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Diagnosis and Treatment for Thoracic Outlet Syndrome

Thoracic Outlet Syndrome (TOS) is a condition that involves the compression of the neurovascular bundle of the brachial plexus as it passes through the thoracic outlet region[1]. There has been a lot of controversy surrounding the existence and exact cause of this condition in the past; however, as medicine has continued to evolve there has been a growing acceptance for this condition in clinical practice. Thoracic Outlet Syndrome is not a one-dimensional condition; there are a variety of different types of TOS as well as different locations that compression can occur. In order to fully understand the condition, its causes, and the treatments available it is imperative to have a strong knowledge of the anatomical composition of the thoracic outlet region and the neurovascular bundle that passes through.

The brachial plexus is the neurovascular bundle that travels through the thoracic outlet region. This complex bundle of nerves innervates the entire upper extremity and some of the surrounding musculature[2]. The plexus begins where the ventral rami of the C5-T1 nerve roots exit the spinal column, these roots merge into trunks with C5-C6 forming the superior trunk, C7 becoming the middle trunk and C8-T1 forming the inferior trunk[2]. Each trunk then divides into anterior and posterior divisions. Anterior divisions eventually form nerves that will innervate the anterior (flexor) compartment of the arm while the posterior divisions merge to form nerves that will innervate the posterior (extensor) compartment of the arm[2]. Specifically the divisions combine to form three main cords: the anterior divisions of the superior and middle trunk combine to form the lateral cord, the anterior division of the inferior cord continues as the medial cord, and the posterior divisions of all three cords unite to form the posterior cord[2]. Finally, the cords branch into the terminal braches of the plexus. The lateral cord splits to become the musculocutaneous nerve and the lateral root of the median nerve. The medial cord splits and gives rise to the ulnar nerve and the medial root of the median nerve. The posterior cord splits and forms both the radial and axillary nerves[2]. Appendix 1 depicts the general schema of the brachial plexus. The complex interactions between the different nerves in the plexus explain the wide array of symptom presentations that are possible with thoracic outlet syndrome.

The thoracic outlet is defined as the region between the first thoracic vertebra, first rib and the manubrium of the sternum[1]. Within this compartment the subclavius tendon lies next to the subclavian vein[1]. The brachial plexus travels posteriorly and laterally to the artery and is accompanied by the middle scalene muscle[1.] The thoracic outlet is depicted in Appendix 2. This very small space is already filled with the anterior scalene muscle, subclavius tendon and prevertebral muscles prior to the arrival of the neurovascular bundle. Additionally, the space can fluctuate in size based on respiration and movement of the neck, arm or trunk[1]. Anatomic anomalies such as a cervical rib or the formation of fibrosis bands or scarring can further crowd the space[1]. Due to these biomechanical flaws, as the person moves and breathes the thoracic outlet expands or contracts leaving the brachial plexus vulnerable to compression with the other anatomical structures in the region.

There are four specific locations within the thoracic outlet that are the most common sites of compression. They are: the sternocostovertebral space, scalene triangle, costoclavicular space, and the pectoralis minor space[3]. The sternocostovertebral space is bound by the sternum, first rib and the vertebrae. The subclavian artery and vein as well as all five roots of the brachial plexus pass through this region[3]. In addition to the structures passing through the sternocostovertebral space, this space also contains the apex of the lung, pleura, many lymphatics, and the jugular vein. Compression of the nerves and vessels that pass through this space is relatively rare. Compression here usually only occurs as the result of tumor formation in or around this area[3]. For this reason, typical tests and conservative treatment techniques for thoracic outlet syndrome are not effective in identifying compression or managing symptoms of compression in this region.

