurrence was determined. In the second study; Lattoo et al. have emphasized that transaxillary surgery was the golden standard in patients with TOS as it is very good for the patient in terms of cosmetics, it ensures a good exposure and surgical results are perfect [39]. In the 3<sup>rd</sup> study, Atasoy combined both surgical procedures (removal of transaxillary first level and cut off of transcervical anterior and medium scalen) in patients with TOS and determined significant relief in complaints of patients [40].

Big neurovascular complications were reported in both approaches [4,11,35].

Posterior subscapular approach, which is the third approach, is used very less frequently. Success rates are reported between 75-99% when all surgical methods are taken into consideration. Success rate with repetitive surgical intervention in cases where first operation failed is around 15% [41].

Mackinnon et al. suggest brachial plexus decompression, anterior-medium scalenectomy and first costa resection to be performed together in cases where operation is needed, since complications increase in repeated operations [4]. Patient should be operated after diagnosis is made with preoperative required imaging techniques and during operation the location of compression should be searched with a good dissection.

## **Supraclavicular Approach**

It is a safe method of approach that is rather preferred by brain surgeons. The patient is operated by turning his head to the opposite side while he is lying on his back. 6 cm skin incision is made parallel to clavicle and from around 2 cm above it, and then dissection is made from outer side of Sternocleidomastoid muscle. Following cutting of platysma, automatic ecarteur is inserted. Sternocleidomastoid muscle can be cut from the point it is adhered to the clavicle. Omohioid muscle is also cut. First of all, Anterior scalen muscle is found, phrenic nerve under the fascia in front part of this muscle is seen and it is protected, then the anterior scalen muscle is cut off. Right below this, subclavian artery and brachial plexus are seen. When brachial plexus fibers are observed, a fibrous band is seen that is generally located in medial of that, compressing the truncus and extends parallel to median scalen muscle, and it is cut off. Median scalen muscle can also be cut off. If cervical level or prolonged C7 transverse protrusion is seen during operation, brachial plexus is carefully protected and removed with a rongeur. After operation is completed, a Penrose drain is inserted, platysma and skin is closed. The best part of this approach is; operation is made by easily seeing and protecting the brachial plexus and patients are very comfortable after the operation [2,42,43].

## **Removal of Transaxillary First Costa**

The purpose is to expand the interscalenic triangle with resection of the first costa. It is an approach preferred by thoracic surgeons. Entry is made from the axilla at position of laying on one's side. Transverse incision is performed at 2<sup>nd</sup>-3<sup>rd</sup> intercostal gap. Entry is made between pectoralis major and latissimus dorsi muscles, scalen muscle adhered to first costa is released and first costa is excised. Advantage of this method is that; it ensures reaching almost all of the first costa from an invisible incision and neurovascular structures do not form a big handicap. The disadvantage is that; neural elements can be limitedly observed. Most congenital bands and cervical costas are located at first costa medial and they are hidden behind neurovascular structures.

## Posterior Subscapular Approach

In this surgical technique, an incision is made between C7-Th1 spinous process and scapula medial kenan and then Trapezius and rhomboid muscles are cut off and upper part of the rib cage is opened. First level is removed and back part of medium scalen muscle is cut off. This approach is rather applied to patients who have previously undergone anterior approach or who have post-radiotherapy scar tissue. Posterior subscapular approach is a challenging technique as it requires intense muscle dissection. Nerves that are likely to be injured during exploration are; long thoracic nerve, dorsal scapular nerve and accessorius nerve. In this approach, as a result of long thoracic nerve injury or incomplete recovery of levator or rhomboid muscles, 5% wing scapula may be caused [5].

## Other Surgical approaches

### Isolated Pectoralis Minor Tenotomy:

It is a rarely applied technique and Vemuri et al. have made a study on 200 patients and indicated that it may be useful in Neurogenic TOS patients from the leg that bears less risk [44].

### Surgical Complications:

Most frequently observed complications following TOS surgery are; hemorrhage, infection, nerve injury, pneumothorax, artery and vein injuries, cheilothorax. When we look at the literature, there is only one case with lung herniation following 1<sup>st</sup> level resection [45].

