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Title: Vascular Injuries in Sports Medicine

Presenter:
Rehal Bhojani, MD, FAAFP CAQSM
Assistant Professor
Fellowship Director, Sports Medicine
McGovern Medical School at UTHealth

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Presenter: Rehal Bhojani, MD, FAAFP CAQSM

Department of Cardiothoracic and Vascular Surgery Grand Rounds

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Vascular Injuries in Sports Medicine

UT Cardiovascular Surgery Grand Rounds, February 4, 2022

Rehal Bhojani, MD FAAFP CAQSM

Fellowship Director & Assistant Professor

Department of Orthopedic Surgery and Family & Community Medicine

UTHealth, McGovern Medical School

My Disclaimers

I will not proclaim myself to be a Vascular Surgeon

I would rather have been there in-person to give this talk

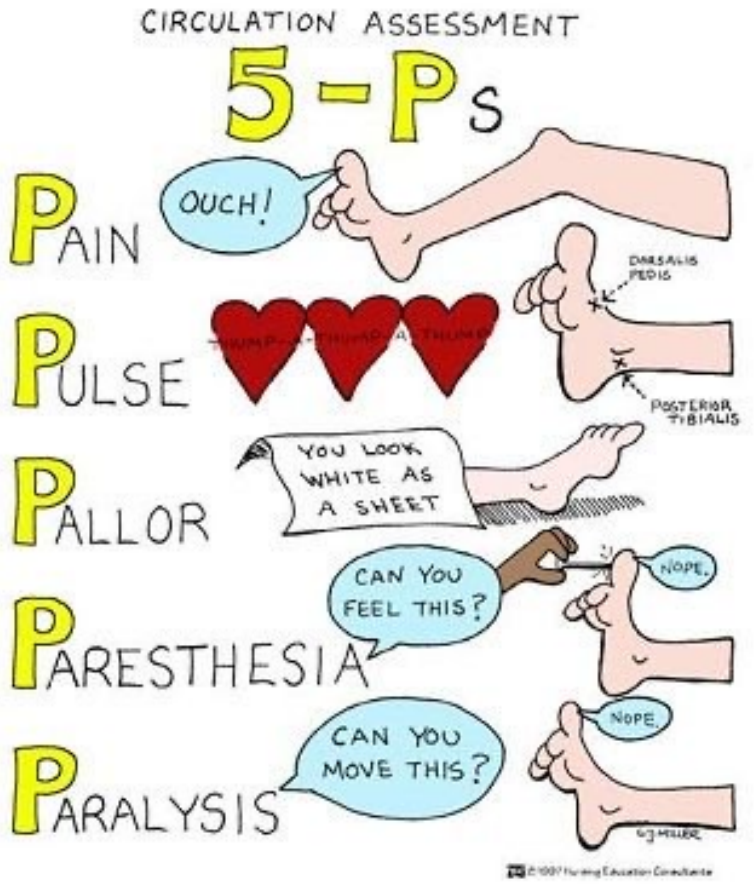
My intent is to expose you a part of your specialty which deals with a unique population with a different mindset than what you typically see

Objectives

Identify	Identify various modalities to diagnose peripheral artery/vein entrapments.
Discuss	Discuss various risk factors, work-up, and diagnosis of Thoracic Outlet Syndrome in Sports.
Review	Review various peripheral entrapments and traumatic injuries

Evaluation of Vascular Injuries in Athletes

- High index of suspicion is most important
  - In athletes, the physical exam may be normal in the office with exercise-induced symptoms
  - Remember your 5 P's (pain, paresthesia, pallor, pulse, paralysis)
- Complete occlusion is rare
- Nonocclusive injuries include:
  - Dissection
  - Aneurysm
  - Entrapment/Intermittent Compression
  - Stenosis
  - Thrombosis



Vascular Diagnostic Testing

From a Sports Medicine Perspective

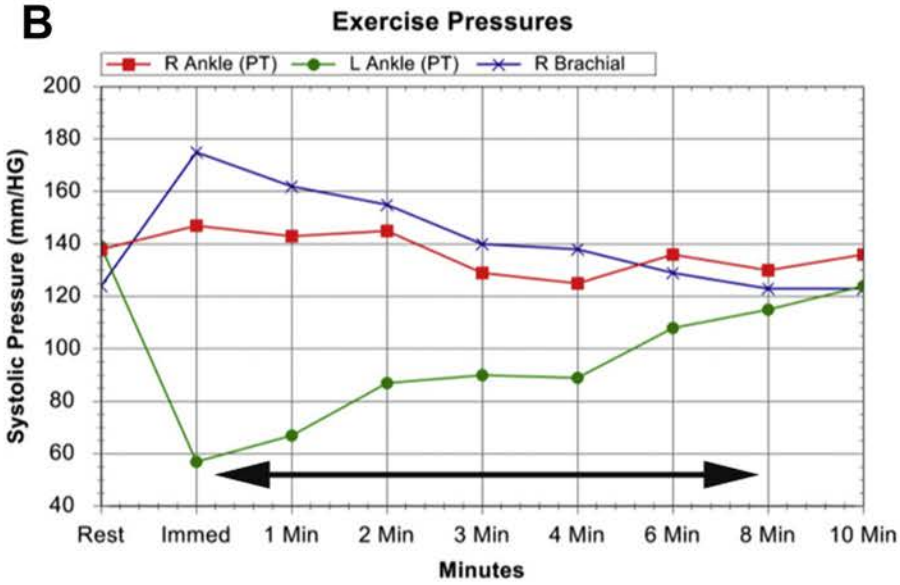
Physical Examination

- **Cervical Quadrant Test** (assess vertebral artery)
- **DeKleyn-Nieuwenhuyse Test** (assess vertebral artery)
- **Allen Test** (assess radial/ulnar artery in hand)
- **Buerger Test** (arterial flow in lower extremity)
- **Homan's Test** (DVT)
- **Trendelenberg-Brodie Test** (assess valvular function in lower extremity)
- **Perthes Test** (assess valvular function in lower extremity)

Tran K, Dossabhoy SS, Sorondo S, Lee JT. Bicycle exercise ankle brachial index recovery time as a novel metric for evaluating the hemodynamic significance of external iliac endofibrosis in competitive cyclists. J Vasc Surg Cases Innov Tech. 2021 Sep 29;7(4):681-685. doi: 10.1016/j.jvscit.2021.08.013. PMID: 34746530; PMCID: PMC8556481.

A

B

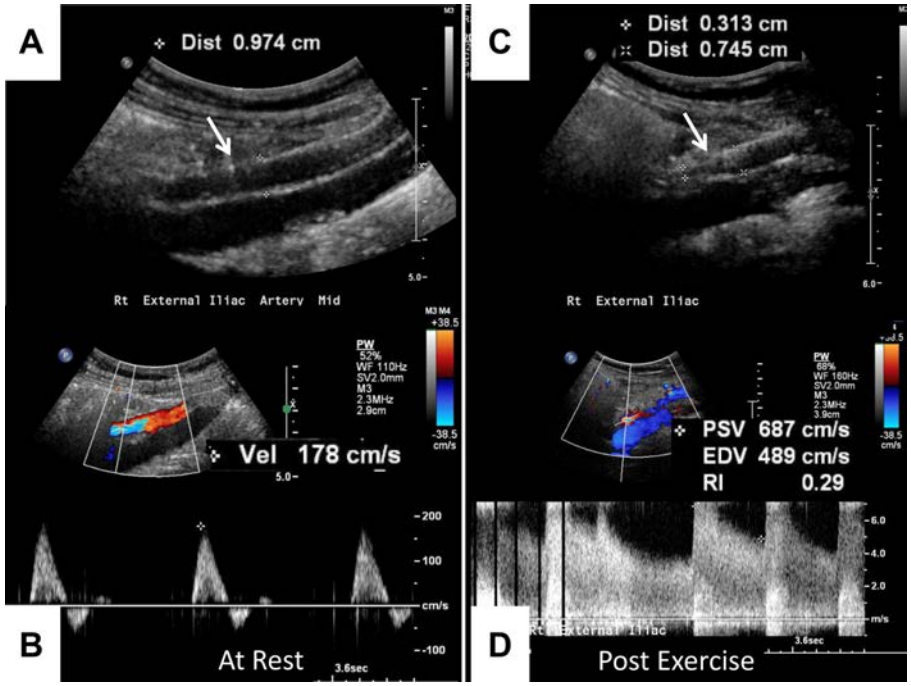


Ankle Brachial Index / Ankle Arm Index (ABI/AAI)

- Will likely need side-to-side comparisons
- Post-exercise or positional measurements may be needed
  - Patients with nontraumatic, exercise-induced leg pain with an ABI 1 minute after maximum exercise of < 0.5 or a side-to-side difference of > 0.18 should be referred for further arterial investigation

Duplex Ultrasound

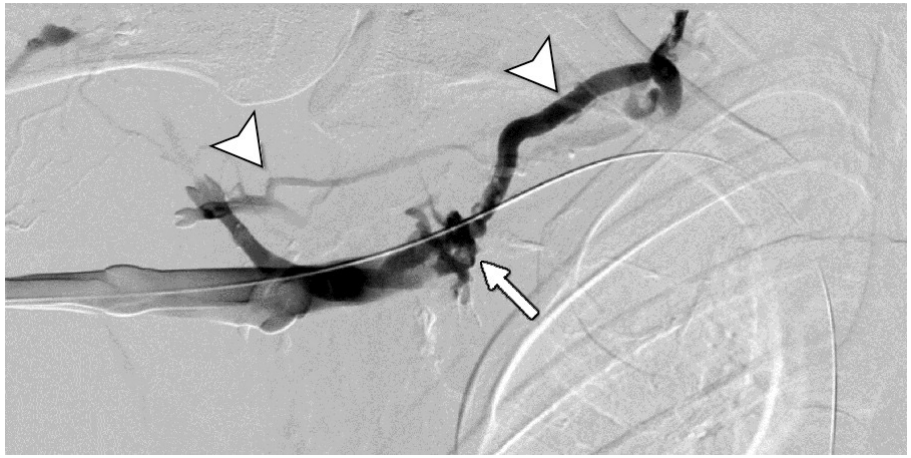
- Identification of thrombi, stenosis, vessel wall thickening
- Sensitivity of 82%–95% and a specificity of 96% in the diagnosis of stenosis > 50% of the luminal diameter
- Sensitivity of 90%–95% and specificity of 96%–97% in the diagnosis of complete occlusions



Shalhub S, Zierler RE, Smith W, Olmsted K, Clowes AW. Vasospasm as a cause for claudication in athletes with external iliac artery endofibrosis. J Vasc Surg. 2013 Jul;58(1):105-11. doi: 10.1016/j.jvs.2012.12.060. Epub 2013 Mar 29. PMID: 23541546.

