

# Ultrasound Evaluation of Peripheral Nerves

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## Disclosures

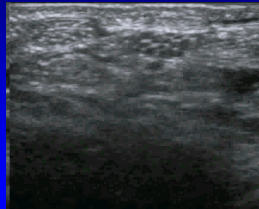
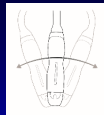
- Book Royalties: Elsevier
- Consultant: Bioclinica
- Medical Director: POCUSPRO
- Not relevant to this talk

Syllabus on line and other educational material:  
[www.jacobsonmskus.com](http://www.jacobsonmskus.com)

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## Normal Peripheral Nerve

- Ultrasound appearance:
  - Hypoechoic nerve fascicles
  - Hyperechoic connective tissue
- Transverse:
  - Honeycomb appearance



Silvestri et al. Radiology 1995; 197:291

Median Nerve

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## Outline

- Entrapment syndromes
- Nerve trauma and transection neuromas
- Peripheral nerve sheath tumors

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## Nerve Compression

- Experimental model (rat, sciatic nv):
  - Compression causes ischemia
  - First pathologic change: edema
    - Correlated with severity of axonal injury
  - Mild compression: demyelination
  - Severe compression: axonal damage

Powell, Laboratory Investigation 1986; 55:91

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## Nerve Entrapment

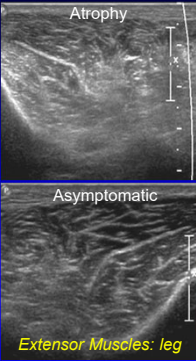
- US findings:
  - Nerve enlargement proximal to entrapment
    - Best appreciated transverse to nerve
  - Abnormally hypoechoic
    - Especially the connective tissue layers
  - Variable enlargement or flattening at entrapment site

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### Denervation

- Edema: hyperechoic
- Fatty degeneration:
  - Hyperechoic
  - Echogenic interfaces
- Atrophy:
  - Hyperechoic with decreased muscle size
- Compare to other side!

J Ultrasound Med 1993; 2:73



Extensor Muscles: leg

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### Nerve Entrapment Syndromes


- Median:
  - Carpal tunnel syndrome
  - Pronator teres syndrome
- Ulnar:
  - Ulnar tunnel syndrome
  - Cubital tunnel syndrome

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### Carpal Tunnel Syndrome:

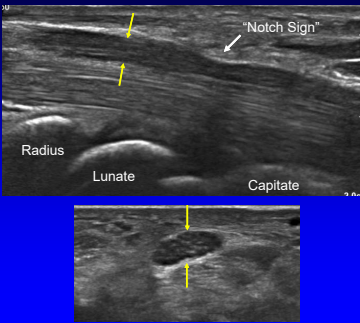
- Proximal median nerve swelling
  - Area: circumferential trace
  - Normal:  $< 9 \text{ mm}^2$
  - Borderline:  $9 - 12 \text{ mm}^2$
  - Abnormal:  $> 12 \text{ mm}^2$ 
    - $12.8 \text{ mm}^2$  = moderate (83% sens, 95% spec)
    - $14.0 \text{ mm}^2$  = severe (77% sens, 100% spec)

Klauser AS et al. Sem Musculoskel Rad 2010; 14:487  
Ooi et al. Skeletal Radiol 2014; 43:1387



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### Carpal Tunnel Syndrome

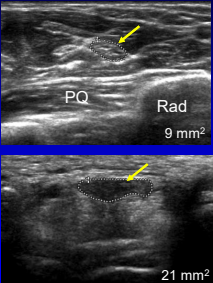


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### Carpal Tunnel Syndrome

- Compare areas:
  - Proximal: pronator quadratus
  - Distal: carpal tunnel
- $\geq 2 \text{ mm}^2$  = carpal tunnel syndrome
- 99% sensitivity
- 100% specificity

Klauser AS. Radiology 2009; 250:171

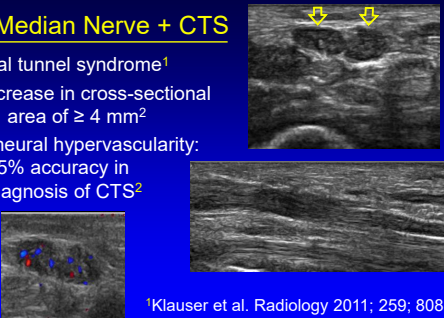


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### Bifid Median Nerve + CTS

