Peripheral Nerve Injury and Associated Reconstructive Options

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Hand and Microsurgery

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Via Christi Therapy Centers
Founders Circle

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Course Outline

9:15 Review of the anatomy and pathology of peripheral nerve injuries

9:30 Repair versus grafting of the acute peripheral nerve injury

9:45 Delayed presentation of injury

10:00 General principles in therapy for the acute peripheral nerve injury

10:15 Break

10:30 Repair and reconstruction of the radial nerve

11:00 Therapy for radial nerve palsy and subsequent rehab after treatment

11:30 Repair and reconstruction of the ulnar nerve

12:00 Therapy for ulnar nerve palsy and subsequent rehab after treatment

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Peripheral Nerve Injury

Wide ranges of severity and loss of function in injury

Sensory Changes → Loss of coordination and strength → Loss of active motion

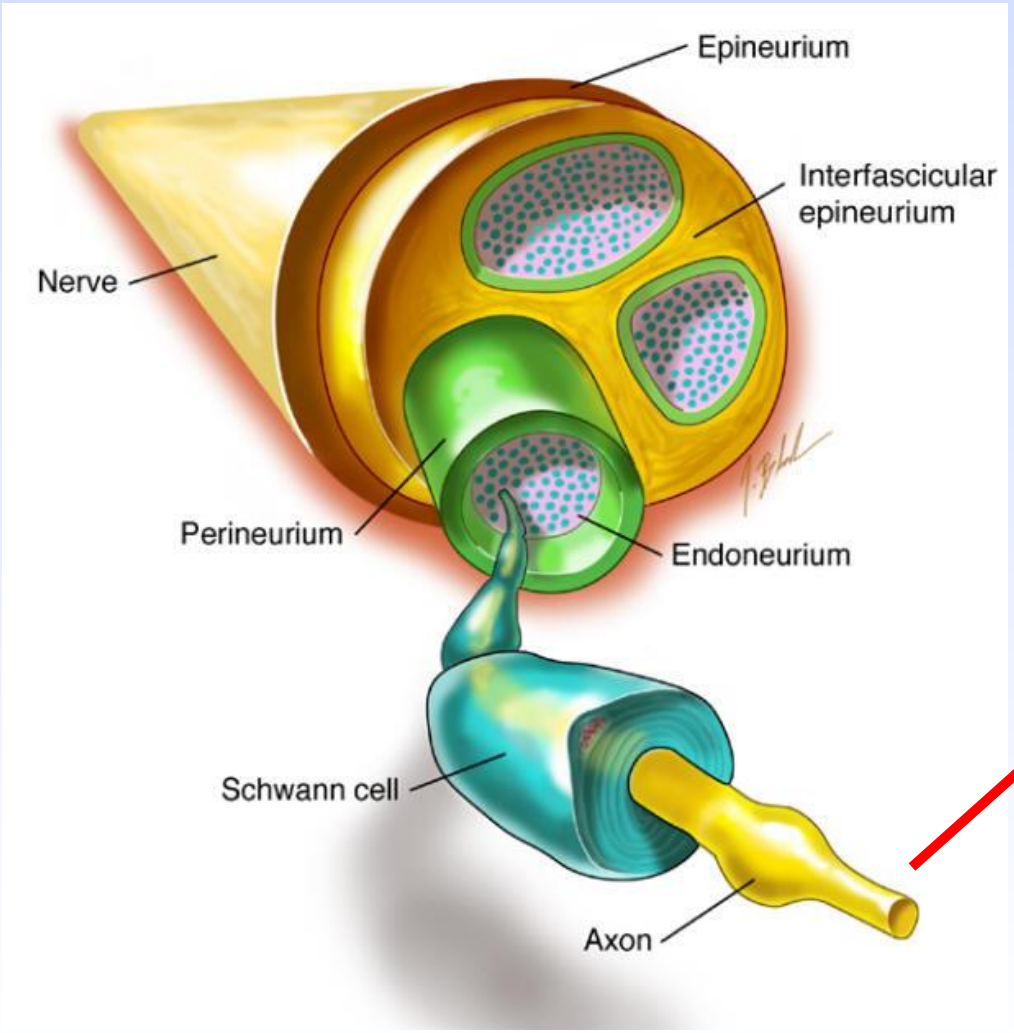


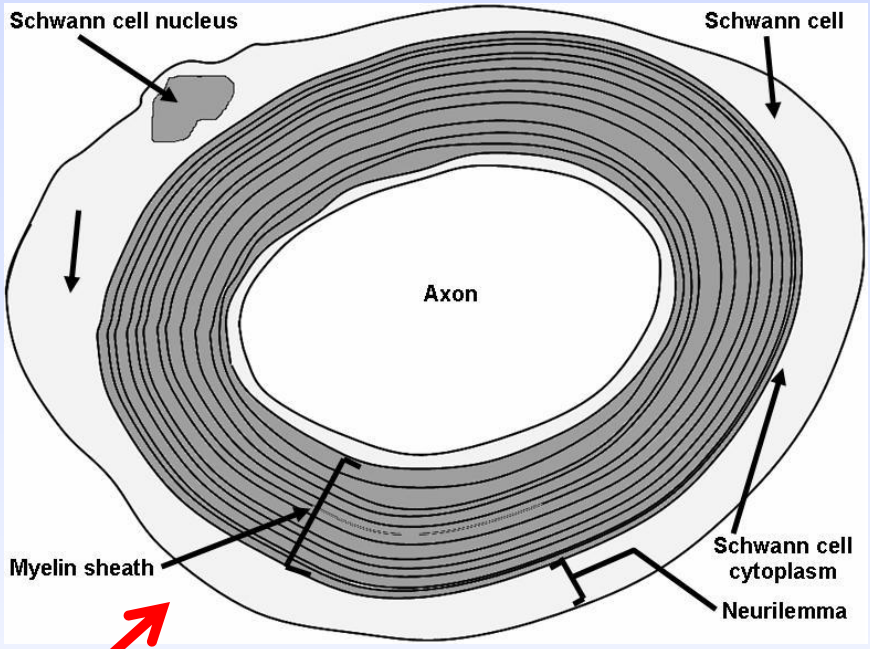




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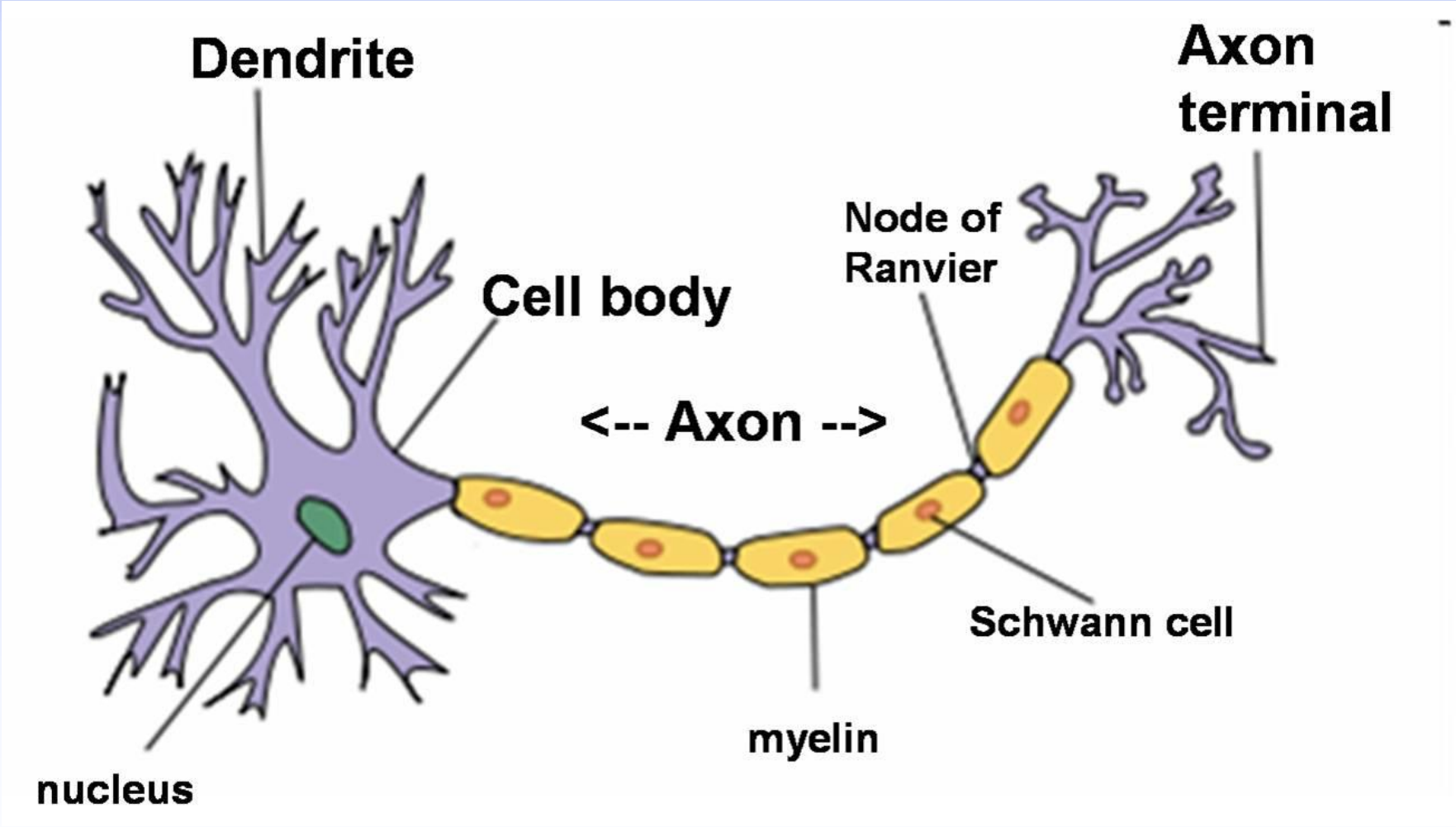
Nerve Anatomy



