

# Plumbing and Wiring

## occupational thoracic outlet syndrome

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Resources for Occupational and Environmental Health

# Conflicts of Interest

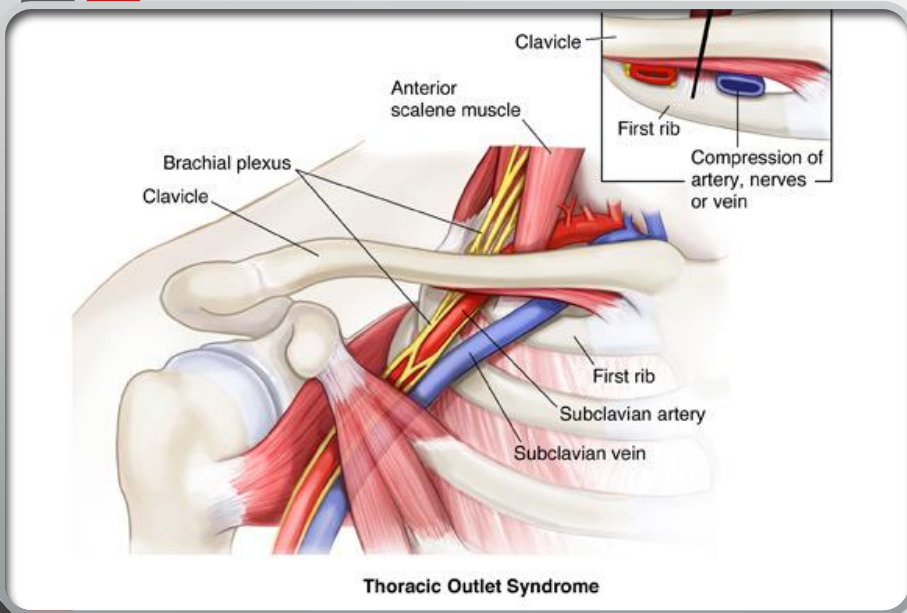
- I am a contractor for Montana State Fund and Montana Municipal Interlocal Authority performing telephonic evaluations and records reviews, respectively.

# Learning objectives

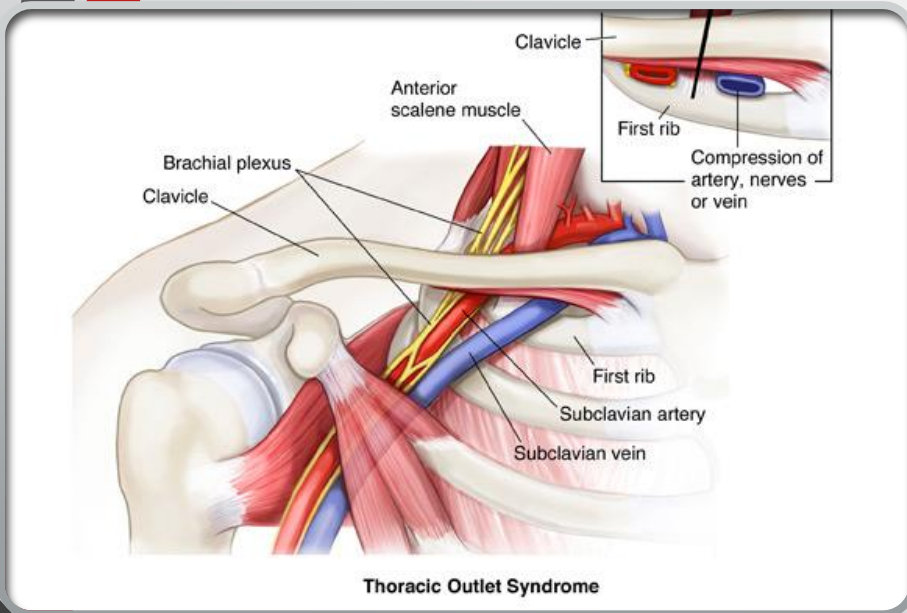
- Upon completion, the participant will understand the differences between three basic forms of thoracic outlet syndrome
- Upon completion, the participant will understand the basic anatomic causes of thoracic outlet syndrome
- Upon completion, the participant will understand how the three forms of thoracic outlet syndrome are diagnosed

# Background

- The symptoms attributed to thoracic outlet syndrome (TOS) were first described in 1818 by the English surgeon and anatomist Sir Astley Cooper [Ranney, 1996]
- In 1956, Peet et al. [1956], coined the term "thoracic outlet syndrome."



