New Perspectives on Neurogenic Thoracic Outlet Syndrome

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Questions

• Three forms of thoracic outlet syndrome exist and the neurogenic form (NTOS) is the most common?

• Histologic findings demonstrate the anterior or middle scalene muscles are the main causative factor for NTOS?

• Chemodenervation of the anterior scalene muscle with botulinum toxin can relieve symptoms of NTOS?

Epidemic

• Undiagnosed, untreated, undertreated pain significant public health problem
• Diminishes quality of life, financial well-being
• Increases disability, functional limitations, depression & anxiety
• Approximately 100 million living with chronic pain
• Economic costs between $560-625 billion annually
• Pain as a disease

Helme R, Gibson S. In Crombie IK (ed): Epidemiology of Pain (1999), 103-112
Institute of Medicine of The National Academies: Relieving Pain in America: A Blueprint for Transforming Prevention, Care, Education and Research to Congress (June 2011)
Central Sensitization

Dorsal horn of spinal cord: Neural injury leads to glutamate release from primary afferent fibers and this triggers intracellular events that lead to activation of gene transcription (Yaksh, TL)

Consequences of Persistent Pain

- Poorer self-rating of health status
- Greater use of healthcare resources
- More tobacco use, alcohol use, diet/weight concerns
- Decreased social and physical activities
- Lower social support
- Higher levels of emotional distress

Haskell et al, 2008; Kerns et al., 2003; Mantyselka et al., 2003
True Neurogenic Thoracic Outlet Syndrome

Figure. Atrophy of left thenar and hypothenar muscles.

Thoracic Outlet Syndrome

[Diagram showing anatomical structures including Scalene muscles, Subclavian artery, Median nerve, Clavicle, Ulnar nerve, etc.]
Thoracic Outlet Syndrome

Overview

- Compression of the brachial plexus or blood vessels (subclavian artery or vein)
  - 95-98% neurogenic source
- Inadequate passageway between base of the neck and the armpit (scalene hypertrophy, fibrosis, cervical rib)
  - Repetitive activities - assembly line, keyboard typing
  - Neck injuries from MVA - whiplash
  - Sports – swimmers, volleyball, baseball pitchers, weightlifters
- Numbness, tingling in fingers, pain in neck, shoulder or arm, muscle spasms around scapula, headaches, upper extremity weakness

Neurogenic Thoracic Outlet Syndrome

Overview

• Congenital predisposition and injury compromises outlet

• Narrowed space affects scalene muscles, brachial plexus, long thoracic and suprascapular nerves, and stellate ganglion

• Complex spectrum disorder provokes controversy

• If untreated, QOL as impaired as those with chronic heart failure


Neurogenic Thoracic Outlet Syndrome

Classification

• Three forms exist
  ✤ Neurogenic (brachial plexus compression)
  ✤ Arterial (subclavian artery compression)
  ✤ Venous (subclavian vein compression)

• True NTOS
  ✤ Subclassification with objective findings; 1% of cases

• Common NTOS; 99% of neurogenic cases
  ✤ Symptoms suggestive of brachial plexus compromise, but no objective findings

Neurogenic Thoracic Outlet Syndrome

**Etiology**

- A Space Problem
  - Congenital anomalies with superimposed traumatic injury, muscle spasm, fibrosis
  - Congenital – cervical rib and fibrous bands narrow space through which nerve roots of brachial plexus pass. Induce symptoms
- Hyperextension-Flexion Injuries, Whiplash, Repetitive Stress Injury
- Histologic studies show either ASM or middle scalene muscle injury main causative factor
  - Muscle fibrosis prime finding upon exam of excised scalene muscles
  - Scar tissue 3 X greater than controls

Neurogenic Thoracic Outlet Syndrome

**Etiology – Anterior Scalene Muscle**

- ASM derives from transverse processes of C3-C6 vertebrae
  - Attaches to first rib
  - Accessory muscle of respiration
  - Bends and rotates neck slightly

- Spasm puts traction on brachial plexus and causes muscle edema, neural edema and limits outlet

