Thoracic Outlet Syndrome:
An Opportunity for Surgical Innovation

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Baylor College of Medicine
**Background** neurogenic TOS (~95% of all TOS)

- **Etiology** is most often hyper-extension neck injury (whiplash; fall) > repetitive work injury

- **Symptoms**: pain, paresthesia, arm/hand weakness

- **Exam**: nTOS vs nPMS (pec minor syndrome)
  - **Tenderness**: scalene vs pec minor
  - **Tinel sign**: scalene vs pec minor
  - **Provacative maneuvers**: scalene vs. pec minor
  - **Reduced sensation** to light touch in fingers

- **Diagnostics**: to exclude non-TOS diagnoses
  - cSpine MRI, cSpine Xray, EMG, Muscle blocks

- **Treatment**: PT or Surgical
INNOVATION in Thoracic Outlet Syndrome

1. Absence of data
   - Non-specific symptoms; poorly understood pathophysiology
   - A “disputed diagnosis”: absence of well-defined diagnostic criteria
   - Rare objective findings\(^1\) (Hand atrophy or EMG findings in ~1%; Cervical rib in 5-9%)

2. Risk
   - Injury precedes nTOS in ~50% of cases, and patients may be concurrently seeking legal or economic redress for such injuries\(^2\)
   - Complex psychological problems including somatiform disorders\(^3\)

3. Fractionated care
   - Thoracic, Vascular, Orthopedic, Plastic, Neurological Surgeons
   - 8 operations/approaches

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1. Sanders. The Neurologist 2008; 14: 365
1. **CONTRIBUTION**
   - Advancement of the field
   - Data-driven criteria for diagnosis and patient selection

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**INNOVATION in Thoracic Outlet Syndrome**

1. **CONTRIBUTION**
   - Advancement of the field
   - Data-driven criteria for diagnosis and patient selection

2. **PROGRAM DEVELOPMENT**
   - Clinical Need & Opportunity
   - Multidisciplinary Team Building
   - Mitigation of Legal Risk

3. **SURGICAL INNOVATION**
   - Transthoracic First Rib Resection
   - Mitigation of Surgical Risk
INNOVATION in TOS: CONTRIBUTION

REFINING DIAGNOSIS

Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome

Karl A. Illig, MD, a Dean Donahue, MD, b Audra Duncan, MD, c Julie Freischlag, MD, d Hugh Gelabert, MD, e Kaj Johansen, MD, f Sheldon Jordan, MD, g Richard Sanders, MD, h and Robert Thompson, MD, i Tampa, Fla; Boston, Mass; London, Ontario, Canada; Sacramento and Los Angeles, Calif; Seattle, Wash; Aurora, Colo; and St. Louis, Mo

*34 page document with 13 references

(J Vasc Surg 2016;64:e23-e35.)
DIAGNOSIS is defined by the presence of 3 of the 4 criteria:

1. LOCAL FINDINGS: History of pain in the scalene triangle or pec minor insertion, or tenderness on exam

2. PERIPHERAL FINDINGS: numbness, pain, paresthesias, vasomotor symptoms, history of arm weakness that can often be provoked on exam by palpation/maneuvers

3. Absence of other reasonably likely diagnoses

4. Response to muscle block

*The terms true, disputed, and non-specific TOS should not be used*
Validation of a diagnostic standard by correlation with clinical outcome
REFINING PATIENT SELECTION for IMPROVED OUTCOMES