Angiography

- Gold standard for arterial disease diagnosis
- Invasive with complications
- Rarely needed in sports-related injuries

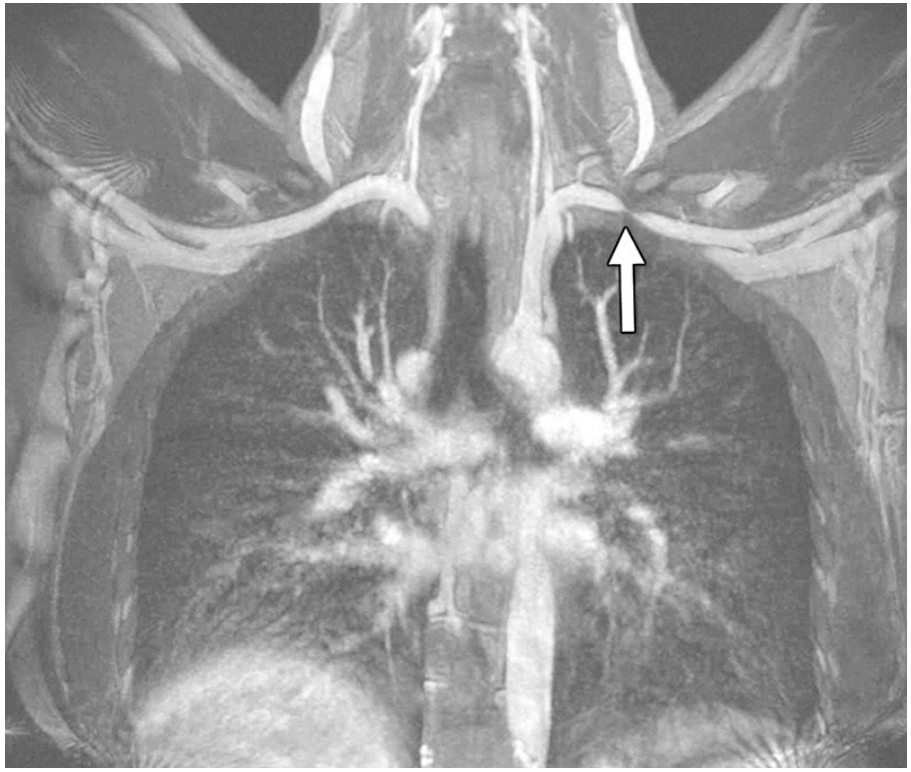


Digital subtraction image from a right-sided venous injection in a baseball player with acute right arm swelling shows abrupt occlusion of the right subclavian vein (arrow) with filling of venous collaterals proximal to the site of obstruction (arrowheads).

Raptis CA, Sridhar S, Thompson RW, Fowler KJ, Bhalla S. Imaging of the Patient with Thoracic Outlet Syndrome. Radiographics. 2016 Jul-Aug;36(4):984-1000. doi: 10.1148/rg.2016150221. Epub 2016 Jun 3. PMID: 27257767.

CTA and MRI/MRA

- Allows simultaneous visualization of vasculature and surrounding structures
- Better side effect profile
- Can also see compression, compartment syndrome, TOS
  - MRI findings for compartment syndrome include edema, hemorrhage, hematoma, vessel injury, inflammation



Coronal venous phase gradient-echo (GRE) image with the arms abducted shows narrowing of the left subclavian artery (arrow) at the costoclavicular interval. The patient had normal left subclavian artery caliber with the arms adducted. There was no evidence of vascular damage or thrombus, and the patient had clinical evidence of neurogenic TOS but not arterial TOS. In cases such as this, where there is isolated vascular narrowing, we report the dynamic vascular compression, but do not label the patient as having vascular TOS to prevent overdiagnosis and possible unnecessary treatment.

Raptis CA, Sridhar S, Thompson RW, Fowler KJ, Bhalla S. Imaging of the Patient with Thoracic Outlet Syndrome. Radiographics. 2016 Jul-Aug;36(4):984-1000. doi: 10.1148/rg.2016150221. Epub 2016 Jun 3. PMID: 27257767.

When do we get Vascular Surgery Involved?

- Acute vascular compromise
- Refractory vascular insufficiency
- Management Prior to Referral:
  - Activity modification
  - Therapeutic Exercises
    - Optimize biomechanics with goal of eliminating functional vascular compromise/microtrauma (kinetic chain concepts)
  - Risk factor reduction i.e. smoking

Peripheral Venous Entrapments/Injuries

Effort Thrombosis (Paget-von Schroetter Syndrome)

Definition: Spontaneous thrombosis of axillary or subclavian vein (Risk of PE: 36%)

Mechanism:

- Acute: clavicular fracture, axillary hematoma, injury to vessels
- Chronic: overhand motions causing microtrauma (hyperabduction, external rotation)

Sports/Positions at Risk: Baseball, Football, Basketball, Tennis, Swimming

- Usually dominant arm

Clinical Presentation:

- Acute: non-pitting edema, cyanosis and pain, distal pulses intact unless thrombus massive
- Chronic/Compression:
  - dull pain in upper limb
  - +/- arm/hand swelling
  - +/- collateral vessel formation
  - Distal pulses intact

Mall NA, Van Thiel GS, Heard WM, Paletta GA, Bush-Joseph C, Bach BR Jr. Paget-schroetter syndrome: a review of effort thrombosis of the upper extremity from a sports medicine perspective. Sports Health. 2013 Jul;5(4):353-6. doi: 10.1177/1941738112470911. PMID: 24459553; PMCID: PMC3899898.

Effort Thrombosis (Paget-von Schroetter Syndrome)

- Diagnosis: duplex ultrasound (make sure to evaluate both sides)
  - Sensitivity 78-100%
  - Specificity 82-100%
- Treatment:
  - Acute: Emergent Thrombolysis with confirmatory venography followed usually by decompression of thoracic inlet + 2-6 months anticoagulation
  - Chronic: Consider anticoagulation, thrombolytics
- Return to Play in Sports: 90% return to sport in 5 months (must be off anticoagulation for contact sports)

Effort Thrombosis with Venous TOS

A-C, Gadolinium-enhanced magnetic resonance (MR) venogram in a 26-year-old right-handed baseball player demonstrates right subclavian vein occlusion *(arrows)* with the arms in (A) neutral and (B) elevated positions that correspond to the lesion subsequently observed by (C) direct contrast venography.

D-F, Contrast venograms in a 26-year-old right-handed baseball pitcher with (D) a long segment subclavian vein occlusion on the initial study *(arrow)*, (E) improved flow and appearance with focal subclavian vein stenosis 22 hours after thrombolysis *(arrow)*, and (F) focal subclavian vein occlusion with arm elevation *(arrow)*.

G, In this typical operative specimen of the left first rib excised during paraclavicular thoracic outlet decompression, the scalene tubercle is indicated *(arrow)*.

H, This operative photograph of the left subclavian vein after circumferential external venolysis shows thick residual scar tissue encasing the proximal subclavian vein and restricting its diameter even after complete mobilization *(arrow)*. A saphenous vein panel graft bypass was performed from the end of the normal subclavian vein to the side of the jugular-subclavian vein junction *(asterisks)*, with excision of the intervening native subclavian vein.

I, Operative specimen of the subclavian vein containing an indwelling stent *(arrow, inset)*, which was excised during paraclavicular decompression and subclavian vein bypass graft reconstruction.

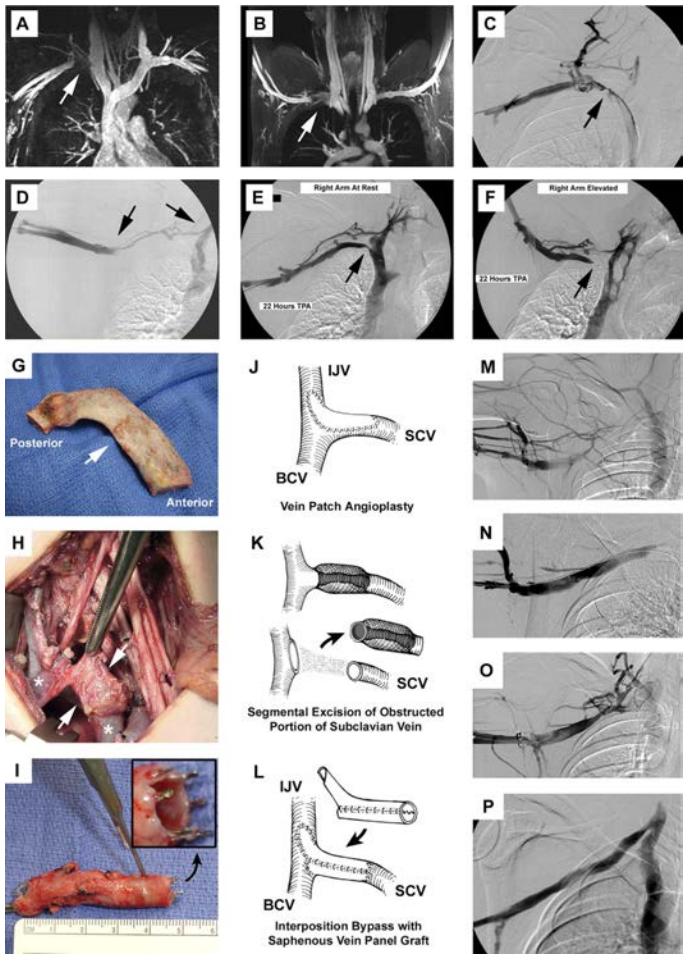
J-L, Drawings show the techniques used for (J) subclavian vein patch angioplasty, (K) excision of the obstructed proximal segment of the subclavian vein, and (L) surgical reconstruction with interposition bypass using a saphenous vein panel graft. *IJV,* Internal jugular vein; *SCV*, subclavian vein; *BCV,* brachiocephalic (innominate) vein.

M, Initial contrast venogram in a 20-year-old baseball pitcher presenting with right arm swelling and extensive axillary-subclavian vein thrombosis.

N, Venogram immediately after thrombolysis and balloon angioplasty.

O, Repeat venogram after 2 months of anticoagulation, during which the patient had persistent symptoms. The appearance of chronic recurrent axillary-subclavian vein occlusion was considered inoperable before referral.

P, Follow-up postoperative venogram after thoracic outlet decompression and subclavian vein reconstruction using a saphenous vein panel graft illustrates a widely patent venous system and absence of collateral flow. The patient experienced prompt relief of arm swelling and returned to competitive baseball 4 months later.



Melby SJ, Vedantham S, Narra VR, Paletta GA Jr, Khoo-Summers L, Driskill M, Thompson RW. Comprehensive surgical management of the competitive athlete with effort thrombosis of the subclavian vein (Paget-Schroetter syndrome). J Vasc Surg. 2008 Apr;47(4):809-820; discussion 821. doi: 10.1016/j.jvs.2007.10.057. Epub 2008 Feb 14. PMID: 18280096.