- Scar development and fibrosis worsen neural compromise and perpetuate pain

- Target ASM to relieve tension, spasm and interrupt events leading to NTOS

Atasoy E. Thoracic outlet syndrome: anatomy. Hand Clin 2004. 20(1); 7-14

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Neurogenic Thoracic Outlet Syndrome

**Clinical Presentation**

- 3-4 Xs more frequent in women than men

- Incidence – 3 to 80 cases per 1,000 people

- Violinists, data entry personnel, assembly line workers especially vulnerable

- Athletes with repetitive overhead arm motion (volleyball, swimming, baseball pitchers, weightlifters)

- History of neck trauma

Neurogenic Thoracic Outlet Syndrome

**Clinical Presentation**

- Classic: Pain from shoulder and radiates down inner aspect of arm
- Often: neck, trapezius, mastoid, anterior chest wall pain, or HAs from upper plexus compression (C5-C7)
- Exam shows:
  - Tender scalene muscles, trapezius, chest wall
  - Positive Tinel sign over brachial plexus in neck
  - Reduced sensation to light touch in fingers
  - Positive provocative maneuvers


Neurogenic Thoracic Outlet Syndrome

**Differential Diagnosis**

- Entire arm often involved without dermatomal preference
- Often nonspecific clinical presentation
- Confounds accurate diagnosis
- Distinguish between:
  - Cervical radiculopathy from disc herniation or stenosis
  - Carpal tunnel syndrome
Neurogenic Thoracic Outlet Syndrome

**Diagnosis**

- Thorough history and physical exam - key
- Ancillary testing lacks sensitivity and specificity
- Provocative testing (Adson maneuver) unknown reliability and specificity
- Provocative Maneuvers
  - Nerve Tension Tests
    - Thumb pressure over brachial plexus
    - EAST (Elevated Arm Stress Test) – maybe most reliable
  - Vascular Tests
    - Adson Test – many false positives
  - Other Tests
    - Spurling test – identify cervical disc disease


Neurogenic Thoracic Outlet Syndrome

**Diagnostic Testing**

- EMG/NCT
  - Often normal
  - Can exclude radiculopathy, carpal tunnel syndrome, cubital tunnel syndrome, polyneuropathy
- Chest X ray
  - Identify cervical rib
- MRI/CT
  - Rule out conditions that can mimic NTOS
- Medial Antebrachial Cutaneous Nerve Conduction Study (MAC)
  - Can detect milder cases of NTOS
  - Measures sensory function of lower trunk of brachial plexus
  - Can be abnormal in pts with normal EMG/NCT
  - Need more validation studies

Neurogenic Thoracic Outlet Syndrome

**Anterior Scalene Block**

- **Intramuscular Confirmatory Test**
- Paralyzes the muscle in spasm, allows first rib to descend, and decompresses thoracic outlet
- First described in 1939
- Positive response correlates well with good surgical outcomes
  - Temporary muscle relaxation helps predict benefit from decompression
  - EMG guided block provided relief in 94% of patients who underwent surgery
- Anatomic Landmarks, EMG, Ultrasound, CT Guidance
- CT minimizes Horner’s sign, dysphonia, brachial plexus block, dysphagia


CT Guided Scalene Injections

middle scalene muscle
overlying clavicle
subclavian artery
subclavian muscle
costoclavicular ligament
subclavian vein
brachial plexus
anterior scalene muscle

Figure 1: Axial view of the left side of the thoracic inlet. The injection is directed into the anterior scalene muscle, the middle/superior scalene muscle complex, the subclavius muscle, and the costoclavicular ligament. A needle is advanced into the anterior scalene muscle followed by contrast according to the type of contrast after injection. (Reused with permission.)
CT Guided Scalene Injections

Neurogenic Thoracic Outlet Syndrome

**Conservative Treatments**

- **Conservative**
  - Ergonomic Correction
  - Posture Correction
  - Nerve Glides
  - Stretching exercises
  - Biofeedback

- These focus on decompressing the brachial plexus, restoring muscle balance in the neck, providing neural mobility

- **Cognitive Behavioral Therapy**
  - Modify pain perception: reframe experience in positive terms
  - Modify self talk
  - Minimize catastrophizing