- Carpal tunnel syndrome<sup>1</sup>
  - Increase in cross-sectional area of  $\geq 4 \text{ mm}^2$
- Intraneural hypervascularity: 95% accuracy in diagnosis of CTS<sup>2</sup>

<sup>1</sup>Klauser et al. Radiology 2011; 259: 808  
<sup>2</sup>Mallouhi et al. AJR 2006; 186:1240



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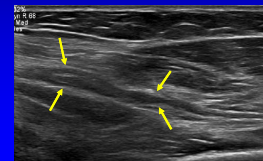
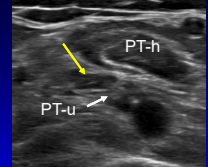
## Nerve Entrapment Syndromes

- Median:
  - Carpal tunnel syndrome
  - Pronator teres syndrome
- Ulnar:
  - Ulnar tunnel syndrome
  - Cubital tunnel syndrome

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## Pronator Teres Syndrome

- Median nerve compression between humeral and ulnar heads
- Trauma, congenital, pronator teres hypertrophy
- Rare
- Forearm pain, numbness, weakness



Jacobson JA, et al. Semin Musculoskeletal Rad 2010; 14:473

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## Nerve Entrapment Syndromes

- Median:
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  - Ulnar tunnel syndrome
  - Cubital tunnel syndrome

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## Guyon's Canal:

- Ulnar tunnel syndrome
  - Ulnar nerve compression
  - Accessory Abductor Digiti Minimi<sup>1</sup>
    - Variant: up to 24% of wrists
- Hypothenar hammer syndrome<sup>2</sup>
  - Trauma
  - Ulnar artery thrombosis + distal emboli

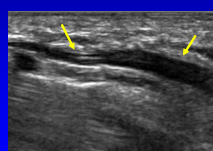
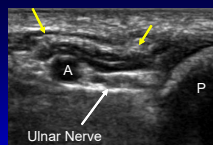
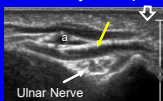


<sup>1</sup>AJR 1999; 172:1397  
<sup>2</sup>J Vasc Surg 1987; 5:838

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## Accessory Abductor Digiti Minimi

- Normal variant: 24%
- Origin: palmaris longus, flexor retinaculum, fascia
- Insertion: abductor digiti minimi
- Superficial to ulnar nerve:
  - Nerve compression
  - Uncommonly interposed



Timins et al. AJR 1999; 172:1397

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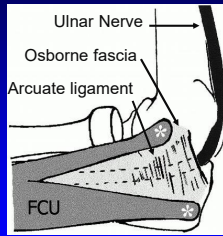
## Nerve Entrapment Syndromes

- Median:
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  - Ulnar tunnel syndrome
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## Ulnar Nerve: anatomy

- Behind medial epicondyle of humerus:
  - Cubital tunnel retinaculum or Osborne fascia
- Distal to epicondyle:
  - True cubital tunnel
  - Between ulnar and humeral heads: flexor carpi ulnaris
  - Under arcuate ligament

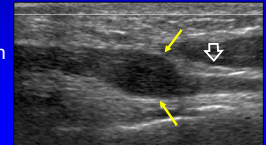
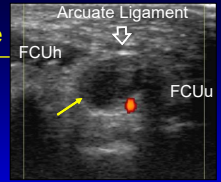


Martinoli, C. et al. Radiographics 2000;20:S199-S217 **RadioGraphics**

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## Ulnar Nerve: cubital tunnel syndrome

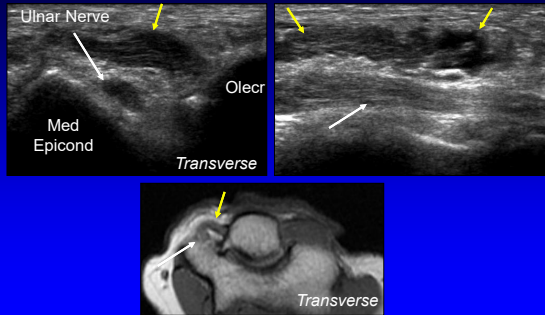
- Hypoechoic and enlarged
  - > 9 mm<sup>2</sup> area<sup>1</sup>
  - 2.8x area compared to proximal<sup>2</sup>
- Mild hypoechoogenicity alone: may be normal
- Causes:
  - Idiopathic, overuse, joint process
  - Anconeus epitrochlearis: compression
    - Normal variant accessory muscle



<sup>1</sup>Thoirs K et al. J Ultrasound Med 2008; 27:737  
<sup>2</sup>Yoon JS et al. Muscle Nerve 2008; 38:1231