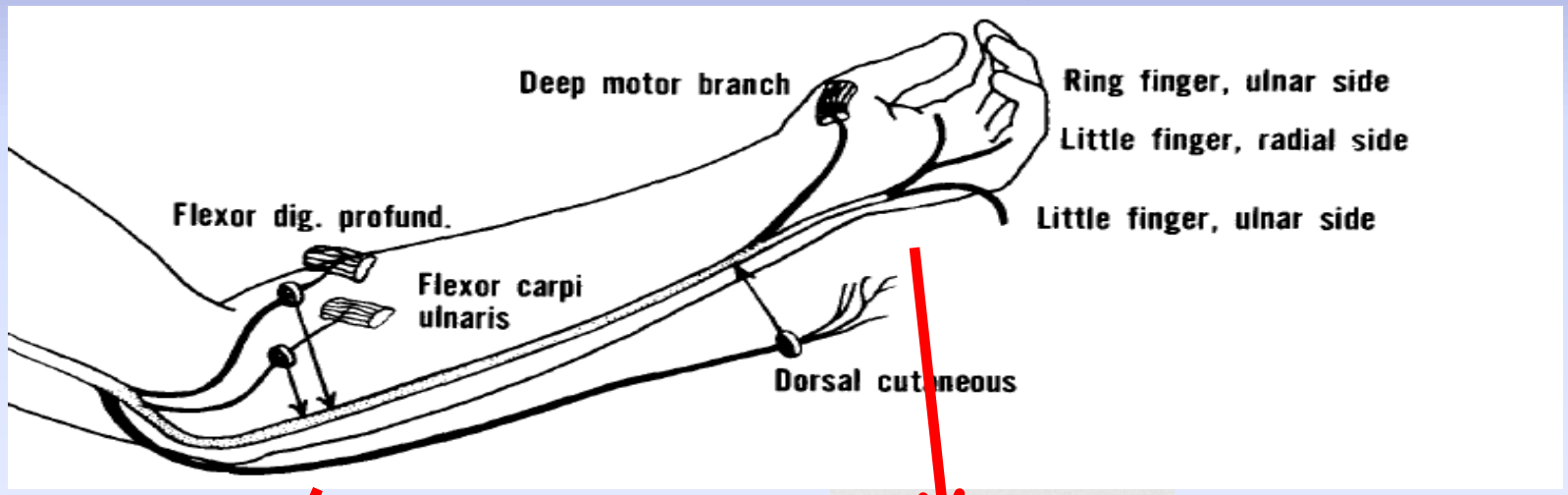


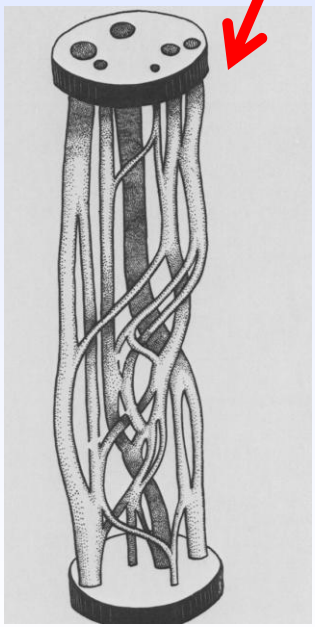
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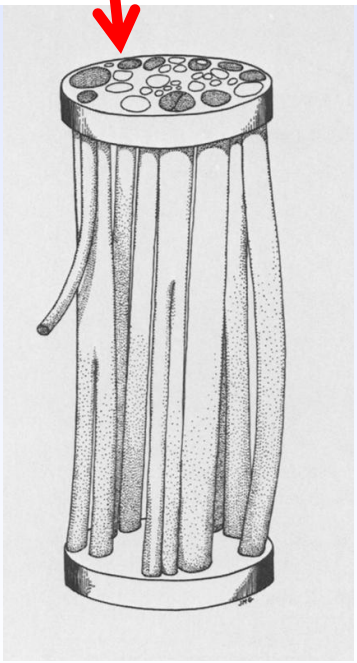
Axonal Anatomy



Internal Topography







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Evaluation

- Sensory
  - 2-point discrimination (5-7 mm static)
- Motor
  - Specific muscle testing
- NCS/EMG

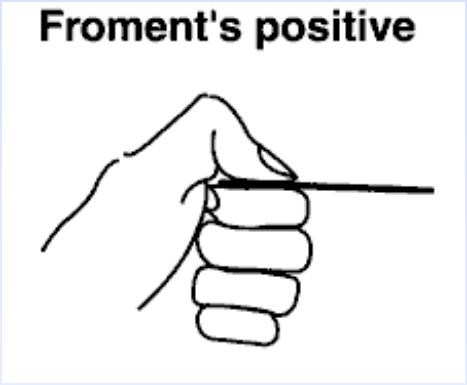
Nerve Specific Sensory Exam

- Median Nerve
  - Pulp of the thumb
- Ulnar Nerve
  - Pulp of the small finger
- Radial Nerve
  - Dorsum of 1st web space



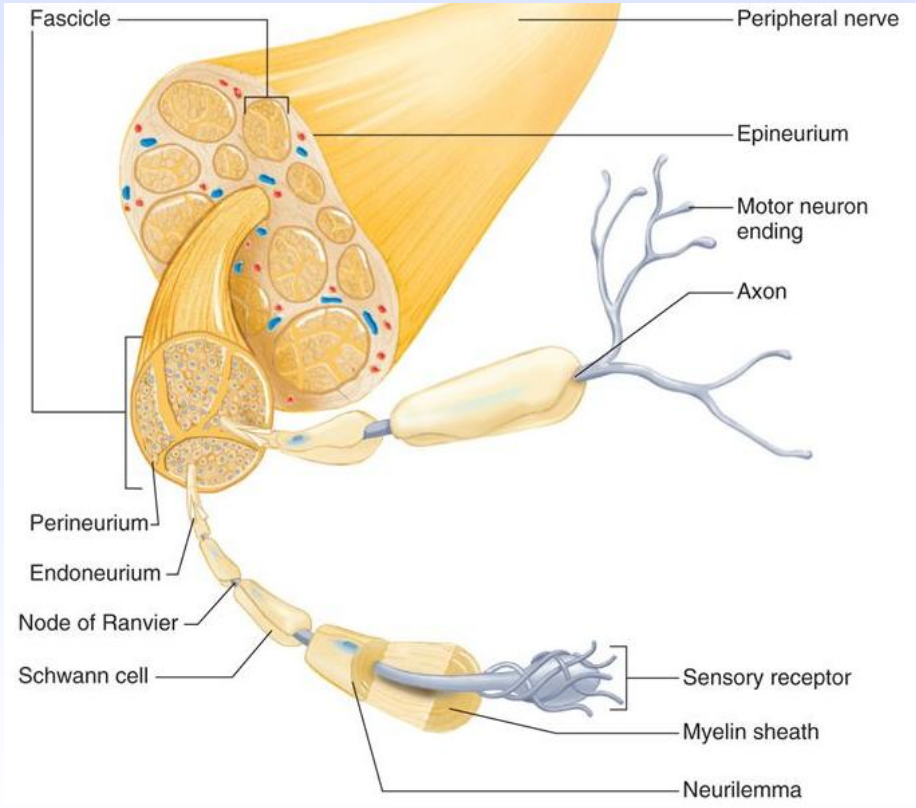
Specific Muscle Testing

- Median Nerve
  - All sublimis, FPL, Index FDP
- Ulnar Nerve
  - First Dorsal IO, Abductor Digiti Minimi
- Radial Nerve
  - Wrist extension
  - PIN – MP joint extension and thumb extension