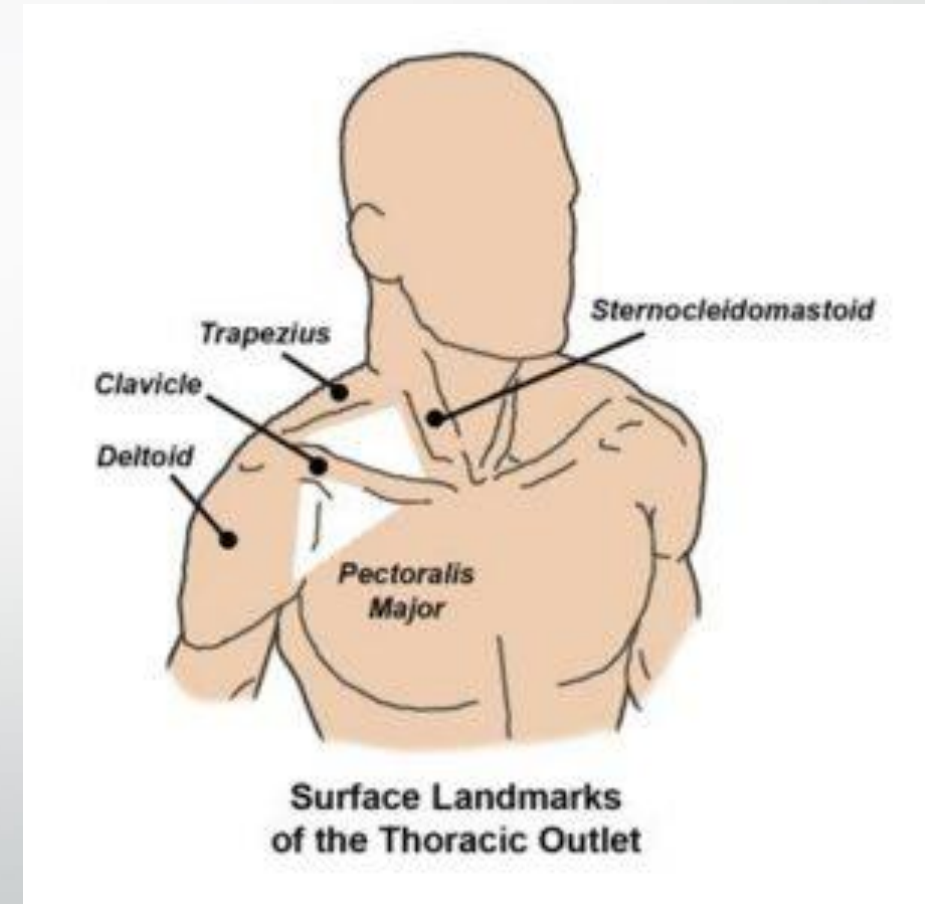
# Long history of TOS



- Cervical rib, one possible cause, was first observed by Galen in 2 AD [Roos, 1996]
- Thomas Murphy [1910] first removal of the first rib for thoracic outlet decompression
- Todd [1912] proposed a drooping shoulder might compress the subclavian vessels and brachial plexus
- Lord and Stone [1956] proposed the pectoralis minor tendon impinged brachial plexus

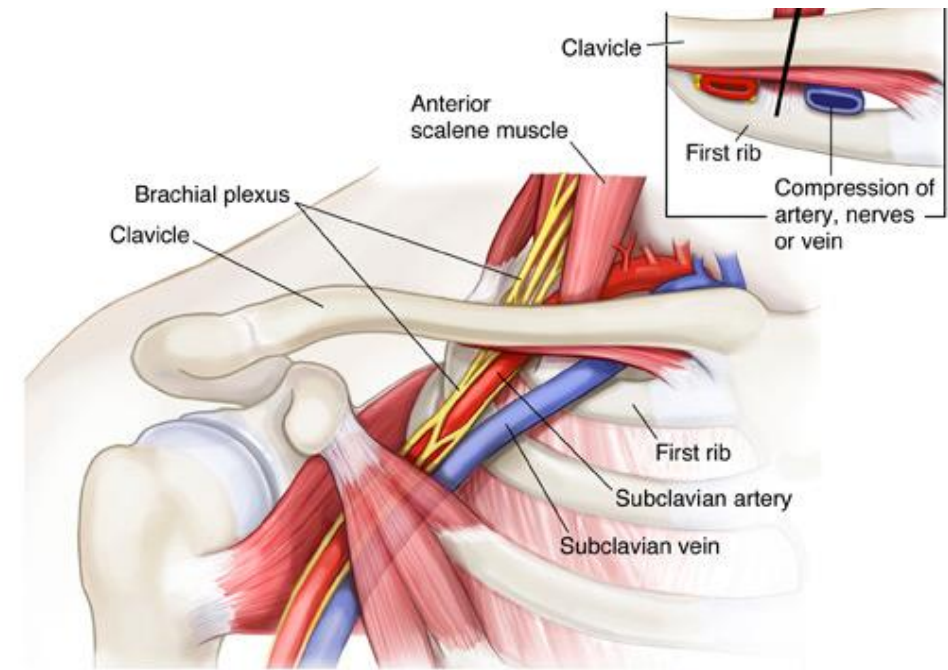
# The thoracic outlet

- Thoracic outlet is located next to the sternocleidomastoid muscle, and in front of the trapezius muscle.
- Thoracic outlet extends behind the clavicle, underneath the pectoralis muscles, and in front of the shoulder



