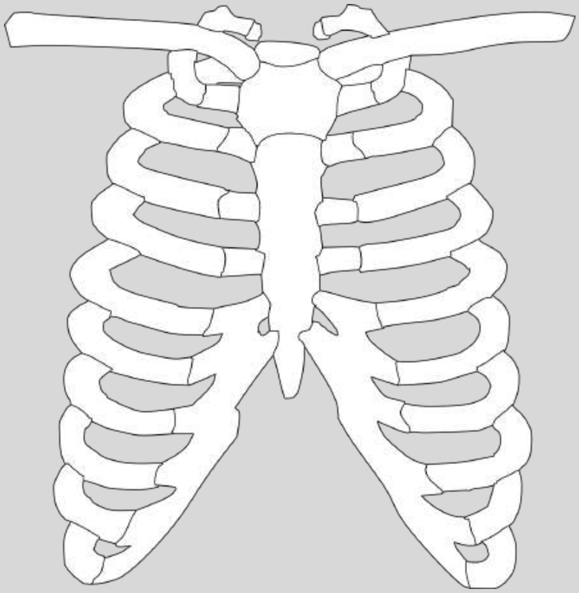
FLEX CEUs

Thoracic Outlet Syndrome



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Introduction

Thoracic outlet syndrome (TOS) describes a group of disorders in the upper extremity and neck where vasculature and nervous structures are compressed, leading to symptoms such as poor circulation, paresthesia and weakness. TOS has a variety of types and is somewhat difficult to diagnose because of many conditions that mimic it. Treatment of TOS is based on decompressing the structures that are restricting the nerves and vessels in the thoracic outlet. Approaches include physical therapy and surgery, which will be discussed in the sections to come. It is important for Physical Therapists and Physical Therapist Assistants to recognize TOS, refer when patients are not improving and intervene appropriately to best manage patients with TOS. This course will describe thoracic outlet syndrome in detail including clinical presentation, most effective treatments and case studies to challenge clinical reasoning.

Section 1

Thoracic outlet syndrome has many distinguishing factors that separate it as a condition. Clinicians must recognize the anatomy, characteristics, common clinical presentation and contributing factors of TOS to manage intervention of these cases. This section will describe everything clinicians should be educated on regarding the background of TOS as a condition. This includes clinical picture, anatomical predisposition to TOS, etiology and population factors that represent thoracic outlet syndrome.

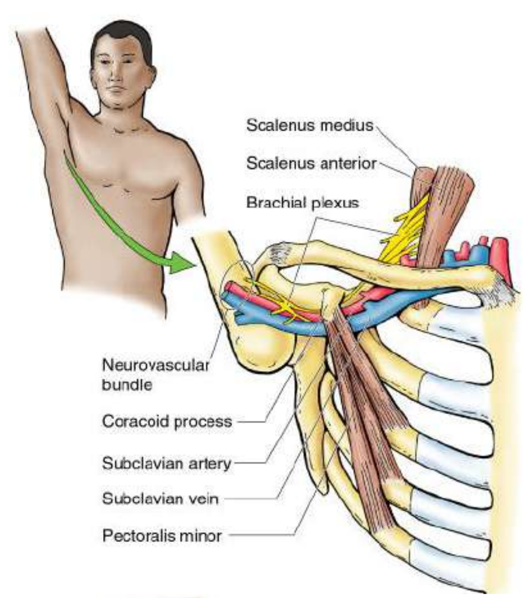
What is Thoracic Outlet Syndrome? [1,2,3,4]

Thoracic outlet syndrome was first reported in 1949 as a disorder. It was first defined and named TOS by Rob and Standeven in 1958, described as a "a set of symptoms that may exist due to compression on the brachial plexus and on subclavian vessels in the thoracic outlet region." TOS is caused by compression of the vasculature (subclavian and axillary artery and vein) and nervous structure (brachial plexus) coming through the thoracic outlet. The thoracic outlet is located at the inferior aspect of the neck between the first rib and clavicle. Neurogenic, venous and arterial thoracic outlet syndrome are categories of TOS based on which structure is compressed. These categories are more recently described as arterial vascular, venous vascular, true neurologic, traumatic neurovascular, and disputed TOS. Diagnosis of TOS is made based on clinical testing, imaging, studies of the integrity of vasculature and excluding other possible diagnoses. Patients will experience pain, numbness and tingling and weakness in the upper extremity that is affected. Additionally with arterial or venous TOS, they may experience upper extremity color changes, diminished pulses in the upper extremity and a cold extremity as well.

Clinically Relevant Anatomy [1,4,5]

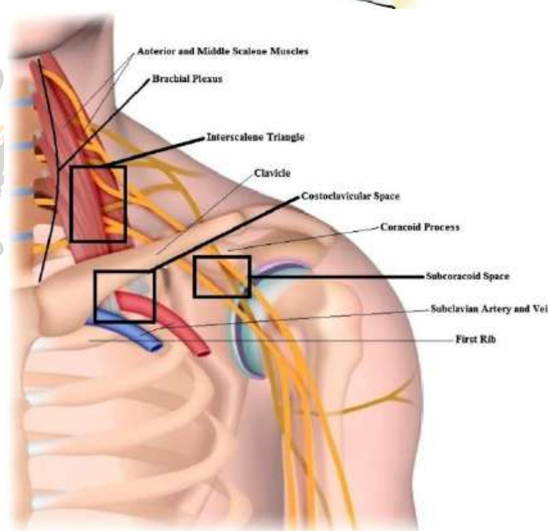
The anatomy comprising the neck and shoulder is complex due to vasculature and nerves coursing through small windows of space. The thoracic outlet is no exception to this and describes the area between the supraclavicular fossa to the axilla. The axilla describes the area inferior to the shoulder, also the first inferior aspect of the upper extremity.

6.86. Compression of the neurovascular bundle in the axilla.



Below is a description of common areas for compression of nerves and vasculature with TOS, which are depicted below. These areas have a neurovascular bundle passing through, including the brachial plexus, axillary and subclavian artery and the axillary and subclavian vein.

1. **Interscalene Triangle** is made of the outline of the anterior scalene muscle at the anterior aspect, the middle scalene muscle at the posterior aspect and the first rib at the inferior aspect. The brachial plexus and the subclavian artery course through this space. Scalenus Anticus Syndrome specifies a disorder that occurs due to the brachial plexus being compressed at the interscalene triangle



2. **Costoclavicular Space** is outlined by the subclavius muscle at the anterior aspect, the first rib and anterior scalene muscle at the inferior aspect and the clavicle at the superior aspect. The brachial plexus and subclavian artery and vein course through this space. Costoclavicular Syndrome specifies thoracic outlet syndrome due to compression at the costoclavicular space. The structures compressed by the first rib and clavicle would be either the subclavian vessels or the brachial plexus.

3. **Subcoracoid Space** is outlined by the pectoralis minor muscle at the anterior aspect, ribs 2-4 at the posterior aspect and the coracoid process at the superior aspect. The brachial plexus, axillary artery and vein course through this space. Hyperabduction Syndrome specifies thoracic outlet syndrome at the subcoracoid space due to compression of the subclavian artery, axillary artery or brachial plexus occurring from the pectoralis minor tendon and the first few ribs.

Musculoskeletal Structure and Innervation of the Upper Extremity [6–8,8]

To visualize the biomechanics of thoracic outlet syndrome, clinicians need to gain understanding of the bony and muscular anatomy of the shoulder girdle. This section will outline joints, nerves, muscles and motions that occur in the shoulder. The shoulder is comprised of the glenohumeral, acromioclavicular, sternoclavicular and the scapulothoracic joints and the muscular and connective tissue attachments to them.

Glenohumeral joint (GH)

The glenohumeral joint represents the articulation between the head of the humerus to the glenoid fossa of the scapula. It allows flexion and extension, abduction and adduction and internal and external rotation in the sagittal, frontal and coronal planes. Normal range of motion is 110 degrees of flexion to 60 degrees extension, 120 degrees of abduction and 0 degrees of adduction, 90 degrees of internal and external rotation. When combined with the other joints of the shoulder listed below, total normal range of motion for the shoulder is 180 degrees of flexion, 90 degrees of extension, 180 degrees of abduction, 30 degrees of adduction and 90 degrees of internal and external rotation.

The GH joint is stabilized by the glenoid labrum, glenohumeral ligaments, and joint capsule. The glenohumeral ligaments include the superior, middle and inferior ligaments which help keep the humeral head in place and prevent anterior dislocation. The coracoclavicular ligament connects the coracoid process of the scapula to the clavicle and the coracohumeral ligament connects the coracoid process to the humerus greater and lesser tuberosities.

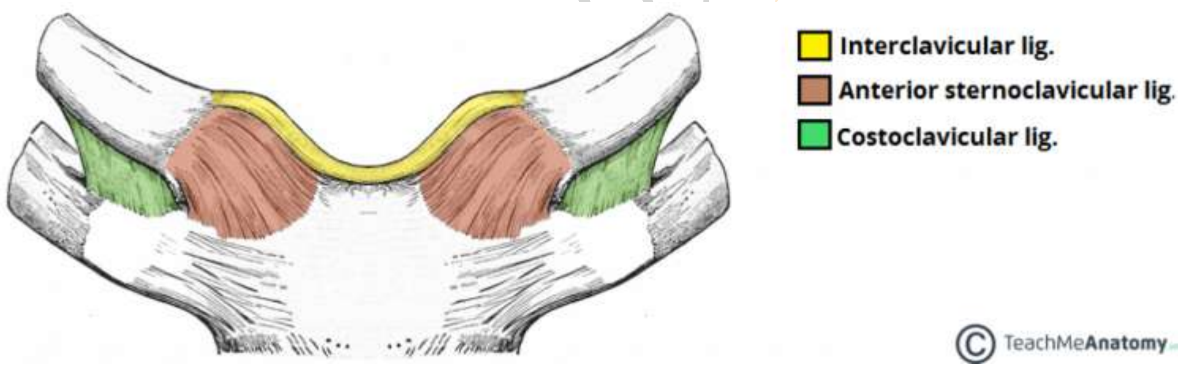
The purpose of the rotator cuff on the GH joint is to keep the humeral head stabilized in the glenoid fossa. The rotator cuff consists of the supraspinatus, infraspinatus, teres minor and subscapularis (SITS). The supraspinatus is responsible for initiating shoulder abduction, the infraspinatus and teres minor act to rotate the shoulder externally, and the subscapularis acts to internally rotate the shoulder. The four rotator cuff muscles attach from the scapula to the greater and lesser tubercles on the humerus.

Acromioclavicular joint (AC)

This joint represents the articulation between the acromion process of the scapulae and the clavicle. All movements that occur here are dictated by other muscles as there are no muscular attachments to the AC joint. The AC joint will flex and extend, abduct and adduct and rotate internally or externally based on the movement of the glenohumeral joint and scapulothoracic joint. Ligaments at the AC joint include the superior and inferior acromioclavicular ligament which stabilize the articulation and the coracoclavicular ligament which connect the coracoid process to the inferior distal clavicle.

Sternoclavicular joint (SC)

The sternoclavicular joint is a saddle joint connecting the proximal clavicle which is rounded or convex to the manubrium of the sternum which is concave. This joint is the only true bony articulation connecting the upper extremity to the skeleton. Four ligaments at the sternoclavicular joint include the anterior and posterior sternoclavicular ligaments, the costoclavicular ligament and the interclavicular ligament which reinforce the stability of the SC joint. This joint rarely separates and it is common to fracture the clavicle rather than separate the joint due to the good stability of the joint capsule and ligaments.



Muscular attachments to the clavicle and actions are listed below.

1. **Pectoralis major** – allows adduction and internal rotation of humerus and pulls the scapula forward and down; attaches the medial clavicle, anterior sternum, cartilage at proximal rib, and fascia of the external oblique to the intertubercular grove of the humerus

2. **Deltoid** – allows flexion, abduction, extension, internal and external rotation of the arm and attaches the scapula spine, clavicle and acromion process to the humerus at the deltoid tuberosity

3. **Trapezius** – allows elevation, retraction and rotation of the scapulae, attaches the nuchal line and ligament, occipital protuberance, and spinous processes of C7 to T12 to the lateral clavicle, acromion and scapular spine
4. **Sternocleidomastoid** – allows cervical flexion, lateral flexion and rotation and attaches on the manubrium of the sternum and the most proximal aspect of the clavicle to the mastoid process
5. **Scalene** – allows cervical flexion, lateral flexion, rotation, first rib elevation and anterior middle and posterior scalene muscles attach from the transverse processes of vertebrae C2 to C7 to first and second ribs
6. **Subclavius** – contributes to stability of clavicle as the shoulder moves, attaches the clavicle to first rib

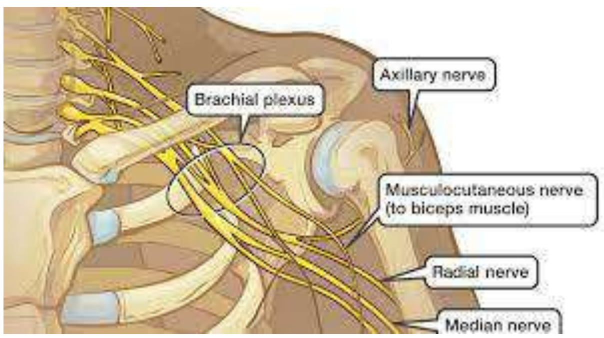
Scapulothoracic joint (ST)

The ST joint represents the area between the anterior aspect of the scapula and the posterior thorax. The scapula will elevate and protract to create anterior elevation, will elevate and retract to create posterior elevation, will depress and protract to create anterior depression and will depress and retract to create posterior depression. The scapula should move one degree into upward rotation for every two degrees of elevation of the humerus. (2:1 for glenohumeral to scapulothoracic movement). There are eighteen muscle attachments to the scapula which comprise many actions of the shoulder girdle as a whole.

Nervous Anatomy of the Upper Extremity [9]

The brachial plexus courses from spinal nerves C5 to T1 and travels through the axilla, inferior to the clavicle to provide motor innervation of the upper extremity muscles, besides the trapezius and levator scapulae. The brachial plexus also contributes to sensory innervation in the entire upper extremity besides the axilla itself and the posterior scapula. In the spinal cord, the nerves leading to the brachial plexus exchange information in the gray rami communicans to relay information to the central nervous system. The brachial plexus courses from spinal nerve roots from near the transverse processes of each vertebra to trunks which pass between the anterior and middle scalene muscles, to divisions which split into anterior (supply flexors of upper extremity) and posterior (supply extensors of upper extremity). The brachial plexus continues to form cords consisting of lateral, posterior and medial cord based on their placement next to the axillary artery. The cords pass the first rib and then travel inferior to the clavicle just behind the subclavian artery. The brachial plexus then forms branches of the musculocutaneous, axillary, radial, median and ulnar nerves which go on to innervate the upper extremity. See figure 4 for innervation of specific upper extremity muscles through branches of the brachial plexus.