The scalene triangle is arguably the most common location for compression associated with thoracic outlet syndrome[6]. This space is bordered by the anterior scalene muscle anteriorly, the middle scalene muscle posteriorly, and the medial surface of the first rib inferiorly[6]. Being completely surrounded by muscles this triangle is extremely dynamic and can be tremendously influenced by muscle spasm or swelling. Additionally, the brachial plexus occasionally exits through the scalene muscles rather than between the different muscles[3]. When this occurs the person is even more vulnerable to TOS because the nerve is being forced directly through the individual muscle fibers, rather than between two sections of muscle. In addition to muscular causes for compression in this area, the presence of a cervical rib may also cause compression. A cervical or anomalous first rib is a relatively rare condition that exists only in approximately 1% of the population[11]. Most of the time there are no symptoms associated with the presence of this rib and they are often discovered incidentally on routine chest x-rays or other examinations. However, occasionally the presence of a cervical rib can produce undesirable symptoms. Particularly with TOS, a cervical rib can occupy space in an already crowed area and cause compression to the neurovascular bundle of the brachial plexus as it attempts to pass through the region[11.] Adson's test is the most effective thoracic outlet test for positively identifying compression within the scalene triangle[3]. To perform this test the patient is seated at the edge of the table or chair and the therapist palpates the radial pulse on the affected limb. Next, the patient is instructed to take a deep breath and hold it in. After doing so, the therapist abducts and extends the affected extremity; the patient is instructed to turn their head toward the affected side. The test is then repeated on the other side. A positive test result is defined as a diminished or abolished pulse or a reproduction of the patient's symptoms. This test has demonstrated to have decent psychometric properties for its validity in diagnosing thoracic outlet syndrome. Specifically, it has been reported to have a sensitivity of 79% and a specificity of 76%; making it a useful test in diagnosing thoracic outlet syndrome.

The costoclavicular space is another anatomical region of the thoracic outlet that can be a potential site of neurovascular compression. This region is bordered anteriorly by the medial third of the clavicle, posteromedially by the first rib, and posterolaterally by the upper border of the scapula[1]. This anatomical organization makes this area especially vulnerable to compression with accessory breathing. Accessory breathing causes the scalene muscles to elevate the first rib further restricting the space. Additionally, calluses from clavicle fractures, variable shapes of the first rib, protracted scapula, a drop at the distal end of the clavicle, an elevated first rib and spasms or tightness of the scalene muscles can narrowing of this space[1]. There are two tests that are especially good at locating compression within the costoclavicular space. They are the costoclavicular test also known as the military bracing test and the Halsted maneuver. The costoclavicular test is performed with the patient sitting at the edge of the table in an exaggerated military position, with both arms placed at their sides. The therapist palpates the radial pulse on the affected arm in this position[10]. The patient is then instructed to retract and depress their shoulders while protruding their chest. The therapist monitors changes in the pulse and symptom provocation in the patient. Numerous studies have evaluated the psychometric properties of this test and have noted a very high specificity for detecting TOS in this region. More specifically, Plewa et. al found that when monitoring for pulse changes the test was 89% specific, when monitoring for eliciting pain the test was 100% specific and when monitoring for numbness/ paresthesia the test was 85% specific[10]. The second test that is useful in detecting compression in the costoclavicular space is the Halsted maneuver. In this test, the patient is sitting at the edge of the table and the therapist palpates the radial pulse of the affected arm with the arm slightly abducted[4]. The patient is then instructed to rotate the head away from the limb being tested, while the therapist applies distal traction to the affected limb. A positive result on this test is a reduction in strength or diminishing of the radial pulse[4]. There is limited information available on the psychometric properties of this test for the diagnosis of TOS.

The pectoralis minor space is the final possible location for compression within the thoracic outlet. In this region the neurovascular bundle passes under the coracoid process deep to the pectoralis minor[1]. Due to this configuration, the neurovascular bundle becomes especially vulnerable to compression with abduction of the upper extremity and tightness or spasm of the pectoralis minor muscle[1]. This anatomical flaw makes the hyperabduction test is the most effective and provocative test for identifying compression within this space. To perform the test the patient is asked to sit very straight at the edge of the table with both arms at his or her side while the therapist palpates his or her pulse on the affected arm. The patient is then instructed to place the affected arm above 90 degrees of abduction and in full external rotation. Their head is maintained in a neutral position and their arms are held in this position for a full minute[10]. The examiner palpates the radial pulse in the hyperabducted position. A positive test result is defined as a diminished or abolished radial pulse and/or a reproduction of the patient's symptoms[10.] The psychometric properties of this test have been studied extensively in comparison to some of the other tests for thoracic outlet syndrome. Gillard et. al found that when using pulse abolition alone as the positive result the test was only 52% sensitive but was 90% specific. However, when using symptom reproduction as the positive result the test was 84% sensitive but only 40% specific[10]. This variability has led many people to question the validity of this test, but anecdotally it has proven to be the most effective test in detecting compromise in the pectoralis minor space.