## Discussion

Significant part of TOS symptoms are derived by brachial plexus nerve compression, therefore, it is important to understand the pathogenesis of chronic nerve compression in order to understand the condition, assessment and treatment of a patient with TOS [17]. Increase of compression duration will lead to fibrosis in internal and external epineurium. Although segmental demyelination starts in myelinated fibers that have been exposed to the most compression and ischemia, axons remain intact. Demyelination that starts focal then reaches axonal injury condition with Wallerian degeneration. These changes in chronic brachial plexus compression forms gradually in the course of time and the duration and amount of compression are effective on this. In chronic brachial plexus compressure, since much more severe changes can be observed typically in some fascicles that have been exposed to more compression within the nerve compared to others, this difference in involvement of fascicles is accountable for electrophysiological studies being regular or near regular although patient symptoms are present.

Clinical symptoms and symptoms in TOS are directly related to hystopathologic process observed in chronic brachial plexus compression. Patient's complaint in the beginning can occur as pain in muscles that have been innerved by the nerve that was compressed. In the course of time muscle weakness may occur and finally muscle atrophy can be observed. With compression on sensual nerves, temporary paresthesia can also be seen in patients. If injury in nerves increases, permanent paresthesia and sensation disorder may be observed.

In the beginning of TOS, symptoms arise in patients only with positional changes or provocative maneuvers. Sensation tests are also normal in resting position. However, abnormal results are obtained in provocative positions such as raising only the arm.

Due to the discomfort as a result of raising the arm in a manner to create compression on brachial plexus in patients who are considered

to have TOS, these patients cannot stay in these positions that "apply compression to the nerve". Therefore, nerve compression derived by TOS rarely advances to more painful phases. Muscle atrophy in hand of patients with TOS is rare, it is generally related to congenital abnormal ligamentous bands or cervical costas. Therefore, patients with significant chronic nerve compression symptoms should also be assessed in terms of areas that may lead to nerve compression in the distal (such as cubital tunnel syndrome, carpal tunnel syndrome, Guyon channel compression).

TOS is a term which is used to define symptoms derived by brachial plexus, subclavian artery and vein compression. Real type neurogenic thoracic outlet syndrome that leads to vascular thoracic outlet syndrome and atrophy of intrinsic muscles in the hand is very rare and its diagnosis is indisputable. However, TOS diagnosis criteria in suspicious neurogenic type TOS patients with subjective complaints that are hard to measure such as pain, paresthesia and tingling in the upper extremity continue to be controversial. Although several clinical, radiological and electrophysiological tests have been defined, there is still no very good diagnosis test that can be called the "golden standard". Since no quantitative test is accepted, the most important factor that makes the diagnosis is clinical suspicion and assessment. In an article that proves this in the literature, published by Atasoy in 2013; it was stated that TOS can be easily noticed especially by hand surgeons by assessing patients, who have complaints of pain and tingling in hands, shoulders and arms, with TOS suspicion [40]. Patients with TOS typically complain from paresthesia and tingling in the hands and arms and from pain in cervicoscapular area. Although pain component is seen as derived basically by muscle dysfunction in the neck, shoulder and back, paresthesia and tingling are related to nerve compression in brachial plexus area. Therefore, in assessment of patients with TOS, it is required to assess muscle and posture kinetics as well in the neck, chest, scapula and shoulder area in addition to sensory and motor examinations like in diagnosis of neuropathies derived by compression. Psychological assessment should definitely be made on patients in order to see the effect of pain assessment and pain on the patient's life and to make a correct diagnosis. Despite everything, diagnosis of TOS is a clinical diagnosis based on subjective and physical assessments and exclusion of other diseases that might lead to a similar situation.

## Conclusion

TOS is a complex of symptoms that are derived by compression of brachial plexus and vascular structures in the upper extremity, at lower limit of the axilla and between the interscalen triangle. One of the most important factors in diagnosing it is to suspect and use advanced diagnosis methods. In its treatment, careful selection of patients and a multidisciplinary team work consisting of brain surgeons, thoracic surgeons, neurologists and physical therapists are important factors to get satisfactory results.

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