Brachial Plexus Anatomy



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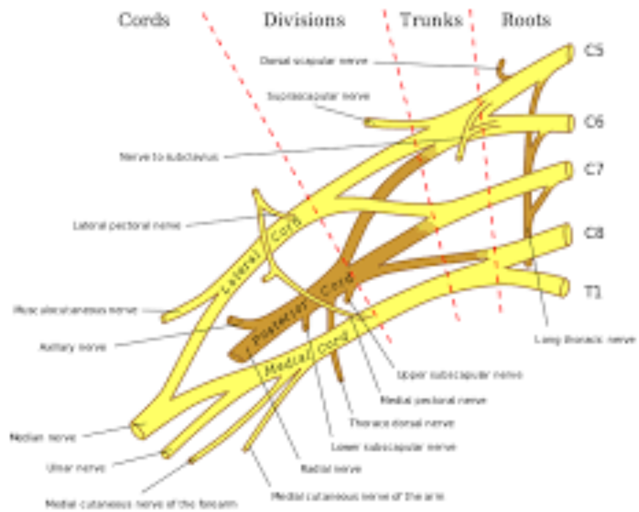


Osteokinematic action and innervation of shoulder girdle by all joints and muscles in the shoulder

Muscle	Innervation	Movement
Trapezius	Spinal accessory	Scapular adduction, elevation, rotation and depression
Serratus anterior	Long thoracic	Scapular protraction and upward rotation, maintains scapular position against chest wall
Deltoid	Axillary	Arm abduction, adduction, flexion and extension
Latissimus dorsi	Thoracodorsal	Humerus adduction, extension, internal rotation
Levator scapulae	Third and fourth cervical	Scapular elevation
Rhomboid major	Dorsal scapula	Scapular adduction
Rhomboid minor	Dorsal scapula	Scapular adduction

Pectoralis major	Medial and lateral pectoral	Adducts and internally rotates shoulder joint and assists in forward elevation
Pectoralis minor	Medial pectoral	Scapular protraction and inferior rotation
Teres major	Lower subscapular	Arm adduction and internal rotation
Triceps brachii	Radial	Forearm extension
Biceps brachii	Musculocutaneous	Forearm flexion and supination
Coracobrachialis	Musculocutaneous	Arm flexion and adduction
Infraspinatus	Suprascapular	Humerus external rotation
Subscapularis	Upper and lower subscapular	Humerus internal rotation
Teres minor	Axillary	Arm external rotation
Supraspinatus	Suprascapular	Humerus abduction

Types of TOS 1,2

The diagnosis of thoracic outlet syndrome is based on etiology and causes of symptoms. Types, or categories of TOS, are listed below and based on which structures are being compressed. The most common cause of TOS is due to compression on the brachial plexus which is called neurogenic TOS. The other main two types of TOS are venous and arterial in origin. Traumatic TOS occurs as a result of an injury or accident with compression either on vasculature or the brachial plexus. Traumatic TOS can also be categorized as vascular or neurogenic TOS.

Neurogenic TOS

Neurogenic TOS is defined by nerve compression of the brachial plexus somewhere between the C5 and T1 nerve roots. This most often occurs at the scalene triangle between scalene muscles and can be caused by factors such as anatomic variance, cervical rib presence and prior injury with tissue scarring. People affected by neurogenic TOS will often have completely reproducible symptoms with specific movements.

1. **True Neurogenic TOS** occurs when nerve conduction studies show evidence of deficit in brachial plexus nerve signaling

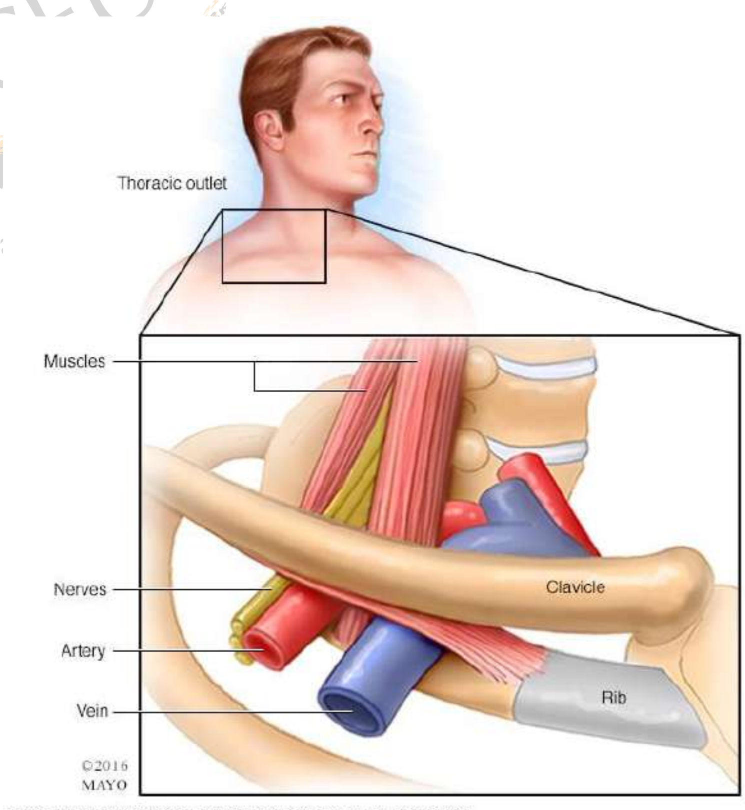
True neurogenic thoracic outlet syndrome typically affects only one upper extremity, not both. True neurogenic TOS is very rare and only affects around one in one million people. It can be caused by the presence of a cervical rib, especially when the lower brachial plexus is affected. It is common for the C8 and T1 nerve roots to be compressed, which causes hand atrophy of the thenar muscles.

2. **Disputed Neurogenic TOS** occurs when there is no evidence of poor nerve signaling from imaging or nerve conduction studies. Disputed neurogenic TOS is also defined as compression of the brachial plexus caused by movement of the upper extremity.

   Disputed neurogenic TOS is often bilateral and affects the inferior aspect rather than the superior aspect of the brachial plexus at a rate of 80 percent. The majority of neurogenic TOS cases are disputed neurogenic TOS and the most common causes are anatomic variation, scalene fibrosis, posture impairment and muscle imbalance. Consensus is low on diagnostic criteria as disputed neurogenic TOS does not show evidence on imaging. Other disorders of the upper extremity and neck are often misdiagnosed as disputed neurogenic TOS. This is due to a similar presentation of diffuse pain, paresthesia and weakness of the upper extremity.

3. **Venous TOS** occurs from compression and restriction of blood flow on the subclavian vein in the costoclavicular space

   Venous TOS represents up to 15 percent of cases of TOS. Thrombosis can occur if venous TOS is not resolved due to repetitive injury to the vein between the clavicle and first rib. Thrombosis blocks venous return from the upper extremity by clot formation in the vessels. Venous thoracic



https://www.mayoclinic.org/diseases-conditions/thoracic-outlet-syndrome/symptoms-causes/syc-20353988 outlet syndrome leads to edema, heaviness, pain and color changes to the upper extremity, including a subtle blue tone. Venous TOS is caused by repetitive motion and in active patients from teenage years to the fourth decade of life. Thrombosis increases the risk of pulmonary embolism (PE). This is due to risk of the clot that formed in the axillary or subclavian vein travelling to the lungs and blocking circulation. PE is a large risk factor for venous TOS and happens in around one fifth of cases

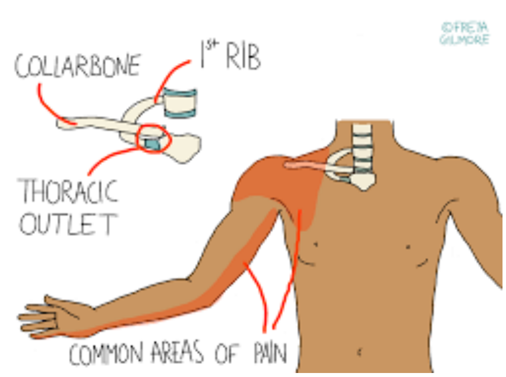
4. **Arterial TOS** is caused by restriction and pressure on the subclavian artery by the scalene muscles or by the tendon of the pectoralis minor

   Arterial TOS represents under five percent of total cases of TOS. It occurs most often in active patients and athletes. With arterial TOS, circulation through the subclavian or axillary artery is altered causing unpredictable blood flow, vessel expansion and lack of blood flow to the upper extremity (ischemia). Ischemia can lead to tissue death, or gangrene. This almost always affects just one upper extremity, not both.

5. **Traumatic TOS** occurs because of an accident involving force to the shoulder or neck. This can create compression of the brachial plexus, subclavian artery and vein or the axillary artery and vein. Further, development of fibrotic and scar tissue near the muscles of the head and neck (such as scalenes) is linked to compression of the brachial plexus and vessels. This leads to TOS as a traumatic type, but also arterial, venous or neurogenic depending on what is compressed.

Characteristics, Signs and Symptoms [1,4]

Thoracic outlet syndrome can result in a variety of upper extremity symptoms. Generally, when the thoracic outlet is compressed with neurogenic TOS, patients will exhibit a gradual onset of paresthesia, muscle atrophy and vague upper extremity pain. More specifically, patients with neurogenic TOS will experience paresthesia, neck, trapezius and shoulder pain at a rate of above 90 percent, and pain above the clavicle, chest pain and occipital headache at a rate around 75%. In addition, patients will have paresthesia in all the



http://www.freyagilmore.uk/2018/08/19/thoracic-outlet-syndrome-tos/

fingers around 60 percent of the time. Clinicians may suspect upper brachial plexus TOS with C5-7 compressed resulting in diffuse pain at the lateral neck extending to the occiput. With lower neurogenic TOS (C8 to T1) patients will report pain at the shoulder and referral to the medial arm, with numbness and tingling at the fourth and fifth digits.

With venous TOS, patients may complain of swelling in the arm, diffuse pain from the hand to elbow and enlargement of the veins of the upper extremity. The onset of venous TOS is typically very gradual with symptoms developing over weeks or months, unless trauma occurs which immediately compresses the veins. Patients will have pain with upper extremity use, especially overhead and repetitive motions.

With arterial TOS, patients may have less color in the extremity from reduced circulation and faint pulses. The onset of arterial TOS is also gradual, unless trauma occurs which blocks the subclavian or axillary artery circulation.

Risk Factors for TOS [4,5,10,11]

TOS is a common disorder and certain factors do increase the risk of development of compression on the thoracic outlet. People with poor posture including forward head position, anterior rounded shoulders and increased thoracic kyphotic posture are at risk for TOS. Patients with tension and short length of the pectoralis major, scalenes and latissimus dorsi are also a risk factor. This is due to these postures and muscle tension further compressing the thoracic outlet and leading to symptoms of paresthesia, pain and weakness of the upper extremity. Patients who have sleep disorders, excess stress and depression are at increased risk of developing TOS as these conditions affect tissue healing and are linked to poor posture and muscle tension. Patients with tumors in the underarm, with past injuries from overhead lifting, and people who weight lift are at increased risk for developing TOS. These factors either occupy space in the thoracic outlet or reduce the available space by scar tissue or muscle bulk leading to compression of the thoracic outlet.

Prevalence and Epidemiology [1,3,4]

Clinicians who treat thoracic outlet syndrome should be familiar with prevalence and epidemiology of the condition. Clinicians who are familiar with these factors will be better equipped to recognize, diagnose and explain the condition to patients. Prevalence is how common a disorder or disease process is, and epidemiology is defined as the amount of pathology or disease process that occurs within a specific population.

Prevalence and Epidemiology [1,3]

Thoracic outlet syndrome is relatively common with an incidence of up to 80 people out of 1000. The majority of cases of TOS fall into the neurogenic category at around 90 to 95 percent of total TOS cases. Nearly five percent of cases are venous in cause and under five percent are arterial. Traumatic TOS cases are categorized based on what is being compressed, whether it is the brachial plexus or vasculature. TOS is difficult for many clinicians to diagnose so it is possible that more people do have TOS that have not been diagnosed accurately.

The majority of people with neurogenic TOS are between the 2nd and 5th decade of life and it is more common in women than men. Arterial TOS has the same rate in women and men but is much more common around the 2nd decade of life. Venous TOS is almost always unilateral and is actually most common in young active males from repetition of activity or sport with the dominant upper extremity.

Etiology [1,4,10,12]

Etiology represents all the contributing causes for a disease to occur. Clinicians should understand the causes of TOS to explain patient specific reasons for development of TOS.

Thoracic outlet syndrome is caused by a variety of reasons. The most common etiology for TOS is not entirely agreed on in the literature. This section will discuss common causes of TOS, but clinicians should realize that consensus for the most common causes of thoracic outlet syndrome is disputed in the literature.

Trauma, Repeated Movements, Malignancy

Trauma to the area, repetition of movements and malignancy can each cause TOS. Trauma is most often caused by an accident, such as a motor vehicle accident. Trauma to the neck happens in about 80 percent of cases of neurogenic TOS. Fractures will easily compress nerves and vessels through the thoracic outlet. Repeated movements of abduction and external rotation is common in athletes who swim or throw and workers who reach and lift overhead repeatedly throughout the day. These movements can increase the size of muscles surrounding the thoracic outlet, muscle hypertrophy, which leads to compression of the nerves and vasculature through the thoracic outlet. Injuries from overuse also contribute to swelling and development of fibrous tissue in response which compresses the thoracic outlet.

Anatomic Variation and Muscle imbalance

Patients can have anatomical variations that predispose TOS symptoms. For example, around one fifth of patients with neurogenic thoracic outlet syndrome have a cervical rib. Cervical ribs grow from one of the lower spinal vertebrae in the cervical spine and occur in just about two percent of the population. The cervical rib can either lead to true neurogenic TOS, arterial TOS or venous TOS due to the potential to restrict circulation in the vasculature. Further, most of the surgery performed for TOS involves resecting a cervical rib, at around 85 percent of cases. Tumors, benign or metastatic, and cysts that develop near the brachial plexus will also compress the nerves that supply the upper extremity. Any space occupying lesion near the thoracic outlet has the potential to compress the neurovascular bundle. Other causes of TOS include imbalances in cervical and shoulder muscle activation. This is especially true with decreased activation of the trapezius muscle as the entire shoulder girdle would be inferior relative to its normal position. This causes increased pressure at the thoracic outlet due to compressing the small space. In addition, patients may have restriction at the clavicle, termed “clavicular hypomobility” which contributes to TOS. The sternoclavicular joint is the only attachment of bone of the upper extremity and articulates from the sternum to the clavicle. The acromioclavicular joint articulates from the distal clavicle to the acromion process of the scapula. This joint is supposed to flex, extend, abduct, adduct or rotate in response to the sternoclavicular joint motion. When the clavicle is restricted, normal arthrokinematics do not occur, leaving the clavicle in a relatively inferior or lacking rotation necessary to clear the subclavian vessels or brachial plexus.