# The thoracic outlet

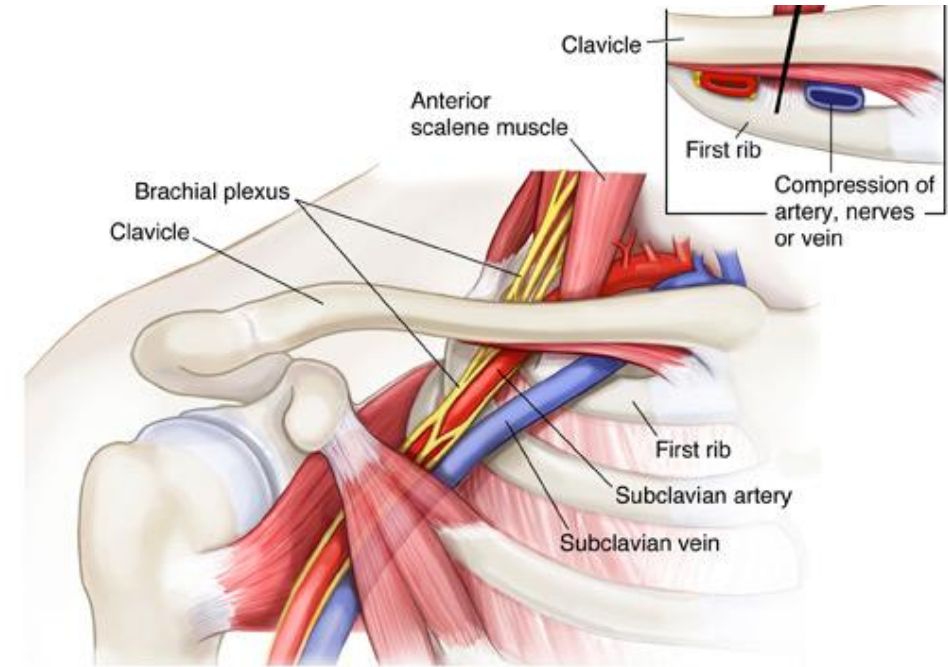
- The thoracic outlet is the space between the clavicle and the rib
- It contains the subclavian artery and vein, and the nerves of the brachial plexus



Thoracic Outlet Syndrome

# Thoracic outlet syndrome

- Thoracic outlet syndrome (TOS) is compression of the subclavian vessels and/or brachial plexus as they travel from the thoracic outlet to the axilla [Klaassen et al, 2014]



Thoracic Outlet Syndrome



# Three forms of thoracic outlet syndrome

- Neurogenic thoracic outlet syndrome (nTOS) 90-95% of cases
  - Disputed thoracic outlet syndrome (dTOS) >95% of nTOS
- Venous thoracic outlet syndrome (vTOS) ~3-5% of cases
- Arterial thoracic outlet syndrome (aTOS) ~1-2% of cases

Hu et al, 2021; Lulan et al, 2011

# Treatment of TOS

- While non-operative and operative approaches have been described in the literature, no firm evidence-basis exists for any approach in any of the three types of TOS [Povlsen et al, 2014]



# Wiring Case 1

# Wiring Case 1

- 35-year-old, right-hand dominant female medical floor nurse squatting in front of obese patient assisting with transfer; patient lost balance and reached out to grab the nurse's right shoulder

# Wiring Case 1 initial complaints

- Concerned about injuring her back, nurse moved away from patient and experienced immediate shoulder, arm, and neck pain
- Later developed right arm and hand numbness, tingling, and weakness

# Wiring Case 1 initial diagnostics

- Cervical spine MR scan was entirely normal

# Wiring Case 1 IME complaints

- Right paracervical and superior shoulder pain
- Dull, achy pain at the extensor and ulnar surface of the right forearm
- Prior weakness is “a lot better” but has hand fatigue at end of workweek
- Positional right upper extremity numbness and tingling when resting her arm on armrest, describes as “funny bone” pain
- “Slight” burning in the fingertips and palmar hand

# Wiring Case 1 IME objective findings

- Tenderness at right paracervical muscle, superior shoulder, and scapula
- Full painfree cervical region range of motion
- Normal strength in bilateral upper extremities
- Deep tendon reflexes symmetric at the biceps, triceps, and brachioradialis
- Spurling's and Hoffmann's tests negative
- Decreased light touch sensation over the right ventral forearm, dorsal and palmar right hand



# Wiring Case 1 IME objective findings

- The elbows and wrists are normal on inspection
- Normal two-point discrimination in all digits of both hands
- Hands are warm, pink and dry with normal capillary refill

# Wiring Case 1 IME objective findings

- No objective evidence of carpal tunnel syndrome or cubital tunnel syndrome

# Wiring Case 1 IME objective findings

- With upper limb tension testing (aka Elvey's test), the individual describes right wrist soreness and whole hand numbness and tingling
- The individual declines doing EAST (elevated arm stress test aka Roos' test) maneuver position for concern of right upper extremity symptoms

# Wiring Case 1 IME diagnostic

- Cervical electromyogram and bilateral upper extremity nerve conduction studies are normal

