**Ultrasound Imaging of the Brachial Plexus**

**Thoracic Outlet Syndrome and The Pectoral Bowing Ratio**

**ETIOLOGY OF TOS**

**Myofascial v. Ribs/Bands**

Between Anterior and Middle Scalenes

Under Pectoralis Minor (against Rib 1,2)

Costoclavicular (between Clavicle and 1st Rib)

Fibrous Bands-off rudimentary Rib/Transverse Process- Roots/Plexus “tethered”

Trauma- Episodic

Insidious- CTD, Postural

**ETIOLOGY OF TOS**

**Myofascial**

Pectoralis Minor (compressed or ‘tethered’)

Cooper’s ligaments - traction

Insidious- Postural

**Suspensory Ligaments**

Often referred to as Cooper’s Ligaments, these are the fibrous connections between the inner side of the breast skin and the pectoral muscles. Working in conjunction with the fatty tissues and the more fibrous lobular tissues, they are largely responsible for maintaining the shape and configuration of the breast. They bear a major portion of the task of preventing breast ptosis (sagging).
**PATHOLOGY / TYPES OF TOS**

**NEUROGENIC**
- True
- Disputed
- Nonspecific
- Postural?

**VASCULAR**
- Venous
- Arterial
- Mixed

**COMBINED**

**INCIDENCE OF NEUROGENIC TOS**

*One per Million*

*Only 250 Surgical Candidates in U.S.*

Cherington, et.al., Muscle Nerve, 1988

**INCIDENCE OF TOS**

*23% (2000 Patients) of Soft Tissue C-Spine Injuries*

*72% Diagnosed Incorrectly*

98% “missed” during initial ED eval

Woods, Modern Medicine, 1978
THE BRACHIAL PLEXUS

DIFFERENTIAL DIAGNOSIS
RADICULOPATHY
PLEXOPATHY (TOS)

Multiple Other Sites of Compression
Consider:
Peripheral Neuropathy
CNS pathology
Vascular pathology
Tendonitis
DJD/OA
Rheumatoid Disease
Ganglion, Tumor
Infection

DIFFERENTIAL DIAGNOSIS OF TOS

1. Carpal Tunnel Syndrome
2. Ulnar Neuropathy-(Cubital Tunnel, Guyon’s Canal)
3. Cervical Radiculopathy
4. Cervical Myelopathy
5. Pancoast Tumor
**DIAGNOSTIC STRESS TESTS FOR TOS**

**SCALENE**
- Focal
- Regional

**PECTORALIS**
- Focal
- Regional

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**DIAGNOSIS OF TOS – STRESS TESTS**

Abnormal Results in Healthy Subjects

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Altered Pulse</th>
<th>Pain</th>
<th>Paresthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adson's</td>
<td>11%</td>
<td>0%</td>
<td>11%</td>
</tr>
<tr>
<td>CostoClavic</td>
<td>11%</td>
<td>0%</td>
<td>15%</td>
</tr>
<tr>
<td>EAST</td>
<td>62%</td>
<td>21%</td>
<td>36%</td>
</tr>
<tr>
<td>Supraclav Press</td>
<td>21%</td>
<td>2%</td>
<td>15%</td>
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</tbody>
</table>

Plewa and Delinger, Acad Emerg Med, 1998

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**DIAGNOSTIC TESTS FOR TOS**

1. X-RAY
2. CT / MRI
3. Doppler / PPG
4. Angiography / Venography
5. EDX- EMG / NCS
6. Autonomic Assessment
7. Ultrasound
**DIAGNOSTIC TESTS FOR TOS**

<table>
<thead>
<tr>
<th>Anatomic v. Physiologic</th>
<th>Vascular v. Neurologic</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Ray</td>
<td>Autonomic Assessment</td>
</tr>
<tr>
<td>MRI Scan</td>
<td>MRI Scan</td>
</tr>
<tr>
<td>Doppler/Photo-plethysmography</td>
<td>Doppler/Photo-plethysmography</td>
</tr>
<tr>
<td>CT Scan</td>
<td>EDX</td>
</tr>
<tr>
<td>Angiography/Venography</td>
<td>MRI Scan</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>Ultrasound</td>
</tr>
</tbody>
</table>