Section 1 Summary

Thoracic outlet syndrome is a condition that causes compression to the vessels and nerves that course through the thoracic outlet including the axillary and subclavian vessels and the brachial plexus. The anatomy of the shoulder is comprised of four joints and multiple ligaments and muscles which are in close relation to each other, to create complex movement of the upper extremity. There are multiple reasons that thoracic outlet syndrome develops, including muscular hypertrophy, abnormal musculoskeletal anatomy, repetitive overhead movement and space occupying lesions. Depending on the structure being compressed, patients will complain of paresthesia, vague upper extremity pain, may have reduced circulation and diminished pulses and weakness. It is important for clinicians to be familiar with the anatomy, clinical picture and populations most affected by TOS to effectively manage patients with TOS.

Section 1 Key Words

1. **Interscalene Triangle** – the space in the lateral neck where the brachial plexus and subclavian artery pass. It is between the anterior scalene muscle, the middle scalene muscle and the first rib.
2. **Costoclavicular Space** – the space in the lateral neck where the brachial plexus, subclavian artery and subclavian vein course through. Its borders are the subclavius muscle, the first rib and anterior scalene muscle and the clavicle.
3. **Subcoracoid Space** – the space in the neck where the brachial plexus, axillary artery and axillary vein course through bordered by the pectoralis minor muscle, ribs 2-4, and the coracoid process.
4. **True Neurogenic TOS** – occurs when nerve conduction studies and imaging show evidence of poor brachial plexus signaling
5. **Disputed Neurogenic TOS** – occurs when nerve signaling from imaging or nerve conduction studies is normal; compression of the brachial plexus caused by movement of the upper extremity

Section 2

Thoracic outlet syndrome has several methods of diagnosis. In patients with suspected TOS, physical therapists should complete an upper quarter examination and recognize symptoms and diagnostic criteria of several conditions that mimic TOS. Therapists should be aware of and competent in performing special tests that confirm the likelihood of TOS. Therapists should also know of and be able to perform special tests for other conditions of the upper extremity and cervical spine to rule differential diagnoses out. Therapists should also know when to refer patients for imaging or red flag conditions. All of these factors will be discussed in Section 2.

Physical Therapy Examination [13–15]

A comprehensive physical therapy assessment for TOS will examine the entire upper quarter. This includes assessment of the cervical spine, upper extremity, and thoracic spine. This is always done bilaterally to detect potential abnormalities to the asymptomatic side and know what "normal" is for the patient. Clinicians should gather a descriptive subjective history and examine posture, cervical, thoracic and upper extremity active and passive range of motion, palpation of muscles surrounding cervical spine and upper extremities, myotome and dermatome integrity, accessory joint motion of the cervical and thoracic spine, upper extremities and special tests to rule out conditions that may mimic TOS.

Subjective History [1]

It is critical for clinicians to take a comprehensive subjective history. The history will lead to specific tests and measures for ruling in or out TOS or other differential diagnoses. Physical Therapists should ask details about a patient's symptoms including when, where and how they started, whether the patient had a gradual or sudden onset of symptoms, whether an injury occurred and details surrounding the event, what improves or worsens pain, details of the patient's daily routine looks like and if any part of it is affected by symptoms. A clinician should ask whether the patient has noticed signs and symptoms that are typical with thoracic outlet syndrome including upper extremity weakness, paresthesia, and upper extremity or neck pain. Good clinicians will also attempt to rule in or out possible referrals screening for red flags of differential diagnoses. This will be detailed in the differential diagnosis section. A patient should fill out outcome measures, which are detailed in a separate section to document progress on neck and upper extremity disability and pain. Intake forms should be thorough and ask details of medications and past medical history to gain information to help with safe and effective management of TOS.

Posture [16]

Posture is an important component of an upper quarter examination due to muscle imbalance and dysfunctional joint position that can lead to symptoms of TOS.

1. Observe and note the position of spine, whether there is lordosis or kyphosis present and any hinged parts of the spine especially at the cervicothoracic or thoracolumbar junction

2. Observe and note head position. Forward head posture is a sign of weak anterior and tight/overactive posterior cervical muscles and is common in patients with neck pain. This is often the case in patients with TOS, especially with overactive scalenes which compress the brachial plexus and vessels in the thoracic outlet.
3. Observe and note the scapula position and level bilaterally. The center of the scapula should be directly inferior to the mastoid processes bilaterally. This maintains balance between the shoulder girdle and the cervical musculature from anterior to posterior. This is important as the shoulder girdle describes the connection of the spine, the scapulae, clavicle and glenohumeral joint.

Active range of motion [17]

Assessment of the upper quarter includes motion in the cervical, thoracic spine and the upper extremity joints. Clinicians should assess cervical flexion, extension, lateral flexion and rotation and note deficits and provocative symptoms bilaterally. For thoracic spine mobility, clinicians must assess flexion, extension, lateral flexion and rotation. For the shoulder, flexion, extension, internal and external rotation, abduction and adduction should be examined for deficits. Range of motion can be measured with a goniometer or inclinometer for accuracy.

Normative values for the cervical and thoracic spine and the shoulder are listed below.

1. Cervical Spine [17]
    a. Flexion is around 80 – 90 degrees
        i. This movement comes from the C1 and occiput articulation and small movements anteriorly and posteriorly on the remaining cervical vertebrae
    b. Extension is around 70 degrees
        i. This movement comes from the C1 and occiput articulation and small movements anteriorly and posteriorly on remaining cervical vertebrae
    c. Lateral flexion is around 20 – 45 degrees
        i. This movement comes from rotation unilaterally as a combination of flexion and rotation throughout the cervical spine

   d. Rotation is around 90 degrees
      i. This movement occurs from C1 rotating on C2 to provide around 50 degrees of motion. The remaining rotation comes from the rest of the cervical spine

2. Thoracic Spine [18,19]
   a. Flexion is around 75 degrees
   b. Extension is around 20 – 25 degrees
   c. Lateral flexion is around 10 – 12 degrees per segment
   d. Rotation is around 30 – 35 degrees

3. Upper extremity [20]
   a. Flexion: 180 degrees
   b. Abduction: 180 degrees
   c. Extension: 50 degrees
   d. External rotation: 90 degrees
   e. Internal rotation: 70 degrees
   f. Adduction: 45 degrees

Passive range of motion

After measuring deficits with active range of motion, clinicians should move the joint into the farthest position allowed limited by pain or physiological end range. It is important to test both active and passive range of motion for clinical decision making. For example, if passive is greater than active motion, a clinician can suspect a muscle length issue and if passive and active are the same but restricted motion, a clinician can suspect a joint restriction.

Palpation [14]

Note and feel for muscle atrophy as this may be related to weakness in pattern with myotomes coming from issue at cervical spine or compression of the brachial plexus with TOS. Detailed notes are helpful for this due to lack of objective testing for muscle palpation. Palpation should be conducted at muscles at the cervical spine and shoulder girdle. Clinicians should also palpate muscles directly innervated by myotomes listed in table in section below to detect nerve hypertrophy or atrophy and rule in or out spinal nerve root pathology.

Myotome Assessment [13,15,21]

Myotomes are the association between spinal nerves and motor innervation of specific muscles. It is important to assess for strength deficits in a myotome pattern as ventral nerve roots from the cervical spine directly innervate muscles from the shoulder down to the fingers. This will allow a clinician to identify weaknesses that are a result of nerve compression in the upper extremity or cervical spine. The following is a list of which spinal segments correspond with strength deficits that can be detected during a physical examination. Spinal nerves in the cervical spine from C1 to C7 leave the spinal cord in the space above the bony vertebrae at the same numbered level while C8 nerve leaves the spinal cord between C7 and T1 bony vertebrae.

Nerve Root	Myotomes – Action, Strength Test	Applicable Muscles for Testing
C1+C2	Cervical flexion	Rectus lateralis, longus colli, cervices and capitis, sternocleidomastoid
C3	Cervical lateral flexion	Trapezius, scalene, longus capitis
C4	Shoulder elevation	Trapezius, levator scapula, scalene, diaphragm
C5	Shoulder abduction	Deltoid, biceps
C6	Elbow flexion, wrist extension	Brachioradialis, wrist extensors, serratus anterior, latissimus dorsi
C7	Elbow extension, wrist flexion	Triceps, wrist flexors
C8	Thumb extension, ulnar deviation	Extensor pollicus longus/brevis, flexor carpi ulnaris
T1	Finger abduction	Lumbricals, interossei muscles

Manual Muscle Testing [22,23]

In addition to myotome assessment, clinicians should test individual muscles with manual muscle testing to determine shoulder girdle weakness. If myotome tests are weak, a clinician should specifically test muscles that are innervated by that spinal nerve to further investigate causes of the weakness.

Muscles that would be appropriate to test bilaterally are listed below, as well as methods to test strength. These muscles are directly linked to weakness, postural impairment and muscular imbalance in one or both upper extremities with thoracic outlet syndrome. Manual muscle tests are graded a 0 for no muscle movement, a 1 for muscle twitching, a 2 for ability to move fully with gravity eliminated, a 3 for full movement against gravity, a 4 for full movement against gravity and moderate resistance and a 5 for full range of motion and ability to hold against maximal resistance.

1. Lower and middle trapezius

   For these muscle tests, the patient should lay prone with their upper extremity at 90 degrees of abduction for the middle trapezius and around 150 degrees of abduction for the lower trapezius. The clinician should stabilize the scapula with one hand and push the upper extremity inferiorly with the other hand to test strength.

2. Serratus anterior

   The patient should be seated without a back support and flex their shoulder to around 120 to 150 degrees of flexion. The clinician will place one hand at the lateral border of the scapula and the other near the elbow. The force of the muscle test is pushing the arm into extension and the scapula into downward rotation and retraction.

3. Deltoid

   The patient should be sitting without a back support and abduct the upper extremity to 90 degrees for testing the middle deltoid and 90 degrees of flexion to test the anterior deltoid. The examiner should stabilize the scapula and clavicle with one upper extremity and push the upper extremity inferiorly to test strength.

4. Deep neck flexors

The deep neck flexor endurance test examines strength of the anterior cervical musculature which supports the cervical spine to prevent forward head posture. Patients should lay supine, perform a chin tuck and lift their head one to two inches. The examiner will time the patient until they observe compensations from the sternocleidomastoid or scalenes. A normative value for this test is around 40 seconds.

5. Rotator cuff – external rotation, abduction of glenohumeral joint

   The patient should be seated for the external rotation test with their elbow at their side at 90 degrees and in no shoulder flexion or abduction. The examiner should attempt to push the shoulder into external rotation while the patient attempts to keep the shoulder position neutral. For shoulder abduction, the patient should also be seated with their shoulder abducted to around 90 degrees. The examiner should stabilize the scapula and clavicle and push the upper extremity inferiorly with their hand near the elbow.

Dermatome assessment [21,24]

Dermatomes are defined as the delivery of sensory information from skin in a distribution, which begin from the posterior/dorsal spinal nerve root at corresponding segments. With TOS, it is important to identify paresthesia and sensory deficits as brachial plexus compression is the most common etiology behind it.

Nerve Root	Dermatomal Distribution	Impairment
C1+C2	Head (lateral, anterior and posterior)	Paresthesia
C3	Neck, inferior to mandible	Paresthesia
C4	Shoulder, scapular, upper clavicular	Paresthesia
C5	Deltoid, front of arm to thumb	Impaired biceps reflex
C6	Front of arm, radial aspect of hand, digits 1 and 2	Impaired brachioradialis reflex, paresthesia in thumb
C7	Lateral arm/forearm, digits 2-4	Impaired triceps reflex, paresthesia in digits 2-4

C8	Medial arm/forearm, digits 2-5	5th digit paresthesia
T1	Medial forearm to start of 5th digit	Paresthesia

Testing dermatomes

Clinical assessment of dermatomes is completed to assess pain and light touch. Dermatomes are also associated with reflexes, temperature, vibration, and pressure. A clinician typically uses various objects to elicit these stimuli to test the skin of respective dermatome patterns. These tests should be performed bilaterally, with the patient's eyes closed. The clinician would give patient instructions to state when and where they feel the sensation. The clinician should vary the speed and randomize the area being tested to get an objective assessment where the patient cannot predict the next chosen dermatome.

1. Pain – Pinprick test
    a. A clinician uses a pin to carefully touch the skin of respective dermatomes and assesses sharp or blunt sensation to test pain response
2. Light Touch
    a. Clinician uses cotton or other object to brush on area of skin to test light touch sensation

Deep tendon reflexes [25]

Deep tendon reflexes (DTR) are important to test as they reveal information of the integrity of the nervous system. It is important to test these in the upper extremities due to neurogenic TOS compressing the brachial plexus and possibly diminishing reflexes. To test the DTRs in the upper extremity, the muscle belly of the tendon that the clinician is testing should be completely relaxed. The clinician should quickly and gently strike the tendon of the respective areas below with a reflex hammer to assess deep tendon reflexes. If the reflexes are hyporeflexive, a clinician may expect a nerve root issue coming from the cervical spine or compression of the nerve somewhere in the upper extremity or neck.

1. Bicep

a. Tests function of C5-6 nerve root

2. Brachioradialis

    a. Tests function of C6 nerve root

3. Triceps

    a. Tests function of C7-8 nerve root

Description	*Score*
Reflex absent	0
Reflex slight, less than normal: includes a trace response or a response brought out only by reinforcement	+1
Reflex in lower half of normal range	+2
Reflex in upper half of normal range	+3
Reflex enhanced, more than normal: includes a clonus if present which optionally can be noted in an added verbal description of the reflex	+4

https://www.researchgate.net/figure/NINDS-scale-for-tendon-reflex-assessment-1_tbl1_13741225

Accessory joint motion [26]

The clinician should instruct their patient to lay in supine to test cervical spine accessory motion and prone to detect thoracic spine mobility. The general idea is to move spinal segments in respective directions to detect decreased mobility or stiffness bilaterally and to reproduce pain in a spinal segment if pain is a symptom. As the clinician moves segmentally, medially and laterally on each spinal segment they should assess whether a patient has pain or stiffness and document these findings. A clinician should examine the cervical and thoracic spine and the shoulder to determine any areas where joints are hypo or hypermobile.