Outcomes

<table>
<thead>
<tr>
<th>Author</th>
<th>Yr</th>
<th>Patients</th>
<th>Good (%)</th>
<th>Fair</th>
<th>Failure (%)</th>
<th>Follow-up (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roos</td>
<td>1982</td>
<td>1315</td>
<td>92</td>
<td>—</td>
<td>8</td>
<td>3–180</td>
</tr>
<tr>
<td>Selke</td>
<td>1988</td>
<td>460</td>
<td>79</td>
<td>14</td>
<td>7</td>
<td>6–240</td>
</tr>
<tr>
<td>Sanders</td>
<td>1989</td>
<td>111</td>
<td>69</td>
<td>—</td>
<td>31</td>
<td>60 Life table</td>
</tr>
<tr>
<td>Green</td>
<td>1991</td>
<td>147</td>
<td>79</td>
<td>—</td>
<td>21</td>
<td>12–144</td>
</tr>
<tr>
<td>Ellison</td>
<td>1994</td>
<td>181</td>
<td>79</td>
<td>13</td>
<td>8</td>
<td>Aug-65</td>
</tr>
<tr>
<td>Mingoli</td>
<td>1995</td>
<td>118</td>
<td>80</td>
<td>14</td>
<td>6</td>
<td>99 average</td>
</tr>
<tr>
<td>Jamieson</td>
<td>1996</td>
<td>228</td>
<td>53</td>
<td>25</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Zatocil</td>
<td>1997</td>
<td>112</td>
<td>45</td>
<td>—</td>
<td>55</td>
<td>Not stated</td>
</tr>
<tr>
<td>Allobelli</td>
<td>2005</td>
<td>254</td>
<td>46</td>
<td>—</td>
<td>54</td>
<td>36 Life table</td>
</tr>
<tr>
<td>Total/range</td>
<td>—</td>
<td>2926</td>
<td>(45–92)</td>
<td>—</td>
<td>(6–55)</td>
<td>—</td>
</tr>
</tbody>
</table>
**Outcomes: MLB as a model for improved metrics**

**Performance Metrics in Professional Baseball Pitchers before and after Surgical Treatment for Neurogenic Thoracic Outlet Syndrome**

Robert W. Thompson,1 Corey Dawkins,2 Chandu Venuri,1 Michael W. Mulholland,3 Tyler D. Hadzinsky,4 and Gregory J. Pearl,3 St. Louis, Missouri, Waltham, Massachusetts, Ann Arbor, Michigan, and Dallas, Texas

- 13 MLB Pitchers w nTOS: rib resection +10.8 mo PT
- 10 (77%) returned to MLB
- Capabilities equivalent or better than before treatment
- Standard MLB pitching statistics
- PitchF/x: velocity, movement, spin rate, spin direction

Ann Vasc Surg 2017; 39: 216
Define preoperative variables associated with favorable surgical outcomes

- **Presentation variables**: time since diagnosis
- **Exam Findings**: tenderness, maneuvers
- **Response to muscle block**
- **Radiographic findings**: US, plexus MRI
INNOVATION in TOS: CONTRIBUTION

REFINING PATIENT SELECTION for IMPROVED OUTCOMES

Prospective data collection in all patients undergoing surgery

Disability Questionnaires
• Cervical Brachial Symptom Questionnaire (CBSQ)
• Disabilities of the Arm, Shoulder, and Hand (DASH)
• SVS TOS Visit Questionnaires
Background: Litigation

The crisis of excellence

Thomas B. Ferguson, M.D., St. Louis, Mo.
Background: Litigation

**Table II. NAIC study, 1975-1978: Thoracic surgery—Transaxillary first rib resection**

<table>
<thead>
<tr>
<th>Total claims closed</th>
<th>71,782</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidents involving thoracic surgery</td>
<td>146</td>
</tr>
<tr>
<td>Percent of total claims</td>
<td>0.2%</td>
</tr>
<tr>
<td>First rib resection</td>
<td>31</td>
</tr>
<tr>
<td>Percent of those involving thoracic surgery</td>
<td>21%</td>
</tr>
<tr>
<td>Average indemnity per claim</td>
<td>$45,542</td>
</tr>
<tr>
<td>Total indemnity</td>
<td>$1,411,806</td>
</tr>
</tbody>
</table>

**Complications**

**Table III. NAIC study, 1975-1978: Transaxillary first rib resection—Injuries on which claims were based**

<table>
<thead>
<tr>
<th>Injuries</th>
<th>No. of claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve injuries</td>
<td>9</td>
</tr>
<tr>
<td>Musculoskeletal injuries</td>
<td>4</td>
</tr>
<tr>
<td>Musculoskeletal deformity of chest</td>
<td>4</td>
</tr>
<tr>
<td>Fracture of clavicle</td>
<td>2</td>
</tr>
<tr>
<td>Artery injury</td>
<td>2</td>
</tr>
<tr>
<td>Spontaneous pneumothorax and emphyema</td>
<td>2</td>
</tr>
<tr>
<td>Injury to lung with pneumothorax</td>
<td>2</td>
</tr>
<tr>
<td>Pain of limb and chest</td>
<td>2</td>
</tr>
<tr>
<td>Injury to other intrathoracic organs</td>
<td>1</td>
</tr>
<tr>
<td>Muscle weakness</td>
<td>1</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>1</td>
</tr>
<tr>
<td>Anesthetic injury with cardiac arrest and brain damage</td>
<td>1</td>
</tr>
</tbody>
</table>
### Complications: no one has them.