**ELECTRODIAGNOSIS OF TOS**

- Low amplitude ulnar sensory response
- Normal median sensory amplitude
- **4. Neurogenic MUP C8-T1**
- Abnormal MAC-low amplitude
- Prolonged F-wave/Axillary F-Loop
- Abnormal C8 Root Stim (amp / latency)
- Abnormal Ulnar SEP: N9, N9 -13

**Wilbourn Tetrad of EDX Abnormalities* with TOS**

1. Low amplitude median CMAP < 50% contralateral
2. Low amplitude ulnar SAP < 50% contralateral
3. Normal median SAP
4. Neurogenic MUP C8-T1
5. Relatively low or normal ulnar CMAP

*In order of prevalence
Why Normal EDX in TOS???

"...in moderate compression...normal fascicles adjacent to abnormal fascicles...suggests the basis for the frequent paradox of the patient...with marked symptomatology but normal electrodiagnostic findings.

The abnormal findings in the 'worst' fascicles account for the patient's symptoms, whereas the normal large myelinated fibers in the 'better' fascicles account for the normal electrodiagnostic studies."

Mackinnon, Hand Clinics, 1992

Ultrasound Imaging of the Brachial Plexus

TOS Case #1

48 y/o female with left UE pain, numbness/tingling and weakness, for the past 2 months. Paresthesias involve the entire hand, especially medial, and medial forearm, worse at night and with driving or keyboard activity, especially with arms overhead. Treatment with wrist and elbow braces did not provide relief.

PE: Normal, except for positive Phalen and Tinel testing over the carpal and cubital tunnels. Posture revealed anterior head/shoulder position, and thoracic outlet stress was positive with abduction and focal pectoral stress.

EDX:

- Median DML 3.4ms / 13mV [Ulnar 2.6 / 17mV; no slowing across elbow]
- Median DSL D-1 2.8ms / 32mcv [Radial 2.5 / 15mcv]
- Median DSL D-2 3.4ms / 38mcv [Ulnar 3.1ms / 39mcv]
- Median F-wave 26.0ms
- Ulnar F-wave 26.2ms
**TOS Ultrasound**

Medial cord plexus irritation During arm abduction

Pectoralis minor

**DIAGNOSTIC ULTRASOUND OF TOS – Abduction Stress - Normal Subject**

Neutral – arm adducted at side
No symptoms
Note linear orientation of pec minor

Abduction stress – 140 degrees
No symptoms
Note persistent linear orientation of pec (no indentation)
Note position of plexus to pec minor
(no compression; good clearance)

**DIAGNOSTIC ULTRASOUND OF TOS – Abduction Stress Test**

Neutral:
Arm adducted at side
No symptoms
Linear orientation of pec minor

Abduction stress:
Progressive, up to 125 degrees
Symptoms exacerbated
Note indentation of pec minor by neurovasc bundle from below (dorsal)

**EDX:**
Median DML 2.8ms / 16mV
Median DDL D-2 3.2ms / 40mV
(Ulnar 2.3 / 15mV; no slowing across elbow)
(Ulnar D5 = 3.6ms / 52mV)
**TOS Case #2**

52 y/o female with right UE pain, numbness and tingling, for the past month. Most paresthesias involve the medial forearm and hand, worse with the hand raised overhead (i.e., grooming).

**PE:** Posture exam revealed anterior shoulder protraction (R>L), and positive thoracic outlet stress testing (with abduction and focal pectoral pressure).