1. Cervical spine, thoracic spine

    a. Posterior to anterior (PA), medial and lateral segmental movement to detect reduced mobility and pain bilaterally

2. Glenohumeral joint

    a. Distraction – joint play in open packed joint position (50 degrees abduction with slight horizontal adduction and external rotation)

b. Inferior glide – joint play of humeral head moving downward in the joint capsule

c. Posterior glide – joint play of humeral head moving backward in joint capsule

d. Anterior glide – joint play of humeral head moving forward in joint capsule

Special Tests [1,12,27]

Thoracic outlet syndrome is identified in the clinic with a few important special tests. These are described below.

1. Adson Test
   a. Clinician passively abducts the shoulder 30 degrees and extends the shoulder fully. The patient then extends neck and rotates their head toward the shoulder that the clinician is testing.
   b. The clinician should assess the radial pulse before putting the shoulder in the position above and the test is positive if the radial pulse on this upper extremity is diminished or decreased
   c. Tests for compression of the axillary artery or vein by a cervical rib or the scalenes
2. Elevated Arm Stress Test (ROOS)
   a. The starting position is shoulders abducted to 90 degrees and externally rotated and elbows flexed to 90 degrees. The clinician then instructs the patient to close and open hands for a time period of three minutes
   b. This test is positive if the patient experiences symptoms of TOS like altered sensation, arm weakness or heavy feeling or pain
3. Wright's Test
   a. The clinician should abduct the shoulder to the limit (hyperabduction) and if the radial pulse is lessened or absent, the test is positive
   b. This test determines whether or not the axillary artery is being compressed by the coracoid process of the scapula or by the pectoralis minor

4. Upper Limb Tension Test (Elvey)

    a. This test examines neural tension of the brachial plexus as a whole. The starting position is shoulder abduction to 90 degrees with full elbow flexion, then flexion of bilateral wrists, followed by lateral flexion of the neck bilaterally.

    b. These positions should be progressed through slowly and clinician should ask patient if/when they feel tension (numbness, tingling, pain) down their upper extremity.

    c. Positive if paresthesia, pain or heaviness result on the same side for the first two conditions, or the opposite side for the lateral flexion

    d. Clinicians may also perform specific median, ulnar and radial neural tension tests to specify other areas nerves may need mobilization.

        i. ULTTa (also named ULTT1) tests for median nerve compression and includes progressive movements to put tension on median nerve. These are shoulder depression, abduction, external rotation, forearm supination, wrist and finger extension, elbow extension and cervical lateral flexion.

        ii. ULTT 2A will also detect median nerve compression and is examined with shoulder depression, elbow extension, external rotation of arm, wrist and finger extension

        iii. ULTT2b will detect compression of radial nerve with shoulder depression, elbow extension, internal rotation of arm, wrist and finger flexion

        iv. ULTT3 will detect ulnar nerve compression with shoulder depression, abduction, external rotation, wrist/finger extension, elbow flexion

5. Cyriax Release

    a. The starting position is the patient either sitting or standing with the clinician's arms elevating the shoulder girdle with grip at the forearms with the elbows in just under 90 degrees of flexion. The clinician should lean the patient posteriorly, elevate the shoulder girdle and hold this position for three minutes

b. This test is positive if it produces symptoms of TOS

6. Supraclavicular Pressure

a. The starting position is sitting with arms adducted to the sides of the body. The clinician should grasp the upper trapezius with fingers and the anterior scalene with the thumb where it attaches to the first rib. After thirty seconds of gripping and releasing in this position, this tests is positive with reproduction of TOS symptoms

b. This tests for neurogenic TOS and compression of the brachial plexus through the scalene muscles

7. Cervical Rotation Lateral Flexion

a. The patient begins in a seated position. The examiner rotates the cervical spine to the limit of the joints opposite to the affected side, then flexes the cervical spine as much as possible

b. This tests for first rib position and is positive when movement of cervical lateral flexion is less than the other side

When completed alone, the Adson and ROOS test have only a 30 percent specificity but when conducted together they have an 82 percent specificity. If the Adson's, Wright's and Roos tests are combined there is a sensitivity of almost 95 percent. Clinicians should always perform multiple of the tests above and especially the Adson's, Wright's and Roos tests.

Diagnostic Imaging and Modalities [1]

The main diagnostic strategy for TOS is thorough clinical examination and subjective history. However, imaging plays a role in classifying and visualizing a TOS diagnosis. Disputed neurogenic TOS is a diagnosis of exclusion and does not show results on diagnostic modalities including electrodiagnostic testing and imaging. Vascular and true neurogenic TOS do benefit from imaging due to the ability to find pathology from the studies. Below are imaging modalities typically done in cases of TOS.

Electrodiagnostic Studies

Although most cases of neurogenic TOS will not show abnormal results on electrodiagnostic testing, it is standard practice to complete electromyography (EMD) and nerve conduction studies. Abnormalities consistent with neurogenic TOS include altered sensation in the antebrachial and ulnar nerves and poor motor response in the median and ulnar nerve distribution. This is from C8 and T1 nerve distribution.

Neurogenic TOS can also be diagnosed by proving symptom relief after injecting anesthetic into the anterior scalene muscle. A good predictor of the success of surgical decompression is if symptoms are after decompressing the neurovascular bundle by effectively numbing the anterior scalene. In fact, patients with success to the scalene block had 44 percent better surgical outcomes than those without success to the block.

Imaging [28]

Imaging includes conventional radiographs, CT, MRI and sonography and are helpful in visualizing the anatomy behind the causes of TOS. Chest radiographs are taken to depict abnormalities in the bone.

Vascular TOS

Ultrasound is the first imaging modality used for vascular TOS as it gives noninvasive adequate detail for planning for surgery. Other helpful diagnostic modalities for vascular TOS are angiography, MRI and CT. These modalities differentiate soft tissue well and depict anatomy in detail which can also aid in surgery planning.

Findings of venous TOS on imaging includes thrombus in the axillary or subclavian veins, stenosis in the vessels and increased size of the vessels surrounding the affected area. Arterial TOS is identified on imaging by widening of the axillary artery or vein (aneurysm), embolus in the area, large supporting vessels and stenosis of the axillary artery or vein.

Neurogenic TOS

Although imaging is often done for patients with neurogenic TOS, there is little effect of this on their outcomes. Diagnosis based on clinical findings is usually sufficient, especially with disputed neurogenic TOS. MRI may depict swelling near the brachial plexus or depleted adipose tissue storage near the brachial plexus.

Differential Diagnosis and Methods of Diagnosis [2,29–34]

Thoracic outlet syndrome symptoms mimic many other pathologies in the neck and shoulder. It is important for therapists to distinguish TOS from other pathologies by knowing differential diagnoses and how to test for them. It is crucial for clinicians to perform an upper quarter examination on each patient who reports upper extremity pain, paresthesia, edema of the upper extremity, neck pain and other upper extremity symptoms. A thorough examination from the section above will lead to an effective differential diagnosis It is also crucial for therapists to refer to primary care or an orthopedist for conditions that require imaging or surgical consideration. Common differential diagnoses, how to diagnose the conditions and whether to refer are described below.

1. **Raynaud's Syndrome** occurs with diminished circulation to the fingers due to cold temperatures or stress and only relieved with warmth to the area.
2. **Vasculitis** is inflammation in the blood vessels which cause pain in more than one area in the body. This can result in organ or tissue damage if the inflammation is so severe that it restricts circulation. This is diagnosed with either organ biopsy or blood cell count looking for inflammatory markers.
3. **Rotator Cuff Tears** typically result from trauma to the shoulder, such as falling on an outstretched hand. They involve a tear to one or more of the four rotator cuff muscles, including the supraspinatus, infraspinatus, teres minor and subscapularis. Patients will have pain with active shoulder movement and weakness in abduction and external rotation. Rotator cuff tears are diagnosed by clinical special tests such as the drop arm test, empty can and external rotation lag sign. Diagnosis is confirmed with imaging which is typically magnetic resonance imaging (MRI).
4. **Cervical Radiculopathy** occurs from pathology in the cervical spine that compress the spinal nerves (disc rupture, spinal stenosis). This causes symptoms of radicular pain, weakness and paresthesia down a spinal nerve route. Cervical radiculopathy is diagnosed by MRI, electromyography and suspected from clinical tests of Spurling's, distraction, degrees of cervical rotation and upper limb tension tests.
5. **Cubital Tunnel Syndrome** occurs with compression on the ulnar nerve through the cubital tunnel at the elbow. This is diagnosed by a nerve conduction study

and a clinical test is a positive Tinel sign. A positive Tinel sign occurs when there is paresthesia down the nerve distribution after tapping the nerve and signifies nerve damage.

6. **Guyon's Canal Syndrome** occurs with compression of the ulnar nerve passing through Guyon's canal in the wrist. This is confirmed by a nerve conduction study and suspected by a positive Tinel's sign tapping over the nerve in the wrist.

7. **Neuralgic Amyotrophy (Parsonage-Turner Syndrome)** occurs with pain that has a sudden and severe onset in the shoulder and upper extremity and results in weakness and atrophy of the area affected. There is little known cause for these attacks besides overuse of the upper extremity and a reaction of the immune system to cause this pain and weakness. It is believed that there is a genetic component to inheriting neuralgic amyotrophy, which is called hereditary neuralgic amyotrophy. This is a very rare disorder and is diagnosed by MRI and ultrasound.

8. **Pancoast Tumors** are characterized by pain in the joint of the shoulder which spreads to the medial scapula due to a tumor on the superior aspect of the lung. Patients may also experience upper extremity edema, chest tightness, fatigue and paresthesia and atrophy in the arm or hand. This is diagnosed by advanced imaging of computed tomography or MRI.

9. **Complex Regional Pain Syndrome (CRPS)** is characterized by pain that is spread out, paresthesia, sensory changes, history of stroke, trauma or nerve damage. CRPS can either be acute if symptoms follow an injury or chronic if symptoms last six months or greater. Patients will experience CRPS in the upper or lower extremity and it will cause skin color changes, temperature changes and extremity edema. CRPS is difficult to diagnose and involves a clinical examination, nerve conduction studies and MRI. Research suggests that early diagnosis is critical for managing this condition as nerve damage will likely be increased if there is a delay in intervention.

10. **Brachial Plexus Injuries** are typically caused by an accident or trauma to the shoulder which damages the network of nerves supplying the upper extremity. This causes a decrease in upper extremity strength, sensation deficits and loss of active movement in the upper extremity. Brachial plexus injury is divided into upper trunk and lower trunk injury. Upper trunk injury the mechanism of injury is typically falling on the shoulder with the upper extremity adducted and the head

being forced to the contralateral side. This can damage nerve roots C5-7 and typically results in inability to complete shoulder abduction and elbow flexion along with paresthesia along the dermatome path from the spinal nerve root. Lower trunk injuries occur when the arm is over head and forced upward even more, supporting weight. For example this injury could occur if a patient was reaching for an object from a ladder and grasps onto a structure to avoid falling. People with lower trunk injuries still have shoulder function but due to C7 to T1 involvement will have altered motor and sensory function in their hand. Plexus injuries are suspected by clinical examination of motor and nerve function and subjective history. MRI, CT and electrodiagnostic studies are helpful in confirming diagnosis.

11. **Cervical Spine Injuries** result from etiologies such as trauma, overuse and degeneration. Some examples are cervical spine fractures, spinal stenosis and disc degeneration. Cervical spine injuries have a wide variety of cause and are typically characterized by symptoms, ranging from subtle to severe. Patients may have pressure or pain in their neck which may or may not radiate (depending if pathology involves pressure on a spinal nerve), paresthesia in the upper extremities, headache and cervical muscle tension. If it is a severe injury, a patient could have symptoms of spinal cord injury which are extreme pain at the neck or head, pronounced weakness and sensation deficits in the upper or lower extremities and inability to control their bowel and bladder. These pathologies are diagnosed by imaging, of xray for fractures and MRI for more detailed imaging of soft tissue. Therapists should always emergently refer a patient who has symptoms or mechanism of injury of a cervical spine fracture due to risk for spinal cord injury.

12. **Elbow Overuse Injuries** occur with repetitive movements to the elbow which stress the tendons, muscles and ligaments that support the elbow. Lateral epicondylitis and medial epicondylitis and radial tunnel syndrome are common overuse injuries at the elbow. Lateral epicondylitis (tennis elbow) as a result of repeated elbow extension putting strain on the common extensor tendon and the lateral elbow. Medial epicondylitis occurs due to repetitive elbow flexion putting strain on the common flexor tendon at the medial elbow. Patients can experience weakness, altered sensation and pain due to the inflammation in the area compressing the muscle and radial nerve (lateral epicondylitis) and median nerve (medial epicondylitis) that supply the area.

With radial tunnel syndrome, the posterior interosseus branch of the radial nerve is compressed through the radial tunnel which courses between the extensors of the wrist and forearm. These muscles include the supinator, extensor carpi radialis longus and brevis and the brachioradialis. Symptoms are paresthesia down to the thumb and second digit, pain in the area, and weakness in forearm supination, wrist extension and first digit abduction and extension. Elbow overuse injuries are typically diagnosed by clinical examination of sensation, strength and subjective history. MRI, CT and nerve conduction studies are used to further investigate the degree of pathology including compression of nerves.

13. **Acromioclavicular Joint Injuries** are common, accounting for nearly 40 percent of all injuries to the shoulder. They are typically caused by trauma, such as falling on a shoulder with abduction or on their extended arm, or overuse of typically repetitive overhead throwing. Acromioclavicular joint injuries are classified in five stages based on severity. Stage one is an acromioclavicular ligament sprain with the coracoclavicular ligament not affected, ranging to stage five, a total separation of the acromioclavicular joint due to the acromioclavicular and coracoclavicular ligaments being completely disrupted. These injuries are diagnosed from a comprehensive examination including screening for fracture, nervous or vascular involvement as well as x-rays and MRI if more detail is necessary.

This section details many conditions that mimic thoracic outlet syndrome, especially regarding upper extremity weakness, altered sensation and pain. Clinicians should be aware of the conditions above and screen for them, refer when there is fracture or risk for imminent neurologic damage and know how to differentiate characteristics of these conditions from those of thoracic outlet syndrome.

