



## NERVE ENTRAPMENTS:

A Surgeon's Perspective



Elisabet Hagert, Md PhD



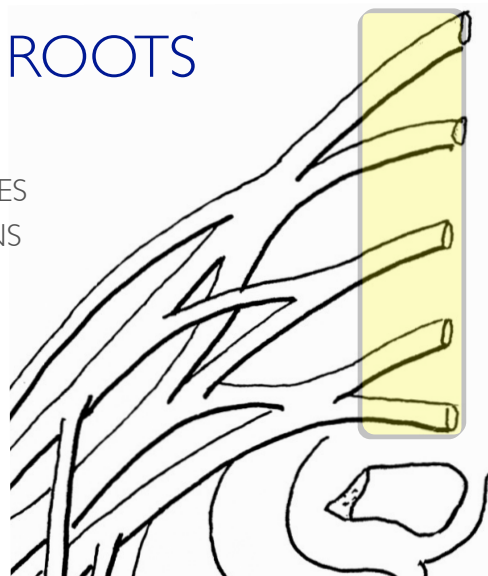
## OUTLINE

- Upper extremity nerve entrapments
- From ROOTS to HAND
- Examination-surgical techniques
- VIDEOS!



## ROOTS

NO "PURE" MUSCLES  
GENERAL MOTIONS  
DERMATOMES



**C5**



SHOULDER ABDUCTION EXT ROTATION

**C6**



SHOULDER ADDUCTION FLEXION

**C7**



ELBOW/WRIST  
EXTENSION

**C8**



WRIST/FINGER  
FLEXION

**T1**



FINGER  
AB/ADDUCTION

MOST UPPER EXTREMITY ENTRAPMENTS ARE

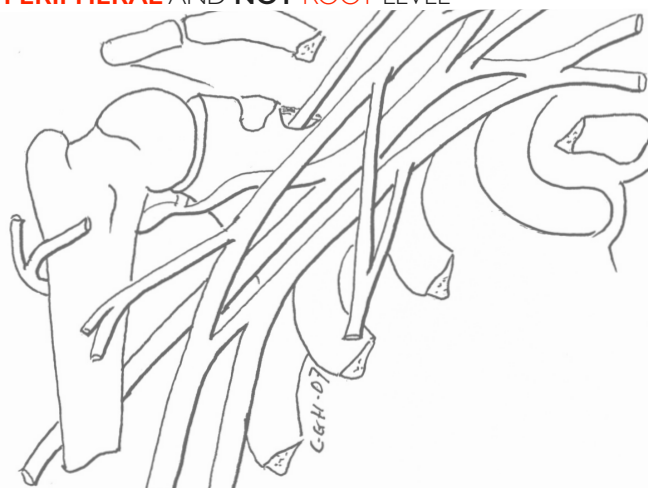
**PERIPHERAL** AND **NOT** ROOT LEVEL

**AXILLARY**  
C5-C6

**RADIAL**  
C5-T1

**MEDIAN**  
C7-T1

**ULNAR**  
C7-T1



## Nerve compressed?

- Peripheral nerve compressions commonly treated by hand surgeons
- Carpal tunnel most common
- Cubital tunnel second most common

HAND FOOT  
SURGERY CENTER



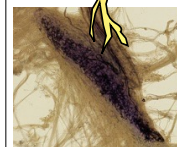
## Nerve compressed?

- Dual-center prospective study, Stockholm - Connecticut 2011-13. >800 operated patients
- Nerve compression #1: carpal tunnel - 50%
- Nerve compression #2: pronator syndrome - 31%
- Nerve compression #3: radial tunnel - 9%
- Nerve compression #4: cubital tunnel - 8.8%



## NORMAL NERVE

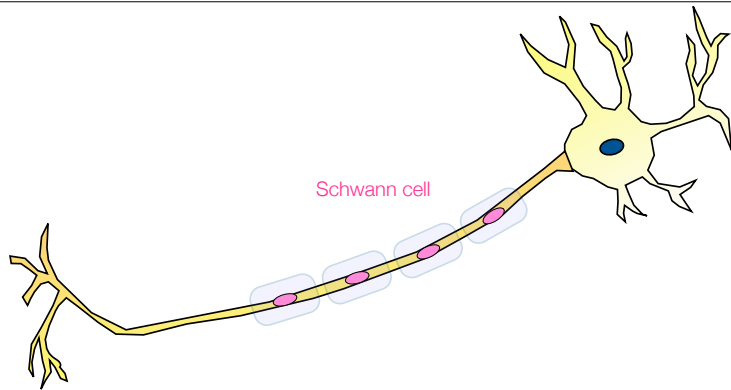
Axon terminal



Ruffini

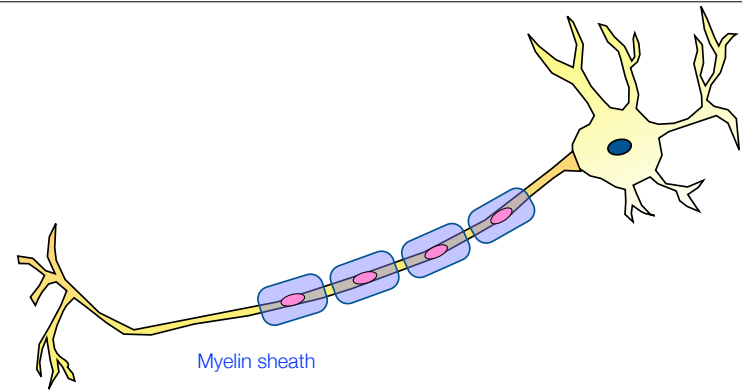
AXON

Nerve fiber - extends into the peripheral target  
Endfeet - neurotransmitters



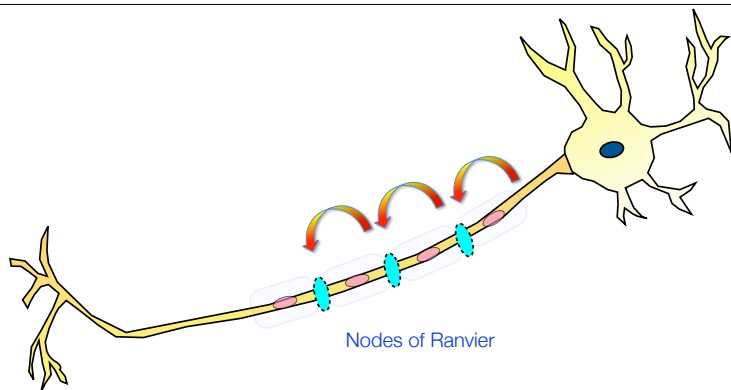
## SCHWANN CELL

Primary supporting cell of the nerve fiber - scaffold



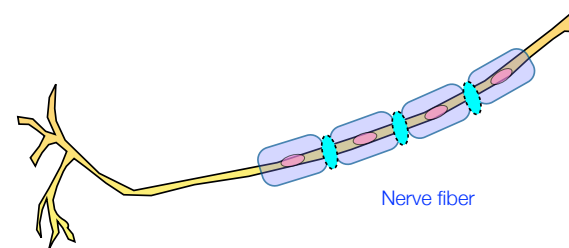
## MYELIN SHEATH

Essential for nerve conduction and normal nerve function  
Unmyelinated fibers - C-fibers



## NODES OF RANVIER

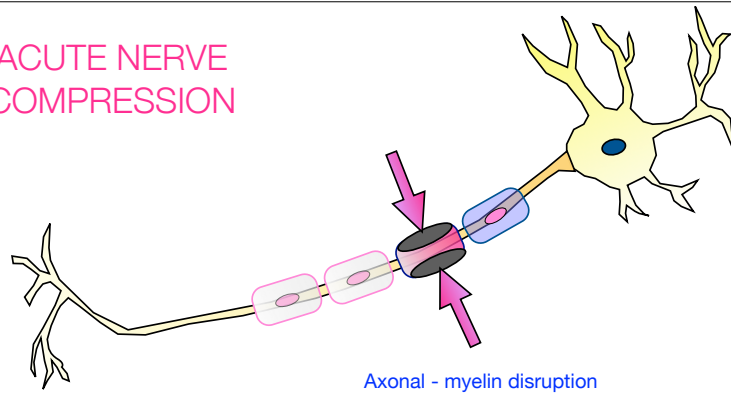
Gaps in myelin sheath - high density of ion channels  
Enhances rapid nerve conduction



## ORGANIZATION OF THE PERIPHERAL NERVE

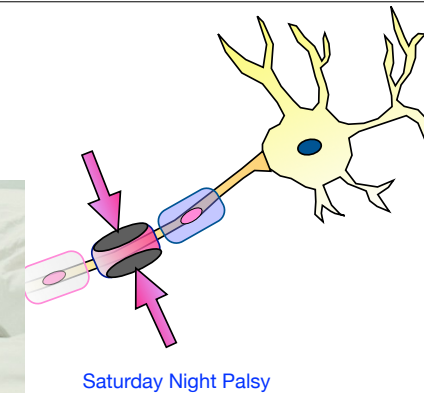
Nerve fiber = axon, Schwann cell, myelin sheath, nodes of Ranvier