# Wiring Case 1 IME diagnosis

- Right brachial plexus traction injury

# Wiring Case 1 TOS classification

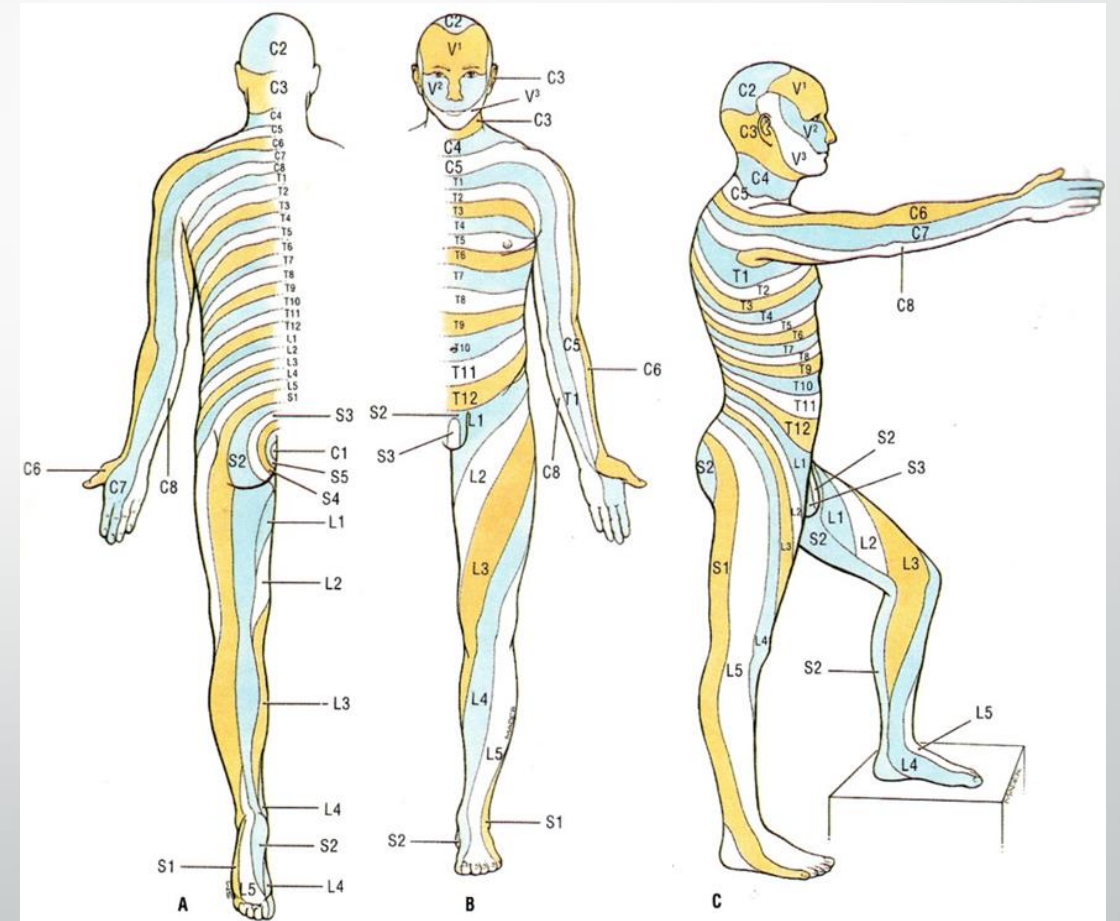
- Disputed thoracic outlet syndrome (dTOS)

# dTOS

- Disputed TOS is the most common form of TOS, accounting for 95% to 99% of neurogenic TOS (nTOS) [Cho et al, 2012; Nichols, 2009; Sanders et al, 2008]
- Disputed TOS most commonly affects the brachial plexus through either direct trauma or repetitive stress

# dTOS

- Signs and symptoms [Klaasen et al, 2014]
  - General neck and arm pain, often accompanied by shoulder pain
  - Arm and hand paresthesias usually in non-dermatomal pattern
  - No muscle atrophy or focal motor weakness



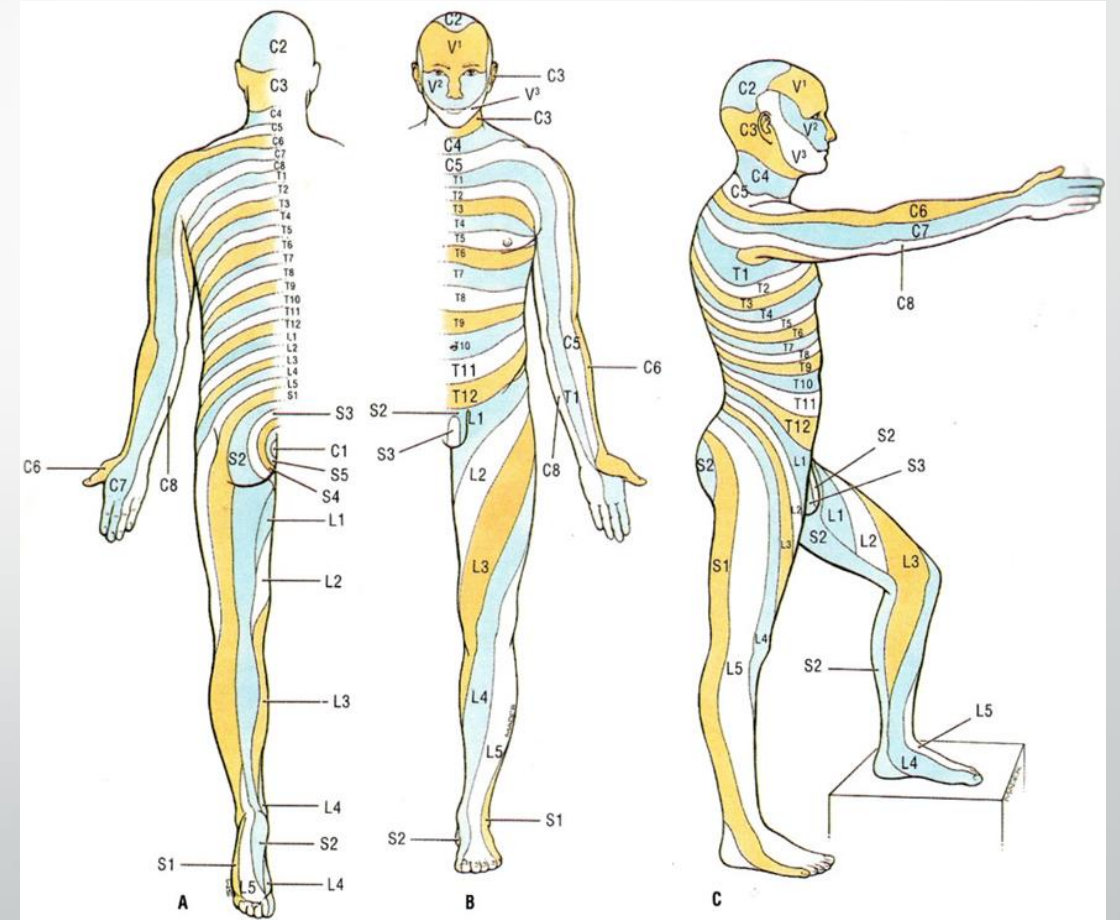


# dTOS

- Signs and symptoms [Stewman et al, 2014]
  - Upper plexus involvement: C5-C6
    - pain and paresthesias in head, neck, thorax, and shoulder
  - Lower plexus involvement: C8-T1
    - pain and paresthesias in neck, medial arm, forearm, and ring and small fingers