Seddon Classifiction

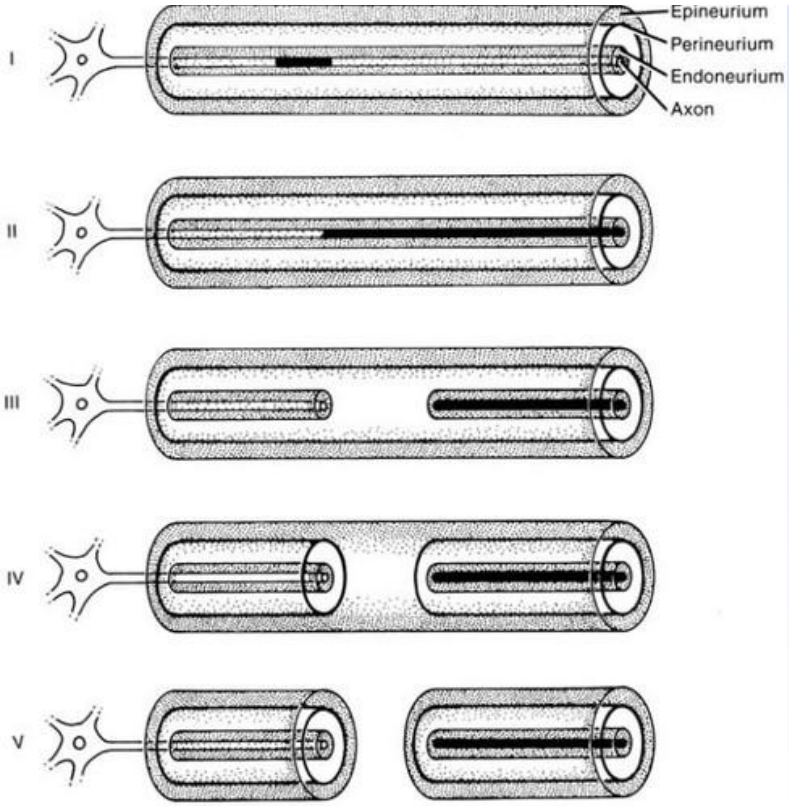
- Sir Herbert Seddon 1945
  - Neuropraxia
    - Complete recovery
  - Axonotmesis
    - Compete →Incomplete Recovery
  - Neurotmesis
    - No Recovery



Classification of Nerve Injury

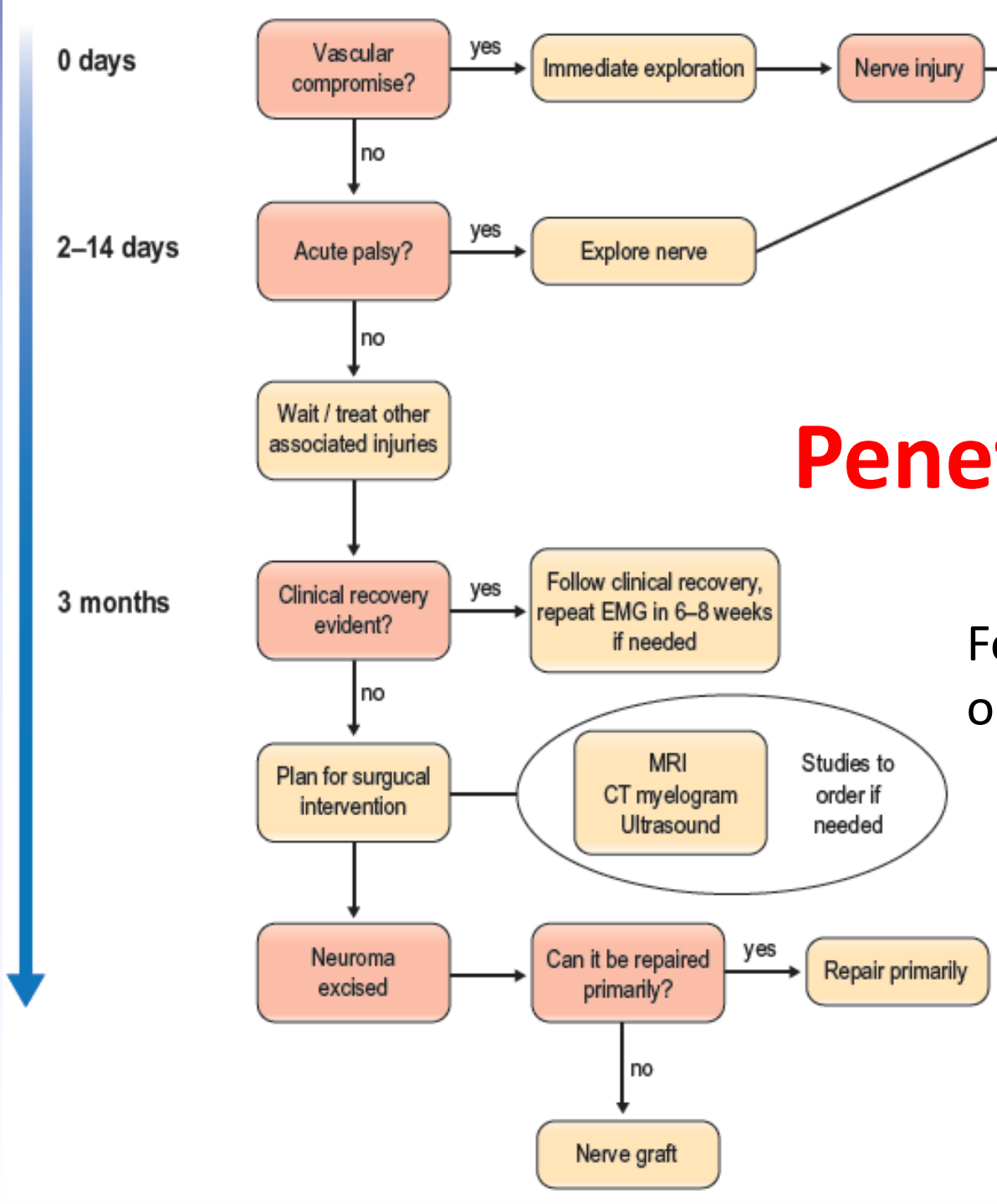
Table 22.1 Classification of nerve injury

Seddon	Sunderland	Injury	Recovery
Neurapraxia	Degree I	Conduction block resolves spontaneously	Fast/excellent
Axonotmesis	Degree II	Axonal rupture without interruption of the basal lamina tubes	Slow/excellent
	Degree III	Rupture of both axons and basal lamina tubes, some scar	Slow/incomplete
	Degree IV	Complete scar block	None
Neurotmesis	Degree V	Complete transection	None
	Degree VI (Mackinnon)	Combination of degree I–IV ± normal fascicles	Mixed



Type of Injury

- Penetrating Injuries
- Crush Injuries
- Stretch/Avulsion injuries.



Penetrating Injuries

For lacerated nerve with obvious transection:

Recommend exploration and repair by day 7

Blunt Penetrating and Blast

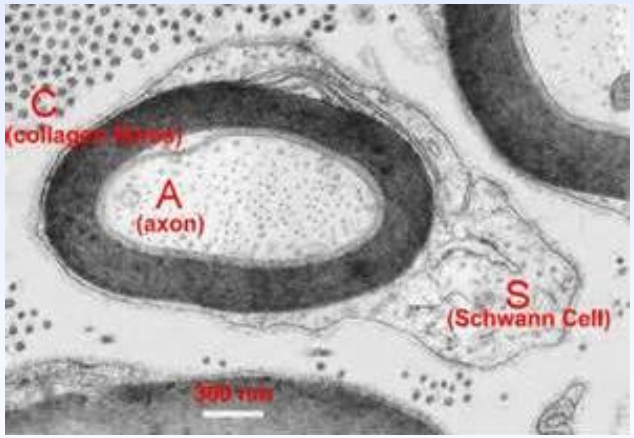
- Treated like crush or avulsion injuries
  - Observe for 3 months.
  - NCS/EmG: not until 6 weeks- 3 months
  - Edema and collateral damage can often elicit neurapraxia