Neurogenic Thoracic Outlet Syndrome

**Physical Therapy**

- Some data support the use of heat packs, exercise program, cervical traction.
- Inpatient rehab followed by home exercise program high % satisfaction rate
- Sig pain decrease and treatment satisfaction with postural correction and shoulder girdle strengthening exercises over 14 months
- In general, some improve but others worsen without other interventions


Neurogenic Thoracic Outlet Syndrome

**Medications**

- Muscle Relaxants
  - Tizanidine
- NSAIDS
  - Ibuprofen
- Trigger Point Injections (with local anesthetic)
- Tricyclic Antidepressants (nortriptyline)
- Serotonin-norepinephrine reuptake inhibitors (duloxetine)
- Membrane Stabilizers (gabapentin)
- If quality of life deteriorates and trials of other therapies fail, consider sustained release opioids

Neurogenic Thoracic Outlet Syndrome

Minimally Invasive Approach – Botulinum Toxin

• Began using/expanding CT imaging to place needle for diagnostic blocks/anterior scalene muscle alone – novel
• Single, low dose injection into anterior scalene muscle with CT – novel
• Botulinum Toxin (Botox) reduces muscle overactivity and may decrease pain and inflammation
• Approved use for hemifacial spasm, blepharospasm, stabismus, chronic migraine, et al.
• Safety and clinical benefit has expanded off-label use for lumbosacral myofascial pain, piriformis syndrome, lateral epicondylitis

Aoki K. Review of proposed mechanism for the antinociceptive action of botulinum toxin type A. Neurotoxicology 2006; 26: 785-793
Neurogenic Thoracic Outlet Syndrome

**Botulinum Toxin**

- **Therapeutic effects**
  - Reduces muscle overactivity
    - Blocks the release of acetylcholine & weakens the muscle for periods up to 3-4 months
  - May decrease pain and inflammation
    - Inhibits release of neuropeptides (substance P, glutamate) involved with nociceptive transmission and central sensitization
  - May improve wound healing in injured muscles & reduce scarring
  - Benefits in muscles affected by radiation fibrosis syndrome
  - 1969 evidence suggests that botox effectively reduces painful muscular contractions from piriformis syndrome, cervical dystonia, foot dystonia, myofascial pain, and facial dystonia


Neurogenic Thoracic Outlet Syndrome

**Chemodenervation Anterior Scalene Muscle**

- Single, low dose injection (20 units botox) into anterior scalene muscle with CT – novel
- Prospective, longitudinal study
- 27 pts underwent 29 procedures under CT-guidance
- SF-MPQ prior to and at 1, 2, 3 months post Botox injection
- Substantial relief at months 1 and 2
- Significant relief at 3 months in sensory and VAS scores
  - 29% decrease in sensory and 15% decrease in VAS
  - Pain scores did not return to pre-intervention levels at 3 months

CT Guided Scalene Injections

Figure 1: Axial contrast CT image of the level prior to injection demonstrating the anterior scalene muscle, the middle-posterior scalene muscle complex. The location of the contrast material within the scalene muscle is marked, as is the location of the anterior scalene muscle for correlation with the cross-sectional view in the PET scan.
**Neurogenic Thoracic Outlet Syndrome**

**CT Imaging**

**Benefits**

- Visualize nearby structures
- Fast, accurate, reliable, safe
- CT fluoroscopy permits real time imaging
- Image not obscured by obesity and adjacent osseous structures
  - Can occur with ultrasound
- Higher percentage of anesthetic injections result in positive blocks
  - 82% under CT versus Ultrasound (38%), EMG + fluoroscopy (18%), EMG alone (72%)
  - Verified by high rate of improvement after surgery (70%) which helps confirm true cases of NTOS using CT blocks
- CT exposure time rarely exceeds 60 seconds


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**Neurogenic Thoracic Outlet Syndrome**

**Chemodenervation and Other Imaging Studies**

**Fluoroscopic and EMG guidance** (Jordan and Machleder 1998)

- 64% of pts experienced more than 50% relief at 1 month
  - ASM, MSM, Trapezius
- Mean duration of relief – 3 months