## ACUTE NERVE COMPRESSION



### AXONOTMESIS

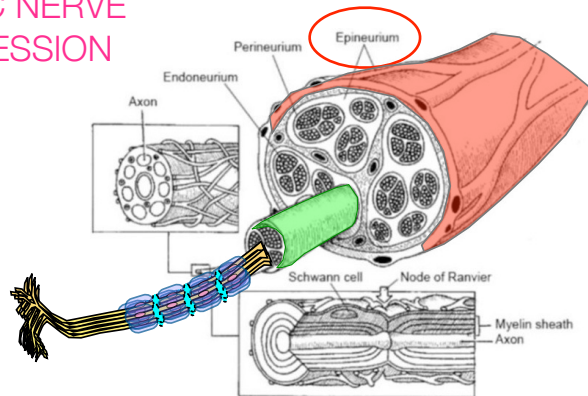
Sensory/motor functional loss  
Recovery 1 mm/day



### AXONOTMESIS

Sensory/motor functional loss  
Recovery 1 mm/day

## CHRONIC NERVE COMPRESSION



Modified image from Dahlin, Lundborg  
Nerve Anatomy 2009

### NO AXONAL INJURY UNTIL LATE STAGES!

Tapadia et al, JHS 2010; Tang et al, PRS 2015

Alterations in epineural blood flow  
and saltatory conduction  
Schwann cell proliferation

## Seddon's grading of muscle strength (M0-5)

Seddon HJ, Peripheral Nerve Injuries, 1954.

| Grade | Muscle strength                                     |
|-------|---|
| 0     | Complete paralysis                                  |
| 1     | Flicker of contraction                              |
| 2     | Contraction only without gravity                    |
| 3     | Contraction against gravity only                    |
| 4     | Contraction against gravity and slight resistance   |
| 5     | Contraction against gravity and powerful resistance |

GRADE 0-3 = AXONAL INJURY

GRADE 5 = NORMAL

### GRADE 4 = NERVE ENTRAPMENTS

| Grade | Muscle strength                                     |
|-------|---|
| 0     | Complete paralysis                                  |
| 1     | Flicker of contraction                              |
| 2     | Contraction only without gravity                    |
| 3     | Contraction against gravity only                    |
| 4     | Contraction against gravity and slight resistance   |
| 5     | Contraction against gravity and powerful resistance |

"HIDDEN PARESIS" - WE MUST LOOK FOR IT!

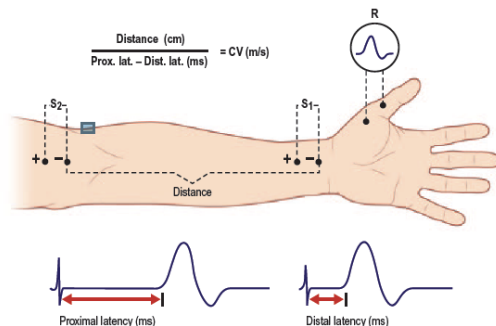
### GRADE 4 = NERVE ENTRAPMENTS

| Grade | Muscle strength                                   |
|-------|---|
| 0     |   |
| 1     |   |
| 2     |   |
| 3     |   |
| 4     | Contraction against gravity and slight resistance |
| 5     |   |

HOW DO WE LOOK FOR IT???

"HIDDEN PARESIS" - WE MUST LOOK FOR IT!

### CHRONIC NERVE COMPRESSION



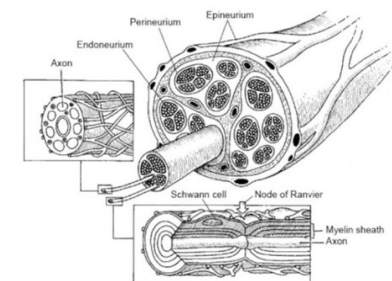
### EMG STUDIES

Tapadia et al, JHS 2010; Tang et al, PRS 2015

Will reveal possible AXONAL damage to the nerve  
Often normal in early entrapments

### Background

- No axonal injury - but changes in axonal transport
- **EMG/NCS specificity:** 30-70% (Bridgeman, *Electro Clin Neurophys*, 2007)
- **Muscle testing algorithm:** Blinded controlled study - 88/93% sensitivity/specificity (Jepsen et al, *BMC Neurology*, 2006)
- **Scratch collapse test:** 89% sensitivity in CTS/cubital (MacKinnon 2011)
- **CLINICAL TRIAD**



Dahlin and Lundborg, 1990.

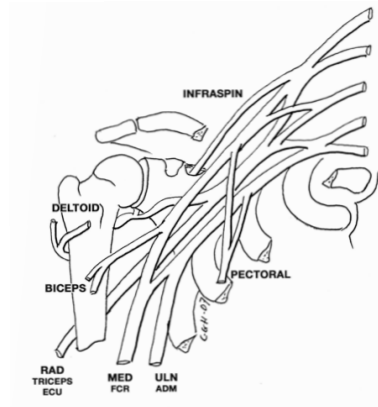
HAND FOOT  
SURGERY CENTER

## CLINICAL TRIAD

1. **Manual muscle testing:**  
specific pattern of muscle  
weakness distal to level of  
affliction - **DELINEATE LEVEL**

93% positive predictive value,  
Jepsen et al BMC Neurol 2006

Weakness in specific muscles is  
based on internal axonal  
organization of the nerve  
(Sunderland, Brain 1945)



Hagert, HAND 2013; PRS 2014



## MANUAL MUSCLE TESTING



MOVE OUT TO THE LIMBS

START FROM THE ROOTS

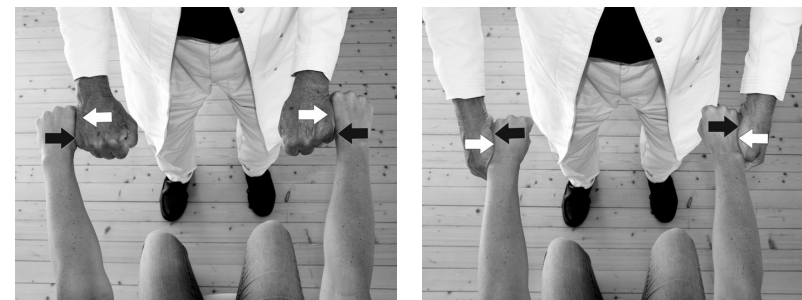


## FOUR POSITIONS

- |     |          |
|-----|----------|
| I   | SHOULDER |
| II  | ELBOW    |
| III | WRIST    |
| IV  | HAND     |

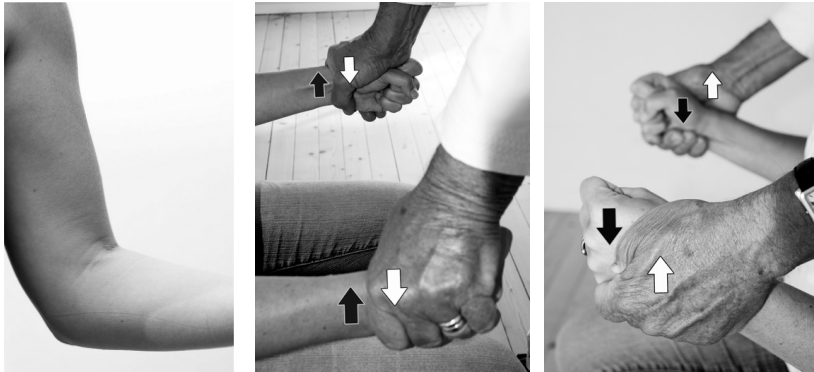


## SHOULDER



## PECTORAL - DELTOID

## ELBOW



INFRASPINATUS - BICEPS - TRICEPS

## WRIST



ECR

ECU

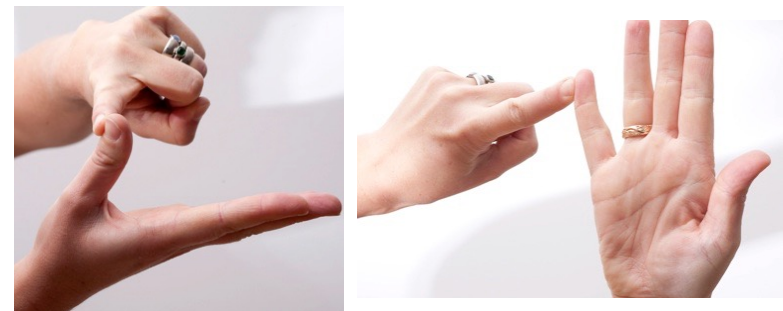
FCR

## HAND - EXTRINSICS



FPL - FDP V

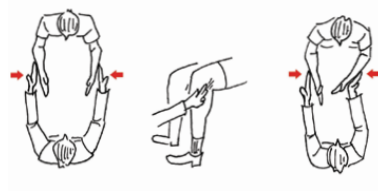
## HAND - INTRINSICS



APB - ADM

## CLINICAL TRIAD

1. **Manual muscle testing:**  
specific pattern of muscle weakness distal to level of affliction - **DELINEATE LEVEL**
2. **Scratch-collapse test:**  
scratching over level of nerve entrapment causes ipsilateral weakness in external rotation - **VERIFY LEVEL**