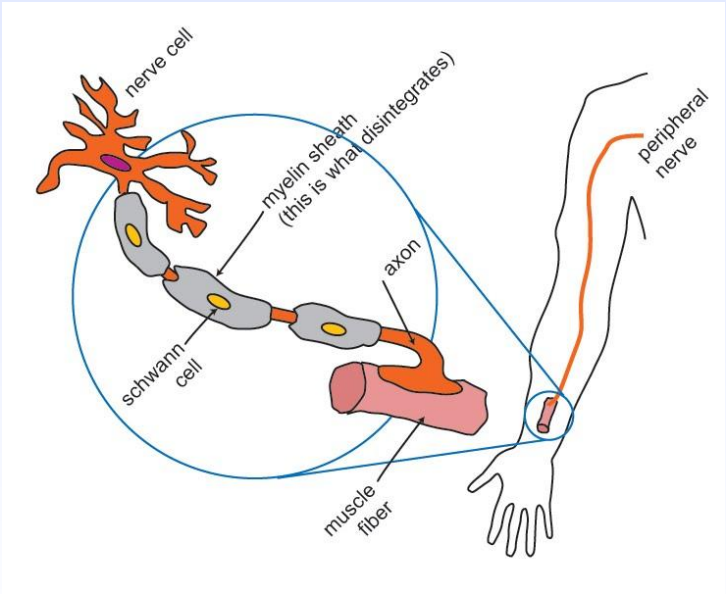




Crush Injury

- May injure myelinating schwann cells
  - Leaves fibers intact but unable to transmit impulses (Neuropraxia)





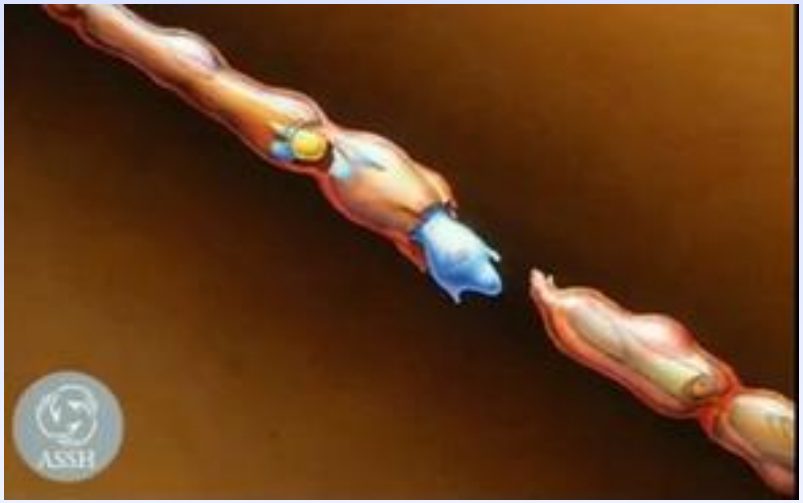
NERVE REPAIR

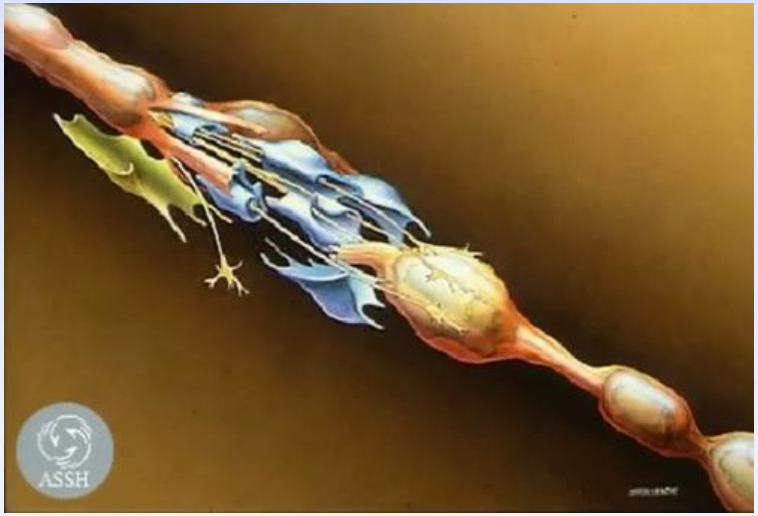
Does Nerve Repair Work?

- Haighton 1795
  - Bilateral Vagotomy of dogs is fatal (duh!)
  - Bilateral Vagotomy with immediate repair is fatal
  - Unilateral Vagotomy and repair followed by contralateral vagotomy 6 weeks later is NOT fatal

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Why Does it Take So Long??





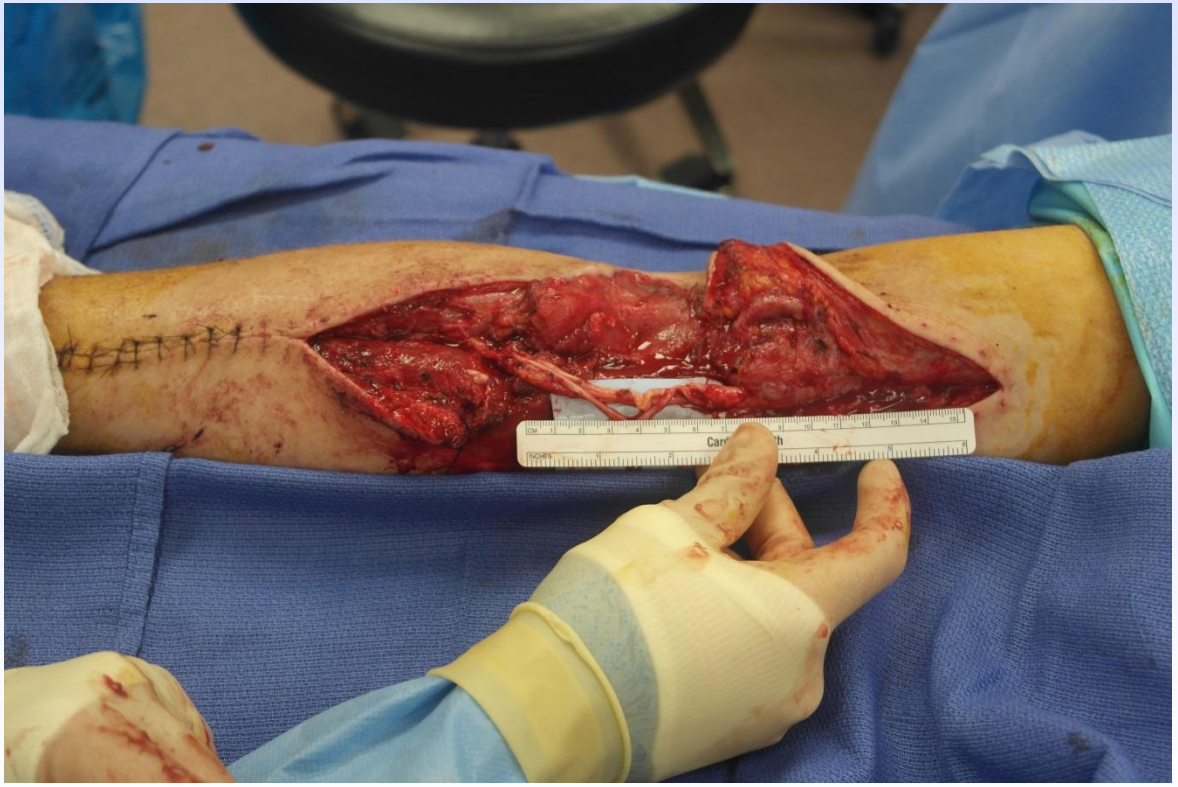
Definitions

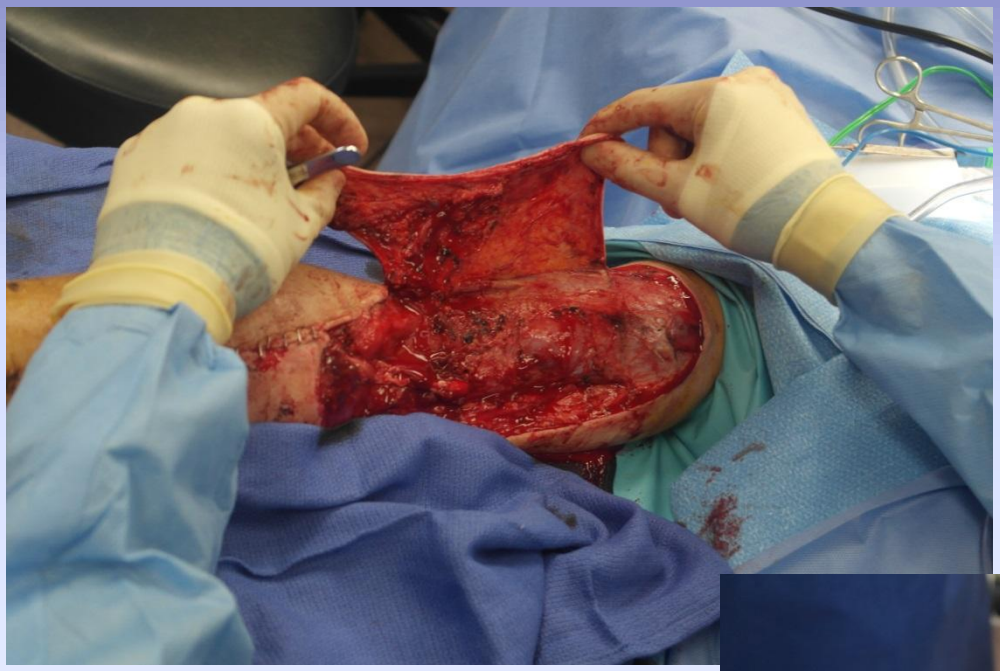
- Primary Repair – that which occurs within 1-3 weeks after the injury
- Secondary Repair – after 3 weeks of injury
- Nerve Conduit – tube used to span the gap between nerve ends (vein, artery, synthetic, collagen)
- Nerve allograft – cadaveric nerve
- Nerve autograft – taken from elsewhere to span the gap

Golden Rule

Nerve Repair should occur in a timely manner with a well vascularized tissue bed and no tension!