TABLE 1

Upper-extremity deep vein thrombosis (N = 89) (e13-e81)

Types of sports		
Weight training N = 30		
Weight lifting		N = 17
	+ Baseball/softball	N = 3
	+ Football/rugby	N = 4
	+ Other*[1]	N = 4
Bodybuilding		N = 1
Not specified		N = 1
Ball sports N = 26		
Baseball	Pitcher	N = 4
	Catcher	N = 1
	Not specified	N = 4
Basketball + other types of sports*2		N = 4
Volleyball		N = 3
Rugby/football		N = 3
Other*[3]		N = 7
Endurance sports N = 15		
Swimming		N = 7
Other*[4]		N = 8
Contact sports N = 7		
Wrestling/judo/pro wrestling		N = 6
+ Football		N = 1
Other*[5] N = 11		

Age (in years)	
14–29	N = 55
30–39	N = 15
40–49	N = 10
50–65	N = 5
> 65	N = 1
Not specified	N = 3
Sex	
Male	N = 67
Female	N = 22
Anatomical changes	
Thoracic outlet syndrome assumed	N = 34
Operative decompression	N = 31
Site localization	
Subclavian vein / axillary vein involved	N = 85
Other*[6]	N = 4

Hereditary thrombophilia*	
Factor V Leiden mutation (N = 1 homozygous; all + other mutation)	N = 4
MTHFR mutation*[7] (C677T) (homozygous, N = 1; heterozygous, N = 5)	N = 6
AT-III deficiency	N = 1
Family history	
Thromboembolism in first-degree relatives	N = 3

Acquired risk factors*	
Contraceptives (oral)	N = 6
Tobacco use	N = 5
Immobilization	N = 0
Other accompanying factors*	
Intensive training	N = 11
Trauma	N = 4
Local compression	N = 3
Infection	N = 3
Other*[8]	N = 3
Complications*	
Pulmonary embolism	N = 10
– With a fatal outcome	N = 1
Post-thrombotic syndrome/ complaints	N = 14
Recurrence	N = 13

* Multiple answers possible
*[1] Alpine skiing (N = 1), soccer (N = 1), swimming (N = 1), basketball (N = 1)
*[2] Softball (N = 1), tennis (N = 1), volleyball (N = 1), wrestling (N = 1)
*[3] Water polo (N = 2), handball (N = 2), softball (N = 1), tennis and Badminton (N = 1), lacrosse (N = 1)
*[4] Rowing (N = 2), running/marathon (N = 2), triathlon (N = 2), Nordic skiing (N = 1), spinning (N = 1)
*[5] Dance (N = 2), climbing (N = 2), recreational sports (N = 2), gymnastics (N = 1), aerobics (N = 1), track and field athletics (N = 1), bowling (N = 1), Kaatsu (N = 1)
*[6] Brachiocephalic vein (N = 1), brachial vein (N = 2), ulnar vein (N = 1)
*[7] With exclusion of hyperhomocysteinemia (N = 3), no further information (N = 3)
*[8] Pregnancy (N = 1), high-altitude exposure (N = 1), Hashimoto's thyroiditis (N = 1)

Hilberg T, Ransmann P, Hagedorn T. Sport and Venous Thromboembolism—Site, Accompanying Features, Symptoms, and Diagnosis. *Dtsch Arztebl Int*. 2021;118(11):181-187. doi:10.3238/arztebl.m2021.0021

TABLE 2

Deep vein thrombosis (DVT) of the lower extremities (N = 53) (e14, e82–e124)

Type of sports		Age (years)		Anatomical changes		Hereditary thrombophilia*		Acquired risk factors*		
Endurance sports N = 24		15–29	N = 26	May-Thurner syndrome	N = 4	Factor V Leiden-mutation (homozygous, N = 2; + other mutation, N = 2)	N = 5	Immo-bilization*3	Long-haul trip	N = 7
Running/marathon	N = 13	30–39	N = 7	**Site of occurrence**					Injury	N = 2
Bicycling	N = 3	40–49	N = 9	**Lower leg/knee N = 16**					Combination*4	N = 2
Triathlon	N = 2	50–65	N = 6	Peroneal vein	N = 3			Contraceptive (oral)		N = 6
Rowing	N = 2	> 65	N = 1	Tibial vein	N = 2	MTHFR mutation*2 (C677T) (homozygous)	N = 2	Tobacco use		N = 2
Hiking	N = 1	Not specified	N = 4	Popliteal vein	N = 4			**Other accompanying factors ***		
Swimming	N = 1			Several	N = 5	Prothrombin G20210A mutation (heterozygous)	N = 1	Trauma*5		N = 13
Not specified	N = 2	**Sex**		Not specified	N = 2			Intensive training		N = 2
Ball sport N = 21		Male	N = 42	**Thigh N = 10**				Suspected dehydration		N = 2
Football	N = 7	Female	N = 9	Femoral vein	N = 8	Protein C deficiency (heterozygous)	N = 2	Other*6		N = 6
+ Volleyball	N = 1	Not specified	N = 2	Not specified	N = 2			**Complications***		
Soccer	N = 5			**Pelvis N = 2**		Protein S deficiency (heterozygous)	N = 1	Pulmonary embolism		N = 17
Basketball	N = 3			Iliac vein	N = 1			– With a fatal outcome		N = 4
Racquetball	N = 2			Caval vein	N = 1	Hyperhomo-cysteinemia	N = 2	DVT with a fatal outcome		N = 2
Ice hockey/hockey	N = 2			**Combination N = 16**				Post-thrombotic syndrome/complaints		N = 5
Baseball (catcher)	N = 1			From lower leg to pelvis	N = 16	Not specified	N = 1			
Weight training N = 2						**Family history**		Recurrence		N = 2
Weight lifting	N = 1			**Not specified N = 9**		Thromboembolism in first-degree relatives 1. Grades	N = 2			
Not specified	N = 1									
Contact sports N = 0										
Other*1 N = 6										

* Multiple answers possible
*1 Track and field athletics (N = 1), alpine skiing (N = 1), mountain sports (N = 1), motorcycle racer (N = 1), not specified (N = 2)
*2 With proven hyperhomocysteinemia (N = 1), not specified (N = 1)
*3 > 4 h within a relative time frame of 8 weeks
*4 Recovery from an injury and additional immobilization due to travel
*5 Four with immobilization
*6 Overweight (N = 1), pregnancy abortion (N = 1), anabolic steroids (N = 1), exposure to high-altitude/cold/virus infection (N = 1), heat (N = 1), Hashimoto's thyroiditis (N = 1)

Hilberg T, Ransmann P, Hagedorn T. Sport and Venous Thromboembolism—Site, Accompanying Features, Symptoms, and Diagnosis. *Dtsch Arztebl Int*. 2021;118(11):181-187. doi:10.3238/arztebl.m2021.0021

DVT in the Athlete (Risk Factors)

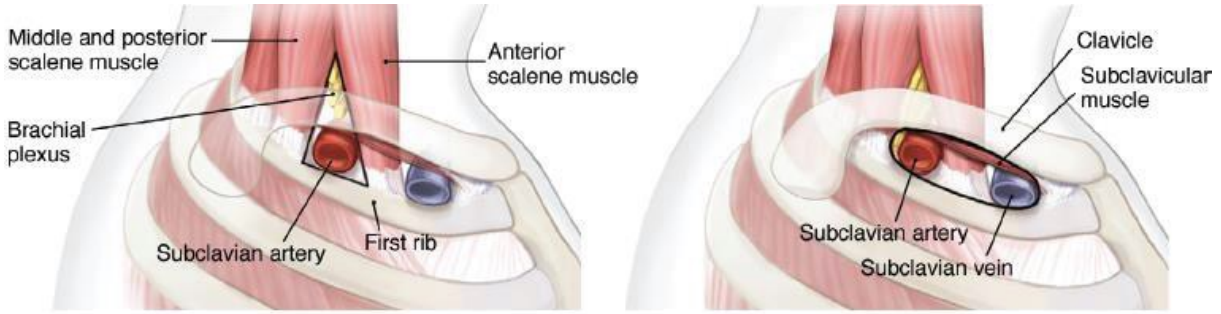
- Traveling long distances to and from a sports competition (by plane, bus, or car)
- Dehydration (during and after a strenuous sporting event)
- Significant trauma
- Immobilization (brace or cast)
- Bone fracture or major surgery
- Birth control pills and patch, pregnancy, hormone replacement therapy
- Family history of DVT or PE
- Presence of an inherited or acquired clotting disorder (Factor V Leiden, prothrombin 20210 mutation, antiphospholipid antibodies, and others)
- Presence of a congenital abnormality of the anatomy of the veins
- May-Thurner Syndrome (narrowing of the major left pelvic vein)
- Narrowing or absence of the inferior vena cava (the main vein in the abdomen)
- Cervical rib causing thoracic outlet obstruction

Vascular Thoracic Outlet Syndrome

- Collection of symptoms brought on by abnormal compression of the neurovascular bundle in the narrow space between the clavicle and 1st rib:
  - Bony obstacles
  - Ligamentous obstacles
  - Muscular obstacles
- **Sports-related events include:**
  - Baseball/softball
    - Arm Fatigue, decrease velocity/grip strength, prolonged recovery between games
  - Volleyball
  - Tennis
  - Track & Field
  - Swimmers/divers
  - Gymnastics/Cheerleading

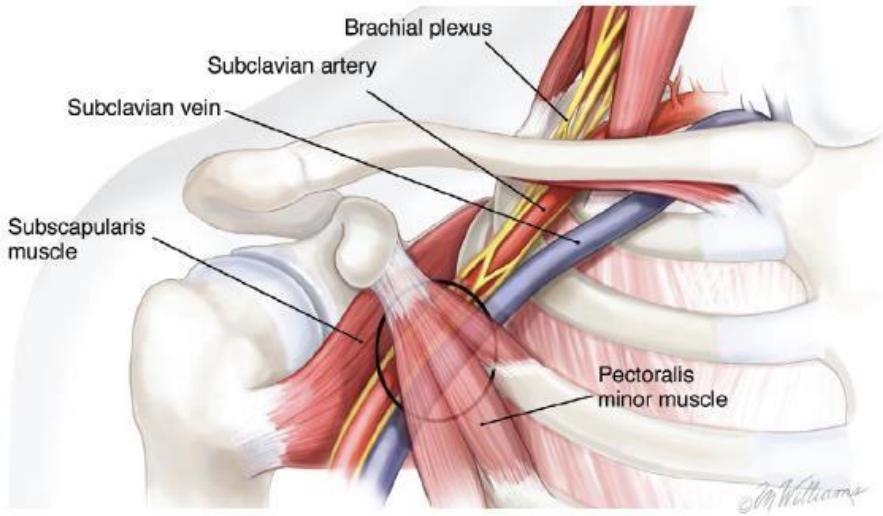
- **Bone Abnormalities**
  - Cervical rib (0.74%)
  - Anomalous 1st rib (0.76%)
  - Elongated C7 transverse process
  - Exostosis/tumor of clavicle/1st rib
- **Soft Tissue Abnormalities**
  - Fibrous band
  - Congenital (insertion variation, supernumery muscle, muscle hypertrophy)
  - Acquired (post-traumatic fibrous scarring, postoperative scarring)