# dTOS

- Some argue dTOS is not true TOS because it causes only subjective symptoms and no objective findings
- dTOS differentiated from true nTOS based on lack of the classic nTOS objective findings such as:
  - Abductor pollicis brevis or 1<sup>st</sup> dorsal interosseous muscle atrophy
  - Electromyographic findings
  - Dermatomal paresthesia pattern [Klaasen et al, 2014]





# Plumbing Case 1

# Plumbing Case 1

- 56-year-old, right-hand dominant male running a remote-control crane injured when a 26-foot floor truss slid off an adjacent truck striking him
- Injuries include concussion with loss of consciousness, and cervical region and thoracic region contusions, and left shoulder contusion

# Plumbing Case 1 initial complaint

- Left shoulder pain and occasional inability to lift his left arm

# Plumbing Case 1 initial diagnostics

- Cervical spine CT scan revealed congenital fusion at C7-T1 and possible posterior element fusion at T2-3
- Left shoulder CT scan revealed mild acromioclavicular joint arthrosis
- Chest CT scan was normal

# Plumbing Case 1 subsequent diagnostics

- Cervical spine MR scan:
  - C3-4: mild posterior disc bulge, mild spondylosis, and moderate bilateral neural foraminal stenosis
  - C4-5: mild bilateral neural foraminal stenosis
  - C5-6: posterior disc bulge, mild central canal stenosis, moderate spondylosis, and moderate bilateral neural foraminal stenosis
  - C6-7: mild bilateral neural foraminal stenosis

# Plumbing Case 1 subsequent diagnostics

- Cervical electromyogram and bilateral upper extremity nerve conduction studies are normal
- Left shoulder MR arthrogram showed "minimal" acromioclavicular joint arthrosis



# Plumbing Case 1 IME complaints

## Right upper extremity

- Numbness and tingling in the dorsal right upper arm, right ulnar forearm, and right hand long, ring, and small fingers
- Symptoms only occur with shoulder elevation

## Left upper extremity

- Pain in the left posterior shoulder, dorsal left upper arm, and proximal dorsal left forearm
- Numbness and tingling in the dorsal left upper arm, the left ulnar forearm, and the left long and ring fingers
- Numbness and tingling occurs only with shoulder elevation
- Loss of hand grip strength

# Plumbing Case 1 IME objective findings

- Strength and sensation intact in bilateral upper extremities
- Deep tendon reflexes symmetric
- Hoffmann's and Spurling's tests negative bilaterally
- Left shoulder examination unremarkable with full rotator cuff strength
- Adson's test was positive on the left with complete obliteration of the radial pulse

# Into the weeds

- Adson's test
  - 79% sensitivity and 76% specificity
- Roos' test
  - 84% sensitivity and 30% specificity

Gillard et al, 2001

# Plumbing Case 1 IME diagnostics

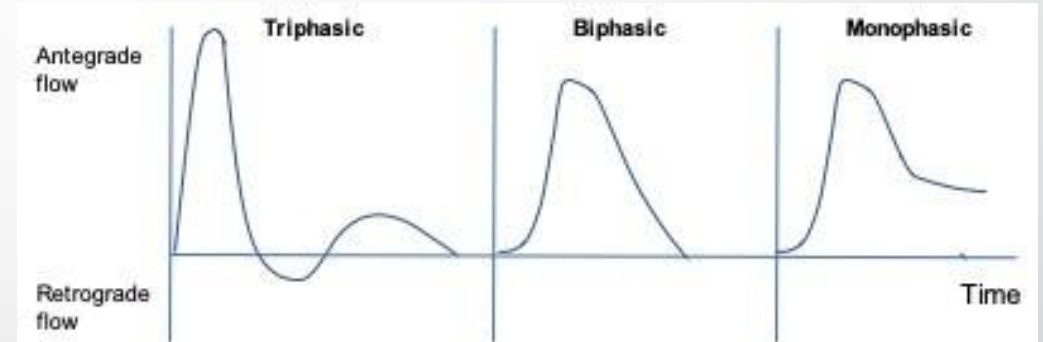
- Cervical spine radiographs with flexion and extension views show no instability
- Thoracic spine SPECT bone scan unremarkable
- Thoracic spine radiographs unremarkable

# Plumbing Case 1 IME diagnostics

- Bilateral upper extremity arterial Doppler ultrasound studies
  - Triphasic flow was noted in bilateral upper extremities with equivocal "suspected" triphasic flow in the right ulnar artery and left ulnar and radial arteries
  - Right radial artery maintained triphasic waveform with provocative maneuvers
  - Left radial artery waveform was not detected with abduction; however, ultrasound localization of the artery was challenging due to motion artifact
  - Left subclavian artery waveform became monophasic and turbulent with abduction and with Adson's maneuvers