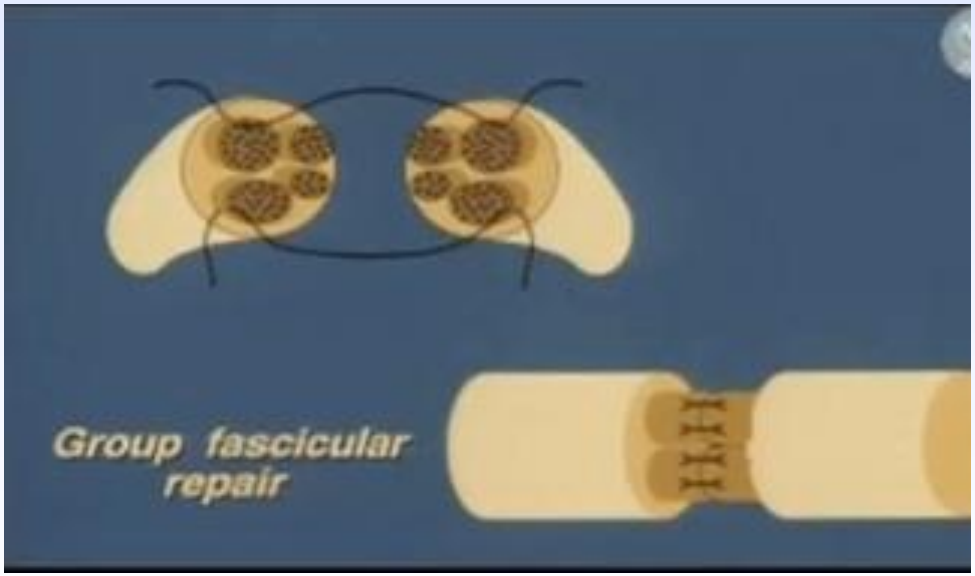


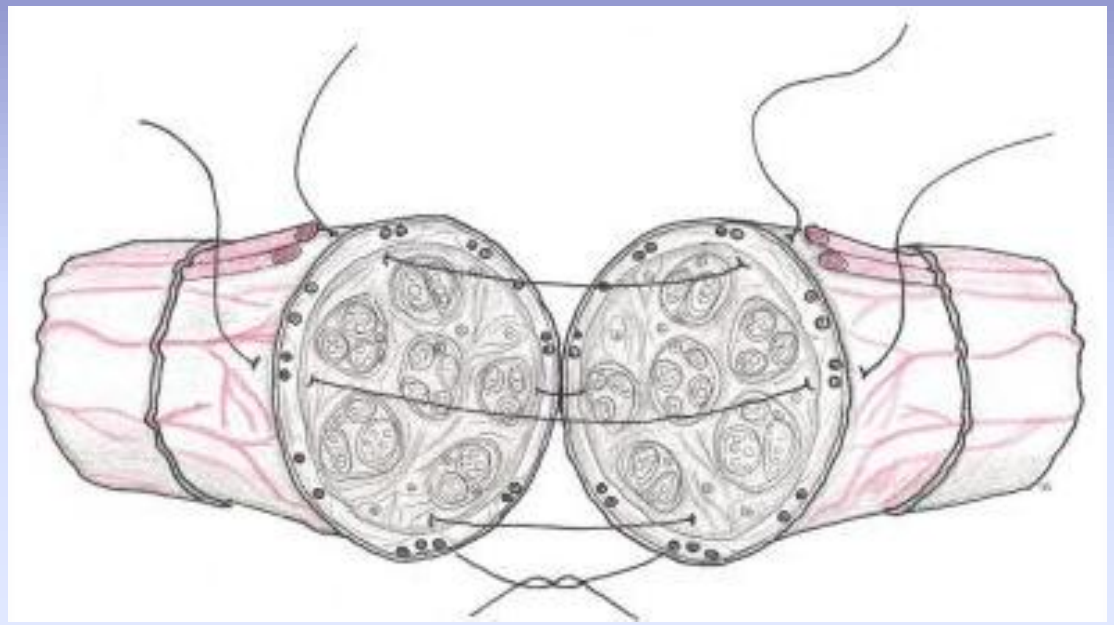


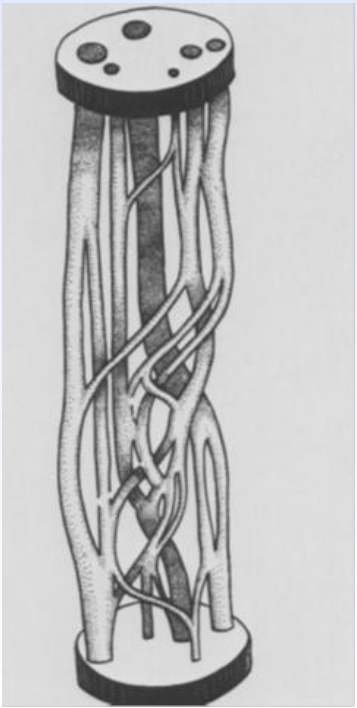


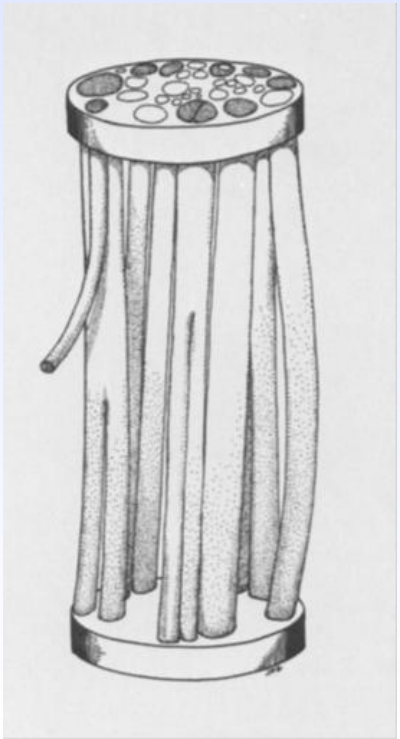
Types of Nerve Repair





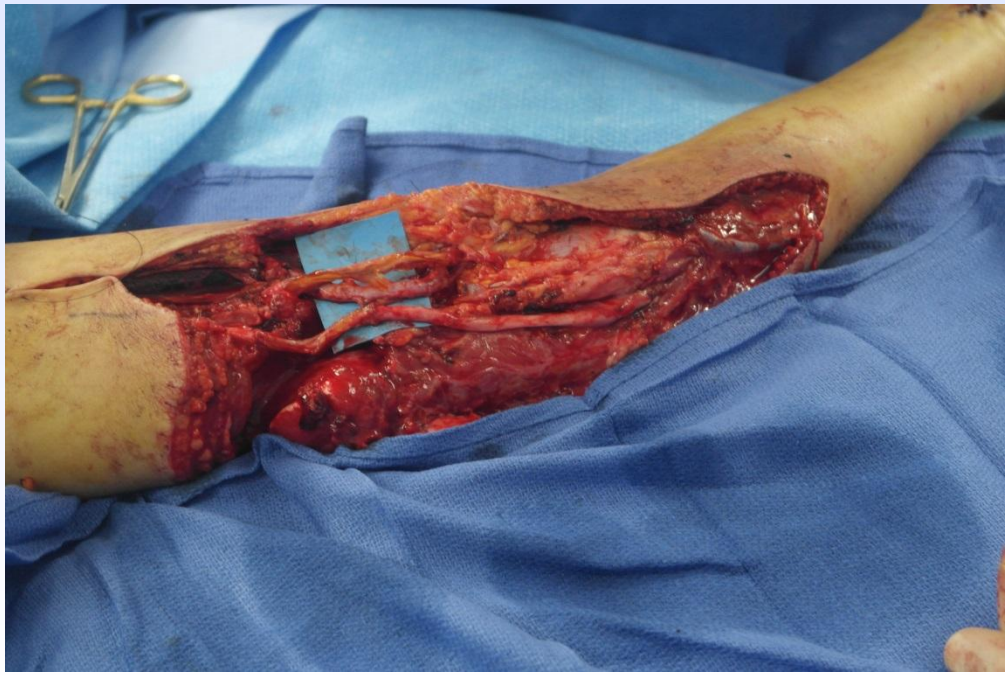






Tension is a Killer

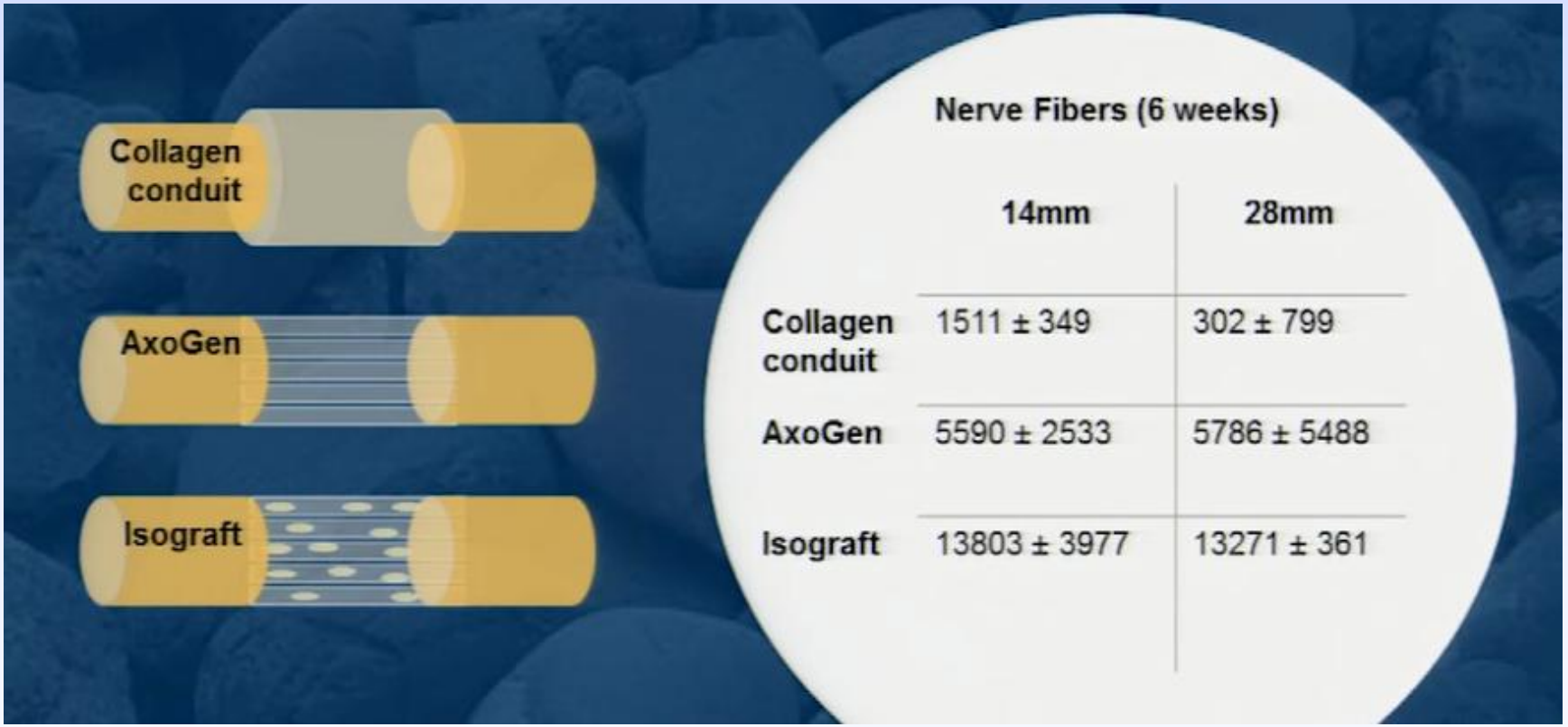
- Nerve mobilization
- Nerve transposition
- Bone Shortening
- Joint Positioning 



Expected Outcomes

- Delay in beginning recovery about 1 month
- 1-2 mm/day
  - Evaluated by an advancing Tinels
- Direct repair with the best outcomes