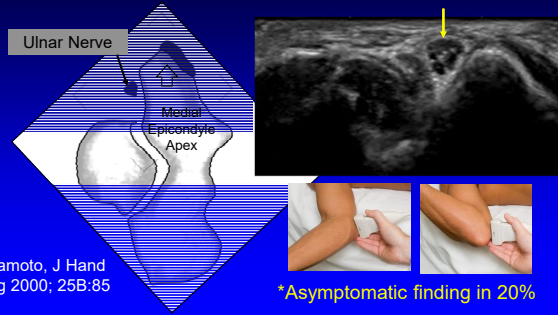
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## Anconeus Epitrochlearis



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## Isolated Ulnar Nerve Dislocation



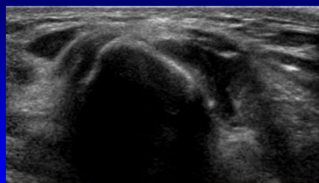
Okamoto, J Hand Surg 2000; 25B:85

\*Asymptomatic finding in 20%

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## Snapping Triceps Syndrome

- Ulnar nerve and medial triceps dislocate over apex of medial epicondyle
- Ulnar nerve and medial triceps remain in contact with each other
- Palpable snap felt through transducer



Jacobson JA et al. Radiology 2001; 220:601

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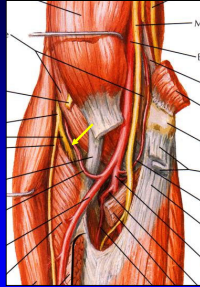
## Nerve Entrapment Syndromes

- Radial:
  - Posterior interosseous nerve syndrome
  - Wartenberg syndrome
    - Superficial sensory branch radial nerve
- Suprascapular: paralabral cyst

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## Radial tunnel

- Radial nerve: deep branch
  - Originates from radial nerve between brachioradialis and brachialis
  - Passes between deep and superficial layers of supinator muscle
  - Exits as posterior interosseous nerve

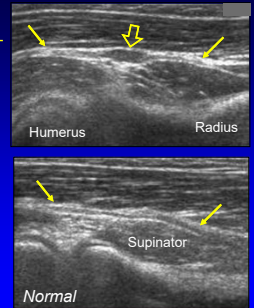


Jacobson JA, et al. Sem Musculoskel Rad 2010; 14:473

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## Radial Nerve: deep branch

- Supinator syndrome:
  - Motor deficits (wrist, finger extension)
  - Abnormal electrodiagnostic studies
  - Nerve enlargement: entrapment
- Radial tunnel syndrome:
  - Pain, no motor deficits, normal EMG
  - Muscle denervation on MRI
  - No nerve enlargement



Ferdinand BD et al. Radiology 2006; 240:161

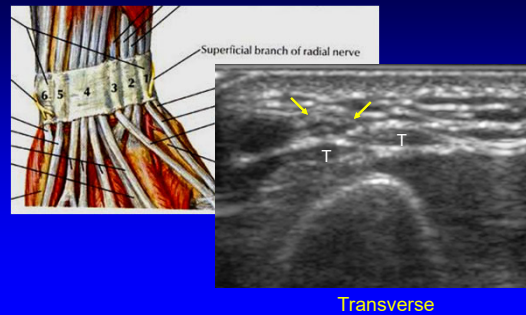
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## Nerve Entrapment Syndromes

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  - Wartenberg syndrome
    - Superficial sensory branch radial nerve
- Suprascapular: paralabral cyst

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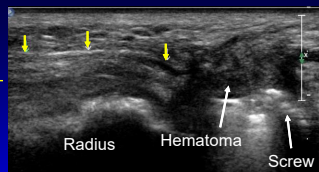
## Wartenberg Syndrome



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## Wartenberg Syndrome

- Superficial branch of radial nerve
  - Sensory branch
  - Crosses over distal radius and first wrist compartment
- Entrapment
- Injury: direct trauma, iatrogenic



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## Nerve Entrapment Syndromes

- Radial:
  - Posterior interosseous nerve syndrome
  - Wartenberg syndrome
    - Superficial sensory branch radial nerve
- Suprascapular: paralabral cyst

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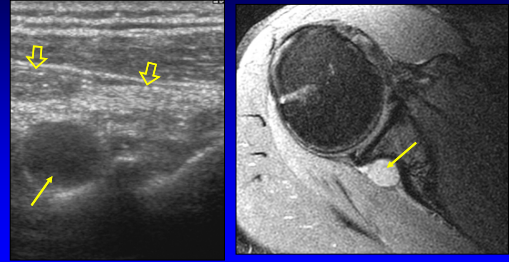
### Paralabral Cyst:

- Most associated with labral tear
- Suprascapular notch:
  - Supraspinatus and infraspinatus atrophy
- Spinoglenoid notch:
  - Infraspinatus atrophy
- US guided aspiration



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### Paralabral Cyst: infraspinatus atrophy



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### Pitfall: suprascapular vein dilation



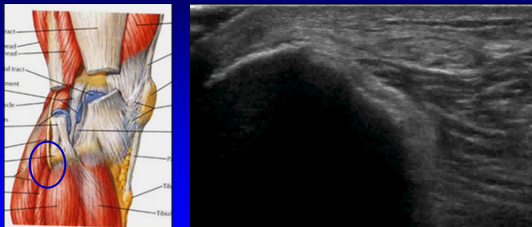
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### Nerve Entrapment Syndromes

- Peroneal (fibular):
  - Common peroneal
  - Superficial peroneal
- Tibial
- Interdigital (Morton neuroma)

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### Common Peroneal Nerve: entrapment



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### Peroneal Intraneural Ganglion

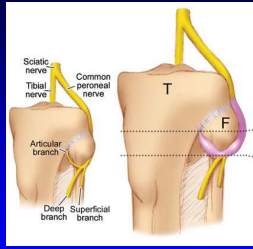
- Pain: knee or peroneal nerve distribution
  - Possible palpable mass, fluctuating course
- 18% of those with foot drop<sup>1</sup>
- No identifiable etiology
  - Weight loss, trauma, leg crossing
- High body mass index<sup>2</sup>
  - Unlike other causes for peroneal neuropathy

<sup>1</sup>Visser et al. Neurology 2006; 67:1473  
<sup>2</sup>Young et al. Neurology 2009; 72:447

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## Peroneal Intranerual Ganglion

- Joint fluid from proximal tibiofibular joint
  - Enters peroneal nerve via articular nerve branches
  - Shown at MR arthrography after exercise
  - Extends proximal via epineurial sheath<sup>1</sup>

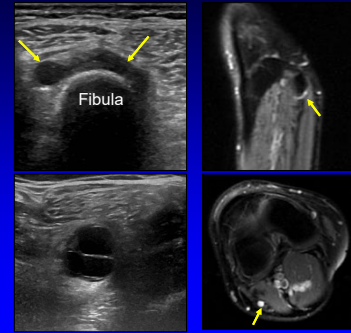


From: Spinner et al. *Skeletal Radiol* 2008;37:1091

Spinner et al. *Clin Anatomy* 2007; 20:826

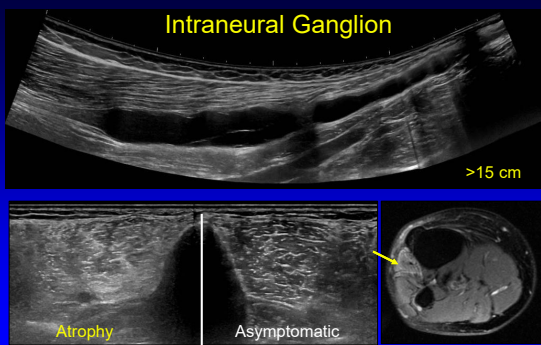
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## Peroneal Intranerual Ganglion



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## Intranerual Ganglion



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## Nerve Entrapment Syndromes

- Peroneal:
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  - Superficial peroneal
- Tibial
- Interdigital (Morton neuroma)

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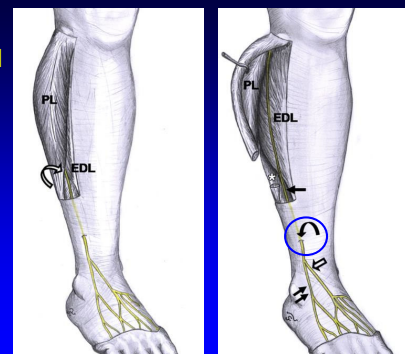
## Superficial Peroneal Nerve

- Pierces crural fascia of leg:
  - 9.2 cm proximal to fibular tip
  - Range: 6 to 16 cm proximal
  - Potential **entrapment site**
- Terminal branches: 6 cm proximal to fibular tip
  - Superficial to inferior extensor retinaculum

Canella, *AJR* 2009; 193:174

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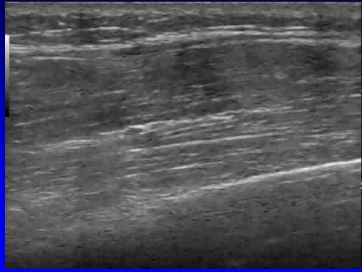
## Superficial Peroneal Nerve



