

Adolescent Thoracic Outlet Syndrome: A challenging diagnosis and management dilemma

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Disclosures

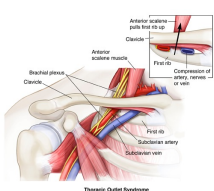
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Thoracic Outlet Syndrome

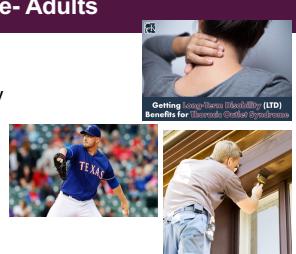
- **TOS is a heterogeneous mix of compressive disorders:**
 - ATOS, VTOS, NTOS, PMS
 - Prevalence 0.3-2%
 - Women (3:1)
 - **80% between 25-40 years**
- Multifactorial pathogenesis:
 - Repetitive overhead activity
 - Hyperextension injury
 - Congenital anomalies
 - Muscle hypertrophy/fibrosis



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Thoracic Outlet Syndrome- Adults

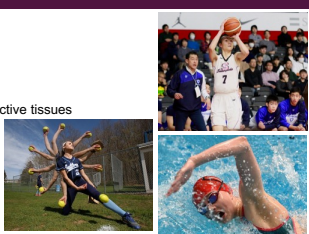
- 1) **Neurogenic TOS: 90-95%**
 - Incidence 3-80/1,000
 - **Work related, repetitive strain injury**
 - UE trauma
- 2) **Venous TOS: 4-5%**
 - Repetitive strain injury
 - SCM hypertrophy
- 3) **Arterial TOS: 1-3%**
 - Incidence 0.03-0.9/100,000
 - Bony anomalies are common



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Thoracic Outlet Syndrome- Adolescents

- 1) **Neurogenic TOS: 30-40%**
 - Female > male
 - Different pathogenesis than adults:
 - **20% congenital anomalies**
 - Development muscles and connective tissues
 - **Repetitive strain/overuse**
- 2) **Venous TOS: >40%**
 - Repetitive strain, SCM hypertrophy
 - Male > female
- 3) **Arterial TOS: 10-15%**
 - >50% bony anomalies
 - Male > female




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Spectrum of Thoracic Outlet Syndrome Presentation in Adolescents

Kevin Chang, BA; Emma Graf, Kylie Davis, Jasmine Demos, CRNP; Taylor Rochle; Julie Ann Freischlag, MD

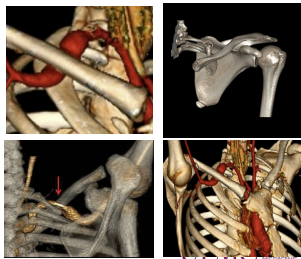
- 35 adolescents (<18 years)
 - Retrospective review, single center
 - 21 females, 14 males
 - **74% vascular (18 VTOS, 8 ATOS, 9 NTOS)**
 - **75% ATOS cervical/rudimentary ribs**
 - All underwent surgical decompression
 - NTOS- sxs began 15 months before operation (delayed referrals)
- **Adolescents more often present with vascular TOS than adults**



6 Arch Surg 2015

Thoracic Outlet Syndrome Pathogenesis

- Adults:**
- 85% hyperextension injury, repetitive strain
 - 15% congenital predisposition
- Adolescents:**
- >50% congenital anomalies
 - Cervical ribs
 - Elongated transverse process
 - Fibrous bands
 - Scalene minimus muscle
 - 40% repetitive stress/overuse

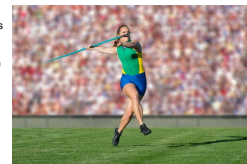


Pearl TOS Springer 2013, Chandra 2011, 2014, Pearl 2016, Baghiani J Med Surg 2021

Adolescent Thoracic Outlet Syndrome

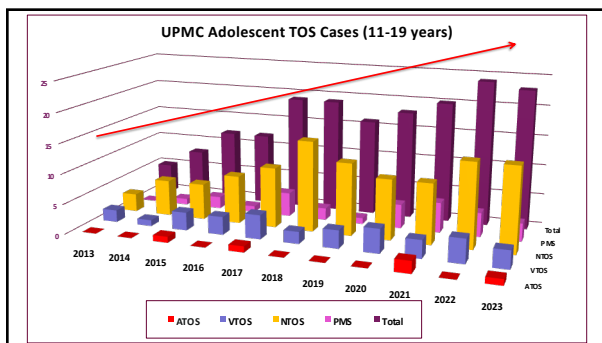
TOS is occurring more frequently in adolescents (11-19 years):

- Combination of maturation and physical activity
 - Max velocity/weight/effort high intensity workout regimens
 - Single sport athletes
 - Repetitive stress/overuse- not just athletes
- Puberty related maturation
 - Increased muscle mass (disproportionate)
 - Rapid growth spurts
 - Joint laxity
- TO small anatomic space
 - Bony anomalies