Autograft Vs. Allograft vs. Conduit



Whitlock et al. Processed allografts and type I collagen conduits for repair of peripheral nerve gaps. Muscle and Nerve. 787-799, 39: 6. 2009.

Allograft

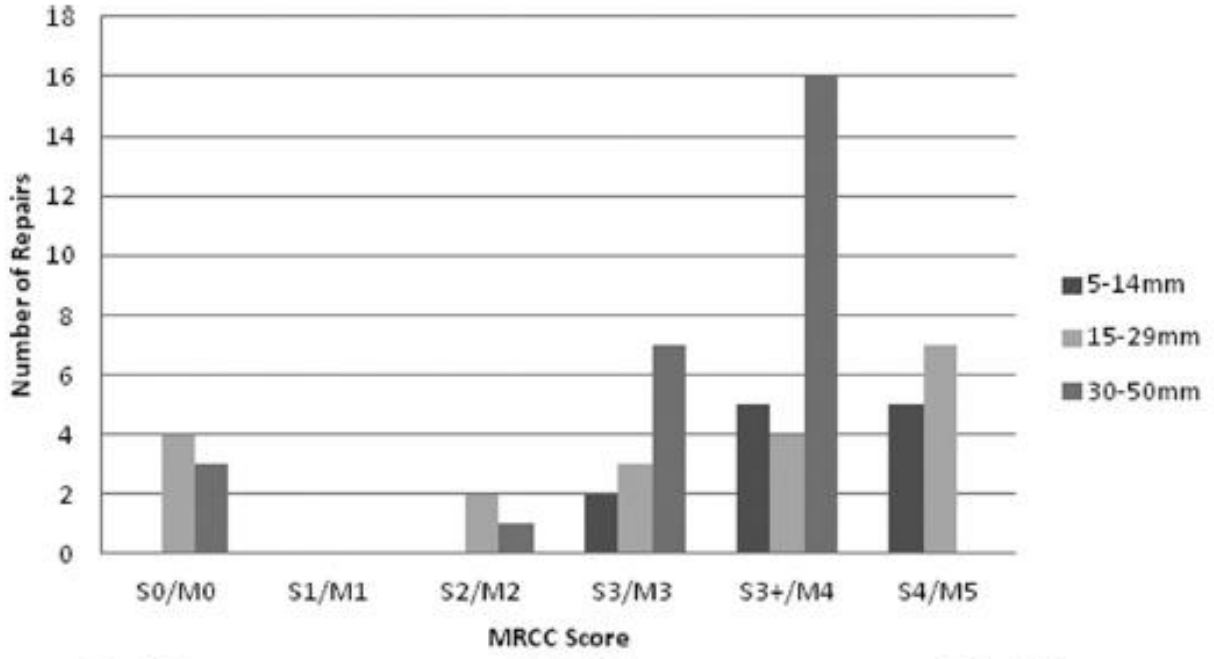
- Near normal 2PD for digital nerve gaps <3cm

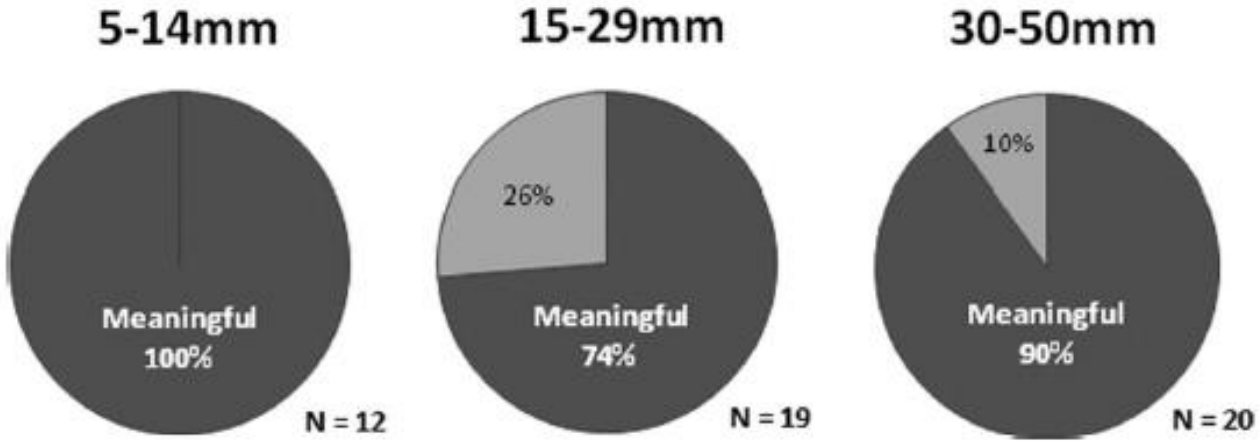
Table 1 A summary of all ten nerve reconstructions with defect length, follow-up, and values obtained on final evaluation of static and moving two-point discrimination (2PDs and 2PDM).