In addition to the space specific shoulder tests, there are a variety of additional tests and diagnostic procedures that can be used in the diagnosis of Thoracic Outlet Syndrome. One of the most well-known generalized tests for this condition is Roo's test or the elevated arm stress test (EAST). In this test the patient sits on the edge of the table with their arms in a goal post position (90 degrees of abduction, external rotation, and elbow flexion), and repeatedly opens and closes their hands into fists for a full minute[10]. A positive test is defined as reproduction of the patient's presenting symptoms during the opening and closing the fists. Some authors have suggested increasing the test time to two minutes may improve the effectiveness of the test; unfortunately, the psychometric properties of the test have continued to demonstrate a high rate of false positives[10]. A study conducted by Gillard et. al examined the psychometric properties of the tests (Wright's test, Adson's test, Hyperabduction test, Roo's test, and Tinel's sign) when used as a group of tests rather than individual tests. They found that the sensitivity declined only slightly with more positive test results, and the specificity increased tremendously with an increased number of positive tests[5]. Based on these results the authors concluded that five positive test results on five tests was the best combination for screening and ruling in a diagnosis of Thoracic Outlet Syndrome[10]. However, there are additional diagnostic procedures that are used to assist in the diagnosis of TOS. These tests include: nerve conduction velocity, magnetic resonance imaging (MRI), and Doppler ultrasound. Nerve conduction velocities emit electrical impulses through the sensory and motor components of different nerves based on their placement on the body. The device then registers velocities, latencies, and response amplitudes for each nerve as the impulse travels up the extremity[5]. These values can then be compared to standard values to assess and locate potential sites for compression. In complex cases of TOS, these tests can reveal decreased amplitude in ulnar sensory action potentials, decreased amplitude in median motor action potentials, normal or slightly decreased ulnar motor potentials and normal median nerve sensory potentials[6]. However, more commonly nerve conduction velocities are used for the exclusion of other neurologic conditions such as carpal tunnel syndrome, ulnar nerve entrapment or the entrapment of C8 and T1 nerve roots, rather than to diagnose TOS[5]. Doppler ultrasound techniques utilize ultrasound waves to assess blood flow through arteries and veins. When used in the diagnostic process of TOS, Doppler ultrasound is performed at rest and in a provocative position, such as the test position for Adson's test, and is considered positive if there is acceleration or turbulence noted in the blood flow with the change of position[5]. This test can provide useful information regarding compression of the vascular structures of the region. Additionally, it is more effective when a positive test result is combined with a series of positive provocation tests such as Adson's test, Hyperabduction test, Wright's test, Tinel's sign or Roo's test[5]. Finally, MRI can be used to specifically locate and visualize the site of compression especially when utilized in a provocative position. Evidence has shown that MRI may be the most effective way to locate the exact site of compression while also revealing any scarring or fibrous band formation that may be contributing to the compression[4]. The complicated nature, many sites of compression and variable symptom presentation of Thoracic Outlet Syndrome have all contributed to the wide array of tests used to diagnose the condition.