Prognosis [1,4]

The prognosis of recovery for patients with thoracic outlet syndrome is based on the individual etiology and plan of care for intervention. In general, patients who undergo conservative management have completely improved symptoms 90 percent of the time. In this case, conservative management involves avoiding movements that exacerbate symptoms, modifying lifestyle to allow for upper extremity healing, and completing mobility and strengthening programs through physical therapy. Patients who do not follow recommendations of their orthopedist and Physical Therapist may deal with prolonged symptoms. Once thoracic outlet syndrome is in the chronic stage it is more difficult to gain complete resolution of symptoms. With vascular and true neurogenic TOS, patients typically need surgery to alleviate vascular and/or nerve compression. Patients who are appropriate for surgical decompression have a good prognosis after surgery. In fact, 95 percent of patients report good results immediately after decompression surgery and at five years of follow up. Patients who have advanced muscular atrophy from neurogenic TOS may also need surgery to prevent continued atrophy to compensate for loss of function.

Section 2 Summary

Thoracic outlet syndrome mimics several conditions in the neck and upper extremity. It is critical for clinicians to recognize these syndromes, when to refer and how to manage both TOS and differential diagnoses. Imaging methods include MRI, CT and ultrasound and nerve integrity is studied by electromyography and nerve conduction studies. Prognosis for TOS is mostly favorable, especially if patients adhere to recommendations of their surgeon and physical therapist.

Section 2 Key Words

1. **Myotome** – a collection of muscles that are innervated by the same spinal nerve root
2. **Dermatome** – a span of the skin where a single nerve root supplies sensory innervation
3. **Accessory Joint Motion** – joint motion that is examined by stabilizing one aspect of a joint and mobilizing the other; joint motions include roll, spin and glide which create voluntary physiologic movement
4. **Neuralgic Amyotrophy** – a disorder of the peripheral nervous system where extreme pain, motor and sensory deficits can occur with no warning
5. **Complex Regional Pain Syndrome (CRPS)** – a chronic pain disorder of an extremity where pain remains very intense due to continued inflammation after an injury heals

Section 3

TOS is managed either surgically or conservatively (non-surgical). With neurogenic TOS, conservative management is almost always the first line of treatment. Physical therapy is initiated as early as possible in patients with neurogenic TOS. With venous and arterial TOS, medical management is the first line of treatment. This section will discuss what treatment strategies per type of TOS are most appropriate.

Medical Management [11,35]

Vascular TOS, whether arterial or venous, need medical management as the first line of treatment. Venous TOS typically requires a medication for removing blood clots in the veins, such as a thrombolytic or anticoagulant. Neurogenic TOS is most often treated conservatively first and surgically only if conservative management fails. Out of all cases of TOS, only up to 20 percent of cases need surgery. However, nearly all patients with vascular TOS will need surgery. The following sections will discuss surgical and nonsurgical approaches to medical management. The medical team for treating vascular TOS may include a primary care physician and general vascular and thoracic vascular surgeons. It is critical for early diagnosis and management of both vascular and neurogenic TOS. Therefore, the first provider that a patient sees is crucial in triaging diagnosis and referral. If a patient has vascular TOS symptoms, they should be referred to primary care for imaging and to the appropriate surgeon. The risk of leaving vascular TOS untreated is chronic edema in the upper extremity, blood clotting, pulmonary embolism, ischemia, and gangrene of a portion of an extremity. The risk of poor management of neurogenic TOS is lasting nerve damage.

Surgical Approaches [4,35,36]

Surgery is indicated for patients with vascular TOS or with neurogenic TOS that has failed conservative treatment. Risks of surgery include infection, damage to the brachial plexus resulting in reduced motor or sensory function in the upper extremity, and persistent symptoms after surgery. The surgery for increasing space for the neurovascular bundle in the thoracic outlet is called thoracic outlet decompression. Decompression surgery is either supraclavicular decompression or subcoracoid decompression. Supraclavicular decompression includes resection of the first rib, removing part of the anterior and middle scalene and possible intentional destruction of part of the brachial plexus to disrupt pain signaling. Subcoracoid decompression includes pectoralis minor tenotomy, involving disrupting the tendon with repeated prodding to break up adhesive tissue and cause the tendon to regenerate. Supraclavicular decompression is more common and is performed when patients have an abnormal first rib or compression from a clinical examination in the interscalene triangle and costoclavicular space. Subcoracoid decompression is chosen when compression exists in the subcoracoid space which does not let up with conservative management.

Venous TOS

A surgeon will complete a comprehensive examination and imaging, most often MRI or diagnostic ultrasound to gain a picture of the surgical field. Surgical decompression will include resecting the first rib and thinning the ligaments in the area. The most common ligament to be resected is the costoclavicular, which attaches the proximal clavicle to the cartilage of the proximal first rib. In severe cases of venous TOS where the vein is severely blocked, patients may need a bypass graft to restore circulation. The surgeon would graft a vein from the arm to complete the bypass.

Arterial TOS

Surgery is the first treatment strategy for arterial TOS as circulation must be restored to regain normal function and avoid tissue damage. Surgery includes removing the abnormal rib that is restricting circulation to decompress the artery. The surgeon will then remove the blood clot, aneurysm or poorly functioning artery, and stitch the ends of the resected artery together. If needed, a graft may be performed to accommodate the length of artery lost in resection.

Neurogenic TOS

Surgery is not indicated in patients with disputed neurogenic TOS as the first line of treatment. This is due to poor accuracy of diagnosis and risk of complications of surgery. With brachial plexus decompression, success rates are about 50 percent in measures of return of function and decreased pain. Around 70 percent of patients report dysfunction at work one year after surgery with neurogenic TOS. However, if patients are not responding to physical therapy intervention in a month to six weeks, they should be referred for imaging and potential surgical consultation.

Nonsurgical Approaches [10,37]

Nonsurgical approaches of medical management include pain or symptom relief through medication. Physicians may prescribe muscle relaxants, nonsteroid anti-inflammatory drugs (NSAIDs) or steroids, and pain medication to provide relief of severe symptoms. It is not recommended for patients with neurogenic TOS to be prescribed muscle relaxants due to the potential for dependence on them. Physicians will most often prescribe NSAIDs and refer to physical therapy first. Venous and arterial TOS may require prescription of thrombolytics to dissolve clots and anticoagulants to prevent clots in the vasculature related to TOS. Physicians may also perform Botulinum toxin injections at the tense muscles in the neck, most often one or more of the scalene muscles. The botulinum toxin injection aims to decrease tension of these muscles, hopefully decompressing the nerves and arteries causing the TOS symptoms.

Outcome Measures

Outcome measures aim to quantify a patient's subjective symptoms of disability, dysfunction and pain. They are an integral part of pre and post surgical or physical therapy intervention strategy to gain understanding of progress or regression from original symptoms. This section will outline common outcome measures that capture thoracic outlet syndrome most accurately.

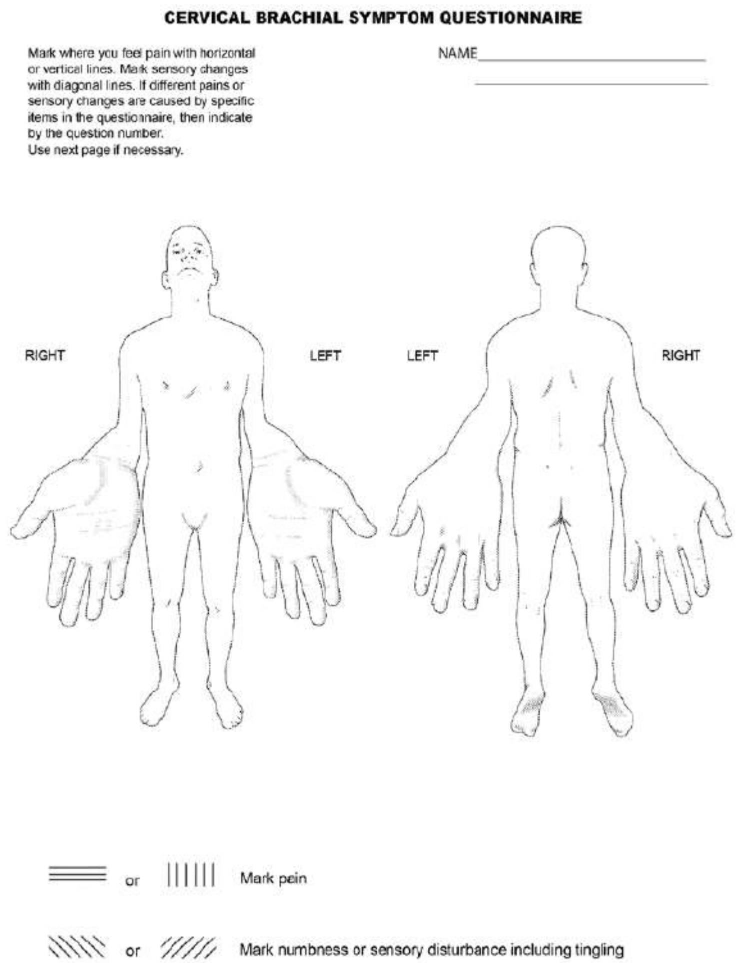
Disabilities of the Arm, Shoulder and Hand (DASH) [38]

The DASH examines function of the upper extremity by ranking the difficulty of activities on a level of 0 to 5. A score of 0 means the patient has no difficulty on the task and a score of 5 means the patient has maximum difficulty. The score is out of 100 points, allowing a percentage from 100 percent for a score of disability. The *Quick*DASH examines dysfunction of the arm, shoulder and hand specifically.

Reliability is excellent for the DASH and *Quick*DASH and the validity is in the acceptable range. The minimal clinical important difference (MCID) for the DASH is around 13 points and 18 points for the *Quick*DASH.

Cervical-Brachial Symptom Questionnaire (CBSQ) [39]

The CBSQ is validated for TOS and measures symptoms on a scale of no symptoms scoring a 0 to incessant symptoms at a score of 120 points. This outcome measure assists in identifying the differences between neurogenic TOS, fibromyalgia, CRPS and cervical brachial pain. Patients will answer 14 questions on a 0 to 10 scale and indicate on a diagram where they have pain or symptoms in the body.



Shoulder Pain and Disability Index (SPADI) [40]

The SPADI assesses symptoms including pain and dysfunction with activities of daily living that involve using the hand, arm and shoulder. This is divided into a pain section and a disability section. There are a total of 13 questions on the SPADI and a lower score indicates less pain and disability while a high score of 100 indicates the highest degree of pain and disability. While it is typically used to evaluate dysfunction in patients with rotator cuff pathology, arthritis, adhesive capsulitis and total shoulder replacement, the SPADI can be used for patients with general shoulder pain (TOS). Reliability and validity are excellent for the conditions listed before and the MCID is 8 points. Clinicians should be aware of the SPADI but apply it more often to patients with general shoulder pain. The SPADI does not capture pathology in the nervous system as is necessary with TOS.

McGill Pain Questionnaire (MPQ)

The MPQ is a questionnaire covering multiple diagnoses that allows patients to communicate their subjective experience of pain to a numeric value. The MPQ consists of 78 words where patients choose seven total to communicate the sensory, affective and evaluative components of their pain. This outcome measure is valid and reliable in patient populations with diagnoses such as neuralgia, sciatica, low back pain, headaches and fibromyalgia. Although it is not validated with TOS, the MPQ is useful in matching the description of pain to the typical presentation of TOS.

Section 3 Summary

Patients with vascular TOS often require surgery followed by physical therapy. Neurogenic TOS is treated by physical therapy first and surgery if PT fails after four to six weeks. Several outcome measures including the DASH, CBSQ, SPADI and MPQ help patients and clinicians understand whether the clinical presentation represents TOS or another upper extremity pathology. These measures are helpful to capture an objective clinical picture prior to and after an intervention over time, whether it is surgery or physical therapy.

Section 3 Key Words

1. **Reliability** – represents the amount of consistency in research upon measuring a score multiple times
2. **Validity** – represents the amount of accuracy in research upon measuring a score multiple times
3. **Minimum Clinical Important Difference** – MCID; represents the score change required for a patient and clinician to note a difference in symptoms
4. **Supraclavicular decompression** – surgical management of TOS that includes resection of the first rib, removing part of the anterior and middle scalene and possible intentional destruction of part of the brachial plexus to disrupt pain signaling
5. **Subcoracoid decompression** – surgical management of TOS including pectoralis minor tenotomy performed by disrupting the tendon with repeated prodding to break up adhesive tissue and cause the tendon to regenerate

Section 4

Physical therapy plays a large role in the treatment of patients with neurogenic TOS. Physical therapy is indicated after decompression surgery for vascular and neurogenic TOS. The surrounding musculoskeletal anatomy must be stabilized and strengthened to prevent recurrence after decompression surgery. Physical therapy focuses on patient education, mobilization or manual therapy, modalities, and therapeutic exercise as a comprehensive plan for treating TOS. Physical therapy programs for TOS typically last four to six weeks. These strategies will be explained below. This section will focus on physical therapy treatment for neurogenic TOS and then discuss strategies for vascular TOS after surgical intervention is complete.

Patient Education [10,12]

Patient education is important throughout any treatment plan to best manage symptoms. Within the initial phase of TOS conservative management, the goal is to lessen the patient's symptoms. Therapists should educate their patients on lifestyle modification. This means education on modifying tasks at work and home that exacerbate symptoms, such as overhead reaching or prolonged sitting in poor postures. Patients should be educated on the process and prognosis of therapy and that success depends greatly on patient adherence to therapist recommendations. Patients should be educated to sleep on the side that is not symptomatic or supine. If patients are waking up at night, therapists may suggest holding the arms down by pinning sleeves to the bed to prevent eliciting symptoms with the arms abducted or flexed.

Education on posture throughout the day and night is an important aspect of physical therapy management of patients with TOS. Therapists should ask a patient what they do for work, examine posture simulating work activities, and ask about sleeping posture. Patients should be sleeping on their side without symptoms or supine. The Cyriax Release Maneuver may be used prior to sleeping if patients have peripheral paresthesia and pain prior to sleeping, as it fully decompresses the nerves and arteries in the thoracic outlet.

Cyriax Release Maneuver

The clinician should instruct their patient to sit on a chair with a back rest with their elbows at 90 degrees and stack towels under arms for shoulder girdle elevation. The patient should hold this position until their symptoms are reproduced and for up to around a half hour. This aims to desensitize and release the neurovascular bundle prior to sleeping, as symptoms should decrease the longer the position is held. Additionally, deep diaphragmatic breathing can be used in this position to encourage relaxation of accessory muscles of inspiration including the scalenes.