Vascular Thoracic Outlet Syndrome



A Interscalene triangle

B Costoclavicular space



C Retropectoralis minor space

Clinical TOS Signs/Symptoms

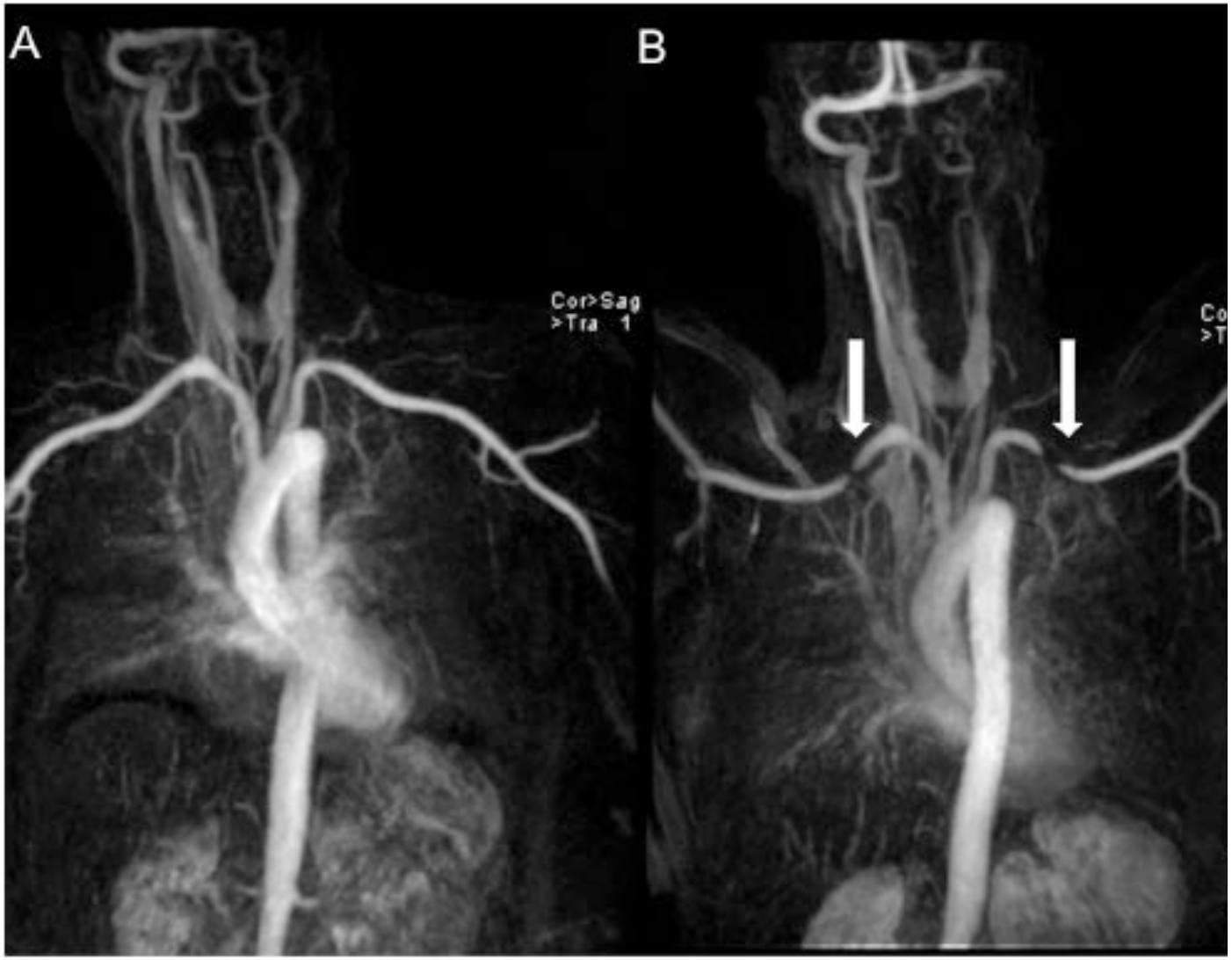
- Venous TOS
  - Pain, tightness, discomfort with exercise, edema, cyanosis, tenderness over axillary vein
- Arterial TOS
  - Digital/hand ischemia, cutaneous ulceration, forearm pain with use, pulsatile supraclavicular mass/bruit

TOS Provocative Testing

Table 8.2 Special tests for thoracic outlet syndrome

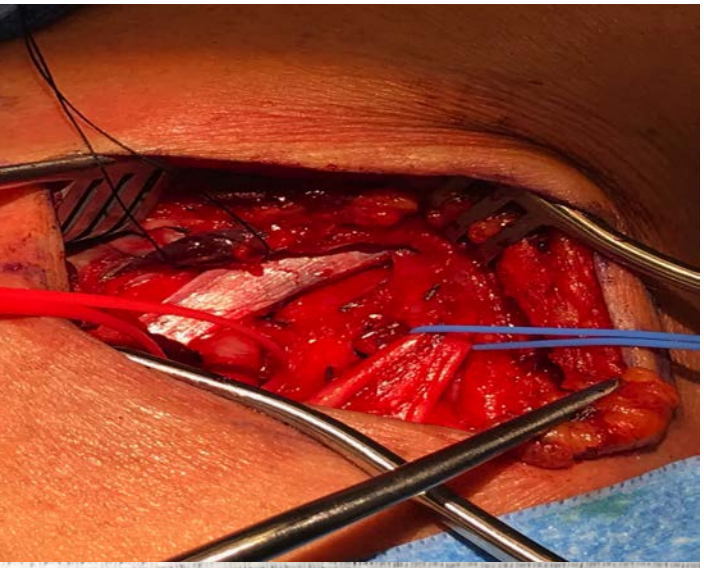
Test	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Roos test	84	30	68	50
Wright's test	90	29	69	63
Adson's maneuver	79	76	85	72
Halstead's maneuver	84	47	74	47

PPV, positive predictive value; NPV, negative predictive value



Vascular Thoracic Outlet Syndrome

- CT/MRI – usually negative but can be used in positions to potentially diagnose
- MR Neurography – newer technology
- Arteriography/Venography with positional maneuvers +/- Duplex U/S
  - Consider bilateral studies
- EMG/NCS
  - Positive results aid in evaluation of other conditions
  - Negative results exclude other conditions



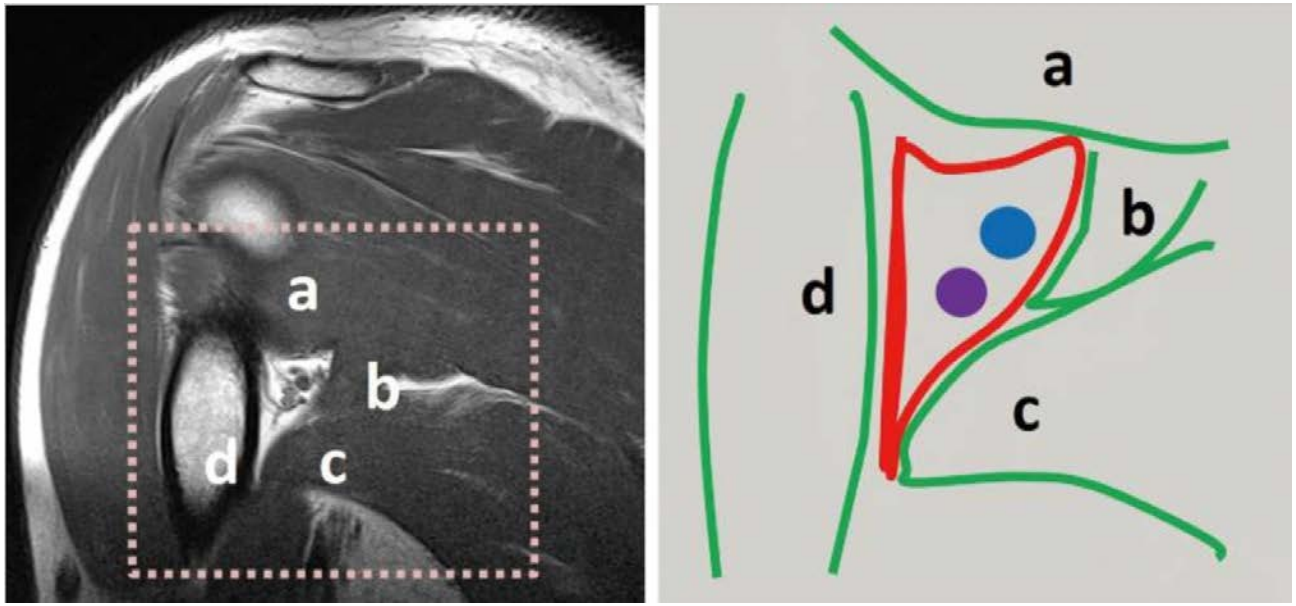
Treatments

- Physical Therapy
  - Therapist must have experience in evaluation/treatment of TOS
  - 20-30% respond and do not need surgical treatment
  - Principles
    - Postural correction (periscapular stabilization)
    - Manipulate/mobilize/relax 1st rib, clavicular, scapular, pectoral muscles
    - Neck side bending, neck rotation, neck flexion
    - Strengthen shoulder girdle muscles
      - Shoulder shrugs, pendulum exercises
    - Stretch scalene muscles
    - Trigger point release
- Surgery
  - 1st rib resection for lower-type TOS
  - Scalenectomy for upper-type TOS

Peripheral Arterial Entrapments/Injuries

Quadrilateral Space Syndrome

- Definition: Entrapment of the posterior humeral circumflex artery (with axillary nerve) secondary to fibrous bands/hypertrophied muscles
- Sports/Positions at Risk: Throwing athletes during shoulder abduction & exertional rotation
- Clinical Presentation:
  - Coolness
  - Pallor
  - Hand cyanosis
  - Concomitant neurogenic symptoms (lateral shoulder numbness/deltoid weakness)



Quadrilateral Space Borders

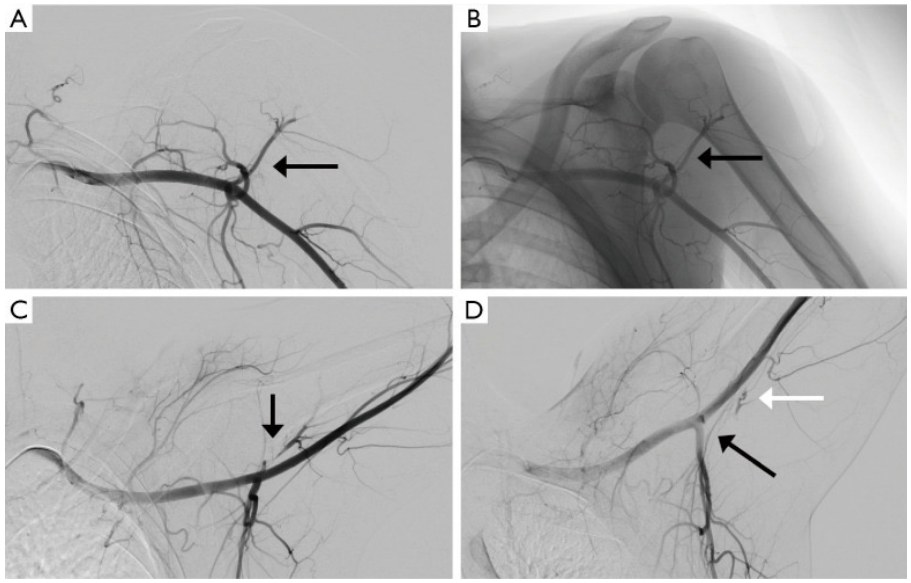
MRI image (left) and pictorial representation of the area enclosed by dotted square (right) showing the structures creating the quadrilateral space, (a) teres minor, (b) long head of the triceps, (c) teres major, (d) surgical neck of the humerus; (blue circle) PCHA, (purple circle) axillary nerve. PCHA, posterior circumflex humeral artery.