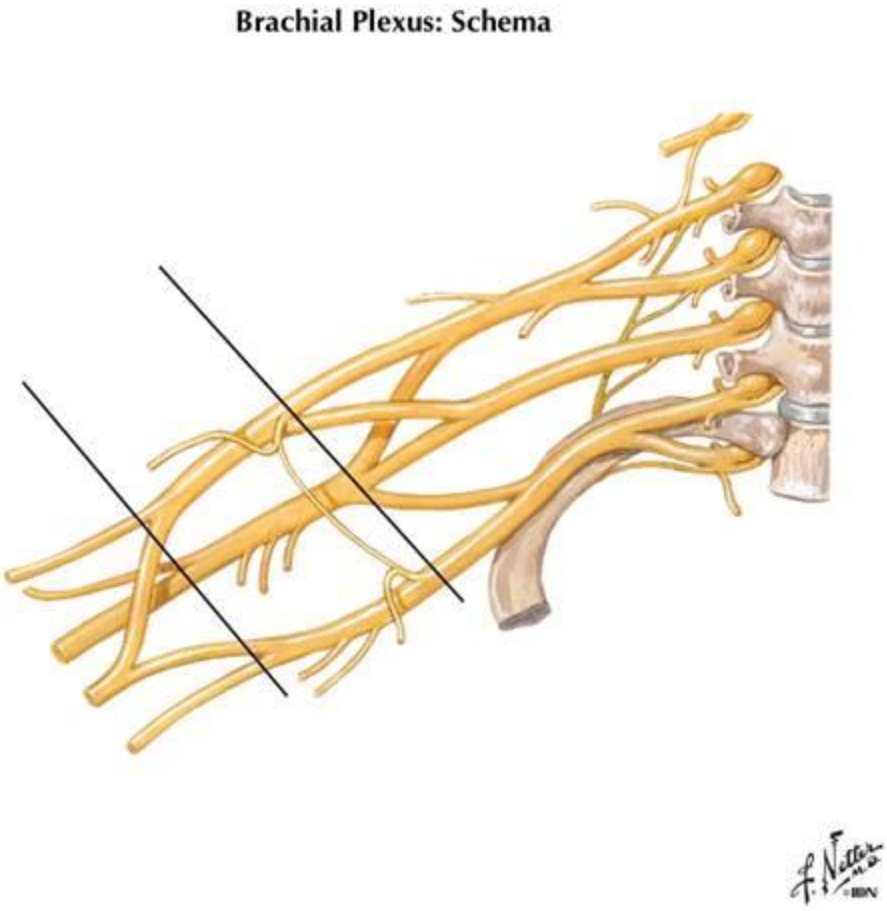
After locating the exact location of the compression, it is imperative to understand why this problem is occurring in the first place. The etiology of Thoracic Outlet Syndrome can vary significantly from person to person and can emerge from both traumatic and non-traumatic causes. Compression secondary to trauma often occurs after a motor vehicle accident or whiplash injury to the scalene muscles and surrounding soft tissue associated with an accident[1]. Additionally, sports injuries especially those that involve the scalenes, clavicle or ribs can cause an increase in swelling in the region, resulting in compression. Finally, work related trauma again to the region of the scalenes, clavicle or ribs can cause swelling and compression. However, non-traumatic causes of compression are the more often the cause of TOS. Activities that can cause this compression include repetitive overhead activities, or poor sitting, standing or sleeping posture[1]. Auto mechanics, painters, assembly workers and construction workers are at a much higher risk for developing non-traumatic TOS due to the repetitive overhead activities required in their daily work routine. However, athletes such as volleyball players, baseball players, and tennis players may also be vulnerable to TOS due to the repetitive overhead nature of their sport. Additionally, posture can play a major role in the development of Thoracic Outlet Syndrome. In sitting and standing, a forward head posture with the shoulders rounded or protracted further compresses the spaces in the thoracic outlet providing the nerves with even less space to pass through[1]. There often are multiple factors that result in the development of Thoracic Outlet Syndrome and for this reason it is especially important to collect a thorough history and in-depth subjective interview to get the best picture of factors creating this pathology.