# Arterial Doppler ultrasound flow interpretation

- Triphasic: having three phases, due to crossing the zero flow baseline twice in each cardiac cycle
- Biphasic: having two phases or variations having forward and reverse flow
- Monophasic: having one phase
- Triphasic arterial flow is considered normal in peripheral arteries; monophasic flow is abnormal



# Plumbing Case 1 IME diagnosis

- Arterial thoracic outlet syndrome (aTOS)

# aTOS

- Signs and symptoms [Aghayev et al, 2015]
  - Pain
  - Claudication
  - Pallor
  - Frigidity
- Potential severe complications
  - Digital ischemia
  - Cerebral vascular accident (i.e., stroke)

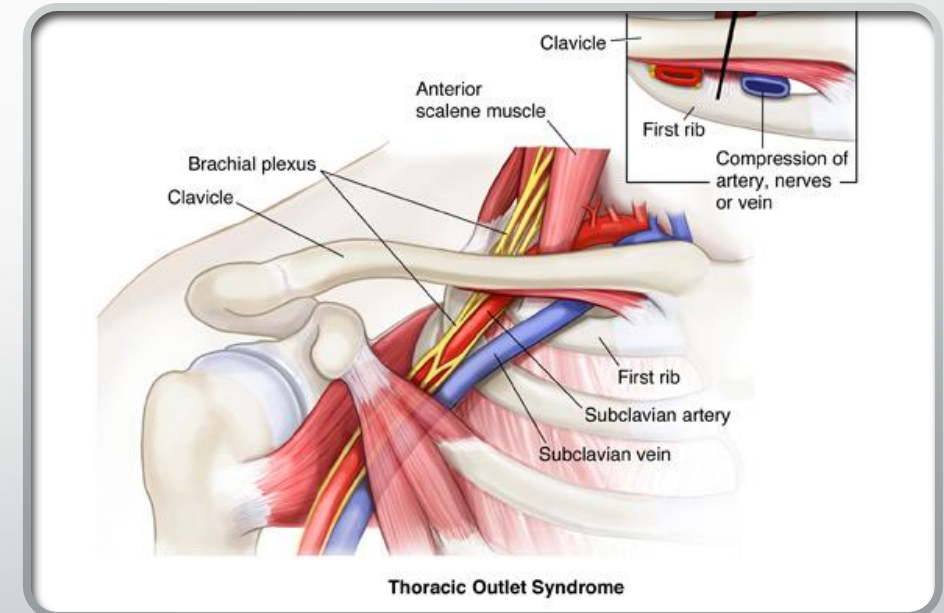


# aTOS

- The Society of Vascular Surgery (SVS) defines aTOS as an objective abnormality of the subclavian artery caused by extrinsic compression [Illig et al, 2016]
- aTOS may be asymptomatic, (e.g., aneurysmal disease) or symptomatic (e.g., objective ischemia during arm elevation)
- Typical chronic symptoms of upper limb ischemia in aTOS include pain in the arm or hand with extreme exertion or arms overhead

# aTOS

- Illig et al [2016] noted aTOS caused by severe positional obstruction or actual injury subclavian artery as it passes over the first rib
- aTOS not considered present unless proven symptomatic ischemia with compression or actual physical injury to the artery



# aTOS

- Injurious causes

- High velocity motor vehicle accident
- Hemorrhage or hematoma or displaced fracture
- Midshaft clavicular fracture
- Jones et al, [2019] observed late-onset fibrosis after the initial traumatic insult

- Non-injurious causes

- Cervical rib
- Pancoast tumors (aka superior pulmonary sulcus tumors)
- Obesity causing costoclavicular syndrome [De Silva, 1986]



# Plumbing Case 2

## Plumbing Case 2

- 26-year-old right-hand dominant female bartender assaulted by a customer
- Assailant grabbed her hair, pulled her neck into left lateral flexion, spun her around to her left, then punched her in the face
- Assailant then spun her around again and tried to hit her in the head with a pint glass but was restrained by onlookers; police were called

# Plumbing Case 2 initial complaints

- Bartender immediately felt right cervical region pain
- Later developed right anterior and posterior shoulder pain, and right arm and hand pain

# Plumbing Case 2 initial diagnostics

- Right shoulder radiographs revealed mild superior positioning of the distal clavicle suggestive of a mild acromioclavicular joint separation

# Plumbing Case 2 subsequent diagnostics

- Chest radiographs were unremarkable
- Right clavicle radiographs revealed "probable very mild elevation of the clavicle relative to the acromion suggesting sprain"



# Plumbing Case 2 subsequent diagnostics

- Cervical spine MR was completely unremarkable
- Right shoulder MR scan was completely unremarkable

# Plumbing Case 2 subsequent diagnostics

- Cervical electromyogram and right upper extremity nerve conduction studies revealed "very mild to minimal" right carpal tunnel syndrome

# Plumbing Case 2 IME complaints

- Complained of right upper chest wall, right medial upper arm and proximal medial forearm numbness
- Complained of right hand and right medial forearm tingling

# Plumbing Case 2 IME complaints

- Complained of intermittent right upper extremity frigidity and medial forearm swelling
- Right hand turns "a deep purple sometimes" during frigidity

# Plumbing Case 2 IME objective findings

- Mild tenderness throughout right shoulder
- No scapular winging
- Impingement tests negative
- Active right shoulder range of motion mildly limited