Zurkiya O. Quadrilateral space syndrome. *Cardiovasc Diagn Ther*. 2021;11(5):1112-1117. doi:10.21037/cdt-20-147

QSS Angiography

(A) DSA in neutral position showing patent PCHA (arrow);
(B) non-subtracted image from the same injection as panel a, to highlight bony landmarks;
(C) DSA obtained in slightly elevated position shows narrowing of the PCHA (arrow);
(D) DSA obtained in overhead position showing complete occlusion of the PCHA (black arrow) with retrograde filling of a portion of the PCHA (white arrow).

QSS, quadrilateral space syndrome; DSA, digital subtraction angiography; PCHA, posterior circumflex humeral artery.



Zurkiya O. Quadrilateral space syndrome. *Cardiovasc Diagn Ther*. 2021;11(5):1112-1117. doi:10.21037/cdt-20-147

Quadrilateral Space Syndrome

- Diagnosis:
  - Angiography
  - CTA
  - MRA
- Treatment:
  - Thrombolysis
  - Surgical thrombectomy
  - Anticoagulation post-procedure x 3 months
- Return to Play in Sports: Surgical healing, off anticoagulation for contact sports
  - Early physical therapy to prevent new adhesions
  - Avoid Shoulder hyperextension/abduction/ER for >4 weeks (can start pendulum exercises immediately)
  - Continue to sport specific exercise >6 weeks post-op

Hypothenar Hammer Syndrome

- Definition: Trauma to the ulnar artery in region of Guyon's canal (against hook of Hamate) leading to constriction, thickening, thrombosis, possible aneurysm
- Sports/Positions at Risk: Judo, karate, lacrosse, manual laborers; also baseball, badminton, biking, golf, tennis, handball, break dancing, hockey
  - Male:Female 9:1
  - 40-50 yo
- Clinical Presentation (unilateral; caused by distal ischemia):
  - Cold intolerance
  - Pain in the palm or ulnar digits
  - Finger claudication
  - Signs include hypothenar callus/tenderness, pulsatile mass (aneurysm)
  - Allen Test = attempt to assess patency of superficial palmar arch

Hypothenar Hammer Syndrome

Diagnosis:

- Doppler US (Digital brachial index <0.7 necessitates reconstruction)
- CTA (can see vascular anatomy and evaluate for hamate fracture)
- MRA (visualize ulnar artery trauma from soft tissue structures)
- Angiography (gold standard)

Treatment:

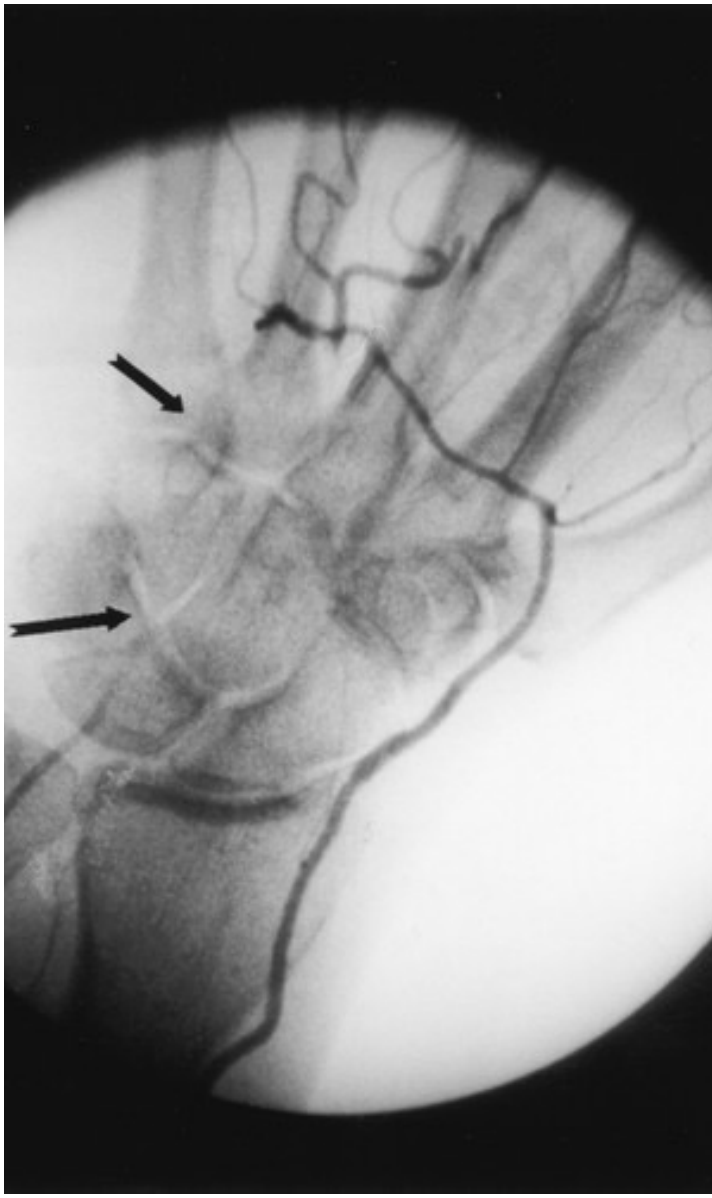
- Activity modification
- Increased padding of hypothenar area
- NHP-CCB
- Vasolytic agents or Pentoxifylline
- Surgical:
  - excision of thrombosed segment and artery ligation/reconstruction

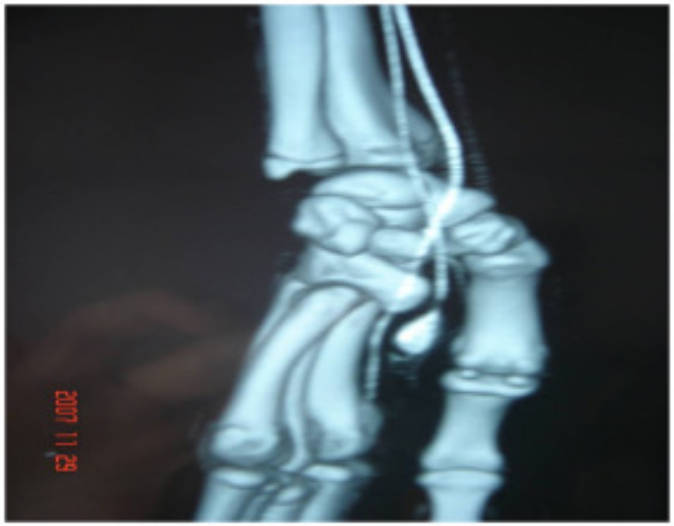
Return to Play in Sports: depends on treatment success, if on anticoagulation, avoid contact sports

Hypothenar Hammer Syndrome

Photograph showing subtotal occlusion of right ulnar artery with poor filling of digital arteries supplying third, fourth, and fifth fingers.

Ravindra Sharma. Circulation. Hypothenar Hammer Syndrome, Volume: 105, Issue: 13, Pages: 1615-1616, DOI: (10.1161/hc1302.104526)





Hypothenar Hammer Syndrome

- Figure 1: Showing extent of palmar aneurysm.
- Figure 2: X-ray films of the hand.
- Figure 3: Digitalized angiography.
- Figure 4: Intraoperative photograph shows the ulnar artery aneurysms.

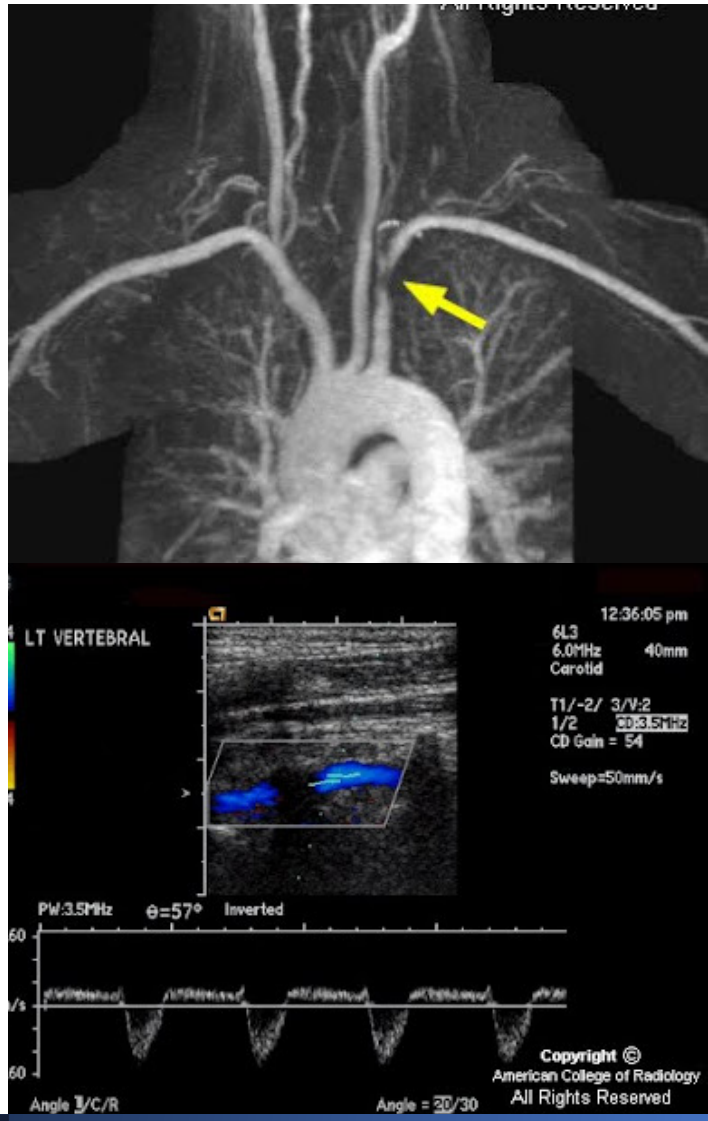
Jmaà HB, Cherif T, Jmal H, Zribi W, Masmoudi S, et al. (2016) Hypothenar Hammer Syndrome Caused by Playing Soccer Goalie. Int J Clin Med Imaging 3: 503. doi:10.4172/2153-0769.1000503