No	Age	Sex	Side	Injured nerve	Etiology	Length	Diameter	Follow-up	2PDS	2PDM
1	47	f	L	Digital nerve	Laceration	0.5	2	5.5	4	4
2	37	f	R	Dorsal sensory branch of the ulna	Neuroma excision	3	1	8.5	*	4
3	37	f	R	Dorsal sensory branch of the ulna	Neuroma excision	3	2	8.5	*	4
4	57	m	R	r ring finger radial digital nerve	Laceration	1	2	12	3	3
5	57	m	R	r ring finger ulnar digital nerve	Laceration	3	2	12	3	3
6	31	m	R	Long finger radial digital nerve	Laceration	3	2	9	6	6
7	48	m	L	Digital nerve	Laceration	3	2	5	10	6
8	65	m	L	Digital nerve	Laceration	3	2	5	4	4
9	23	m	L	Thumb radial digital nerve	Laceration	1	2	12	7	5
10	23	m	L	Thumb ulnar digital nerve	Laceration	1	2	12	7	5
Average	43					2.15	1.90	8.95	5.50	4.40

Karabekmez FE, Duymaz A, Moran SL. Early Clinical Outcomes with the use of Decellularized Nerve Allograft for Repair of Sensory Defects Within the Hand. Hand (NY) 2009; 4(3): 245-9

Ranger Study



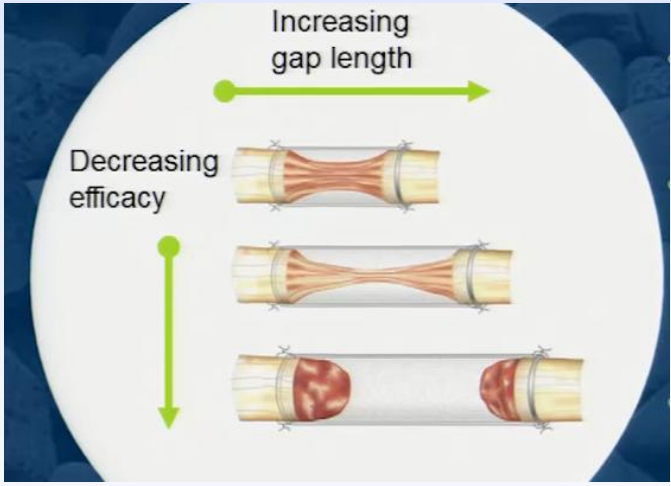


Cho MS1, Rinker BD, Weber RV, Chao JD, Ingari JV, Brooks D, Buncke GM. Functional outcome following nerve repair in the upper extremity using processed nerve allograft. J Hand Surg Am. 2012 Nov;37(11):2340-9.

Nerve Conduits



- Benefits
  - No donor site
  - Simple use
- Only for Sensory nerves
- Gaps less than 15mm???
- Different types
  - Axoguard – porcine submucosa
  - Neuragen – bovine flexor tendon



Conduit Results

- Compared to Direct Repair
  - Sullivan
    - 17% Good, 30% Fair, 53% Poor
  - Buncke
    - 50% Good, 28% Fair, 22% Poor

D. J. Sullivan, “Results of digital neurorrhaphy in adults,” Journal of Hand Surgery, vol. 10, no. 1, pp. 41–44, 1985.
Buncke HJ. Digital nerve repairs. Surg Clin North Am 1972;52:1267–85.

Avulsion or Stretch Injuries

- Usually a mixed injury (Grade VI)
- Can be open or closed
  - Open injuries associated with worse outcomes
- Degree of soft tissue injury bears weight on the outcome
  - May require a delay in treatment

Classification by Location of Injury

- Spinal root avulsions are treated very different than peripheral lacerations
- Muscle Belly avulsions
  - Possible nerve transfer with implantation into the muscle
  - Spinal root = Nerve transfer or tendon transfer

Nerve Recovery Based on Class

Table 22.1 Classification of nerve injury

Seddon	Sunderland	Injury	Recovery
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	Degree IV	Complete scar block	None
Neurotmesis	Degree V	Complete transection	None
	Degree VI (Mackinnon)	Combination of degree I–IV ± normal fascicles	Mixed

I – relatively quick, 6-12 weeks

II , III - 1-1.5 mm a day

IV, V – no recovery

Factors Affecting Nerve Recovery

- Age
- Type of Injury
- Comorbidities
  - Renal Disease
  - Diabetes
- Radial>Median>Ulnar

Delayed Presentation

Timeline

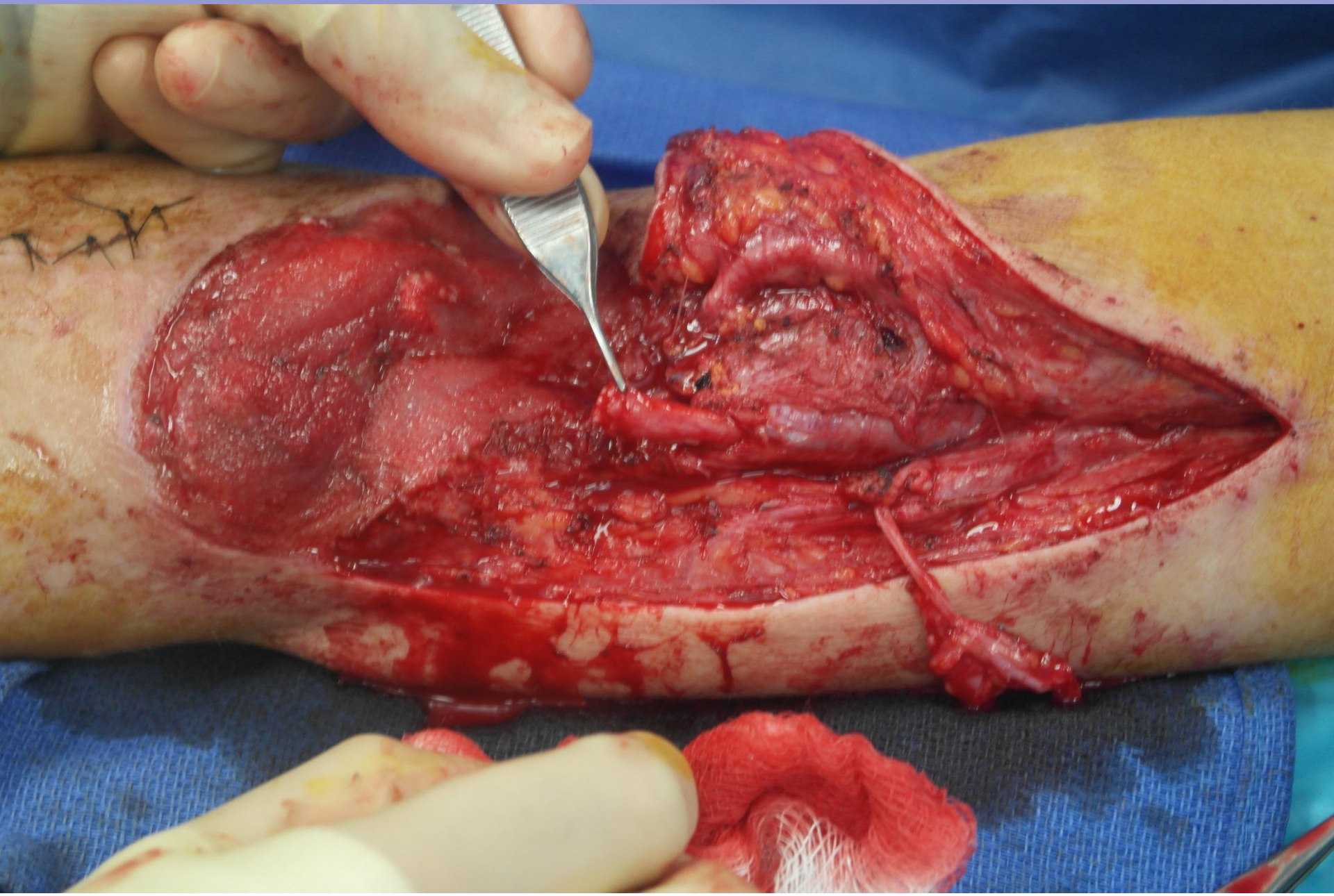
- Nerve reconstruction after 6 months of transection decreases the regenerating axons by 2/3.
- Very different for mixed peripheral nerves versus sensory nerves
  - Sensory end organs respond up to 5 years after injury
  - Muscle atrophy occurs over 18-24 months

Treatment Options

- Dependent on the distance to innervation
- Radial nerve
  - End organ receptors generally much closer to the site of injury.
- Ulnar nerve
  - Intrinsic musculature too far for meaningful recovery

Factors in Decision Making

- Time
- Is there a known level of injury?
- Is there pain at the injury site?
- What is the distance to muscle interface?
- Is there still Passive mobility of the Joints?
- Age
- Are there factors preventing reconstruction at the injury site?