# Plumbing Case 2 IME objective findings

- Strength was 5/5 throughout bilateral upper extremities
- Deep tendon reflexes symmetric
- Spurling's and Hoffmann's tests negative
- Right forearm 1 cm larger than left forearm

# Plumbing Case 2 IME objective findings

- Elbow flexion test was equivocal on the right
- Tinel's test positive at right cubital tunnel
- Tinel's test was positive at the right carpal tunnel
- Phalen's test was positive on the right

# Plumbing Case 2 IME objective findings

- Allen's test was negative bilaterally
- Adson's test was positive on the right
- Roos' test (aka EAST) was equivocal on the right with a palmar sensation of "a little bit" of swelling as well as swelling in the forearm



# Plumbing Case 2 IME diagnostics

- Bilateral upper extremity arterial Doppler ultrasound studies
  - Reveal triphasic Doppler waveforms and volume pulse recording were unremarkable
  - With provocative maneuvers particularly with the arms at 180 degrees and in the military press position, triphasic waveforms became blunted
  - Both arms' waveforms equally affected but only symptomatic on right

# Plumbing Case 2 IME diagnostics

- Bilateral upper extremity venous Doppler ultrasound studies
  - The right subclavian vein was felt to be larger than the left with possible mild collateral flow present
  - There was no definite stenosis seen in the neutral position
  - With the arms in the military press position and with the arms at 180 degrees of abduction, there was evidence of extrinsic compression and occlusion of the right subclavian vein which resolved with the arm placed in a neutral position
  - There was no evidence of associated thrombus and no acute or chronic right upper extremity deep venous thrombosis present

# Plumbing Case 2 IME diagnosis

- Venous thoracic outlet syndrome (vTOS) with component of aTOS

# vTOS

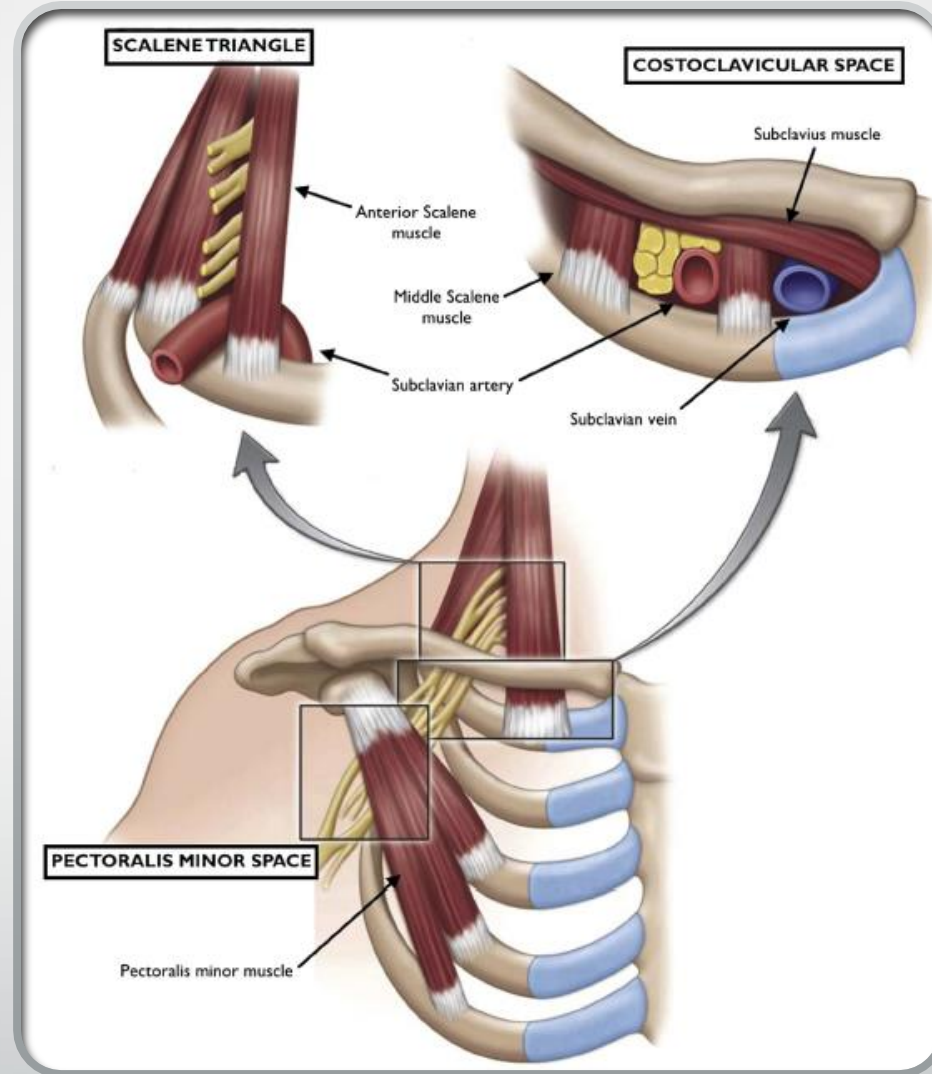
- Signs and symptoms [Aghayev et al, 2015]
  - Paresthesia
  - Hand swelling caused by edema
  - Feeling of tightness worsens with exertion
  - Venous engorgement with collateralization
- Potential severe complications
  - Venous gangrene of the hand
  - Pulmonary embolism (occurs in 10-20% of patients) [Jones et al, 2019]

# vTOS

- vTOS results from compression of the subclavian vein as it re-enters the chest more anteriorly, passing adjacent to the junction of the clavicle and first rib which is further reinforced by the subclavius muscle and tendon