Subclavian Steal Syndrome

- Definition: Proximal stenosis/occlusion of subclavian artery leading to reversal of blood flow down ipsilateral vertebral artery at expense of vertebrobasilar circulation
- Sports/Positions at Risk: similar to Vascular TOS (cricket bowlers, baseball pitchers/catchers)
  - In non-athletes, atherosclerosis most common cause)
- Clinical Presentation:
  - Vertebrobasilar Insufficiency (presyncope/syncope, CNS deficits)
  - Subclavian insufficiency (arm weakness, paresthesia, exertional claudication)

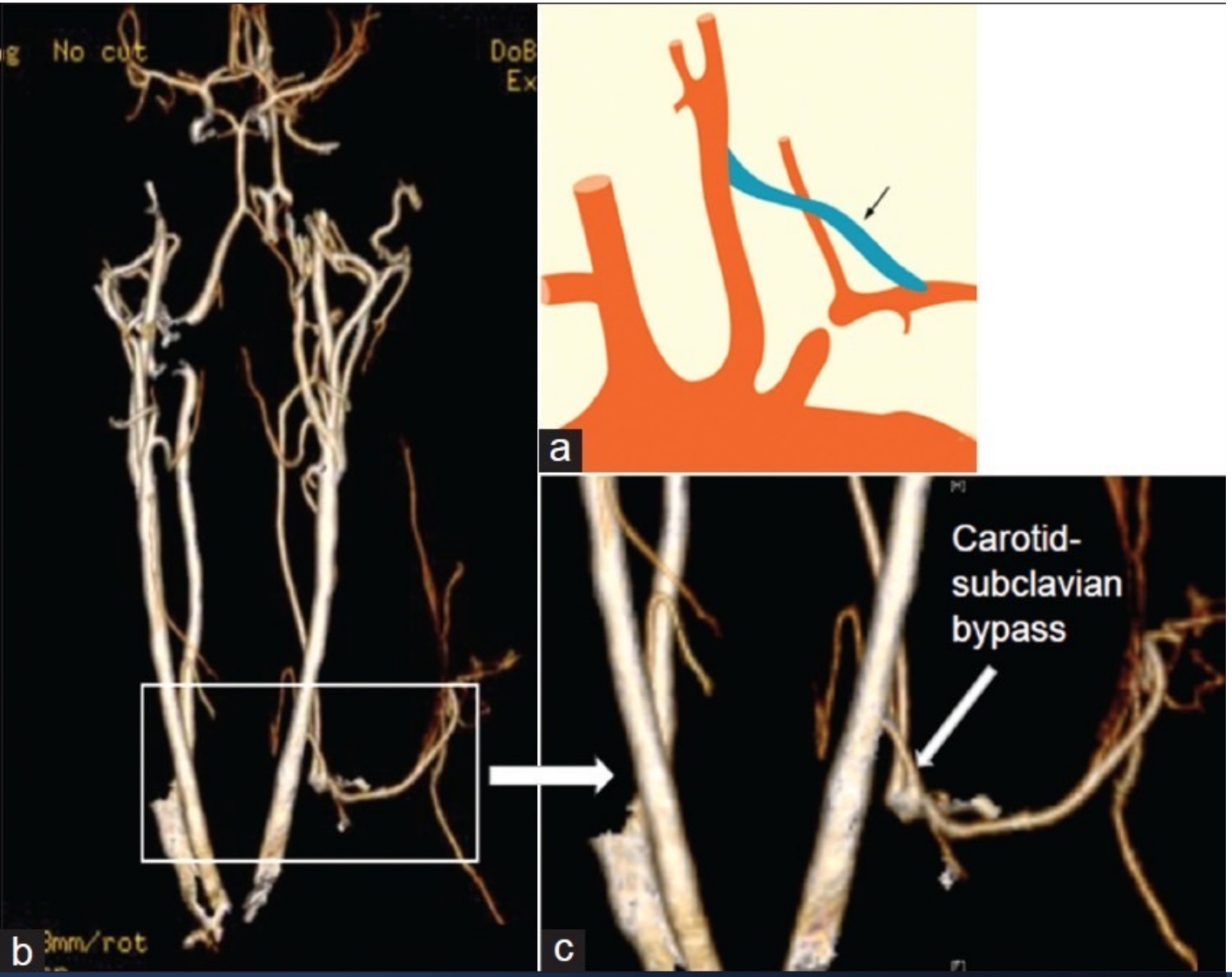
Subclavian Steal Syndrome Imaging

- Doppler evaluation demonstrates reversal of flow in the left vertebral artery
- 3D MIP reconstruction of a contrast-enhanced MRA of the aorta and great vessels demonstrates a focal left subclavian artery stenosis



Subclavian Steal Syndrome

- Diagnosis:
  - Clinical: Vigorous exercise of affected arm causing symptoms or loss of radial pulse
  - Blood pressure difference >20 mmHG between arms, consider ABI (pre-/post-exertion)
  - Subclavian bruit
  - Imaging:
    - Duplex U/S (peak systolic velocity > 240cm/sec in subclavian artery)
    - MRA (accurate, can also aid in evaluation of intracranial cerebrovascular circulation as well as extracranial vessels)
    - CTA (indicated in patients with abnormal findings on duplex ultrasound)
    - Digital Subtraction Angiography (if stenting has been decided)
- Treatment:
  - Open Surgical Bypass (extra-anatomic revascularization (i.e. carotid transposition, carotid-subclavian bypass)
  - Endovascular Stenting (short proximal stenosis/occlusion)
  - High risk patients: consider antiplatelet therapy or anticoagulation (restriction from contact sports)



SSS Post-Bypass Imaging

(a) Diagram demonstrating an idealized carotid-subclavian bypass.

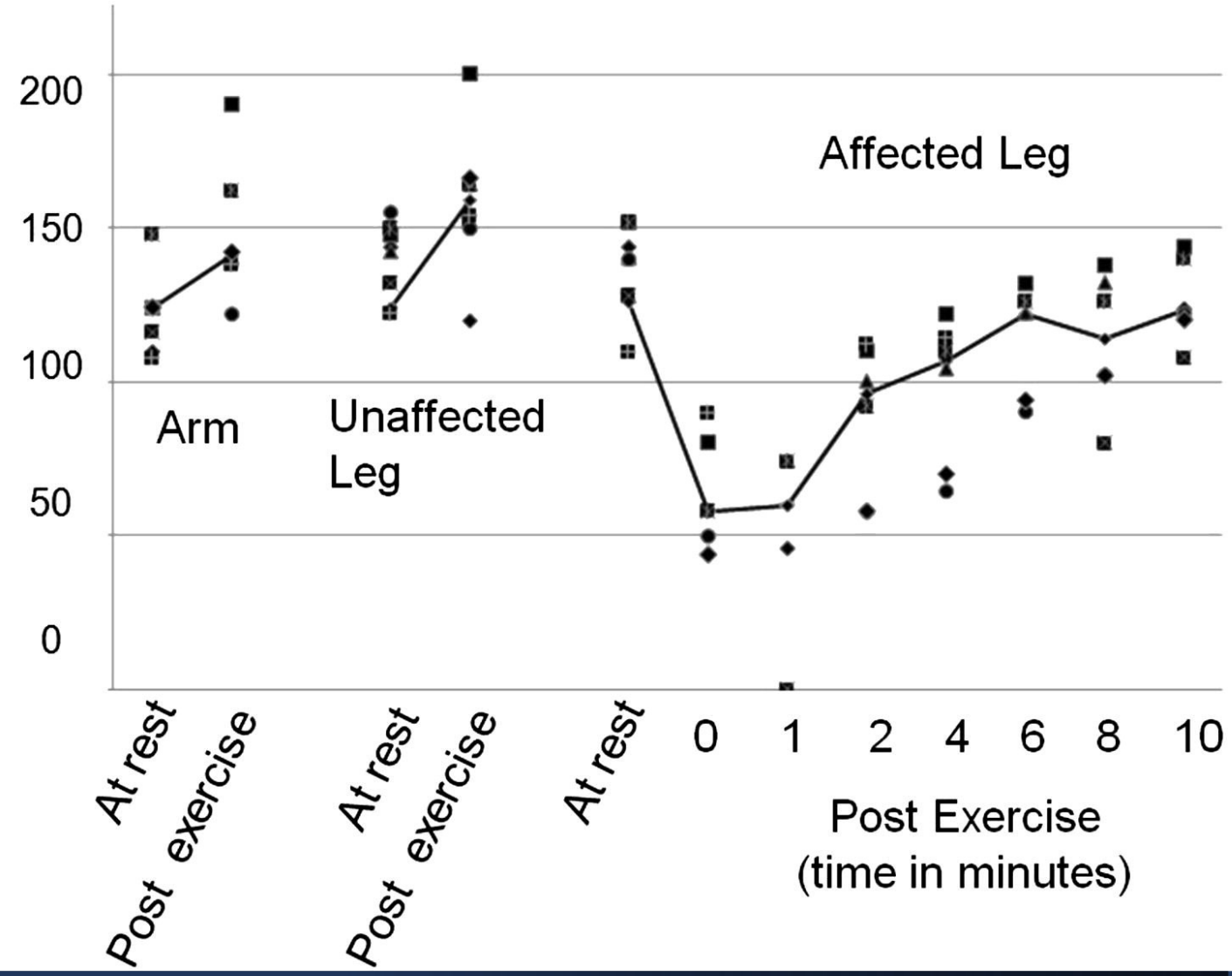
(b) Head/neck CT angiogram of the patient showing 2 common carotids.

(c) Expanded view of lower right segment demonstrating left carotid-left subclavian bypass.