<table>
<thead>
<tr>
<th>n</th>
<th>Approach</th>
<th>PTX</th>
<th>Chest tube</th>
<th>Phrenic nerve Injury</th>
<th>Brachial Plexus Injury</th>
<th>Vascular Injury</th>
<th>Hematoma</th>
<th>Wound infection</th>
<th>Removal 2nd rib</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axelrod 2001</td>
<td>Supraclav</td>
<td>0%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Chang 2007 (NISP)</td>
<td>?</td>
<td>1.1%</td>
<td>-</td>
<td>-</td>
<td>0.6%</td>
<td>1.7%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Orlando 2015</td>
<td>Transax</td>
<td>23%</td>
<td>-</td>
<td>0%</td>
<td>0%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>1.3%</td>
<td>0%</td>
</tr>
<tr>
<td>Jamieson 1996</td>
<td>Transax</td>
<td>-</td>
<td>&lt;1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Hempel 1996</td>
<td>Supraclav</td>
<td>20%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Nerve injuries are mostly graded as “permanent”.*
Only after conservative therapy has failed and all these test results are evaluated and discussed with you should surgery be considered. Your doctor or surgeon must inform you about the risks that surgery will cause further nerve damage. The risk varies widely from 5 to 50 percent that your surgery will result in negligently inflicted injury. If your doctor performed surgery too early, failed to inform you of the risks and alternatives or breached any other standard of care negligently, then a lawsuit may be appropriate.
INNOVATION in TOS: PROGRAM DEVELOPMENT

MULTIDISCIPLINARY TEAM

**Director:** Thoracic Surgeon

**Co-Director:** PMR Physician

**Neurologist**

**Spine Surgeon**

**Endovascular Surgeon**

**Orthopedic Surgeon**
INNOVATION in TOS: PROGRAM DEVELOPMENT

**DIAGNOSTIC & TREATMENT ALGORITHM**

**New Office Visit**
- Thoracic Surgeon
- PMR Physician
- DASH

**Diagnostics**
- C-spine x-ray
- C-spine MRI
- EMG
- Muscle block
- Plexus MRI
- ultrasound
- Specialist Consult

**Therapy**
- TOS targeted PT
- First Rib Resection & Scalenectomy
- Pec Minor Release

**Follow-up**
- If <25% improvement in 2 weeks
- 2 weeks
- 2 months
- 6 months
- yearly
- DASH
Thoracic Surgery Visit and Procedure

Patient Information

I acknowledge that I have become a patient of Dr. Bryan Burt in the Division of Thoracic Surgery and CHI St. Luke's Health Baylor St. Luke's Medical Center and I am scheduled for __________ on ____________.

Anatomy

Initial

Initial

Initial

Initial

Phrenic nerve injury (~5%)

Recurrence of symptoms (~15% at 5 years)

Incomplete symptom resolution (~50%)

Diaphragm: elevation, dysphagia, dysphonia, coughing

Injury to pleural structures, surgery in rare cases

Brachial plexus injury (~5%)

Intraoperative bleeding (~1%)

Chyle leak (~5%)

Parachondritis: involvement of trachea with or without infection, coughing

Injury to spinal nerves, surgery in rare cases

I understand that the above list does not include all possible complications or outcomes as a result of this procedure or hospitalization and that it is not possible for my doctor to predict whether these complications, known or unknown, may occur. My doctor has told me that the estimated risk of dying from this procedure is _____%.

My doctor has explained that the Thoracic Surgery Team includes surgeons, residents (physicians in training), fellows, nurses, nurse practitioners, and physician assistants, under the direction of my doctor and these individuals will participate in all stages of my care and treatment.