Gillenwater, Cheng, Mackinnon; PRS, 2011



## SCRATCH COLLAPSE TEST (SCT)

First proposed by Dr Susan Mackinnon in 2008

Uses the "cutaneous silent period"

Allodynia over the level of nerve entrapment

Scratching the nerve causes a spinal reflex with temporary inhibition of voluntary muscle contraction

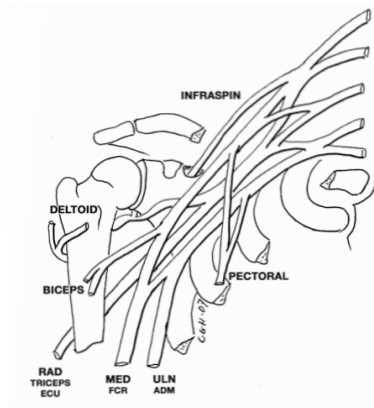


Pos SCT - bilateral carpal tunnel syndrome



## CLINICAL TRIAD

1. **Manual muscle testing:**  
specific pattern of muscle weakness distal to level of affliction - **DELINEATE LEVEL**
2. **Scratch-collapse test:**  
ipsilateral weakness in external rotation - **VERIFY LEVEL**
3. **Pain and/or positive Tinel's** at level of entrapment



Hagert, HAND 2013; PRS 2014



## MANUAL MUSCLE TESTING

- **KEYPOINTS:**
- Bilateral testing to compare strength
- Consistency in testing
- Isolate the muscle examined
- WORK THE PATIENT!
- Expect EMG/NCS to be negative



## MANUAL MUSCLE TESTING

START FROM THE  
ROOTS

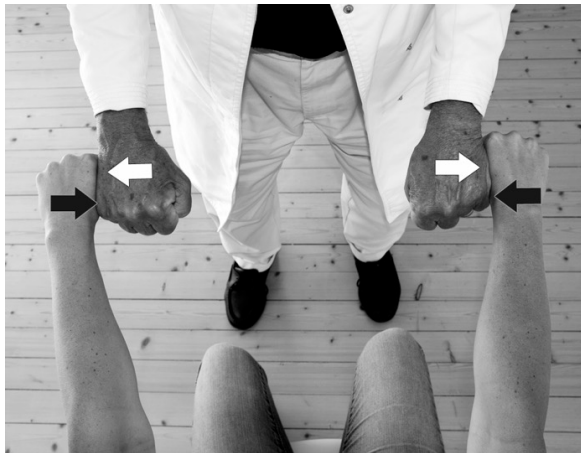


## FOUR POSITIONS

- I SHOULDER
- II ELBOW
- III WRIST
- IV HAND



## SHOULDER

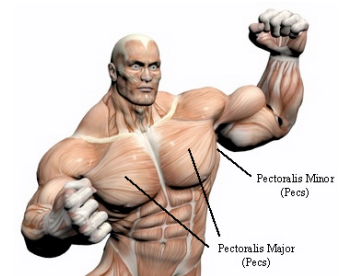


PECTORAL - DELTOID

## SHOULDER



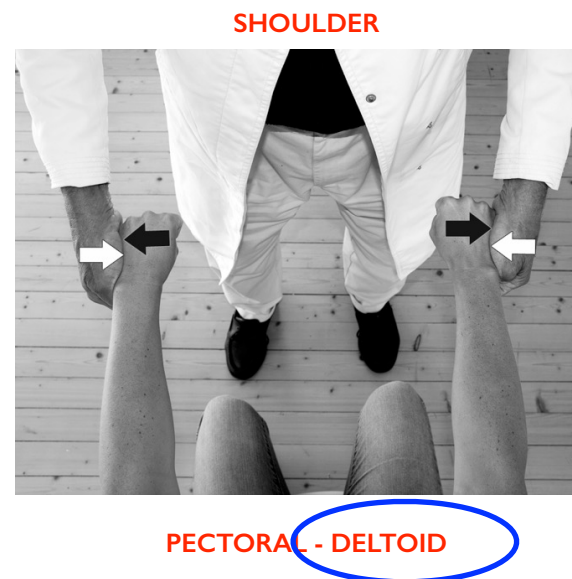
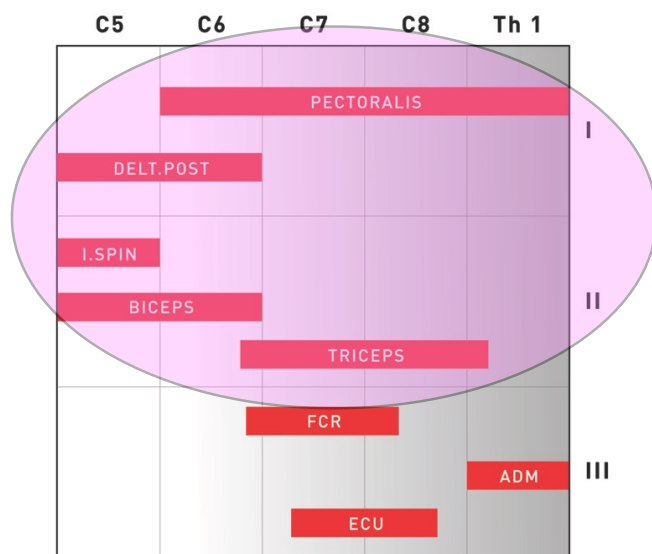
All roots contribute  
Very rarely weak  
Patient cooperation



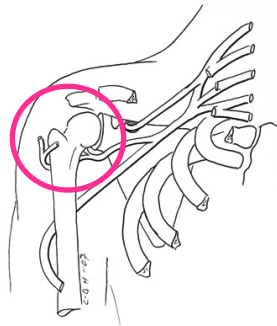
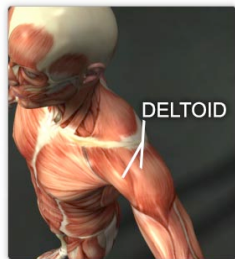
PECTORAL - C5-T1

# Case

- 54 yr old, right hand dominant male
- car accident 4 yrs previously
- whiplash injury
- primarily left side traction whiplash of cervical column



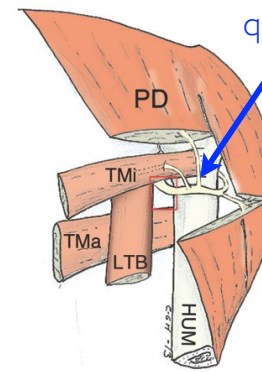
## SHOULDER



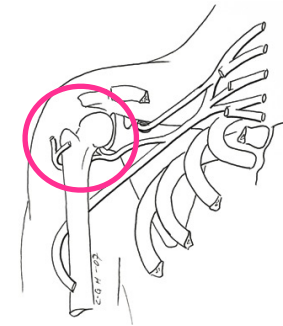
Anterior view

## DELTOID - AXILLARY NERVE

## AXILLARY NERVE



Posterior view



Anterior view

## OVERHEAD ATHLETES

McAdams and Dillingham, Am J Sports Med, 2008

## Case

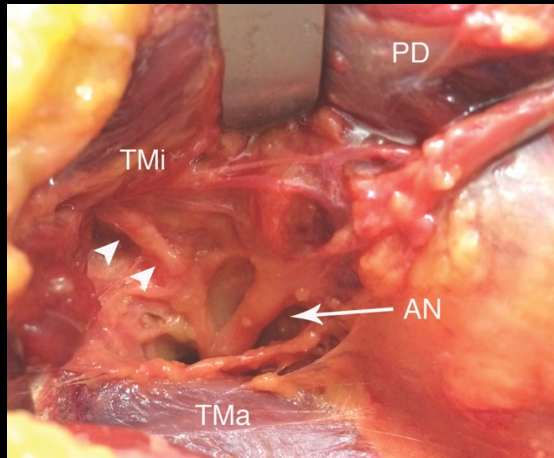
- 48 yr old, right hand dominant male
- Carpenter, builds houses
- Works repetitively with hand over shoulder
- Presents with chronic shoulder pain, night pain