Chowning S, Stowell D, Ponniah U. Carotid-subclavian bypass for subclavian steal syndrome following coarctation repair in infancy. Ann Pediatr Card 2012;5:207-9

External Iliac Artery Endofibrosis (EIAE)

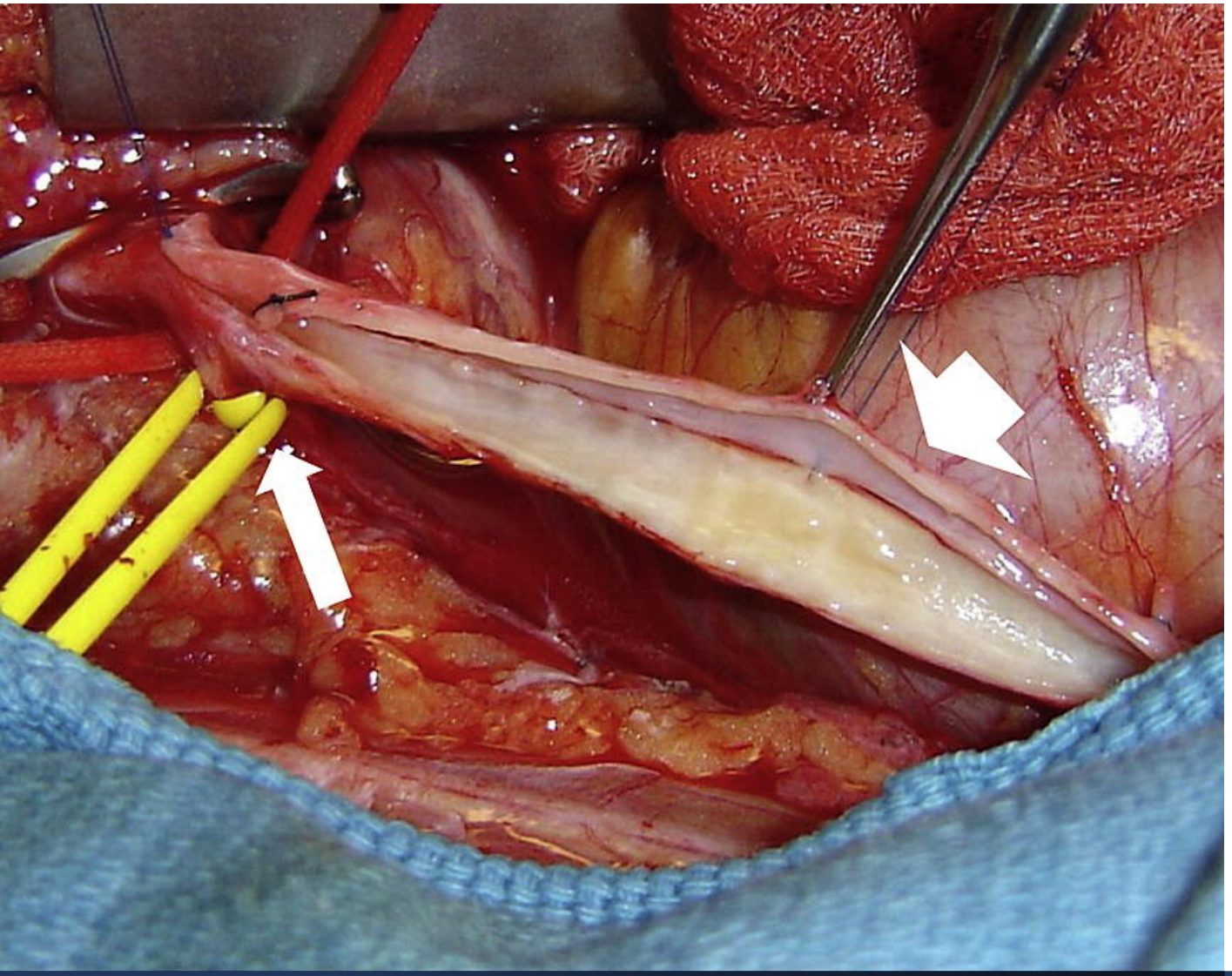
- Etiology:
  - Mechanical stress (repetitive hip flexion) coupled with shear stress from increased blood flow during exercise
  - May get arterial kinking/compression from hypertrophied psoas muscle/inguinal ligament
  - Leads to smooth muscle hyperplasia → collagen deposition → arterial stenosis
  - NO ASSOCIATION WITH ATHEROSCLEROSIS
- Sports/Positions at Risk: Elite cyclist (20-30yo) with increased proportional risk based on distance travel; also can affect cross-country skiers, runners, weightlifters, speed skaters, rugby
  - Mostly men, 7% female
- Clinical Presentation:
  - Unilateral limb pain with lack of power during intense exercise
  - Subjective Thigh Edema
  - 15% bilateral
  - Physical exam at rest, normal!



EIAE Exercise ABIs

Graph depicts measured blood pressures during the exercise treadmill examination of female athletes diagnosed with exercise-induced external iliac artery endofibrosis (EIAE). In the postexercise period, blood pressures are measured until they normalize. The *solid line* is the median of these blood pressures, demonstrating the overall trend.

Shalhub S, Zierler RE, Smith W, Olmsted K, Clowes AW. Vasospasm as a cause for claudication in athletes with external iliac artery endofibrosis. J Vasc Surg. 2013 Jul;58(1):105-11. doi: 10.1016/j.jvs.2012.12.060. Epub 2013 Mar 29. PMID: 23541546.



EIAE Surgical Intervention

Intraoperative photograph shows great saphenous vein patch angioplasty in a patient with external iliac artery endofibrosis (EIAE). The angioplasty spans the entire length of the external iliac artery (EIA) (*short white arrow*). The *long arrow* shows the hypogastric artery.

Shalhub S, Zierler RE, Smith W, Olmsted K, Clowes AW. Vasospasm as a cause for claudication in athletes with external iliac artery endofibrosis. J Vasc Surg. 2013 Jul;58(1):105-11. doi: 10.1016/j.jvs.2012.12.060. Epub 2013 Mar 29. PMID: 23541546.

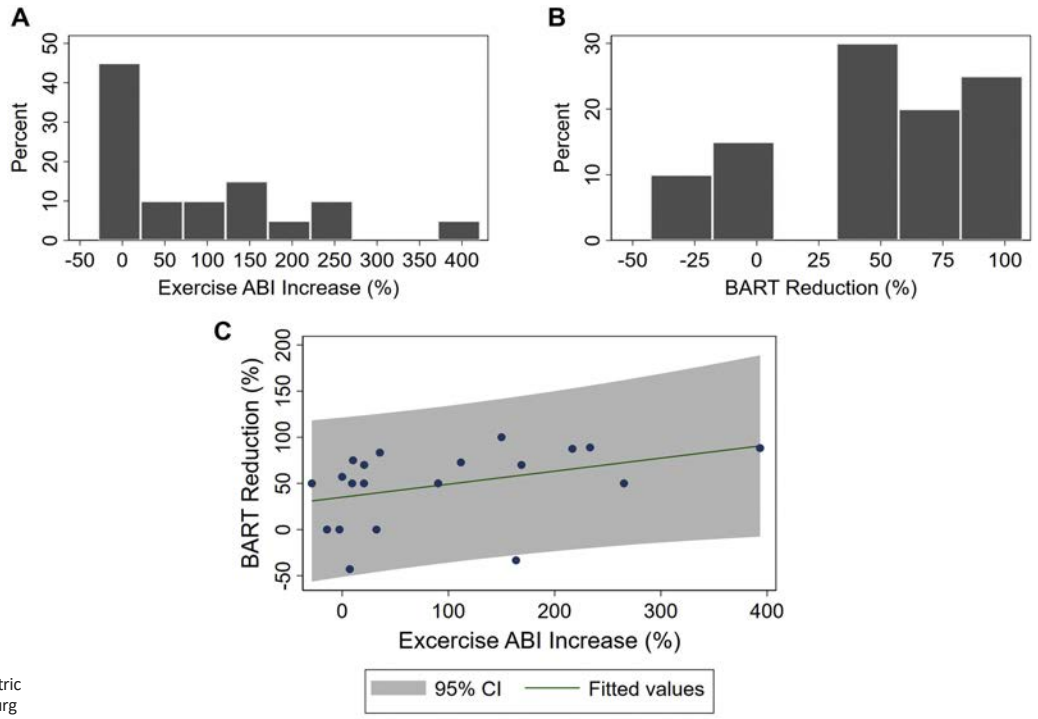
External Iliac Artery Endofibrosis (EIAE)

- Diagnosis:
  - ABI (pre-/post-exercise) or duplex US
  - MRA (can distinguish kinking/luminal stenosis)
  - Angiography for surgical staging
- Treatment: (Little consensus)
  - Nonoperative treatment (activity modification) may help but not for elite athletes
  - Medications do not work (statins, anticoagulation, antiplatelets)
  - Percutaneous angiography with stenting may work (increased risk of arterial dissection)
  - Iliac endarterectomy/endofibrinectomy with patch angioplasty & vein grafts
- Return to Play in Sports: 3 months after surgical intervention

Bicycle Exercise ABI Recovery Time (BART) for EIAE

- A, Histogram of postoperative percentage of change in exercise ankle brachial index (ABI) compared with preoperative values.
- B, Histogram of postoperative percentage of change in bicycle exercise ABI recovery time (BART) compared with preoperatively.
- C, Scatter plot of relative changes in exercise ABI against changes in BARTs.

- *CI,* Confidence interval.



Tran K, Dossabhoy SS, Sorondo S, Lee JT. Bicycle exercise ankle brachial index recovery time as a novel metric for evaluating the hemodynamic significance of external iliac endofibrosis in competitive cyclists. J Vasc Surg Cases Innov Tech. 2021 Sep 29;7(4):681-685. doi: 10.1016/j.jvscit.2021.08.013. PMID: 34746530; PMCID: PMC8556481.

Popliteal Artery Entrapment

- Congenital Type (I-V): fibromuscular anomalies in the popliteal fossa causing extrinsic compression of the neurovascular bundle
- Functional Type (VI): physiologic impingement of popliteal artery secondary to increased blood flow during exercising and muscle hypertrophy of gastroc-soleus complex, plantaris, or semimembranosus
  - 15:1 male: female, young healthy athlete
- Clinical Presentation (usually not at rest):
  - Calf claudication, paresthesia, exertional calf muscle fatigue
  - Usually unilateral (25% bilateral)
  - Decreased tibial pulse with active ankle plantarflexion (watch for false positive)

Popliteal Artery Entrapment Types

Type 1: Aberrant medial deviation of the popliteal artery around a normal medial gastrocnemius;

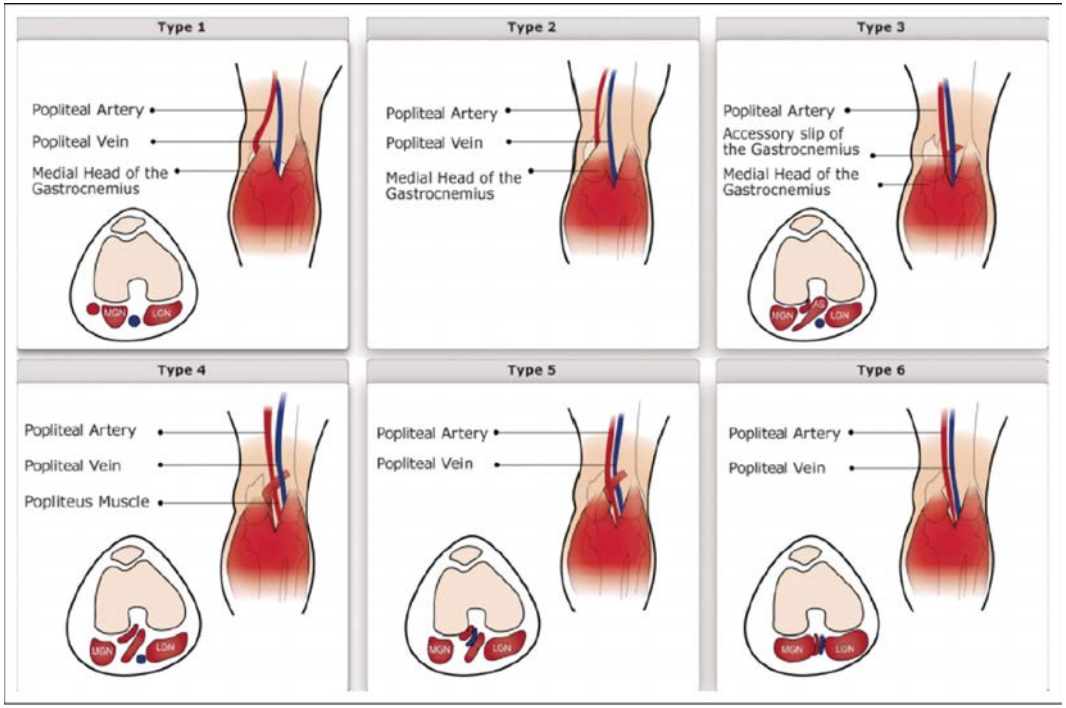
Type 2: popliteal artery is displaced medially by abnormal gastrocnemius that inserts laterally on the femur;