All of my questions and the questions of my family regarding the potential risks and benefits of the recommended procedure have been answered. If I have further questions or concerns, I know that I can contact my doctor's office and request a meeting to address these concerns. I am now requesting that I be scheduled for surgery.

Date ________ Time ________ Patient Signature

Date ________ Time ________ Physician MD ID 

Establishment of a multidisciplinary program will improve outcomes, mitigate legal risk, and increase volume.
## TECHNIQUE

<table>
<thead>
<tr>
<th></th>
<th>Supraclav</th>
<th>Inflaclav</th>
<th>Paraclav</th>
<th>Transaxillary</th>
<th>Transthoracic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portion of 1\textsuperscript{st} Rib Resected</td>
<td>Posterior</td>
<td>Anterior</td>
<td>Total</td>
<td>Anterior</td>
<td>Total</td>
</tr>
<tr>
<td>Visualization</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Favorable</td>
</tr>
<tr>
<td>Traction on Brachial Plexus</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Favorable</td>
</tr>
<tr>
<td>Cosmesis</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Unfavorable</td>
<td>Favorable</td>
<td>Favorable</td>
</tr>
<tr>
<td>Cervical Rib Resection</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
TECHNIQUE: supraclavicular first rib resection
Exposure: supraclavicular first rib resection
Exposure: TRANSTHORACIC first rib resection
TRANSTHORACIC first rib resection

George. *Annals Thorac Surg* 2017
VATS: n=10

Gharagozloo. *Innovations* 2012
Robotic: n=8 for Effort Thrombosis

Soukiasian. *Innovations* 2015
VATS transaxillary: n=66

Robotic: Technique Article

Gharagozloo. *Innovations* 2012
Robotic: n=8 for Effort Thrombosis
TECHNIQUE:
Transthoracic robotic-assisted first rib resection
TRANSTHORACIC first rib resection

ADVANTAGES

• Excellent Visualization
• Body Habitus is not important
• Resection of the entire rib
• No retraction of neurovascular bundle
• Hypothesis: decreased complications
Transthoracic first rib resection will result in improved short-term and long-term outcomes for patients with nTOS
A thoughtful multidisciplinary treatment approach can improve the lives of nTOS patients, with minimal risk.

A diagnostic standard for nTOS requires validation and will improve patient selection and surgical outcomes.

All nTOS patients should have prospective data collection.

Transthoracic first rib resection may result in improved short-term and long-term outcomes for nTOS.
THANK YOU
Background: Litigation

Malpractice Risk According to Physician Specialty

Anupam B. Jena, M.D., Ph.D., Seth Seabury, Ph.D., Darius Lakdawalla, Ph.D., and Amitabh Chandra, Ph.D.

Abstract

Exposure: TRANSTHORACIC first rib resection
### INNOVATION in TOS: CONTRIBUTION

#### REFINING PATIENT SELECTION for IMPROVED OUTCOMES

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>nTOS</th>
<th>Approach</th>
<th>FU period</th>
<th>Outcomes</th>
<th>Outcomes Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axelrod 2001</td>
<td>170</td>
<td>100%</td>
<td>Supraclav</td>
<td>47 mo</td>
<td>65% improvement; 64% satisfied; 35% on medication; 18% disability</td>
<td>Retrospective Postop Questionnaire</td>
</tr>
<tr>
<td>Orlando 2015</td>
<td>538</td>
<td>52%</td>
<td>Transax</td>
<td>&gt;12 mo</td>
<td>93% positive outcome (nTOS)</td>
<td>Clinical assessment of positive/negative outcome</td>
</tr>
<tr>
<td>Likes 2015</td>
<td>286</td>
<td>100%</td>
<td>Transax</td>
<td>13.5 mo</td>
<td>92% improved symptoms</td>
<td>Clinical assessment of positive/negative outcome</td>
</tr>
<tr>
<td>Karamustafa 2011</td>
<td>131</td>
<td>98%</td>
<td>Supraclav</td>
<td>12 mo</td>
<td>Favorable outcome 95%</td>
<td>Clinical assessment of favorable/poor outcome</td>
</tr>
</tbody>
</table>