## PREOP TESTING



## WEAK SHOULDER ABDUCTION

## AXILLARY NERVE



## TESTING - 2 HOURS POSTOP

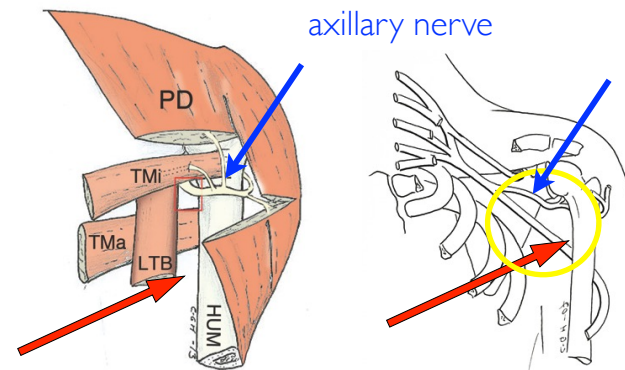


## STRONG SHOULDER ABDUCTION

## FOUR POSITIONS

- |     |          |
|-----|----------|
| I   | SHOULDER |
| II  | ELBOW    |
| III | WRIST    |
| IV  | HAND     |

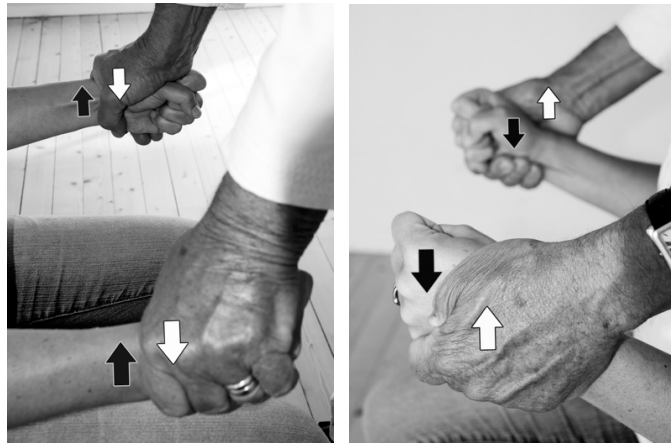
## POSTERIOR SHOULDER



radial nerve - triangular interval

PROXIMITY AXILLARY - RADIAL NERVE

ELBOW



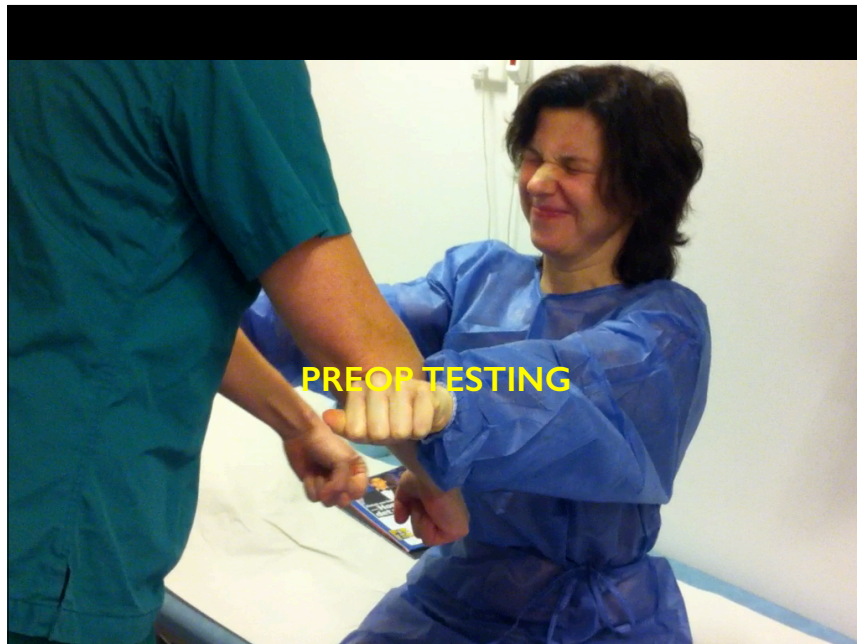
BICEPS - TRICEPS

## Case

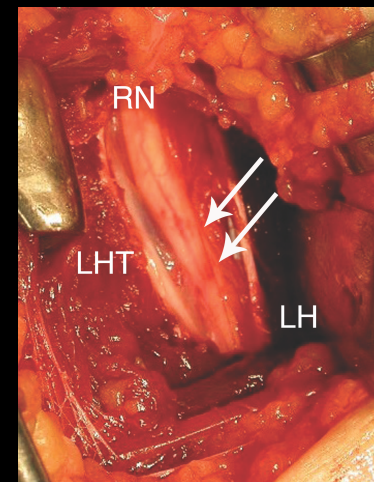
- 43 yr old, right hand dominant female
- bike accident 12 yrs ago
- landed on her left shoulder
- chronic pain since the injury, night pain

HAND FOOT  
SURGERY CENTER

PREOP TESTING



## PROXIMAL RADIAL NERVE

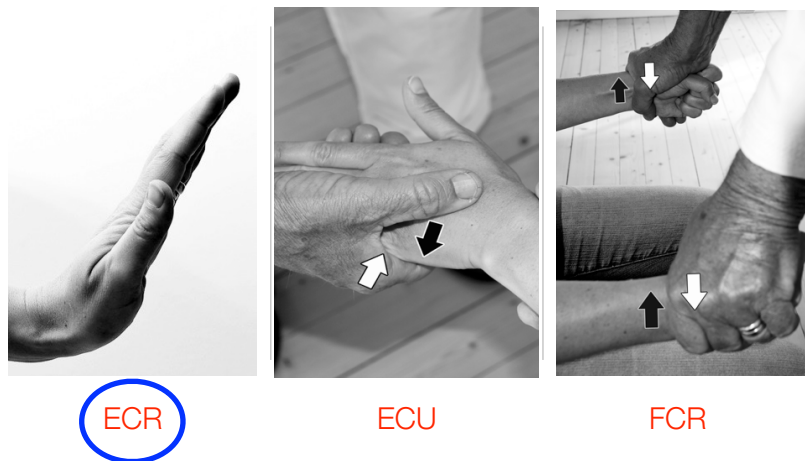




## FOUR POSITIONS

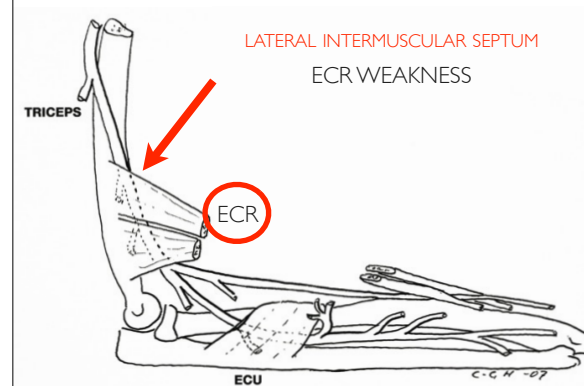
- I SHOULDER
- II ELBOW
- III WRIST
- IV HAND

## WRIST



## RADIAL NERVE

C5-T1



## Case

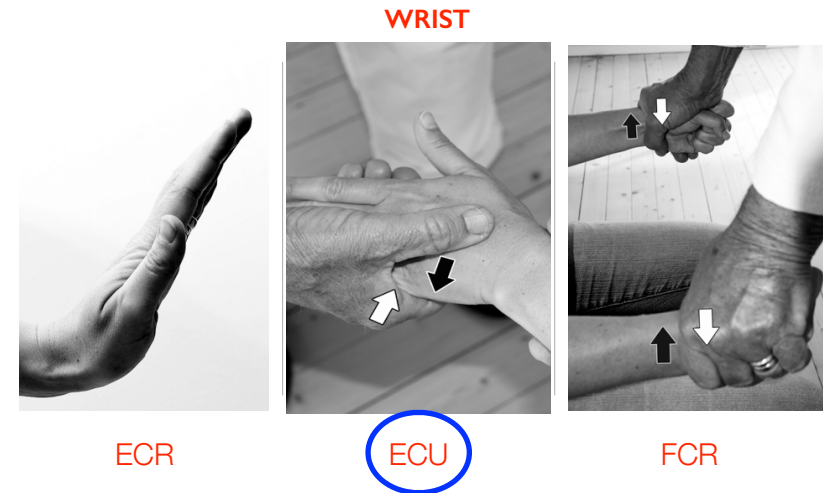
- 45 yr old, left hand dominant carpenter
- repetitive work with tools, hammer
- pain in lower upper arm, radiating into forearm
- paresthesias on dorsal thumb-index finger
- complains of pain and weakness during work