Lifestyle and Work Modification [41]

As part of a thorough ongoing subjective history, clinicians should ask patients what activities they are doing on a daily basis, including work, daily routine and hobbies. Jobs that require a lot of upper extremity use including overhead reaching or lifting should be modified at the beginning of treatment for TOS to manage symptoms. Patients who have desk jobs should be examined and educated on best positions for optimizing ergonomic space. Modifications include having their computer at eye level, having a lumbar support in the desk chair, seat height so thighs are parallel to the ground and having armrests that support the shoulder girdle. Patients should be educated that posture is dynamic and to avoid sitting or completing repetitive work activities in the same position all day. Patients who have office jobs sitting at a desk all day should stand and complete stretches or walk to change positions at least once every hour. Patients who have repetitive laborious jobs should attempt to complete work tasks with both sides of the body rather than completing a repetitive movement all unilaterally. Patients should be educated to complete light to moderate aerobic exercise and strength training only if it does not exacerbate symptoms. This is to optimize overall health and tissue healing while undergoing physical therapy for TOS. Physical therapists should ask what activities exacerbated symptoms throughout the plan of care and make recommendations for pain and symptom control. Once patients have controlled pain and symptoms, it is appropriate for gradual reentry to tasks as long as symptoms remain controlled.

Manual Therapy

Manual therapy is a critical component for improving compression on the thoracic outlet. The first rib, cervical spine, thoracic spine and glenohumeral joint should be considered for mobilization or manipulation depending on deficits in the examination. This section will discuss management strategies for the clinic in person and self-mobilization to implement in-home exercise programs for patients to strive for independent management of their condition. Therapists should use manual therapy to achieve physiologic and joint mobility improvements but always empower the patient with home exercises to self-mobilize joints and follow with exercises to maintain balance in the area mobilized. It is imperative that therapists do not rely on manual therapy as patients may become dependent on this and not take on independence in managing their condition.

Mobilization [42–46]

Joint mobilization refers to passive accessory motions of the joint on its opposing surface to improve the range of motion, reduce inflammation and edema in muscles, improve muscle balance and promote muscle relaxation. Mobilization is graded from 1 to 5, depending on the amplitude and depth of tissue accessed by the mobilization. Grade 1 is generally for pain control, is a small amplitude movement and is at just the beginning range of movement where there is no tissue resistance. Grade 2 is also for pain control and is a large amplitude of movement in the joint where there is no resistance. Grade 3 is a large amplitude of movement that stretches into tissue resistance (whether from the muscle or joint) and is for improving joint mobility. Grade 4 is a small amplitude of movement at the end range of a joint to gain mobility, stretching into tissue resistance. A Grade 5 mobilization is a manipulation, or a thrust movement at the end range of joint mobility. With TOS, Grade 1 and 2 should be performed until pain is under control in the first stages of rehabilitation. When pain and symptoms are more controlled, Grades 3 through 5 are appropriate to restore normal mobility in the joints. Mobilizations should be completed at 2-3 sets of 30 seconds to 1 minute and mobility of the joint should be assessed prior to and after treatment, along with symptoms. Directions of mobilization described below are anteroposterior, posteroanterior, joint distraction, medial glide and lateral glide. The most common mobilizations performed for TOS include posterior and inferior glenohumeral glides, first rib mobilization and cervical mobilization depending on restrictions found on the examination. These mobilizations should be followed by exercises in the therapeutic exercise section to gain stability and strength after joints are mobilized.

Cervical Mobilizations should be performed if there are deficits in range of motion or neck pain associated with TOS. Mobilization should be performed on the side of the range of motion deficit, not necessarily on the involved side with TOS symptoms. Lateral glides are performed with the patient in supine and the clinician's hands are stabilizing the neck with one hand and mobilizing a specific vertebra with the other hand. The clinician will mobilize in the direction that resolves symptoms. Posterior to anterior mobilizations are performed with the patient in prone and the clinician placing pressure over vertebrae with reduced mobility found in the examination. Both of these mobilizations can be performed from Grade 1 to 4, and the lateral glide can be performed at a Grade 5 thrust.

Thoracic Mobilizations can be performed supine, prone or seated. The thoracic spine is important to mobilize when deficits are found in the examination due to the concept of regional interdependence. Regional interdependence refers to the connection of surrounding areas of anatomy that are impaired that contribute to a patient's symptoms. Posterior to anterior mobilizations and manipulation in prone are effective in gaining mobility and achieving increased circulation and neurophysiologic effects. Further, mobilizing the spine has been shown to improve symptoms of shoulder pain because nearly half of patients with neck or shoulder pain have symptoms in their thoracic spine as well. These mobilizations can be performed from Grade 1 to a Grade 5 thrust manipulation. For the prone posteroanterior mobilization, the therapist will put each hand over the transverse process of the two adjacent vertebrae and push superior with one hand and inferior with the other on the thrust manipulation. Patients are also able to mobilize their thoracic spine with a home exercise. Patients may sit in a sturdy chair and extend over the back of the chair at one vertebra at a time using small movements. Patients should remain as relaxed in the cervical spine and thoracic paraspinals so mobilization can occur. Clinicians should instruct patients to limit this to once every other day and instruct them to move slightly upwards and downwards to mobilize stiff vertebrae. Clinicians should detect vertebrae that need mobilization into extension and direct the patient to complete mobilization at those segments. Patients may add a towel roll over the back of the chair for comfort.

http://physicalsolutionsli.com/mobility-in-injury-prevention-for-golfers

Glenohumeral Mobilizations are an important part of the plan of care for patients with TOS. Clinicians should examine how the humeral head is moving within the glenoid fossa and mobilize to achieve normal joint mobility where it is needed. Patients with TOS most commonly have an anteriorly displaced humeral head and respond best to posterior and inferior humeral glides. Posterior glenohumeral glides are performed in supine with one hand mobilizing the humeral head with a posterior to anterior force and the other stabilizing near the elbow with the shoulder in mid-range flexion and abduction. Inferior glenohumeral glides are performed in supine with the clinician stabilizing the superior shoulder near the acromioclavicular joint and the mobilizing hand at the proximal humerus directing the force inferiorly. Anterior glenohumeral glides are performed in prone with the stabilizing hand at the elbow with the patient's shoulder in 90 degrees of abduction and the mobilizing hand at the posterior humeral head directing the force anteriorly.

Posterior Glenohumeral Glide

https://www.physio-pedia.com/Thoracic_Outlet_Syndrome_(TOS)

Scapular Mobilization is an important technique for restoring normal mobility in patients with restricted scapular mobility, scapular dyskinesia or aberrant movement patterns, which is quite common with TOS. The patient should be side lying with their symptomatic side up. The clinician will rest the patient's arm on their arm with hands at the inferior border of the scapula and at the acromion. Mobilization direction depends on the restricted movement noted in the examination, whether superior, inferior, upward or downward rotation.

First Rib Mobilizations are crucial in the plan of care for patients with TOS due to the proximity of the first rib to the thoracic outlet. First rib mobilization can be performed sitting or supine and from Grade 1 to a Grade 5 thrust manipulation. Deficits in mobility of the first rib are identified with the cervical rotation lateral flexion test. When seated, the clinician should instruct the patient to rotate their head toward the involved first rib and laterally flex the neck away from the involved side. The clinician should stabilize the body with the patient's opposite shoulder on the therapist's knee and the mobilizing hand just lateral to the neck above the upper trapezius with force directed inferomedial to mobilize. After mobilization or manipulation if the patient tolerates it, the clinician should recheck the cervical rotation lateral flexion test to verify if the mobilization helped first rib mobility. First rib mobilization can also be taught in a home exercise program. For this the patient should be seated with a strap or sheet across their body around the impacted first rib. They should contralaterally laterally flex their cervical spine and rotate toward the involved side and pull the strap down with small or large amplitude movements to achieve first rib mobility.

First Rib Mobilization - Self

https://www.physio-pedia.com/Thoracic_Outlet_Syndrome_(TOS)

First Rib Mobilization - Therapist

https://www.medbridgeeducation.com/techniques/technique/74/

Suboccipital Release is a helpful technique to relieve tension at the base of the occiput around C1 and C2. This can help remediate forward head posture and should be performed in conjunction with deep neck flexor strengthening in the exercise section. In the clinic, the patient should lay supine with the clinician's hands curled to put pressure at the suboccipital muscles at the fingertips. This can be held for up to a couple minutes, until the patient and therapist feels a release in tension. This can also be performed as a home exercise. Patients would lay supine with the base of their occiput over a foam roller or two tennis balls. A progression would be to gently flex the cervical supine by competing chin tucks as tolerated for the 30 second to one minute time frame.

http://www.yourmusculoskeletalspecialist.com/august-1.html

Neurodynamic mobility [47,48]

Neural tension is often a part of the clinical picture surrounding TOS. Upper limb tension tests from the examination portion will lead clinicians to instruct ULTT nerve sliders and tensioners within the plan of care. Patients should only complete movement that is pain free and symptom free for sliders and tensioners, meaning progressively adding motion at the wrist, elbow, shoulder and cervical spine one joint and movement at a time and stopping when there is pain or nerve symptoms (radicular symptoms, paresthesia, numbness). It is very easy to complete excess movement and irritate the nerve further rather than mobilize it within the nerve sheath and surrounding structures. The theory of how sliders and tensioners improve symptoms is increasing fluid surrounding the nerve and allowing inflammation and swelling to dissipate. Sliders should be attempted initially as they do not provoke symptoms. Sliders aim to mobilize the nerve at one end rather than at the same time by mobilizing two joints at the same time. The nerve mobilizes by two joints moving in the same direction sliding the nerve rather than adding tension to it. Tensioners aim to mobilize the nerve by moving just one joint at a time, which lengthens the nerve bed and adds tension to the system. Sliders and tensioners will be based on the test positions described above in the examination section and repeated below for reference

1. The ULTTa (also named ULTT1) treatment position for the median nerve includes progressive shoulder depression, abduction, external rotation, forearm supination, wrist and finger extension, elbow extension and cervical lateral flexion.

2. The ULTT 2A treatment position for the median nerve includes progressive shoulder depression, elbow extension, external rotation of arm, wrist and finger extension

3. The ULTT2b treatment position for the radial nerve includes shoulder depression, elbow extension, internal rotation of arm, wrist and finger flexion

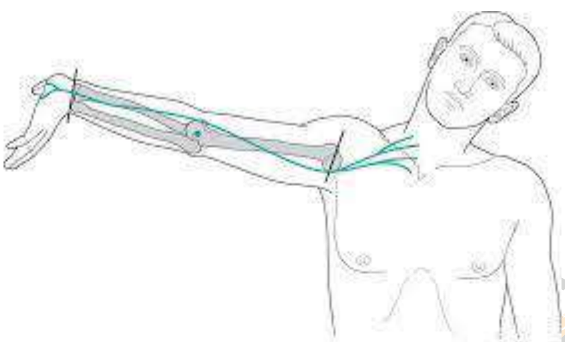
4. The ULTT3 treatment position for the ulnar nerve includes shoulder depression, abduction, external rotation, wrist/finger extension, elbow flexion

Prescription: 2-3 sets of 10 repetitions daily

Median Nerve Slider

https://www.calibratepilates.com/blog/neurodynamics

Median Nerve Tensioner



(i) Median neurodynamic test (von Lanz T and Wachsmuth W 1959 Praktische Anatomie. Springer-Verlag, Berlin, p. 38, with permission).

Therapeutic Exercise

Exercise has been shown to improve TOS symptoms in half to 90 percent of cases. Exercise should focus on correcting muscular imbalance in the neck, shoulder girdle and spine. A comprehensive therapeutic exercise program for TOS will include progressive range of motion to resistive exercise of scapular, cervical, thoracic and glenohumeral mobility and strength. It will also include stretching and activation exercises to improve posture. This section will outline protocols for improving neurogenic TOS based on severity of symptoms.

Initially after diagnosis (Stage 1)

It is important to gain activity of appropriate muscles in the first stage of physical therapy for patients with TOS. It is important to gain activation of scapular and glenohumeral supportive muscles while maintaining good posture throughout the movements. It is also appropriate to gently mobilize nerves and stretch certain cervical muscles. This stage is also for pain control and management including gentle mobilization, education and lifestyle modification. This stage is considered finished when pain and paresthesia are under control.

Activation Exercises

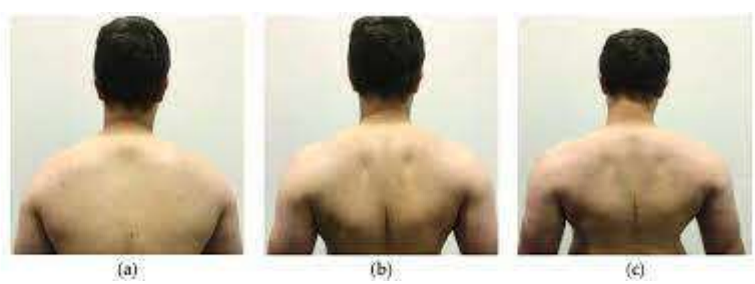
Scapular Position and Gentle Glenohumeral Range of motion

During the first phase of rehabilitation for TOS, it is important to restore mobility in safe ways, educating the patient that it is not harmful to complete these motions. These motions include controlling the position of the humeral head and setting the scapula.

Exercises for recruitment of supporting scapular muscles include activating scapular retractors, protractors, upward and downward rotators during glenohumeral abduction and flexion. This progression will begin with the glenohumeral joint in an open packed position, at up to 30 degrees of flexion and 40 degrees of abduction and progress up to 90 degrees of flexion. Clinicians should avoid adduction because it could further compress and damage the neurovascular bundle.

Prescription: 3 sets of 15 repetitions (pain free and gentle range) beginning in 30 degrees of glenohumeral flexion and 40 degrees of horizontal abduction. The clinician should ensure there is no scapular tipping or winging or anterior displacement of the humeral head. If these occur, sets and repetitions should be adjusted to the level of form fatigue.