After a final diagnosis of Thoracic Outlet Syndrome is achieved, the job of a physical therapist is just beginning. For most patients with TOS conservative management is often sufficient to correct for and manage their condition. However, in extreme cases more invasive surgical treatment is required. Specific treatment techniques for TOS may vary from provider to provider; however, the basic principles of conservative management remain the same. The first principle of conservative therapy is activity modification[6]. Symptoms can be provoked by a variety of situations, including: poor occupational ergonomics, extreme arm positions, heavy lifting, carrying heavy bags, and having an increased body mass index (BMI). The patient should be advised initially to avoid any and all aggravating positions or activities until their symptoms are under control. If these activities must be re-introduced into the patient's daily activity later on, the therapist will help the patient develop alternative strategies and positioning to perform the activity in a less provocative manner[6]. In addition to activity modification, current conservative therapy is focusing on mobilization treatments, relaxation techniques, and strengthening. Specifically, mobilizations are applied to the scapulothoracic, acromioclavicular, and sternoclavicular joints in order to ensure all boney borders to the thoracic outlet are properly aligned and moving appropriately[7]. Relaxation and stretching techniques are also commonly used in the conservative treatment of TOS in attempt to relax the muscles and release any associated compression to the neurovascular structures in the region. Relaxation exercises often include abdominal breathing, manual therapy and massage, and nerve glide exercises for the neck and upper extremity[6]. Some of the most common stretches used are shoulder shrugs, neck rolls, and door-way stretches. The door-way stretch is noted to be most effective for stretching of the pectoralis minor region. Alternatively, some therapists choose to utilize positional release techniques, and moist heat to aide in relaxation and stretching of the muscle groups. Finally, strengthening of the postural muscles is essential to successfully managing Thoracic Outlet Syndrome long-term. The postural muscles including the abdominals and upper back and the pectoral girdle are often the target of TOS strengthening exercises. It is important to note that this component of therapy should only be initiated after the resting symptoms have resolved. Additionally, strengthening activities should not cause symptom provocation and should be initiated at a very low weight, low rep structure to acutely assess the patient's tolerance of the activities. Some additional recommendations that may help to reduce the symptoms of Thoracic Outlet Syndrome include: avoiding carrying heavy objects (i.e. purses, groceries, etc…) on the involved side, avoiding pulling, pushing or lifting with the affected arm, avoiding sleeping on the affected side, avoid stressful situations, avoid tight bra straps or seat-belts, keep hands low and relaxed on the steering wheel while driving, trigger point injections, muscle relaxers, and anti-inflammatory medications[6]. Unfortunately, not all patients respond to conservative treatment and must resort to surgical interventions. Surgery is typically not advised unless that patient has failed at least 3 months of conservative treatment. There are three commonly used surgical techniques for managing Thoracic Outlet Syndrome, they are: an anterior and middle scalenectomy, a 1st/cervical rib resection, and supraclavicular neuroplasty. An anterior and middle scalenectomy can be performed independently from or in conjunction with a cervical rib resection. When a total anterior and middle scalenectomy is performed without an accompanying first rib resection the most effect approach has been defined as a supraclavicular approach[6]. However, when there is only a partial scalenectomy performed as a part of a 1st/ cervical rib resection a transaxillary approach has proven to be more effective, although both procedures have been performed with equal success in the past[6]. A supraclavicular neuroplasty is another surgical technique in which the nerve roots are freed from the scalene muscles, as well as any fibrous or connective tissues adhesions that have formed around it[13]. However, evidence shows that a first rib resection provided better relief of symptoms than a supraclavicular neuroplasty.

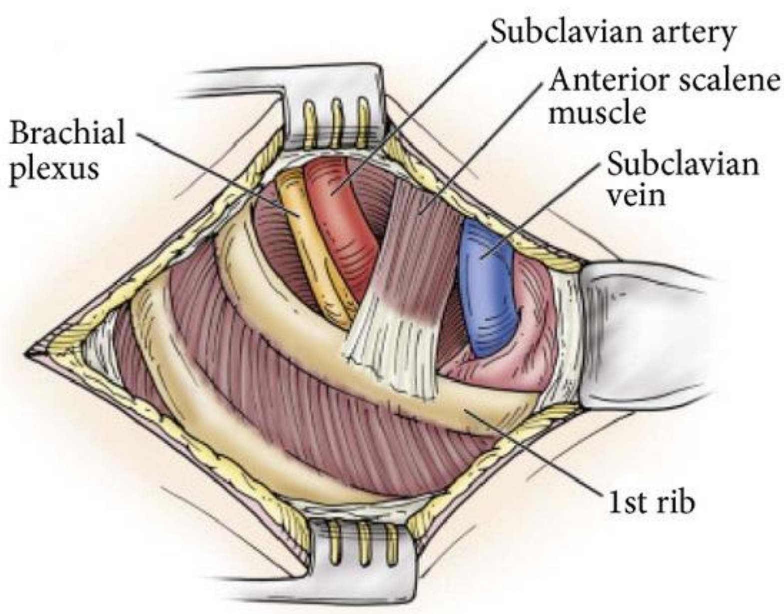
In conclusion, Thoracic Outlet Syndrome is a complex condition that involves the compression of the brachial plexus neurovascular bundle as it passes from its origins in the cervical and thoracic spine out to the upper extremities. This compression can occur at multiple points throughout the thoracic outlet including the sternocostovertebral space, scalene triangle, costoclavicular space and the pectoralis minor space. The diagnostic process for Thoracic Outlet Syndrome can be extremely complicated and include a variety of special tests and other imaging studies. However, some tests have been identified as being better at identifying compression in specific regions of the outlet. Finally, after diagnosis, Thoracic Outlet Syndrome is most commonly treated with conservative management including activity modification and elimination, relaxation and stretching exercises, mobilizations and postural strengthening exercises. However, if conservative treatment fails there are surgical approaches available to remove the source of compression and relieve the patient’s symptoms.

Appendices

Appendix 1



Appendix 2



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