**Ultrasound + EMG** (Jordan, Ahn, et al 2007)

- 91% good outcome

**Fluoroscopy + EMG** (Jordan, Ahn, et al 2007)

- 81% good outcome

**Ultrasound** (Torriani, Gupta et al 2009)

- 69% pain relief after injection into ASM and pectoralis
- Mean duration of relief 31 days
## Overview of neurogenic thoracic outlet syndrome

**Etiology [10, 58-61]**

- Cervical trauma (hyperextension/whiplash injury, exercise-induced scalene muscle hypertrophy, sagging shoulders), cervical rib, hypertrophied anterior scalene muscle, repetitive work-related injury, anomalous first ribs, congenitally narrowed interhumeral triangle, fibrous bands.

**Clinical presentation [2, 4, 55]**

- Upper plexus (C5—C7) symptoms: ipsilateral neck or ear pain; pain in face, temple, mandible, and/or occipital areas with headaches; clavicular and pectoral pain that moves to trapezius and deltoid down lateral arm.
- Lower plexus (C8–T1) symptoms: anterior and posterior shoulder pain that radiates down medial arm forearm to hand and fourth and fifth fingers. Pain may occur in bilateral neck, mastoid, or occipital, causing headaches.
- General: aching, radiating down arm. Arm elevation (eg, brushing hair, working overhead, painting, housework) or carrying heavy objects exacerbates pain. Numbness, paresthesias, progressive weakness, fatigue, hand dysfunction. Symptoms may be worse at end of day; sleep disruption and cold weather worsen symptoms. Sympathetic disturbance rare: bluish-red discoloration of arm, blanching of hand.

**Diagnostic measures [4, 8*, 15, 21-24]**

- No definitive test. Careful history and physical examinations are critical (pressure over anterior scalene muscle and supraclavicular fossa may reproduce symptoms). SAEF is most reliable provocative maneuver. Electrodagnostically, radiographs, ad MRI useful for excluding other causes (carpal or cubital tunnel syndrome, cervical disc disease, cervical ribs, shoulder problems). Anterior scalene block may be an effective confirmatory test by relaxing muscle, letting first rib to descend, and decompressing brachial plexus.

**Minimally invasive therapies [6*, 17**, 27, 48, 49, 54, 62, 63]**

- Physical Modalities: physiotherapy, ergonomic correction, work limitations, postural correction.
- Medications: muscle relaxants, NSAIDS, TCAs, StHIs, membrane stabilizers, opioids.
- Intramuscular cervicothoracic botulinum toxin injections: Guided by CT, ultrasound, fluoroscopy, and/or EMG. Targeting various muscles: anterior scalene, middle scalene, trapezius, pectoralis minor, sphenius cervix, supraspinatus, rhomboid major, subclavius.

**Surgical interventions [3**, 33**, 56]**

- Procedure and approach: first rib resection, scalenectomy, or first rib resection and scalenectomy either by supravascular and/or transaxillary techniques.

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### Neurogenic Thoracic Outlet Syndrome

- **Minimally Invasive Therapy with Botox**
  - Pain reduction for 3 months
  - Avoids surgery, surgical complications, time off work
    - PT starts 2 wks after surgery for 8 weeks; 2-3 months off work; no lifting 10 lbs for 6 months
  - Value – non surgical candidates, bridge to surgery, trial before surgery

Neurogenic Thoracic Outlet Syndrome

Surgical Approach

- Different Approaches

- Comparative efficacy data lacking on approaches

- Reports of high success and low complication rates
  - 90% success rate

- Longitudinal Studies
  - 60% recurrence within first year after surgery, and 80% within 2nd year

- Persistent disability in 60% of pts 1 year after surgery
  - Complication rate higher than 30%

Neurogenic Thoracic Outlet Syndrome

**Conclusion**

- Most common type of TOS
- Often overlooked and misdiagnosed
- Persistent pain, impaired function, emotional distress
- If untreated, QOL as impaired as those with chronic heart failure
- Emerging evidence supports minimally invasive chemodenervation of cervicothoracic musculature with botulinum toxin
  - Before surgical decompression


**Questions**

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