Scapular Retractions



https://www.researchgate.net/figure/Demonstration-of-scapular-retraction-and-depression-in-the-a-start-position-b-end_fig1_325868461

Prescription: 3 sets of 15 repetitions (or up to amount where form fatigue is observed)

Patients should be instructed to sit without a back rest or stand if recruitment of muscles is sufficient after checking for form and posture. Patients should retract and depress their scapula, achieved with the cues of "squeeze your shoulder blades together" and to achieve upper trapezius deactivation "relax your neck and the area above your shoulder". If verbal cues are unsuccessful, tactile cues should be used by tapping near

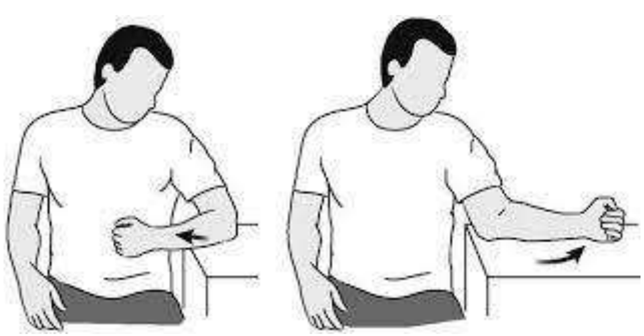
T4-T7 of the thoracic spine while the patient is retracting their scapulae. This exercise will activate the scapula retractors, including the middle and lower trapezius, rhomboids and latissimus dorsi muscles and the depressors, the latissimus dorsi, serratus anterior, pectoralis major and minor and the trapezius. Clinicians must cue patients from using their cervical spine to compensate or if their upper trapezius is firing to achieve scapular elevation. Patients should have a neutral cervical spine with their chin tucked to avoid forward head posture.

External Rotation and Internal Rotation

Patients should begin sitting or standing with their shoulders neutral and elbows flexed to 90 degrees. If patients are showing poor recruitment of scapular muscles, they should begin this exercise sitting with their elbow supported (depicted below). From there, clinicians will instruct for gentle external rotation, followed by internal rotation simultaneously. The scapula should be in proper position, not tipping or winging, while the glenohumeral joint goes through external rotation. It is good practice to palpate the humeral head and ensure it avoids anterior displacement during the movement. If this happens, the clinician should cue for further scapular setting, including retraction and depression, to hold the humeral head posterior in the glenoid fossa. Anterior position of the humeral head also indicates tension in the anterior cervical and shoulder girdle musculature, which is also concurrently addressed with stretching and postural control.

Prescription: 3 sets of 15 (or stopping when the patient demonstrates form fatigue)

Glenohumeral External Rotation with Elbow Stabilization



https://orthoinfo.aaos.org/en/recovery/shoulder-surgery-exercise-guide/

Stretching

After assessing the length of supporting cervical and shoulder girdle muscles, it is helpful to develop a stretching program for short muscles. It is important in initial stages of treatment to complete only gentle stretches to not provoke pain and increased muscular tension. The scalenes, pectorals, latissimus dorsi and levator scapulae are commonly short with TOS. Stretches for these muscle groups are listed below.

Scalene Stretch

Clinicians instruct patients to sit and stabilize their affected side with the ipsilateral upper extremity. Depending on which scalene is targeted, the patient will move their head and stabilize it with the other hand as depicted below.

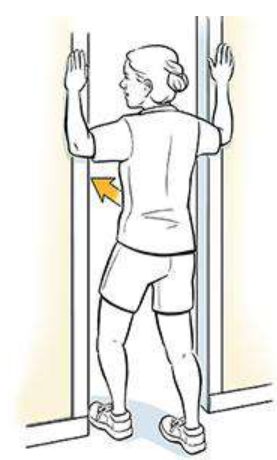
Prescription: 2 to 3 sets of 30 second holds per day of a gentle stretch

1. Middle Scalene 2. Anterior Scalene 3. Posterior Scalene

http://www.361clinic.com/2020/03/03/try-these-3-stretches-that-target-your-scalene-muscles-in-your-neck/

Pectoral Stretch

After finding that the pectoralis major or minor is short in length, using a doorway stretch is appropriate. Patients should stand in the middle of a doorway as depicted below with the elbow stabilized on the doorframe, gently pushing the chest forward until a gentle stretch is felt in the pectorals. The picture below will best stretch the pectoralis major. To target the pectoralis minor the patient should flex the shoulder 30 degrees or so more in the same position, so their elbow is at eye level.



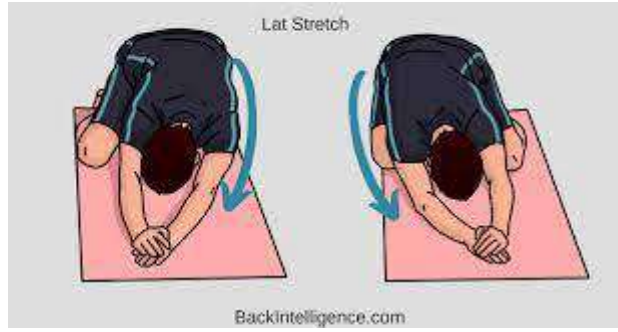
Prescription: 2 to 3 sets of 30 second holds of a gentle stretch

https://www.saintlukeskc.org/health-library/doorway-pectoral-stretch-flexibility#

Latissimus Dorsi Stretch

The latissimus dorsi is best stretched with glenohumeral flexion and trunk extension as depicted. Patients who do not tolerate the quadruped flexed position depicted may stand with their hands on a table or mat to achieve a similar stretch. If this position elicits TOS symptoms, patients may extend their hands straight in front shoulder width apart.

Prescription: 2 to 3 sets of 30 second holds of a gentle stretch

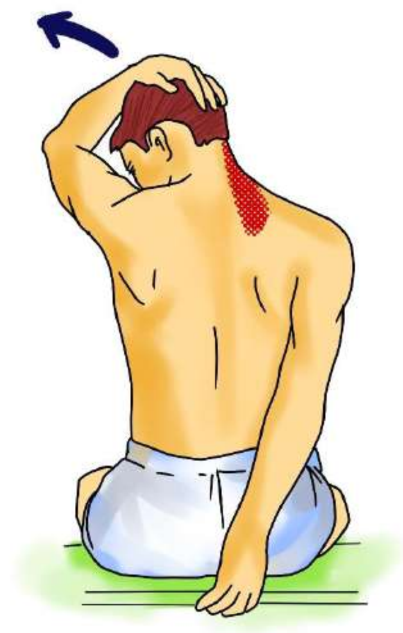


https://backintelligence.com/7-stretches-for-lower-back-pain/

Levator Scapula Stretch

Patients should complete this stretch in sitting with their ipsilateral upper extremity stabilized as depicted. The contralateral upper extremity should flex and rotate the head and neck away from the affected upper extremity.

Prescription: 2 to 3 sets of 30 second holds of a gentle stretch



www.precisionmovement.coach/levator-scapulae-stretch/

Stage 2 of Exercises

Stage 2 should begin when symptoms of TOS are under control. This means that patients are not having moderate or higher pain and paresthesia levels. This stage is meant to correct the biomechanical reasons that the thoracic outlet is compressed, through mobilization, exercise and postural improvements. Strategies to achieve this are widely researched in the literature but it is important to identify specific deficits in each patient with TOS as they do present differently. Progression of each of the exercises below would include adding resistance and completing standing rather than sitting, with cues for core activation while decreasing compensations.

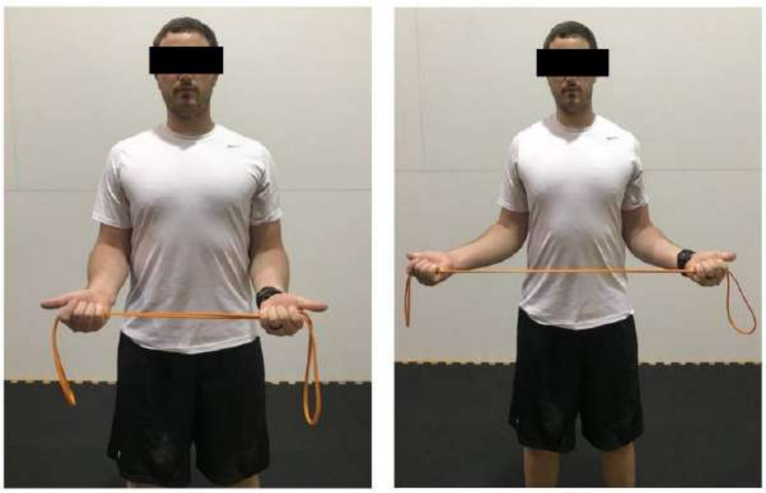
Strengthening

Full Range of Motion of Glenohumeral Joint

In Stage 2, patients can progress to exercises utilizing the full range of motion of the glenohumeral joint. This includes setting the scapula with movement of glenohumeral flexion, extension, abduction, internal and external rotation. Clinicians should start this progression with patients moving without resistance. Once patients can get through a full two sets of fifteen repetitions with good form, resistance should be added and progressed with more weight for strengthening.

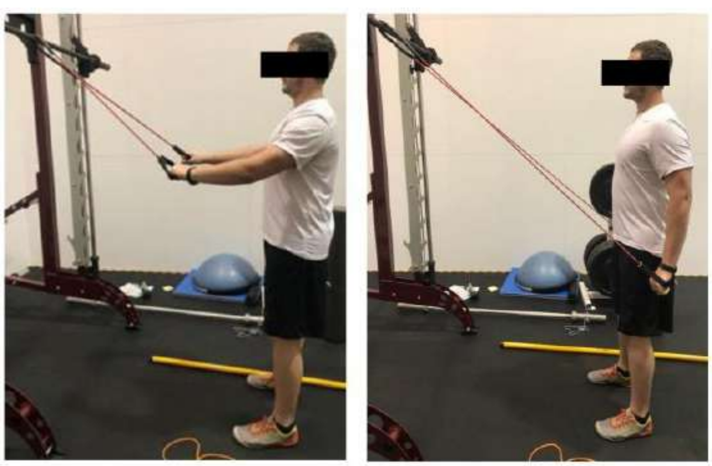
Prescription: 2 to 3 sets of 15 repetitions without resistance for mobility and activation and 2 to 3 sets of 8-12 repetitions with resistance for strengthening

Resisted External Rotation



(a) (b)

Resisted Shoulder Extension



(a) (b)

Prone shoulder extension, abduction, horizontal abduction

https://www.pinterest.com/pin/696651254633092228/

Patients should perform a series of retraction strengthening exercises to assist with decompression of the thoracic outlet. Common exercises for this include prone shoulder extension, abduction and horizontal abduction. These are called "I's, Y's, and T's and activates and strengthens the rhomboids, middle and lower trapezius, supraspinatus, infraspinatus, deltoid, latissimus dorsi, and teres major. Extension of shoulders with arms adducted ("I") will strengthen scapular retractors, rotator cuff, middle and lower trapezius. The lower trapezius and rotator cuff are strengthened by resistive shoulder flexion and slight abduction, which occurs with a "Y". Horizontal abduction in prone ("T") will strengthen the rhomboids and middle trapezius.

Prescription: 3 sets of 15 daily with no resistance. Progress to 3 sets of 8-12 when the clinician slowly adds weight (starting with one pound)

Scapular Retraction

Targeting the rhomboids and trapezius, scapular retractions are important for achieving postural balance of scapular position. This exercise should begin in stage one, sitting without resistance to achieve scapular retraction and depression. It should be progressed with adding resistance, such as a seated row. While progressing resistance and monitoring for compensation, clinicians should stop adding resistance and prescribe the exercise repetitions and sets at 3 sets of 8-12 with no form fatigue. Compensation would include excess cervical movement, upper trapezius activation or trunk extension.

Prescription: 3 sets of 8-12 daily

Serratus Anterior Strengthening

The action of the serratus anterior is to provide stability and protraction for the scapula. It acts to keep the scapula along the posterior thorax as it moves into protraction and upward rotation. Upon examination, if the scapula does not protract fully or if scapular winging is observed with full glenohumeral abduction or flexion, the serratus anterior needs strengthening.

Serratus Anterior Push

Instructions for this exercise include laying in a hooklying or supine position with no weights at first, progressing slowly with adding one pound at a time. Patients should flex shoulders to 90 degrees with their elbows fully extended and push the bar or weights anteriorly creating serratus anterior action. Another method for this exercise is pushing their body weight against a wall with elbows fully extended and shoulders flexed to around 90 degrees.

Prescription: 3 sets of 15 with no resistance and 3 sets of 8-12 with resistance for strength

(a) (b)

https://www.hep2go.com/exercise_editor.php?exId=56188&userRef=gciaake

Full Range of Motion of Cervical and Thoracic Spine

Cervical range of motion

It is important to get the cervical spine mobile to restore any deficits that could be compressing the thoracic outlet or that are a result of thoracic outlet compression. Patients should gently move their cervical spine in flexion, extension, rotation and lateral flexion at 10-20 repetitions repeated throughout the day (up to 10 times).

Lateral Flexion of Cervical Spine

D

Rotation of the Cervical Spine

E

https://learnmuscles.com/blog/2017/08/03/motions-cervical-spine/

Chin Tucks for upper cervical mobility

Deep neck flexor and proper position of the cervical spine is a critical component of TOS rehabilitation. Progression for deep neck flexor strengthening includes supine chin tucks, supine chin tucks with cervical flexion and sitting or standing chin tucks with scapular stabilization. Similar to scapular retraction, chin tucks will remediate postural deficiency due to weakness of the deep neck flexors and tension of cervical extensors, creating a balance between the cervical and thoracic spine and shoulder girdle. Clinicians should watch for compensations of activation of the sternocleidomastoid, scalenes and levator scapulae and progress patients to holding the chin tuck for endurance.

(a) (b)

Prescription: 3 sets of 15 supine, sitting or standing. Progressing to 30 to 60 second holds

Thoracic range of motion

Mobilizing the thoracic spine is important to increase space for the thoracic outlet as well. Mobilization will be discussed in another section, but clinicians should instruct patients in flexion, extension and rotation depending on their deficits.

Stretches

The stretches from Stage one of exercises should be continued if these muscles are still short in length upon assessment. These muscles include the scalenes, latissimus dorsi, pectorals and levator scapulae.

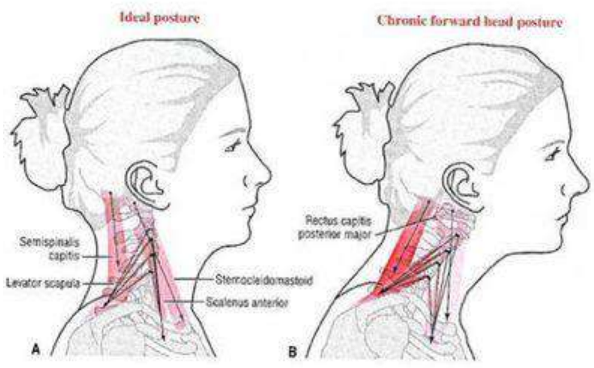
Home Exercise Programs are important for patients to take charge of their condition and should be implemented in the beginning of the plan of care. Initially, home exercises should include gentle range of motion of the cervical and thoracic spine and the glenohumeral joint. They should progress to activation exercises without resistance for scapular, cervical and glenohumeral muscles and stretches to achieve balance within the cervical spine and shoulder girdle. Eventually, patients should be completing nerve sliders or tensioners, self mobilization (suboccipital release, first rib mobilization, thoracic extension), stretching and resistive exercise. Once symptoms are managed and reduced to very low levels per outcome measures and patient report and patients are independent in a maintenance exercise program they can be discharged from physical therapy. If symptoms do not improve within four to six weeks or vascular TOS is suspected, therapists should refer to primary care for medical management.