Positive scratch-collapse test  
Left sided weakness in external rotation

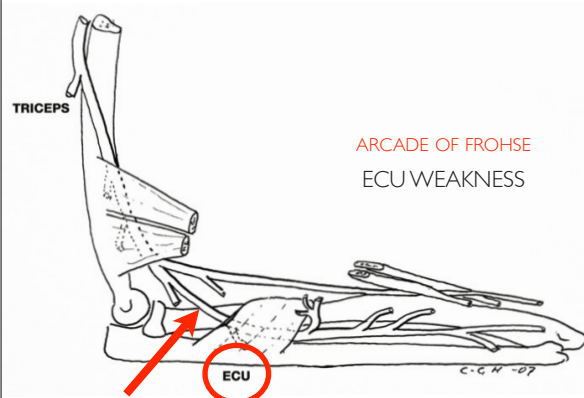


## Clinical examination after radial nerve release: two hours postop



## RADIAL NERVE

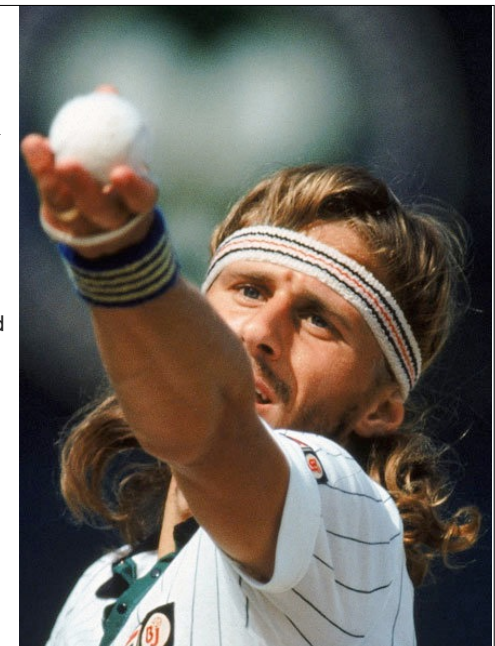
C5-T1



## RADIAL TUNNEL SYNDROME (RTS)

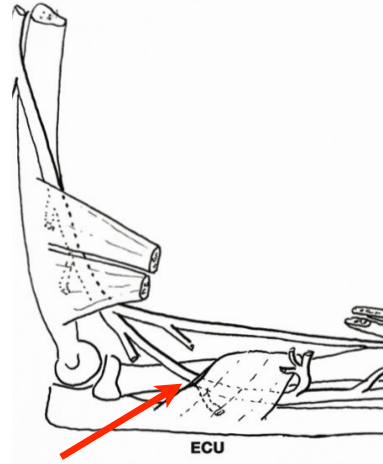
- Often found in conjunction with or misdiagnosed as **lateral epicondylitis**
- 95% of RTS treated patients 2002-2008 had been diagnosed as EPICONDYLITIS
- All had failed conservative treatment
- No longer pain at activity but pain at REST and NIGHT

Hagert CG, Hagert E, ASSH  
Master Skills Nerve Repair 2008



## RADIAL TUNNEL SYNDROME- DIAGNOSIS

- Weakness in ECU



## RADIAL TUNNEL SYNDROME- DIAGNOSIS

- Weakness in ECU

- Scratch-collapse test



## Case

- 27 yr old female marine archaeologist
- 12 yr history of forearm pain in dominant arm
- All conservative treatment w/out success



**PREOP TESTING**

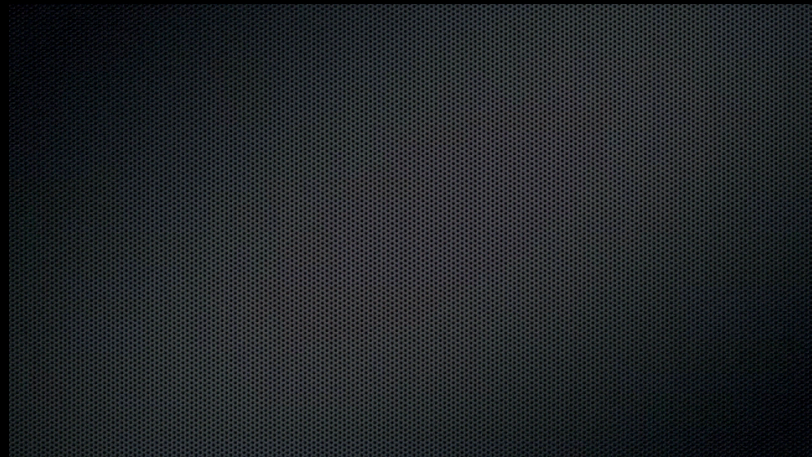
## RADIAL TUNNEL SYNDROME- DIAGNOSIS

- Weakness in ECU
- Scratch-collapse test
- Pain over arcade of Frohse



**PREOP TESTING**

HAND FOOT  
SURGERY CENTER



**SURGICAL TECHNIQUE**

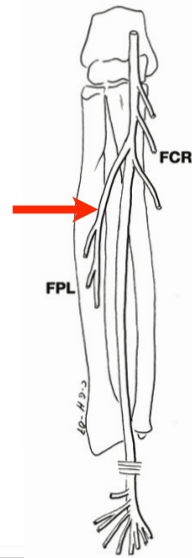


**3 HRS POSTOP**

HAND FOOT  
SURGERY CENTER

## RADIAL TUNNEL SYNDROME - EPIDEMIOLOGY

- 74 patients treated surgically - 45 followed retrospectively, 29 prospectively
- 64% manual workers
- 75% dominant hand



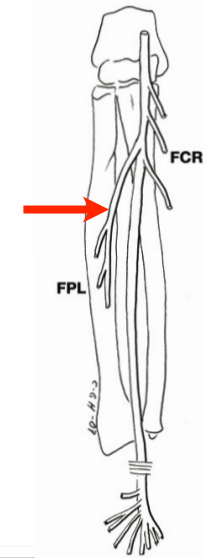
Hagert E, Hagert CG Master Skills Nerve Repair, 2008

## RADIAL TUNNEL SYNDROME - RETROSPECTIVE

| Ritts Score | %  |
|-------------|----|
| I           | 88 |
| II          | 10 |
| III         | 2  |

2004-2008: 45 pat operated - follow-up 6 months

Hagert E, Hagert CG Master Skills Nerve Repair, 2008



## RADIAL TUNNEL SYNDROME

|            | preop | postop | p =    |
|------------|-------|--------|--------|
| quick DASH | 40.6  | 13.9   | <.0001 |
| work DASH  | 48.9  | 10.7   |        |

2012-13: 45 patients released, 29 patients followed 6 mths postop

Hagert E, Hagert CG, PRS, July 2014



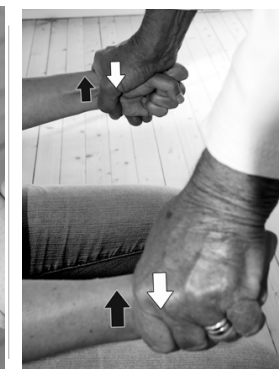
## WRIST



ECR



ECU



FCR

## FOUR POSITIONS

- I SHOULDER
- II ELBOW
- III WRIST
- IV HAND

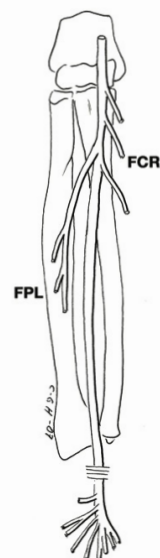
## HAND - EXTRINSICS



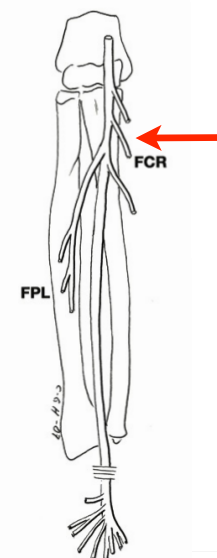
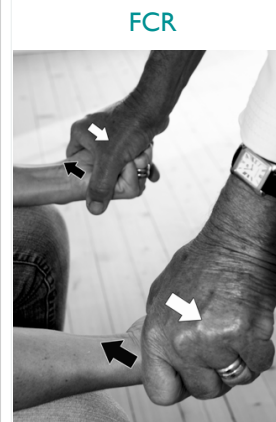
FPL - FDP V