**EDX:**
- Median DML: 3.3ms / 10mV [Ulnar 3.1 / 12mV; no slowing across elbow]
- Median DSL D-1: 2.6ms / 55mcv [Radial 2.8 / 16mcv]
- Median Antebrachial Cutaneous amplitude = 8mcv R; 18mcv L
- Median F-wave: 28.2ms [L side = 27.2]
- Ulnar F-wave: 27.4ms [L side = 26.4]

**DIAGNOSTIC ULTRASOUND OF TOS – Abduction Stress Test (case #2)**

**Neutral:**
- Arm partially abducted
- No symptoms
- Linear orientation of pec minor

**Abduction stress:**
- Progressive, up to 130 degrees
- Symptoms exacerbated
- Note indentation of pec minor by neurovasc bundle from below (dorsal)
- Medial cord ‘tucked’ against underside of pec minor; lateral cord is clear

**Pectoral Bowing Ratio - Normal**

- Normal Subject

  - A-B = 28mm
  - C-D = 1mm
  - C-D/A-B = .036 = 3.6% Pectoral Bowing Ratio
**Pectoral Bowing Ratio - TOS**

A-B = 21mm
C-D = 5.5mm
C-D/A-B = .262 = 26.2% Pectoral Bowing Ratio

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**TOS Case #3**

41 y/o female with right UE pain, numbness/tingling and weakness, for the past year. Paresthesias involve the entire hand (all digits), worse at night or with activity (drawing, painting).

**PE:** Posture exam revealed moderate anterior head protrusion and shoulder protraction (R>L), and positive thoracic outlet stress testing (with hyperabduction).

**EDX:**
- Median DML 2.9ms / 19mV [Ulnar 2.9 / 21mV; no slowing across elbow]
- Median DSL D-1 2.7ms / 39mcv [Radial 2.7 / 13mcv]
- Median Mixed Nerve latency = 2.0ms [Ulnar = 1.9ms]

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**DIAGNOSTIC ULTRASOUND OF TOS – Abduction Stress Test (case #3)**

Neutral:
- Arm slightly abducted
- No symptoms

Abduction Stress:
- Progressive, up to 120 degrees; Symptoms exacerbated
- Note indentation of pec minor; Medial and lateral cords 'tucked' against underside of pec minor

Left side:
- Asymptomatic
39 y/o female with 3mo hx R-UE pain, numbness/tingling, weakness primarily lateral arm and first 2-3 digits, worse with keyboard use

PE unremarkable: neg Spurling, Tinel, Phalen tests; but posture revealed anterior/protracted right shoulder, and positive TOS stress with hyperabduction and focal pectoral pressure.

EDX:
Median DML = 2.8ms / 14mV  [ulnar 2.6ms/15mV]
Median DSL = 2.6ms / 44mcv [radial 2.4ms/15mcv]
Median F-wave = 25.6ms  [ulnar 26.0ms]

28 y/o female with several mo hx R-UE pain, tingling and weakness; all digits, diffuse upper limb symptoms worse with typing, driving and arms elevated

PE unremarkable: neg Spurling, Tinel, Phalen tests; but posture anterior head protrusion and shoulder protraction, and positive TOS stress with hyperabduction.

EDX normal:
Median DML = 2.8ms / 14mV  [ulnar 2.6ms/15mV] Median DSL = 2.3ms / 64mcv [radial 2.2ms/25mcv]
Median F-wave = 24.2ms  [ulnar 23.4ms]

A-A = 15mm    B-B = 3.5mm
B-B/A-A = .233  = 23.3% Pectoral Bowing Ratio
**DIAGNOSTIC ULTRASOUND OF TOS – Abduction Stress Test**

**Neutral:**
- Arm adducted at side
- No symptoms
- Linear orientation of pec minor

**Abduction stress:**
- Progressive, up to 125 degrees
- Symptoms exacerbated
- Note indentation of pec minor by neurovasc bundle from below (dorsal) [lateral cord; medial cord on video]

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**Prior Case:**

53 y/o female with 5mo hx R-UE numbness and tingling, primarily in the first 3-4 digits (and forearm), worse at night and with keyboard use

PE: neg Spurling test, pos Tinel and Phalen tests; posture revealed anterior/protracted right shoulder, and positive TOS stress w/ hyperabduct.