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Hong JMS 2016, Big 2021, Al Shakerchi 2020, Murthy 2022



Adolescent Thoracic Outlet Syndrome

- TOS is an especially difficult diagnosis:
 - Pediatricians lack of familiarity
 - Parents and patients minimize symptoms
 - Difficulty communicating neurogenic symptoms
 - Reluctance for invasive testing
 - NIL and college scholarships...plausible deniability
- Delayed/missed diagnosis



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Diagnosing Adolescent TOS

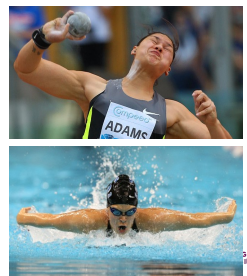
- Vascular TOS:** careful history and physical exam
- Presenting features are objective
 - Misperception nerve compression is causing symptoms
 - Appropriate diagnosis made after vascular changes reoccur
 - Hx- repetitive strain/overuse
- Features of venous TOS: SCV thrombosis
 - Fatigue, fullness, cyanosis, prominent chest wall veins
 - Features of arterial TOS: SCA compression
 - Pulsatile mass, bruit, digit embolization, fatigue
 - Bony anomalies



Pearl 2016, Chandra 2014, Lee 2011, Tatala 2023

Diagnosing Adolescent TOS

- Neurogenic TOS:**
- Careful history and physical exam
 - Wide constellation of symptoms
 - >40% co-existing musculoskeletal injuries
 - Nuanced symptoms, exacerbated by overhead activity
 - Transient pain, paresthesia, weakness, fatigue, loss dexterity
 - Diagnosis delay 11-36 months



Pearl TOS Springer 2013, Langsch 2013

Diagnosing Adolescent TOS

Neurogenic TOS: no pathognomonic finding

- P/E findings are less reliable:
 - **Subjective weakness, hand atrophy, slouching, rolled shoulders**
- Provocative maneuvers- normal 1/3rd
 - ULTT, EAST, Wright, Adson
- Tenderness to palpation scalene triangle
 - **Cervical rib with referred paresthesia**
- **Compensatory muscle spasm**
 - scalene, pect minor, rhomboid, trapezius



Pearl TOS Springer 2010, Langwisch 2013

Diagnostic Imaging TOS

X-rays: chest and c-spine all TOS cases

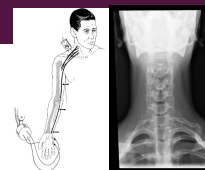
- Evaluate for bony anomalies (50%)

Vascular TOS:

- **Duplex imaging:** ATOS/VTOS 90% sensitive
- **CTAV:** bony anomalies in relation to vessels

Neurogenic TOS:

- **Duplex imaging:** NTOS 66% sensitive
- **MRI =>** negative 75% cases
 - Fibromuscular anomalies
- **Nerve conduction testing =>** unreliable
- **Muscle blocks:** ant scalene, pect minor
 - >80% sensitive
 - Determine symptoms related NTOS
 - Predict response surgical decompression



Huang 2004, Pearl TOS Springer 2010, Chandra 2014, Kashi MN 1995, Safian AJSM 2004, Brighton

Treatment Adolescent TOS

ATOS:

- **Early intervention**
- Decompress 1st rib, bony anomalies, ASM resection
- **SCA repair infrequent**

VTOS:

- **Treat like adults**
- Anticoagulate, lysis/thrombectomy
- Decompress 1st rib and SCM resection
- **Selective SCV repair based on symptoms**

NTOS:

- **Conservative treatment 3-6 months**
- Avoid provocative activities
- PT- stretching, deep tissue massage, posture correction
- Anti-inflammatory meds, Botox inj. scalene triangle
 - PT- mild sxs more likely to respond
 - **PT- athletes higher failure rates**
 - **Anatomic anomalies- consider early decompression**



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Huang 2004, Pearl TOS Springer 2010, Chandra 2014, Kashi MN 1995, Safian AJSM 2004

UPMC Experience

- **176 patients** 2013-2024, mean age 16.1 years
- **72% female, 76% high school/college athletes**
 - **61% NTOS, 21% VTOS, 3% ATOS, 15% PMS**
 - 45% combined orthopedic and TOS diagnoses
 - **42% cong. anomalies, 6% bilateral TOS**
- **NTOS:** 100% focused PT (3 months)
 - 45% decompression with neurolysis
 - 6% recurrent NTOS symptoms at 18 months
- **VTOS:** 93% decompression following lysis/thrombectomy
 - 7% VTOS symptoms at 24 months
- **ATOS:** all decompression, 1 SCA patch and 1 bypass
 - **95% returned to academics (2 weeks)**
 - **93% returned to athletics (4.5 months)**