From Canella, *AJR* 2009; 193:174

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**Muscle Hernia (extensor digitorum):  
superficial peroneal nerve entrapment**



Longitudinal

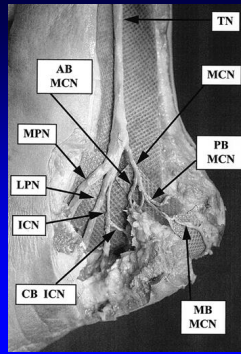
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**Nerve Entrapment Syndromes**

- Peroneal:
  - Common peroneal
  - Superficial peroneal
- Tibial
- Interdigital (Morton neuroma)

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- TN = tibial nerve
- MPN = medial plantar nerve
- LPN: lateral plantar nerve
- MCN = medial calcaneal nerve
- ICN = inferior calcaneal nerve

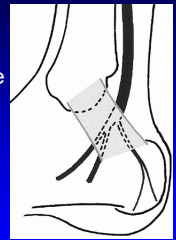


From: Louisa, Surgical and Radiologic Anatomy, 1999; 21:169.

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**Tarsal Tunnel:**

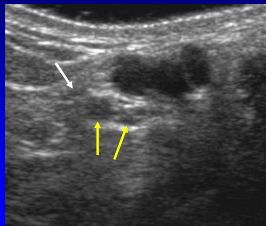
- Osteofibrous tunnel: medial ankle
- Tibial nerve
- Tendons: tibialis posterior, flexor digitorum longus, flexor hallucis longus
- Entrapment: mass, ganglion



From: Martinoli, RadioGraphics 2000; 20:S199

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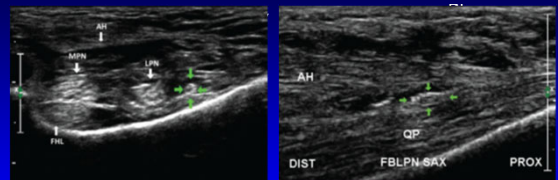
**Tibial Nerve:  
Medial, lateral plantar nerve and  
medial calcaneal nerve branches**



Transverse

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**Inferior Calcaneal (Baxter) Nerve**



Location (green arrows) is plantar to the lateral plantar branch of the tibial nerve (LPN) in between abductor hallucis muscle (AH) and quadratus plantae (QP)

From: Presley JC et al. J Ultrasound Med 2013; 32:1643

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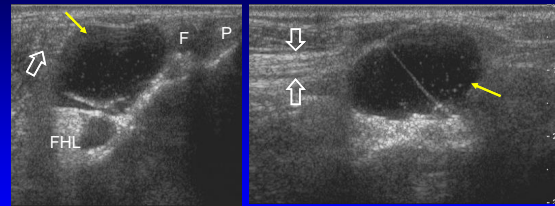
## Tarsal Tunnel Syndrome

- Entrapment of tibial nerve
  - Ganglion cyst: most common
  - Varicose veins, tenosynovitis
  - Trauma, deformity, coalition, idiopathic
- Tibial nerve:
  - May appear normal
  - May be hypoechoic and swollen

Nagaoka, J Ultrasound Med 2005;24:1035

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## Ganglion Cyst: tarsal tunnel syndrome

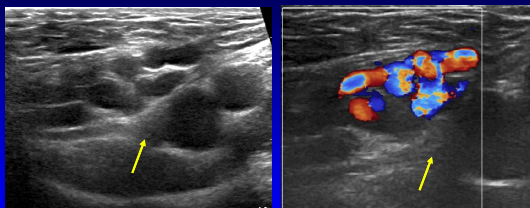


Axial

Sagittal

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## Tarsal Tunnel Syndrome: Varices



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## Nerve Entrapment Syndromes

- Peroneal:
  - Common peroneal
  - Superficial peroneal
- Tibial
- Interdigital (Morton neuroma)

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## Morton Neuroma:

- Digital nerve entrapment
  - Common plantar digital nerve
- Edema, fibrosis, necrosis
- 3<sup>rd</sup> intermetatarsal space > 2<sup>nd</sup>
- Sharp, burning pain from metatarsal head to toes
- Females: pliable foot, high-heeled narrow-toed shoes



From: Martinoli, RadioGraphics 2000; 20:S199

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## Technique:

- Interdigital space
  - Transducer:
    - Plantar
    - Dorsal
  - Normal digital nerve difficult to visualize
  - Correlate with symptoms