## vTOS

- Potential sites of vascular occlusion [Aghayev et al, 2015]



# vTOS

- vTOS has four distinct presentations:
  - Acute thrombosis
  - Chronic stenosis (effort thrombosis)
  - Intermittent obstruction without thrombosis
  - Complete obstruction

# vTOS

- vTOS also tends to be
  - Unilateral
  - More common in men than women.
  - More common in younger (15-45 y.o.) and able-bodied
  - Most often affects the dominant upper extremity

Ferrante and Ferrante, 2017





# Wiring Case 2

## Our Changing Workplace

## Wiring Case 2

- 58-year-old male mental health worker tested on multiple occasions in late November and December of 2021 for the presence of SARS-CoV-2 viral RNA
- On 6 January 2022, SARS-CoV-2 viral RNA was detected in this individual's saliva specimen by reverse transcriptase polymerase chain reaction testing
- The individual's test result remained positive on 12 January and 18 January 2022

## Wiring Case 2

- He had no history of risk factors that would complicate COVID-19 (e.g., no hypertension, diabetes mellitus, asthma, chronic kidney disease, heart disease, immunocompromise, obesity, pregnancy, sickle cell disease, known autoimmune disorder, age over 65)
- Had no history off musculoskeletal conditions

## Wiring Case 2

- The individual reported he had no significant symptoms initially
- Returned to work two weeks after testing positive and developed numbness in his right-hand ring and small fingers and right arm
- One week later developed burning pain in right-hand ring and small fingers, right arm and right shoulder
- One week later, burning pain became excruciating; individual unable to work

# Wiring Case 2 initial treatment

- Primary care provider prescribed Medrol Dosepak and IM corticosteroid injection
- Burning pain disappeared in approximately 2½ months after initial COVID-19 diagnosis
- Right hand and arm numbness, hand and arm weakness, and right shoulder pain remained

# Wiring Case 2 teleIME complaints

- Right posterior shoulder pain and weakness
- Right medial upper arm pain
- Right hand weakness
- Right thenar muscle pain (during typing)
- Right hand ring and small fingers numbness

# Wiring Case 2 teleIME objective findings

- Right shoulder MR scan
  - Supraspinatus and infraspinatus partial-thickness tears and tendinosis
  - Superior labral tear
  - Mild acromioclavicular joint arthrosis
  - No evidence of supraspinatus or infraspinatus muscle belly atrophy or fatty infiltration; presence/absence of edema not reported by radiologist

# Wiring Case 2 teleIME diagnostics

- Cervical electromyogram and right upper extremity nerve conduction studies
  - Incomplete inferior trunk brachial plexus lesion
  - Typical lower plexus involvement: C8-T<sub>1</sub> pain and paresthesias in neck, medial arm, forearm, and ring and small fingers
- No electrophysiologic evidence of a right cervical radiculopathy or right upper extremity focal peripheral neuropathy



# Wiring Case 2 teleIME diagnosis

- Parsonage-Turner syndrome aka neurogenic amyotrophy aka true neurogenic TOS (nTOS)

# nTOS

- Multiple case reports of COVID related nTOS [Mitry et al, 2021; Alvarado et al, 2021; Zazzara et al, 2022]

# nTOS

- Mitry et al [2021] reported the case of a 17-year-old female patient with no significant past medical or surgical history who presented with several weeks of severe joint pain in the setting of a recent SARS-CoV2 infection
- MRI of the left shoulder showed uniform increased T2 signal of the supraspinatus, infraspinatus, teres minor, teres major, and trapezius muscles, consistent with Parsonage-Turner syndrome

# nTOS

- Alvarado et al [2021] reported the case of a 38-year-old male who developed Parsonage-Turner syndrome after severe bilateral pneumonia due to SARS-CoV-2 infection
- The individual had with right scapular winging and limited range of shoulder movement

# nTOS

- The individual had with right scapular winging and limited range of shoulder movement



# nTOS

- Right shoulder MR scan results
  - T1-weighted MRI sequence of the shoulder showed right infraspinatus and teres major muscles edema
  - Fatty infiltration in the belly of the infraspinatus muscle

# nTOS

- Electrodiagnostic studies revealed [Alvarado et al, 2021]
  - brachial plexopathy with predominant involvement of the segment proximal to the upper trunk and distal to the C5 nerve root
  - absence of sensory response in the lateral antebrachial cutaneous nerve
  - signs of acute motor axon loss in the trapezius, deltoid, and serratus anterior muscles

# nTOS

- Mitry et al [2021] hypothesized multisystem inflammatory syndrome in children (MIS-C) explained their 17-year-old patient's symptoms
- Alvarado et al [2021] hypothesized that SARS-CoV-2 infection triggered an immune-mediated reaction involving the brachial plexus



# nTOS

- Reports in the literature describe neurological symptoms and diseases in patients with SARS-CoV-2 infection including:
  - Ischemic cerebrovascular disease
  - Polyneuropathies
  - Necrotizing encephalomyelitis
  - [Wu et al, 2020; Shimabukuro-Vornhagen et al, 2018]

# Summary

- Three general types of thoracic outlet syndrome
  - ask which type provider has diagnosed and on what basis
- Remember disputed TOS is the most common form
  - Be prepared for no objective findings beyond non-dermatomal sensory loss
- COVID-19 is associated with nTOS and other plexopathies and neuropathies but in general, they get better



QUESTIONS?

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