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Conclusion

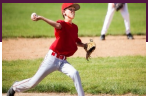
- Adolescent TOS is a challenging diagnosis to make and has a different pathogenesis than adults
- Vascular TOS is more common in adolescents and often associated with bony anomalies
- Conservative management should be attempted for 3-6 months in most neurogenic TOS patients
- Longitudinal outcomes after decompression are very favorable
- TOS has profound effects on education and athletic endeavors, and requires early diagnosis and timely treatment

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Sports-Related Injuries in Adolescent Athletes: A Systematic Review

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¹ Penn Medicine, Health Trust Health System, Health, LLC; ² Epidemiology and Public Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania; ³ Sports and Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania; ⁴ Sports and Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania; ⁵ Sports and Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania; ⁶ Sports and Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania; ⁷ Sports and Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania; ⁸ Sports and Health, Leonard Davis Institute of Health Sciences, University of Pennsylvania

Sports related overuse injuries are increasing:

- Sports specialization at a young age
- Intense contact sports
- Failure to take time off between seasons
- Failure to take rest days during the week
- Inadequate warm-ups and cool-downs
- Not wearing appropriate protective gear
- Unable to be honest about injuries
- Limited recovery time after injury

Abstract
Sports-related injuries among adolescents is increasing, affecting numerous health benefits and impairing their ability to participate in sports. The review aims to evaluate risk factors for primary and overuse injuries associated with these injuries and to provide evidence-based recommendations for prevention and management of these injuries.

This systematic review synthesizes the existing literature on sports-related injuries in adolescent athletes. A comprehensive search was conducted, yielding 11 relevant studies. The studies were analyzed to determine the prevalence of injuries and identify associated risk factors. A significant proportion of the findings was performed.

The review includes a meta-analysis highlighting the specific risk factors of sports-related injuries among adolescent athletes, with primary overuse injuries being the most common. Sports-related injuries were most commonly associated with intense contact sports, prolonged activity patterns, age, gender, sport type, previous injury, and wearing protective gear. These findings suggest a need to improve warm-up and cool-down practices, and to encourage athletes to be honest about injuries and to take adequate recovery time.



Sports-related injuries in adolescent athletes are a multifactorial issue influenced by various factors. Tailored injury prevention strategies are essential, considering the specific needs of adolescent athletes. Multifactorial approaches, including education on proper warm-up and cool-down practices, appropriate protective equipment, and addressing psychological factors, are needed to reduce injury rates and optimize performance. This systematic review contributes to our understanding of sports-related injuries in adolescent athletes and provides evidence for targeted injury prevention efforts.

J Child Fam Stud 2022; 31(12): 1899-2001. DOI: 10.1007/s10826-022-02000-0

Presentation, management and outcome of surgically managed pediatric thoracic outlet syndrome

Nikhil K. Murthy^{1,2}, Rashmi Kabra^{3,4}, Kristina S. Corkum⁵, Mandana Behbahani⁶, Vineeth Thirunav⁷, Constantine L. Karras^{1,2}, Todd D. Alden^{1,2}

- 44 patients single center, 15.5 years, 72% female
- 80% NTOS, 20% Vasc TOS
- Symptom duration 35.2 months
- Numbness 72%, pain 66%, weakness 4%
- 50% unremarkable exam
- 59% sports activities
- 32% underwent PT
- 50 supraclavicular operations
- NTOS: 90% scalenectomy, 72% FRR, 92% neurolysis
- Post-op PT: NTOS 21%, Vasc TOS 47%
- Follow-up 11 months: 22% pain, 26% numbness, 6% weakness

Child's Nervous System 2022

Long-term outcomes after surgical treatment of pediatric neurogenic thoracic outlet syndrome

Jennifer Hong, MD¹, Jared M. Pisapia, MD², Zarina S. Ali, MD¹, Austin J. Heuer,¹ Erin Alexander, BS¹, Gregory G. Heuer, MD, PhD,^{1,2} and Eric L. Zager, MD¹

¹Division of Neurosurgery, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire; ²Department of Neurosurgery, University of Pennsylvania, Philadelphia; and ³Division of Neurosurgery, The Children's Hospital of Philadelphia, Pennsylvania

- 12 patients 2010-2016, single center, 66% female
- Mean age 15.2 years (range 8-18)
- Duration of symptoms 15.8 months (± 6.6)
 - 75% sports related activities
 - 75% bony anomalies
 - 33% c-ribs, 33% transverse process
- Follow-up: 57% excellent results, 43% good results
 - Better results- shorter duration symptoms, younger age
- Pediatric NTOS often associated with bony anomalies, early decompression results in excellent symptom resolution

J Neurosurg Pediatr 2018