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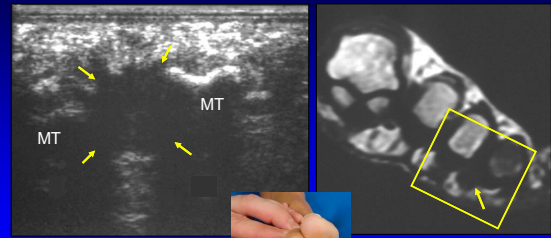
### Morton Neuroma:

- Hypoechoic 5 mm mass
  - Sensitivity: 100% ; Specificity: 83%
- Digital nerve continuity\*
  - Excludes other causes for mass
- Compression:
  - Produces symptoms
  - Bursa (compressible) vs. neuroma (not compressible)

Redd et al. Radiology 1989; 171:415  
 Quinn et al. AJR 2000; 174:1723

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### Morton Neuroma



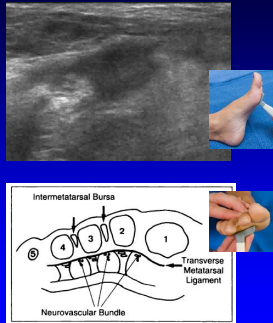
Transverse

Coronal T1w

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### Dynamic Evaluation

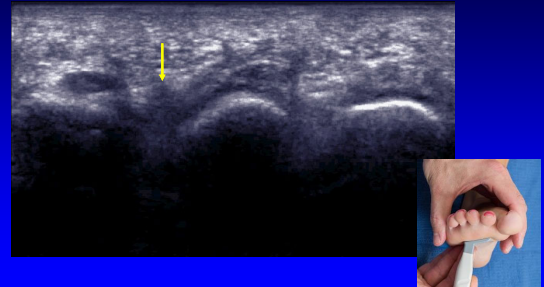
- Compression
  - Between transducer and palpation
  - Bursae (dorsal) compress, neuromas (plantar) do not
- Sonographic Mulder Sign
  - Scan plantar: coronal plane
  - Neuroma displaces: plantar
  - Palpable click



Torriani M et al. AJR 2003; 180:1121  
 Zanetti M et al. Radiology 1997; 203:516

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### Dynamic imaging: Mulder's Maneuver



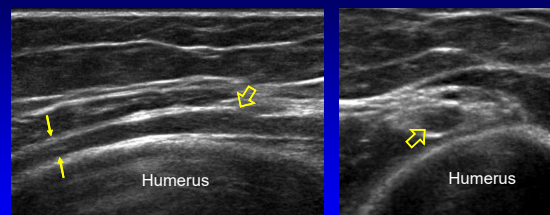
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### Outline

- Entrapment syndromes
- Nerve trauma and transection neuromas
- Peripheral nerve sheath tumors

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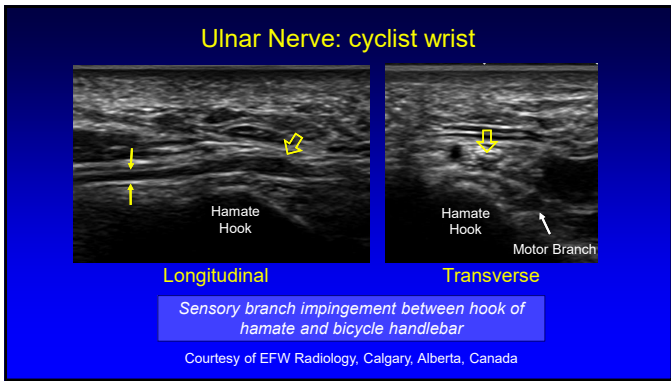
### Radial Nerve Compression: Saturday Night Palsy



Long Axis

Short Axis

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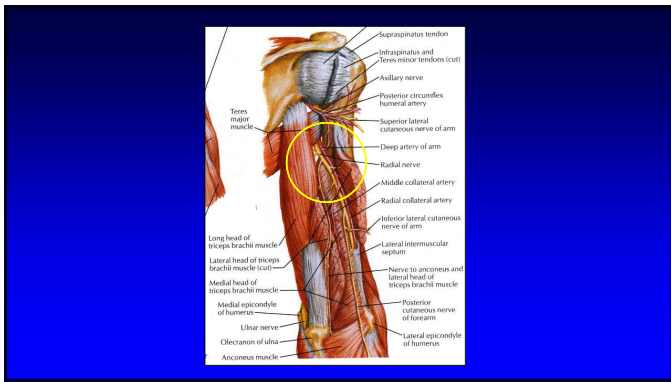
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### Nerve Transection