Type 3: normally positioned popliteal artery entrapped by aberrant accessory slip from the medial head of the gastrocnemius;

Type 4: popliteal artery is entrapped by its location deep in the popliteus muscle or beneath fibrous bands in the popliteal fossa;

Type 5: popliteal artery and vein are both entrapped;

Type 6: normally positioned popliteal artery is entrapped by a normally positioned hypertrophic gastrocnemius muscle



Eliahou R, Sosna J, Bloom AI: Between a rock and a hard place: Clinical and imaging features of vascular compression syndromes. Radiographics 2012;32:E33-E49

Popliteal Artery Entrapment

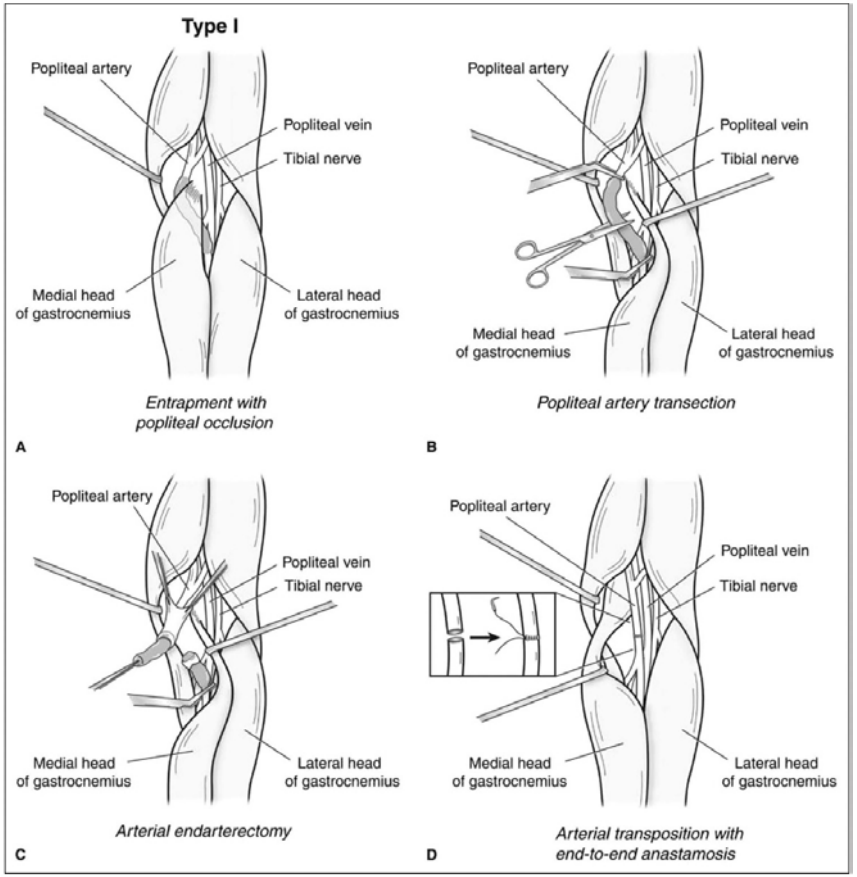
Diagnosis:

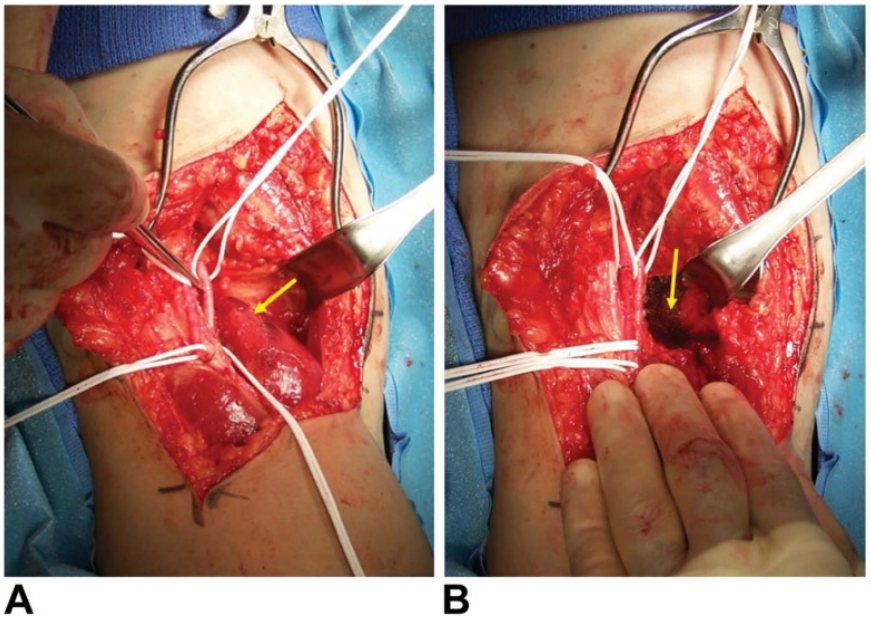
- Post exertional ABIs
- Arterial Doppler CT
- MRA (modality of choice) – consider post-exertional and pre-exertional

Treatment:

- Functional: relative rest, compression stockings, stretching, lower-limb elevation
- Congenital/Refractory: surgical exploration for release of fascial/myotendinous band compressing the artery (may include resection of medial head of gastrocnemius)

Popliteal Artery Entrapment Intervention





A, Intraoperative photograph showing the popliteal fossa of a left knee from a posterior approach demonstrating aberrant medial head (arrow) of gastrocnemius muscle crossing the popliteal artery (forceps) and originating from the lateral femoral condyle (type 2).

B, Partial excision has been done to the proximal aspect of the medial head (arrow) to decrease pressure on the artery.

Miller TL, Backs R, Vaccaro PS. Popliteal Artery Entrapment Syndrome: A Diagnostic and Treatment Enigma for Orthopaedic Surgeons. J Am Acad Orthop Surg. 2021 Sep 1;29(17):e834-e845. doi: 10.5435/JAAOS-D-21-00151. PMID: 34106091.

Other Peripheral Vascular Injuries

Chronic Digital Ischemia

- Chronic Compression/Microtrauma to hand/digits
- Sports at Risk: Baseball (pitchers/catchers), Handball players
- Symptoms:
  - Cold Intolerance
  - Pallor/Pain
- Treatment:
  - Increased padding during causative activities
  - Pharmacological agents
  - Surgical Exploration

Axial Vascular Injuries

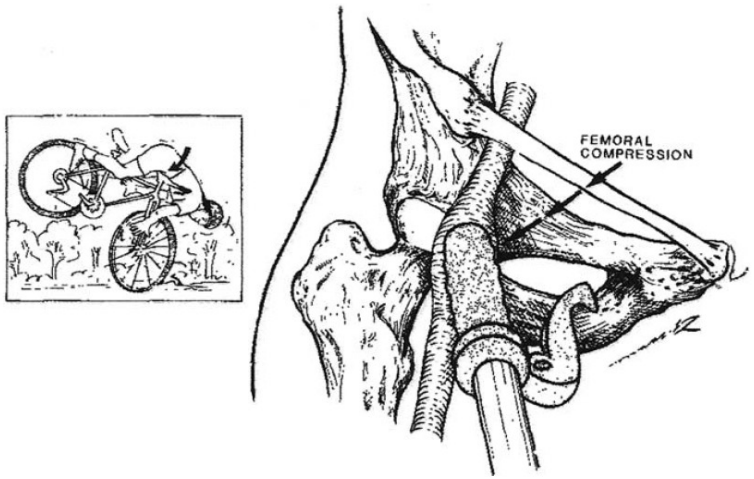
Celiac Artery Compression Syndrome "Median arcuate ligament syndrome"

- Rare and controversial cause of chronic exertional abdominal pain, usually diagnosis of exclusion
- External compression of celiac and SMA by median arcuate ligament of diaphragm with multiple "proposed mechanisms" for pain
- No clear diagnostic criteria nor imaging modality of choice
  - May use angiography or high duplex ultrasound
- Risk factors in Sports: Young, recent weight loss, female > male
- Clinical Pearls: loud systolic bruit in epigastrium

Traumatic Vascular Injuries

Traumatic Arterial Injuries

- External Iliac Artery/Common Femoral Artery
  - 0.4-7.0% all vascular injuries; blunt
  - Sports: Bicycle Handlebar Trauma
  - Present hours to months after inciting event
- Popliteal Artery
  - 30-50% of all knee dislocations
  - Common in contact sports
- Anterior Tibial Artery
  - Creates a pseudoaneurysm
  - High-velocity blunt trauma OR severe hyper plantarflexion with inversion ankle injury



Acute Compartment Syndrome

- Blunt Trauma in Sports (handball, soccer, rugby, cycling, kickboxing, lacrosse, baseball, football)
- Anterior compartment most commonly affected
- Measurement of compartment pressures is controversial because of the wide range of values thought to be diagnostic (normal is 0–8 mm Hg; abnormal is anywhere from > 30 to 55 mm Hg), which contributes to the low sensitivity and specificity of intercompartmental pressures.
- Magnetic resonance imaging (MRI) can also be used in the diagnostic workup as it can show edema, hemorrhage, hematoma, vessel injury, and inflammation.
- Liberal use of fasciotomies when the history and physical examination findings are suggestive of compartment syndrome

Pearls for this Talk

- Athletic vascular injuries require a high index of suspicion
- Diagnostic modalities will need to be done after exercise most of the time
- Recognize sport-based risk
- Work with your sports medicine counterparts to determine return to play
- Be available and be accessible – Sports Medicine world is on 24/7/365

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Title: Vascular Injuries in Sports Medicine

Presenter:
Rehal Bhojani, MD, FAAFP CAQSM
Assistant Professor
Fellowship Director, Sports Medicine
McGovern Medical School at UTHealth

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