## MEDIAN NERVE - ELBOW

- Lacertus Syndrome
- Weakness in median innervated muscles



## LACERTUS SYNDROME- DIAGNOSIS

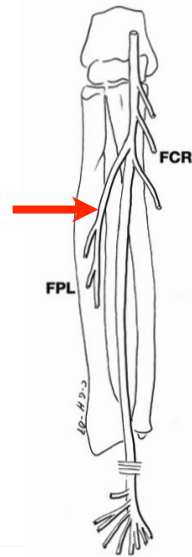


### LACERTUS SYNDROME- DIAGNOSIS

FCR



FPL



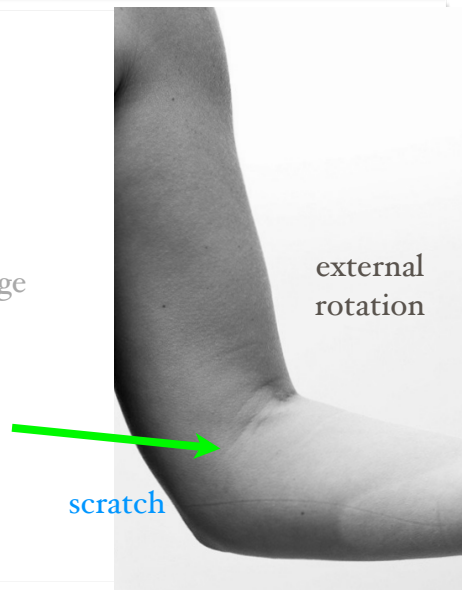
### LACERTUS SYNDROME- DIAGNOSIS

- Weakness in median innervated muscles
- Pain upon pressure at edge of lacertus



### LACERTUS SYNDROME- DIAGNOSIS

- Weakness in median innervated muscles
- Pain upon pressure at edge of lacertus
- Scratch-collapse test



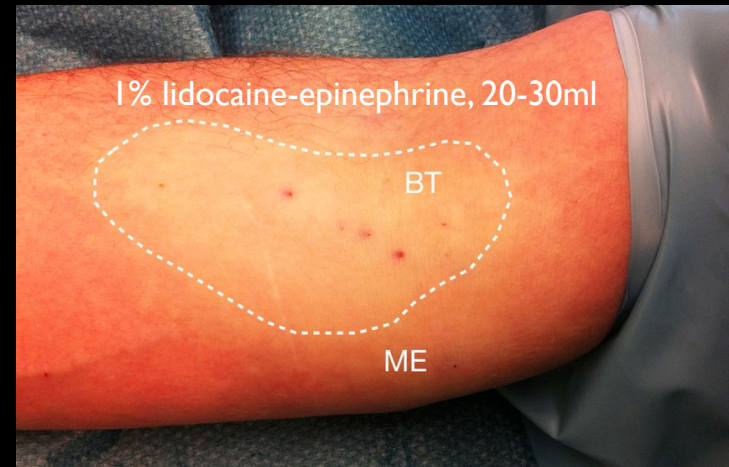
external  
rotation



Scratch Collapse Test



**PREOP TESTING**



**WALANT**  
**wide awake local anesthesia no tourniquet**



**SURGERY**

### LACERTUS SYNDROME - EPIDEMIOLOGY

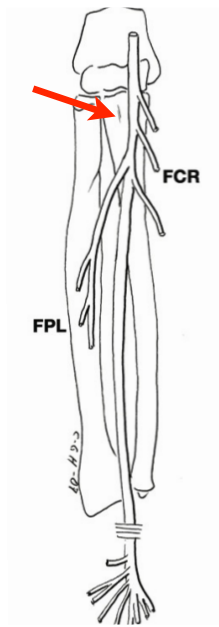
- 2011-2013: 156 patients treated surgically - 119 filled in DASH, 70 completed follow-up (59%)
- 42 women/28 men, mean age 50 (24-72)
- 59% office workers
- 58% dominant hand
- All patients went through trial of local triamcinolone and nerve gliding exercises



## LACERTUS SYNDROME - PROSPECTIVE

|            | preop | postop | p =    |
|------------|-------|--------|--------|
| quick DASH | 37.4  | 13.3   | <.0001 |
| work DASH  | 40.8  | 10.4   |        |

Ritt's Score: 83% good-excellent



## HAND - EXTRINSICS



FPL - FDP V

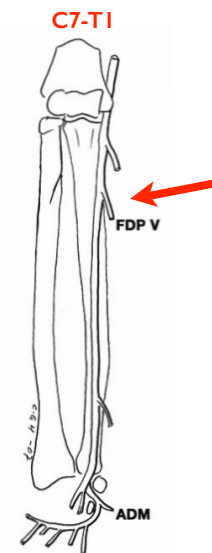
## HAND - INTRINSICS



APB - ADM

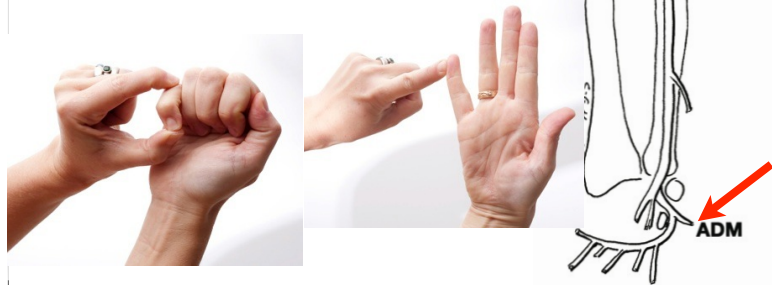
## ULNAR NERVE

MOTOR



### CUBITAL TUNNEL SYNDROME- DIAGNOSIS

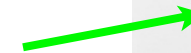
- Weakness in FDP V-ADM



### CUBITAL TUNNEL SYNDROME- DIAGNOSIS

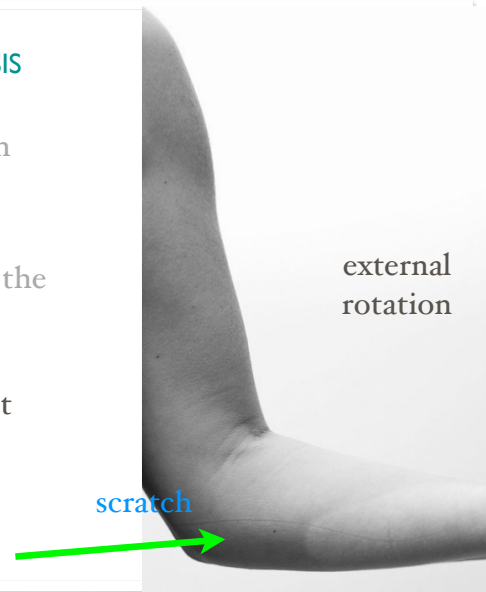
- Weakness in FDP V-ADM
- Positive Tinel's test at the ulnar sulcus

Tinel's



### CUBITAL TUNNEL SYNDROME- DIAGNOSIS

- Weakness in median innervated muscles
- Positive Tinel's test at the ulnar sulcus
- Scratch-collapse test