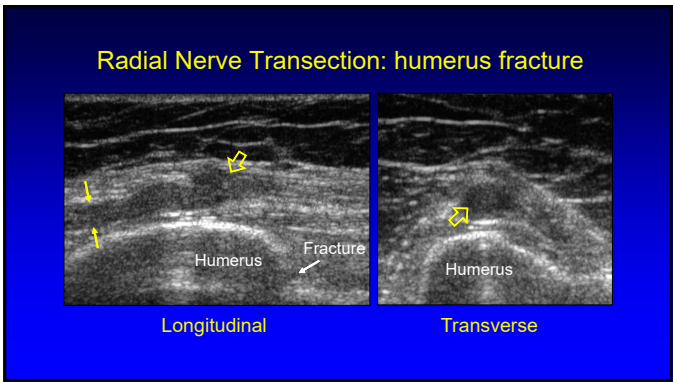
- Hypoechoic and retracted nerve ends if complete
- Neuroma formation:
  - Disorganized and tangled nerve end
  - Normal response to nerve transection
- After amputation:
  - US important to determine if symptomatic

J Clin Ultrasound 1997; 25:85

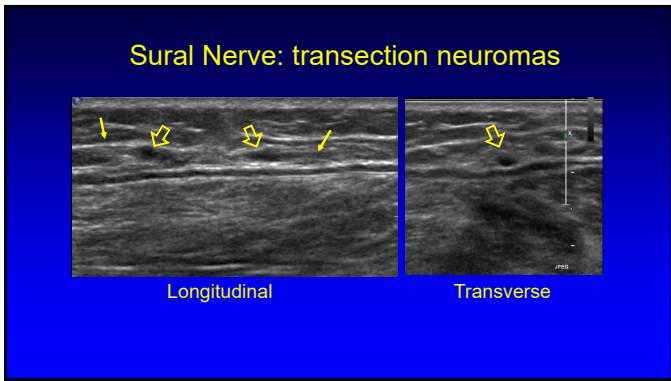
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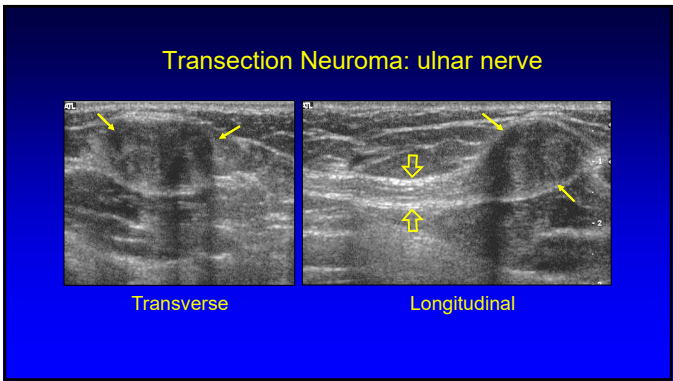
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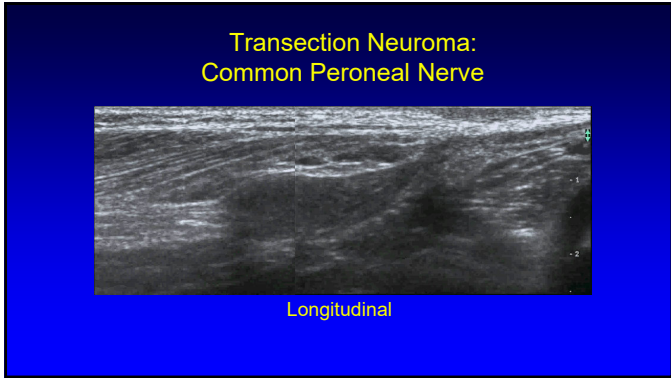
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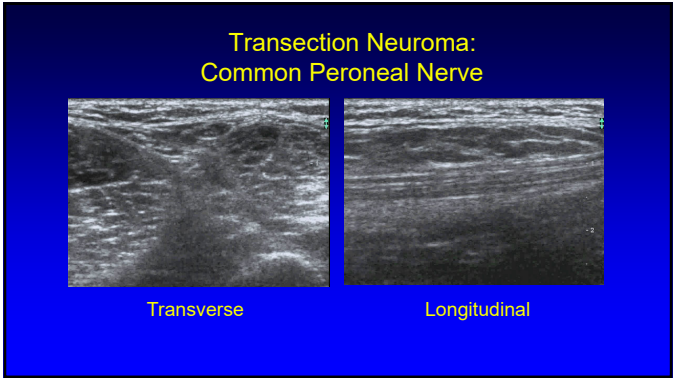
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- ### Outline
- 
- Entrapment syndromes
  - Nerve trauma and transection neuromas
  - **Peripheral nerve sheath tumors**