**EDX:**
- Median DML = 4.0ms / 11mV [ulnar 2.8ms/16mV]
- Median D1 DSL = 2.9ms / 29mcv [radial 2.6ms/13mcv] Dif = .3ms
- Median D4 DSL = 3.5ms / 17mcv [ulnar 3.1ms/21mcv] Dif = .4ms
- Median Mixed latency = 2.2ms [ulnar 1.9ms] Dif = .3ms
- CSI mildly elevated = 1.0ms

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**44 y/o female with 6 month hx diffuse R-UE pain, tingling and weakness, worse at night.**

PE: unremarkable: neg Spurling, Tinel, Phalen tests; but posture revealed moderate right shoulder protraction, and positive TOS stress w/hyperabduct.

**EDX:**
- Median DML = 3.3ms / 10mV [ulnar 3.3ms/16mV]
- Median D1 DSL = 2.9ms / 29mcv [radial 2.6ms/13mcv]
- Median F-wave = 27.5ms [ulnar 27.2ms]
DIAGNOSTIC ULTRASOUND OF TOS -

Abduction Stress Test

Neutral:
Arm adducted at side
No symptoms
Linear orientation of pec minor

Abduction Stress:
Progressive, up to 135 degrees
Symptoms exacerbated
Note indentation of pec minor by Neurovasc bundle from below (dorsal)
[lateral cord + medial cord]

30 y/o male with 1yr hx diffuse R-UE tingling, worse with activity
PE unremarkable: neg Spurling, Tinel, Phalen tests; but posture revealed moderate anterior head protrusion
and right shoulder protraction, and positive TOS stress with hyperabduction

EDX:
Median DML = 3.6ms / 14mV  [ulnar 3.0ms/17mV]
Median DSL = 2.7ms / 41mcv [radial 2.7ms/10mcv]  
Median F-wave = 27.3ms  [ulnar 27.0ms]

THE ELECTRODIAGNOSTIC REPORT

Report the abnormality (Interpretation):
Most often: "No abnormalities noted".....or:
"....prolongation of the F-wave latencies on the left, consistent with proximal
slowing (at the plexus level) due to focal demyelination....low amplitude of
the left medial antebraebral cutaneous nerve response, consistent with
partial axon loss...."

Diagnostic ultrasound imaging (high resolution, 4-15MHz linear transducer) of the left shoulder
(infraclavicular region) reveals normal appearance of the neurovascular bundle and pectoralis
minor muscle (transverse imaging). However, during progressive arm abduction, the medial and
lateral cords of the brachial plexus (and axillary artery) contact and indent the posterior edge of
the pectoralis minor, as upper limb symptoms develop and increase. The pectoral bowing ratio
is abnormally elevated at 120 degrees of abduction to 16.2% (normal <10%).

Summarize with ‘Impressions’ or ‘Conclusions’:
1. No electrical evidence of radiculopathy, plexopathy, nerve injury...
2. Left thoracic outlet syndrome (brachial plexopathy) - postural type;
   electrically negative (or....‘very mild, electrically’)

MANIPULATIVE TREATMENT of TOS

PECTORALIS MINOR
MANIPULATIVE TREATMENT of TOS

SCALENUS ANTERIOR & MEDIUS

Post-manipulation abduction stress: No symptoms, PBR = 0

Pre-manipulation abduction stress: Symptoms, PBR = 13.6%

32 y/o female, 18mo history of left UE pain, numbness, weakness. Numbness into all digits, especially digits 3-5 and medial forearm, worse with arm elevated. EDX completely normal. Position: protracted shoulder, positive hyperabduction stress test.

Ultrasound-Guided Manipulation of TOS

Local Twitch Response
Ultrasound-Guided Manipulation of TOS

48 y/o female, several year hx of Right upper limb pain, numbness, and weakness.
Symptoms into the lateral 3 digits, worse with arm elevated. EDX completely normal.
Posture - protracted shoulder. Positive hyperabduction stress test and focal pectoral pressure.

Notice change in lateral cord shape
(from oval to ellipsoid)

Ultrasound-Guided Manipulation of TOS

42 y/o female, 3 mo hx of left UE pain, numbness, tingling, weakness. Numbness into all digits, and the forearm. EDX completely normal.
Posture - protracted left shoulder. Positive hyperabduction and focal pectoral stress test.

Ultrasound of the Brachial Plexus - Supraclavicular
REFERENCES


References (cont)