Common Compensations to Monitor

The three most common compensations clinicians should be aware of during therapeutic exercises for TOS as outlined above are forward head position, scapular winging and anterior humeral head position. These demonstrate weaknesses and muscular imbalance that must be addressed in the plan of care, along with treatment of thoracic outlet syndrome. In fact, these compensations may be exacerbating TOS symptoms. Each is discussed and depicted below.

Forward Head Posture

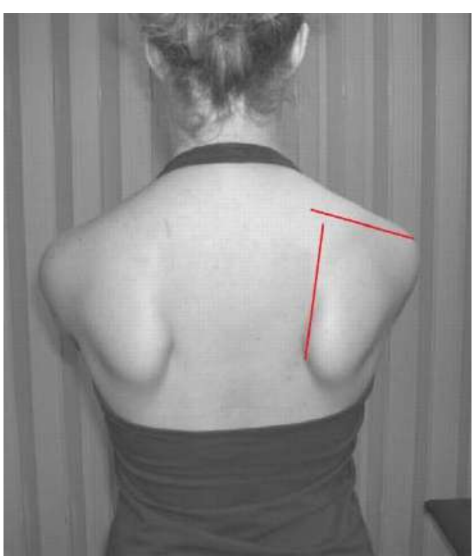
This compensation will result when a patient has overactive and taut upper trapezius, levator scapulae, suboccipital and scalene muscles with weak deep neck flexors, scapular retractors and depressors. Patients may exhibit forward head posture at rest or with scapular or glenohumeral mobility. If a patient does have forward head posture, clinicians should focus on strengthening the scapular retractors and depressors (rhomboids, lower trapezius) and mobilizing, deactivating and possibly stretching the scapular upward rotators and taut anterior and lateral cervical musculature (upper trapezius, sternocleidomastoid, scalenes).



https://www.physio-pedia.com/Forward_Head_Posture

Scapular Winging Compensation

Patients who demonstrate a tipping or winging scapula as depicted below have muscular imbalance of overactive upward rotators and elevators including the upper trapezius and levator scapula and weakness in the retractors and downward rotators including the rhomboids, serratus anterior and the middle and lower trapezius. Patients who demonstrate this compensation need extra activation and strengthening of the listed muscles in order to restore normal shoulder and scapular function.



https://mskneurology.com/permanently-resolve-scapular-dyskinesis/

Anterior Humeral Head Compensation

This may occur when a patient is attempting to extend or rotate the glenohumeral joint. It occurs most often from weakness in the rotator cuff which fails to stabilize the humerus inside the glenoid fossa. Rotator cuff strengthening and scapular stabilization cueing out of this compensation are very important for restoring normal movement patterns in the shoulder. Glenohumeral mobilization may also help this movement pattern, which is discussed in the mobility section.

https://m.blog.naver.com/pyn0105/220949376925

Modalities [49]

Many conditions respond well to modalities in physical therapy practice. This section will list common modalities that may be effective in managing symptoms of TOS. However, evidence suggests mobilization, patient education and exercise are the most effective physical therapy treatments for TOS. This means that clinicians should only use modalities as an adjunct to exercise and manual techniques. Patients with a high level of pain or patients who focus on their pain may respond best to modalities for pain control prior to other forms of physical therapy intervention. Superficial heat from a hydrocollator pack can improve muscular tension surrounding the cervical spine and shoulder girdle. This is beneficial at the beginning of a therapy session aimed at mobilization of joints or stretching as muscles may be more responsive to relaxation. Electric stimulation can be used for pain control in the form of transcutaneous electrical nerve stimulation (TENS). TENS units pass electric impulses through the skin to stimulate superficial nerve fibers and limit pain signaling and would be used surrounding cervical or shoulder girdle muscles where the patient indicates it is most painful. Ultrasound is another popular modality used for providing deep tissue heating of surrounding muscles such as the scalenes and pectoralis minor. Deep tissue heating to these muscles prior to manual therapy and exercise has been proven to improve patient tolerance to further intervention and tissue extensibility. Once patients have exited the acute phase, where pain is heightened and pain control is the goal, therapists should begin to omit modalities from the plan of care. This is to empower patients with exercise and lifestyle modifications and educate that pain does not always equal harm to the area.

Vascular TOS Physical Therapy Management [10]

Vascular TOS is managed by surgical intervention first. Therefore, it is important for physical therapy to follow the surgeon's protocol until cleared for progressive mobility and strengthening. Initially the protocol will limit active movement at the glenohumeral joint and cervical spine, progress to active assisted, active then resistive movement. Patients will have precautions until cleared by the surgeon for a lifting restriction of around five points, avoiding cervical flexion and active movement of the shoulder initially after surgery. Physical therapy exercises post operatively include active assisted shoulder flexion using the non-involved side to assist with movement which progresses to active shoulder flexion only if there is no pain, internal and external shoulder rotation, chin tucks, cervical lateral flexion and rotation with chin tuck and scapular retractions. These exercises should be performed two to three times per day at ten repetitions as a guide. Therapists should only progress to joint mobility and strengthening phases as outlined above for neurogenic TOS treatment at the direction of the surgeon to avoid tissue damage.

Section 4 Summary

Physical therapy intervention strategy for thoracic outlet syndrome depends on whether TOS is neurogenic or vascular, on the severity of symptoms patients are experiencing, individual patient factors such as work and lifestyle and rate of recovery or regression as the plan of care continues. Plan of care should include patient education on modifying activities, range of motion and mobilization for the spine and shoulder girdle, therapeutic exercise including stretching and strengthening in the accessory spinal and shoulder girdle muscles and modalities as indicated for pain relief. Progression should occur on an individual basis and only progress to the next stage when patients are not experiencing pain or paresthesia with their current exercise program. Patients should be educated throughout the plan of care to modify activities that are exacerbating symptoms such as overhead lifting. With vascular TOS after surgical intervention physical therapy should follow the protocol of the surgeon and progress only when the protocol allows to avoid tissue damage.

Section 4 Key Words

1. **Form Fatigue** – observed during therapeutic exercise if a patient is compensating with muscles not targeted by the exercise. Clinicians should stop repetitions of exercise or cue out of this aberrant movement pattern.
2. **Nerve slider** – neurodynamic mobility technique that mobilizes the nerve at one end rather than at the same time by mobilizing two joints at the same time
3. **Nerve tensioner -** mobilizes the nerve by moving just one joint at a time, which lengthens the nerve bed and adds tension to the system
4. **Mobilization** – refers to adding mobility to joints by stabilizing one component of the joint and producing small or large amplitude movements at another aspect of the joint
5. **Manipulation** – refers to a small thrust movement at the end range of a joint to achieve increases in functional joint mobility

Section 5

Case Study 1

Mike is a 54-year-old male who has recently noticed numbness and tingling in his right hand after a few hours of work. He used to notice this sensation after a week of work, which involves overhead reaching to stock shelves at a grocery store. A few weeks ago he felt sharp pain when he reached overhead to put a jar on a shelf above his head and has had intermittent dull pain in his upper extremity since then. He has not sought any treatment besides NSAIDs and icing and arrives to a physical therapy clinic to be evaluated due to persistent pain in his right shoulder and elbow as well as dull neck pain. Upon examination, the physical therapist finds that pain free range of motion in the right glenohumeral joint is limited to 50 degrees of abduction, 100 degrees of flexion and the patient has paresthesia down his right forearm and first through third digits. The

ULTT in median nerve on the right upper extremity is positive and the patient reports inability to perform work tasks of reaching and lifting due to pain and numbness in his upper extremity.

Reflection Questions

1. What additional assessment items should the physical therapist assess?
2. What type of imaging would be most useful in detecting abnormalities in this patient, and when should a clinician refer for imaging?
3. Based on the information above, what diagnosis may the therapist suspect and what clinical tests should be performed to confirm the diagnosis?
4. What interventions may be useful for managing symptoms in this patient?
5. What modalities and when may they be useful in managing this patient?
6. What outcome measures may be helpful in capturing Mike's symptoms?

Responses

1. The clinician should complete an upper quarter examination and perform tests for differential diagnoses. The clinician should test strength, range of motion passively, actively and joint mobility in the cervical spine, thoracic spine and glenohumeral joint, assess posture, sensation and try to reproduce the patient's main symptom of pain with overhead reaching and paresthesia. Differential diagnosis includes ruling out conditions such as cervical radiculopathy and rotator cuff tear with distraction and Spurling's test, empty can test and the external rotation lag sign.
2. Useful imaging modalities include Magnetic Resonance Imaging (MRI) and diagnostic ultrasound because they differentiate soft tissues well. Clinicians should refer for imaging if they suspect vascular TOS and if patients are not improving within four weeks of physical therapy treatment for neurogenic TOS.
3. Neurogenic TOS may be suspected and confirmed with the Adson Test, Elevated Arm Stress Test, Wright's Test and Upper limb tension test (Elvey) for brachial plexus tension.

4. Intervention strategies include pain control, range of motion of the spine and shoulder girdle, activation to resistive exercise for the shoulder girdle, patient education on lifestyle and work modification while pain is being managed, neurodynamic mobilization and joint mobilization/manipulation.

5. Modalities such as TENS, ultrasound and hot packs may be used just initially in treating this patient to control acute severe pain and improve muscle extensibility for exercise. It is important to only use modalities in the beginning of treatment or when symptoms are exacerbated. Clinicians should empower the patient with active interventions of exercise, including gentle range of motion and stretching with exacerbated symptoms.

6. The SPADI, DASH or CBSQ will capture upper extremity pain and disability. These outcome measures should be filled in the beginning, mid point and end of treatment to determine progression or regression of symptoms.

Case Study 2

Emily is a 22 year old female who presents to physical therapy direct access. She complains of left arm pain and occasional numbness throughout her upper extremity. She is very active, is a collegiate softball pitcher and is left handed. She first noticed these symptoms a month into the season, which was a few weeks ago, and the athletic trainer at her college informed her that her symptoms are probably from overuse and to pursue physical therapy. Upon examination, the Physical Therapist notices diffuse swelling from the elbow to the left hand and discoloration compared to the patient's right arm. Her left arm appears slightly blue. When asked what relieves her symptoms, Emily states that rest and ice somewhat help the pain and swelling but it is getting worse. Emily's concern is that her softball season could be over.

Reflection Questions

1. What condition may a Physical Therapist expect based on Emily's symptoms and why?
2. What differential diagnoses should a Physical Therapist consider in this case?
3. What tests should a Physical Therapist perform to narrow down diagnosis?
4. How should a Physical Therapist manage this condition after the first visit?

5. What should a clinician educate this patient about prior to her first visit concluding?
6. What would physical therapy include immediately after surgery if this patient has decompression surgery?

Responses

1. A clinician may suspect vascular TOS based on upper extremity color changes and edema. Because there was not an acute injury and Emily is young, it is unlikely to have something like a rotator cuff tear or cervical radiculopathy. Venous TOS is more likely than arterial TOS based on upper extremity edema and bluish tint.
2. Due to sensation changes and pain down the upper extremity, a PT may consider diagnoses such as neurogenic TOS, cervical radiculopathy, cubital tunnel syndrome, and complex regional pain syndrome.
3. Clinicians should first perform an upper quarter examination before moving onto special tests. Due to sensation being altered in the upper extremity, clinicians should rule out cervical radiculopathy with Spurling's, distraction, cervical rotation and ULTT1. Therapists should perform the Adson Test, Elevated Arm Stress Test, Wright's Test and Upper limb tension test (Elvey) for brachial plexus tension to determine whether neurogenic TOS is a factor.
4. This patient has suspected venous TOS which needs to be evaluated by a physician who intervenes surgically. Emily is at risk for thrombosis and pulmonary embolism due to the restriction of venous return in her left upper extremity. She should be referred to have imaging which is typically an MRI, angiography or ultrasound to determine the extent of her condition and plan for surgical and medical management. She may later be referred for physical therapy to restore normal upper extremity functioning after surgery.
5. The largest topic of patient education for this case would be activity modification. It is crucial that Emily would stop pitching and completing overhead activities that exacerbate her symptoms. The therapist should educate Emily that continuing these activities increase her risk for permanent damage to the vasculature and put her at a risk for clot formation and pulmonary embolism.

6. Immediately after surgery, a clinician would educate this patient to avoid using the left upper extremity at the time period indicated by the surgical protocol. The patient would begin with passive range of motion and active assisted range of motion into glenohumeral flexion, abduction and external rotation generally for a couple weeks. The surgical protocol will specify timing, but the general progression is from passive to active assisted to active range of motion and activation to strengthening exercises. Activation exercises typically would begin around two weeks and progress to strengthening around four to six weeks after surgery. At this point, four to six weeks after surgery to allow for tissue healing, physical therapy for post surgical venous TOS will resemble that of neurogenic TOS.

Conclusion

Thoracic outlet syndrome refers to either neurogenic or vascular etiology and is a disruption in the nerve or vascular network from the neck to the hand. This occurs in the thoracic outlet, either the interscalene triangle, the costoclavicular space or the subcoracoid space. Thoracic outlet syndrome affects active people the most and occurs most often from the second to fifth decade of life. Common symptoms of TOS include upper extremity pain, paresthesia, swelling and positive provocative special tests including Adson's, Roos, and Wright's test. Ninety percent of TOS cases are neurogenic. Disputed neurogenic TOS has no deficit in electrodiagnostic studies and is mostly what physical therapy will treat. Vascular TOS represents around ten percent of cases and should be referred out for surgical intervention. Intervention strategies for neurogenic TOS includes a comprehensive plan of care. Parts of the plan of care are manual therapy such as joint mobilization, manipulation, and neurodynamic mobility, modalities for pain control, patient education on lifestyle modification and therapeutic exercise. Exercise should progress from activation, gentle stretching and range of motion to resistive exercise to strengthen muscle imbalances and support the mobility gained in manual therapy. Physical Therapists and Physical Therapist Assistants should gradually wean from manual therapy techniques in favor of education and exercise to encourage independence with the patient's ability to manage their own condition. Therapists should also know to refer out to a primary care physician if patients are not improving after around one month to six weeks for medical management. Thoracic outlet syndrome is a complex condition overall that mimics many other conditions in the cervical spine and upper extremity. Therefore, it is imperative that clinicians understand the condition, differential diagnoses and management strategies including rehabilitation and referral to best manage patients with TOS.

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