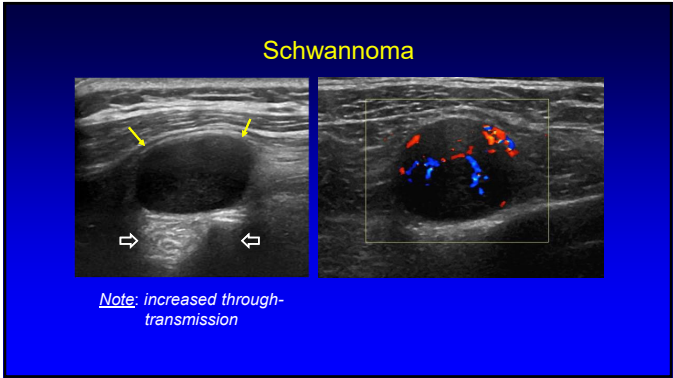
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- ### Peripheral Nerve Sheath Tumor
- 
- **Benign:**
    - Schwannoma (neurilemoma)
      - Solitary, <5 cm, flexor surfaces
    - Neurofibroma: 3 forms
      - Localized: 90%, painless, < 5 cm
      - Diffuse: subcutaneous, 90% associated with NF1
      - Plexiform: associated with neurofibromatosis
  - **Malignant**
- Murphy MD, RadioGraphics 1999; 19:1253

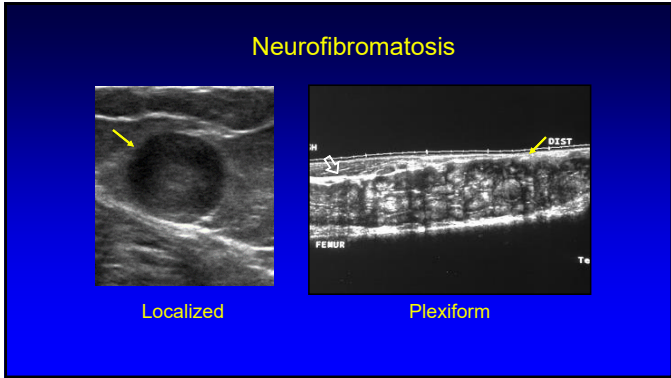
70

- ### Peripheral Nerve Sheath Tumor
- 
- Hypoechoic mass
  - Nerve continuity (most important)
  - Posterior acoustic enhancement
    - Possible pseudocyst appearance
  - Neurofibroma
    - Central, fusiform, lobular, and avascular
  - Schwannoma
    - Eccentric, possible calcifications, cystic
- Ryu JA et al. J Ultrasound Med 2015; 34:2253  
Reynolds D et al. AJR 2004; 182:741

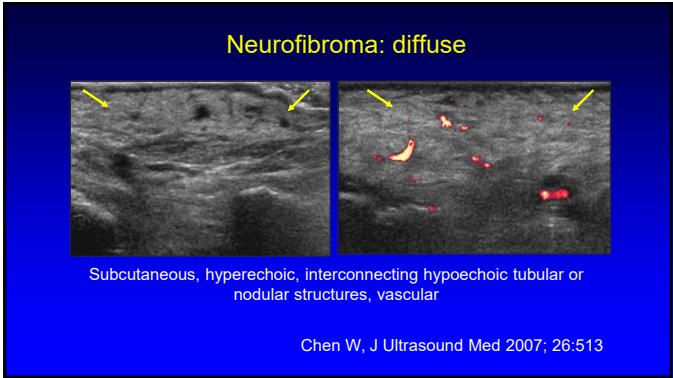
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### Malignant Peripheral Nerve Sheath Tumor

- Hypoechoic
- Heterogeneous
- Variable blood flow
- 25 -70%: NF 1 or prior radiation
- Rapid growth or increased pain

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### Summary: peripheral nerve US

- Evaluate entire limb efficiently
- Easy comparison to contralateral side
- Direct correlation: signs and symptoms
- Complements electrodiagnostic testing
- Dynamic imaging

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Thank you!

Syllabus on line and other educational material:  
[www.jacobsonmskus.com](http://www.jacobsonmskus.com)

Twitter handle: @jjacobsn

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