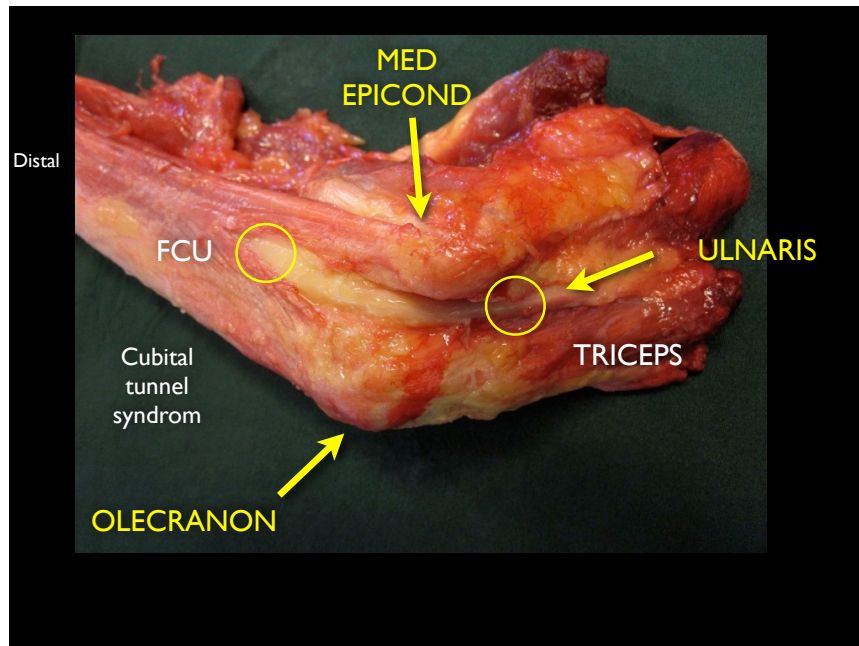


## Wide Awake Ulnar Nerve



Preop testing  
FDP-V + ADM  
Scratch collapse

HAND FOOT  
SURGERY CENTRE



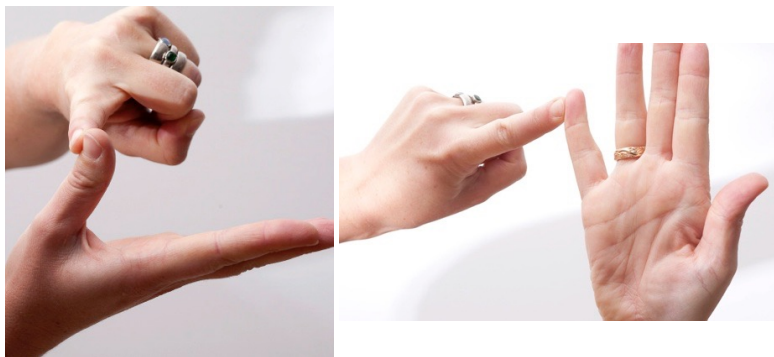
## Wide Awake Ulnar Nerve



Postop testing  
FDP-V + ADM

HAND FOOT  
SURGERY CENTER

## HAND - INTRINSICS



APB - ADM

## CARPAL TUNNEL SYNDROME



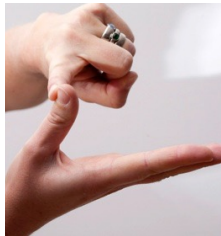
Phalens test



Tinells test

HAND FOOT  
SURGERY CENTER

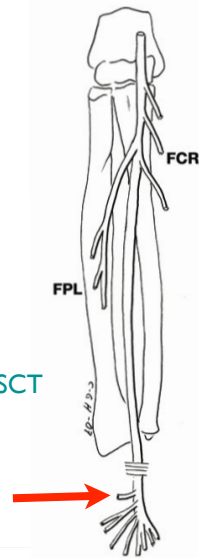
## CARPAL TUNNEL SYNDROME- DIAGNOSIS



WEAK APB



POSITIVE SCT



## HAND - INTRINSICS

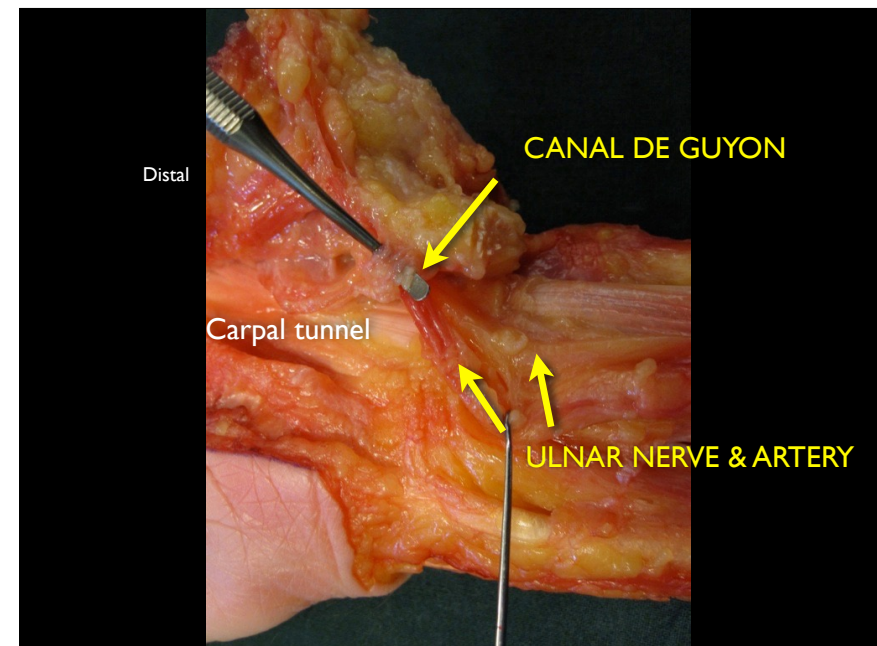


APB ADM

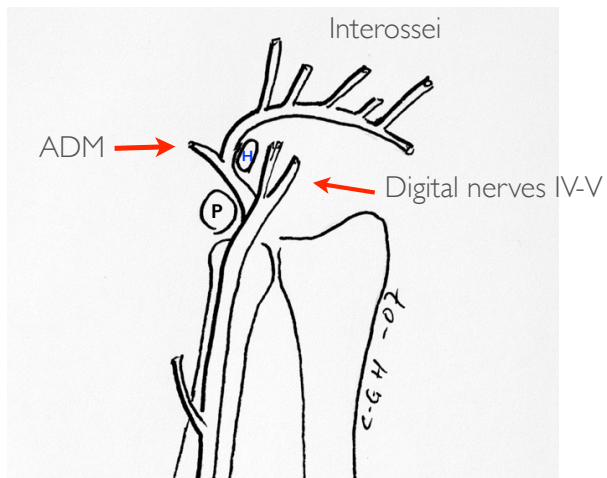


## ULNAR NERVE HAND

HYPOTHENAR MUSCLES  
INTEROSSEI (DORSAL/VOLAR)  
LUMBRICALS IV-V  
ADDUCTOR POLL  
FLEX POLL BREVIS (DEEP)



### GUYONS CANAL



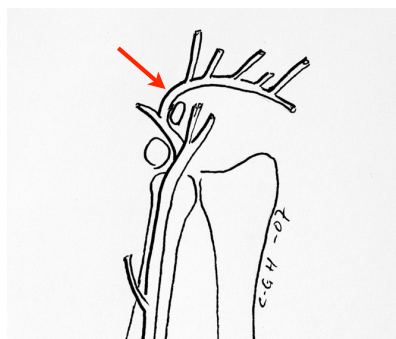
within a 2 cm distance, we can diagnose 4 different entrapments

### GUYONS CANAL PREOP

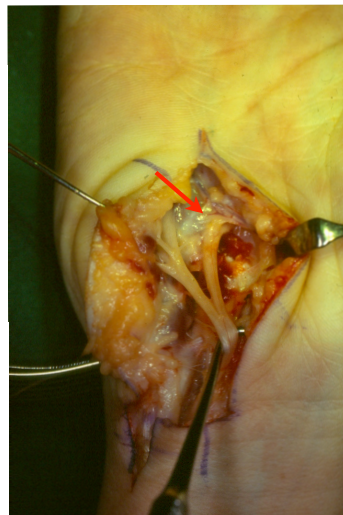


HAND FOOT  
SURGERY CENTRE

### GUYONS CANAL



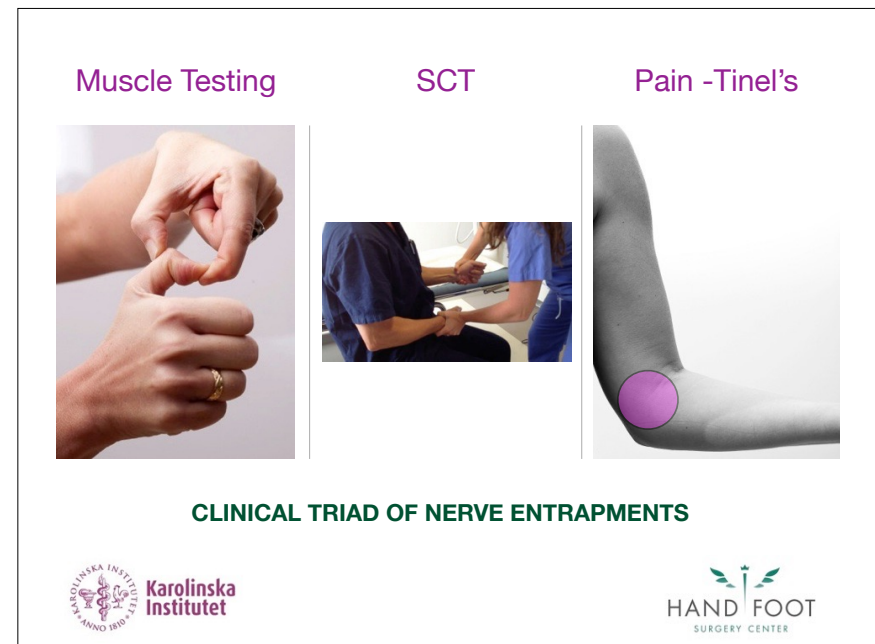
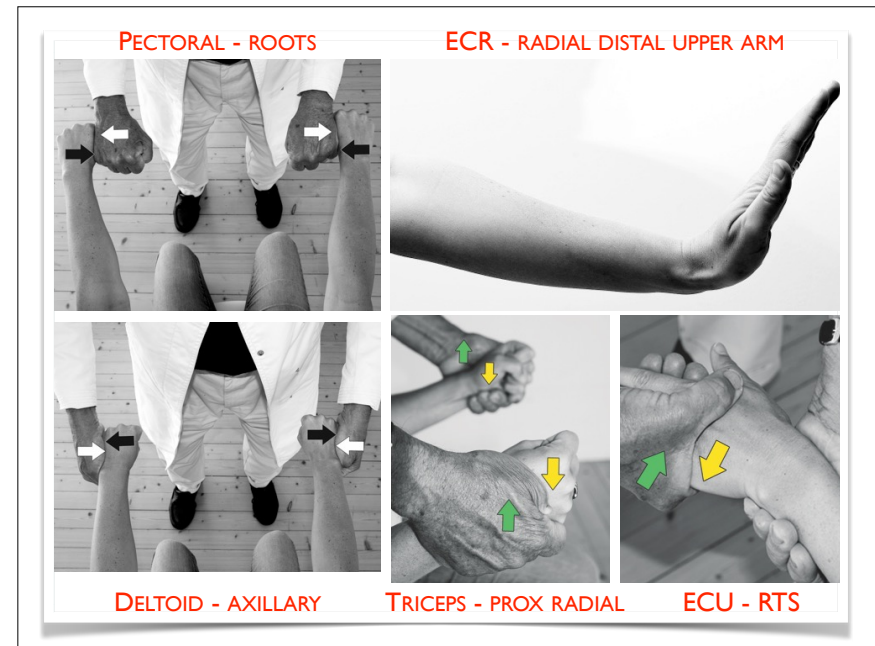
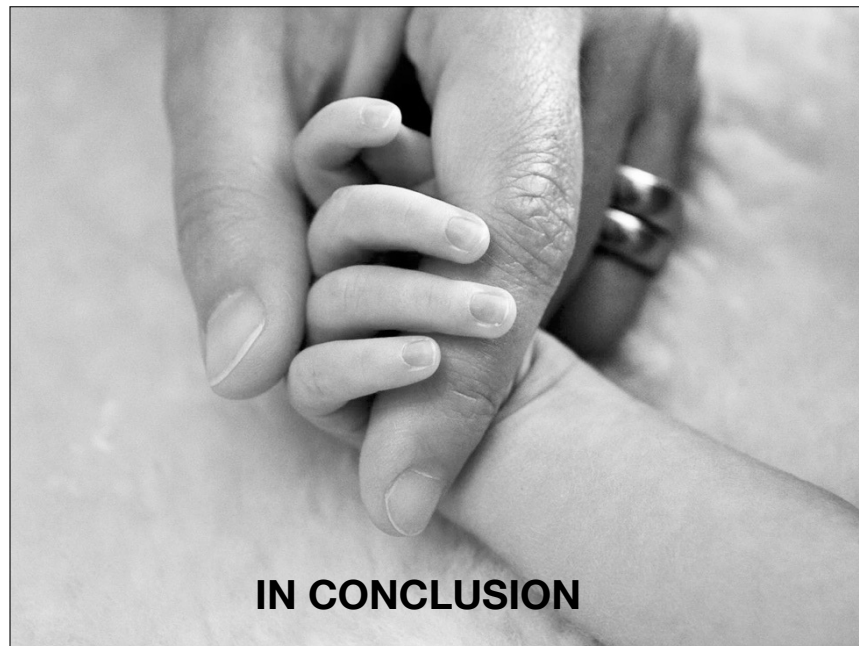
Hook of hamate

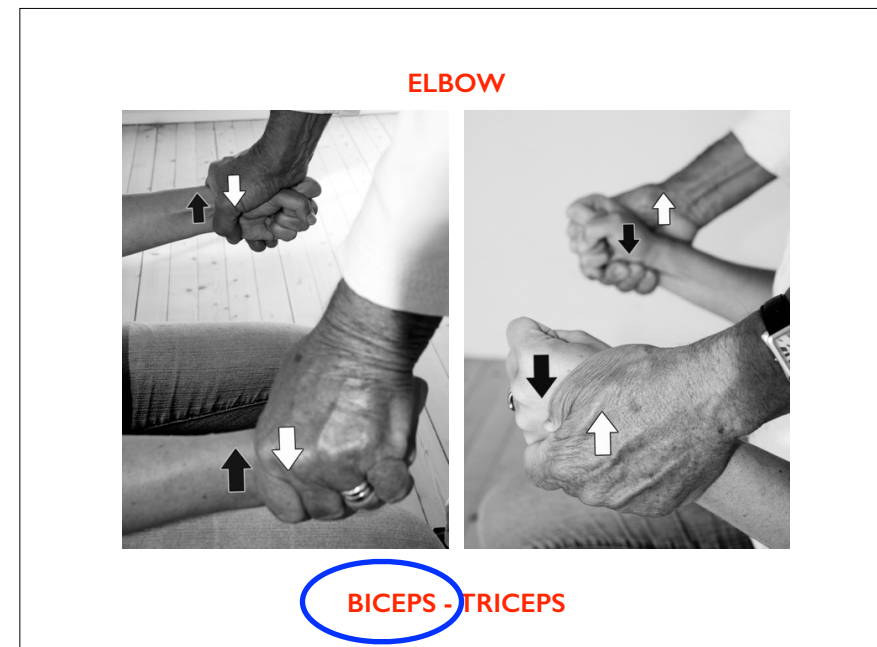
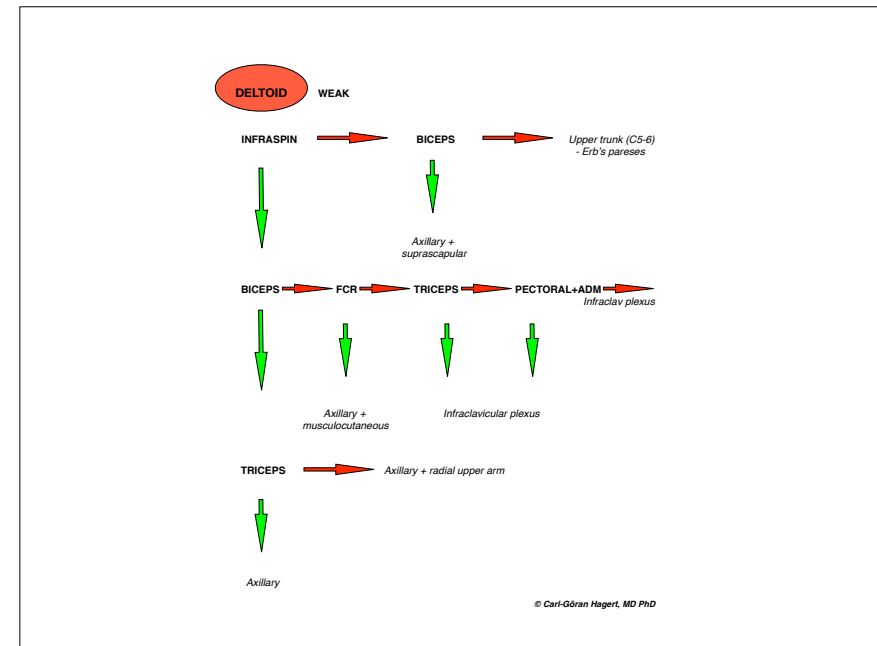
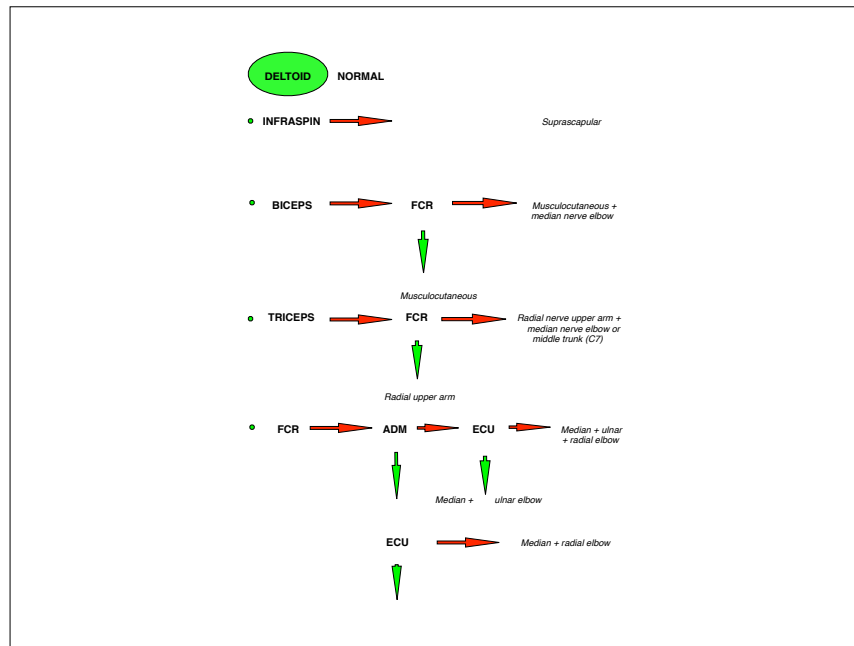


### GUYONS CANAL 2 WEEKS POSTOP



HAND FOOT  
SURGERY CENTRE





# Case

- 52 yr old, right hand dominant carpenter
- repetitive work with tools, hammer
- weakness upper arm rt side
- pain after working