Nerve Transfers

- Often a better option in high injuries
  - Time is muscle
  - Muscle fibers replaced by fat cells
  - Faster innervation than grafting
  - Operation outside of the zone of injury
  - Less chance of adhesions from scarring as with tendon transfers
  - Maintains anatomical biomechanics of the muscle

Rules to Nerve Transfers

- Must be either redundant or expendable donor.
  - Several branches to the FCR tendon from the median nerve
  - AIN to the Pronator Quadratus is expendable with active Pronator Teres Function
- Donor Distal / Recipient proximal
- Adequate mobilization with no tension

Nerve Transfer

- Donor Nerves
  - Appropriate size (specifically axonal count)
  - Proximity to the recipient nerve
  - Synergistic muscle
  - Readily accessible fascicular groups
    - Not mixed fascicles

Tendon Transfer

- Tried and True
- Dr. Paul Brand keys to success in tendon transfer
  - Tissue “equilibrium”
    - Stable skeleton, minimize scar, maximize PROM
  - Strength and excursion should match the native muscle
  - Encourage Straight line of Pull

General Principles in Therapy for the Acute Peripheral Nerve Injury

- **Primary objective**:
  - Protection of the traumatized or surgically repaired nerve
  - Prevention of joint contracture and further injury secondary to decreased sensibility.
  - Example diagnoses include: acute nerve compression, postsurgical decompression and release, postsurgical repair of a lacerated nerve

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Required Information Treatment Implications

Nerve involvement

A. Specific nerve injured

B. Classification and level of injury
Mechanism of injury; clean vs crush

C. Other structures involved

Surgical Management

A. Date of repair

B. Position of joints to allow relaxation of the nerve juncture

C. Type of repair

Skirven TM, Callahan AD : Therapist's management of peripheral-nerve injuries. In Hunter JM, ed al, editors: *Rehabilitation of the hand 5th edition*, St. Louis, 2002, Mosby

A. Indicates sensory and motor impairment; provides focus for evaluation

B. Indicates prognosis and facilitates goal setting

C. Indicates degree of tissue reaction and scar to anticipate more damage with crush injuries than with clean

D. Treatment protocols must be integrated to allow appropriate management for all injured structures.

A. Nerve repairs protected from stress for 3-5 wks

B. Tension at the nerve juncture can compromise results; relaxation of the nerve juncture achieved by flexing the joints across which the nerve passes

C. Early repair is superior to late repair; with nerve grafts, axons must regenerate across junctures.

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Expected Pattern of Motor Return

- Usually a 3-4 week latent period, after which axonal regeneration occurs at the rate of 1 mm/day.
- Once regeneration begins, the muscle will demonstrate these 4 stages
  1. Observable and palpable contracture without production of motion
  2. Ability to hold a test position without being able to produce that position
  3. Ability to move the joint though the test motion
  4. Ability to move the joint through the test motion and hold the position against resistance.

Haymaker W, Woodhall B: *Peripheral nerve injuries: principles of diagnosis*, ed 2, Philadelphia, 1967, WB Saunders

Baxter-Petralia P: Therapist's management of carpal tunnel syndrome. In Hunter JM, ed al, editors: *Rehabilitation of the hand*, St. Louis, 1990, Mosby

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Expected Patterns of Sensory Return

- Recovery occurs in the following sequence
  - Deep pressure and pinprick (protective sensation)
  - Moving light touch
  - Static light touch
  - Discriminative touch

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Immobilization

- **Purpose**:
  - Minimize tension at the repair site
  - Protect the nerve from disruption
  - Incase of nerve compression or following decompression, immobilize or splint to minimize and facilitate the resolution of the inflammatory reaction.

Skirven TM, Callahan AD : Therapist's management of peripheral-nerve injuries. In Hunter JM, ed al, editors: *Rehabilitation of the hand 5th edition*, St. Louis, 2002, Mosby

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Immobilization

- Positioning with casting or splinting is done to avoid tension at the repair.
- Determined by physician.
- 3-4 weeks of immobilization typical
- consider compromised sensation when splinting to avoid pressure areas.
- Monitor status of immobilized joints, educate on ROM.

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Post Immobilization

- Recover lost ROM (consider tension at repair site when progressing motion)
  - If nerve was repaired under tension, therapy approach may be to increase incrementally the amount of ROM.
  - Splints may require serial adjustments to ensure that ROM limits are followed.
    - Ex: radial nerve repair at spiral groove or anticubital fossa- immobilize elbow in 90° flex and wrist ext x 6 weeks

      Laubscher M et al: *Radial nerve lacerations- the outcome of end-to-end repairs in penetrating trauma,* Hand Surg, Vol 2. 2015, 67-72

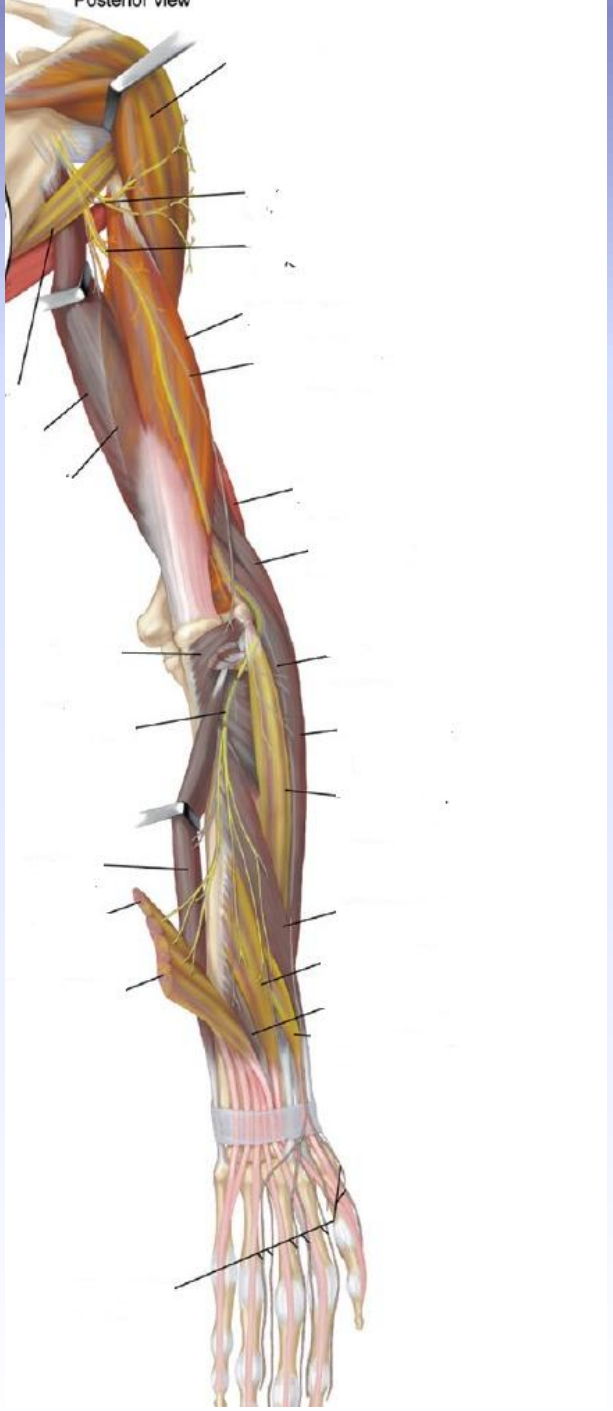
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General Principles of Splinting for Peripheral nerve injuries

1. To keep denervated muscles from remaining in an overstretched position
2. To prevent joint contractures
3. To prevent the development of strong substitution patterns
4. To maximize functional use of the hand.

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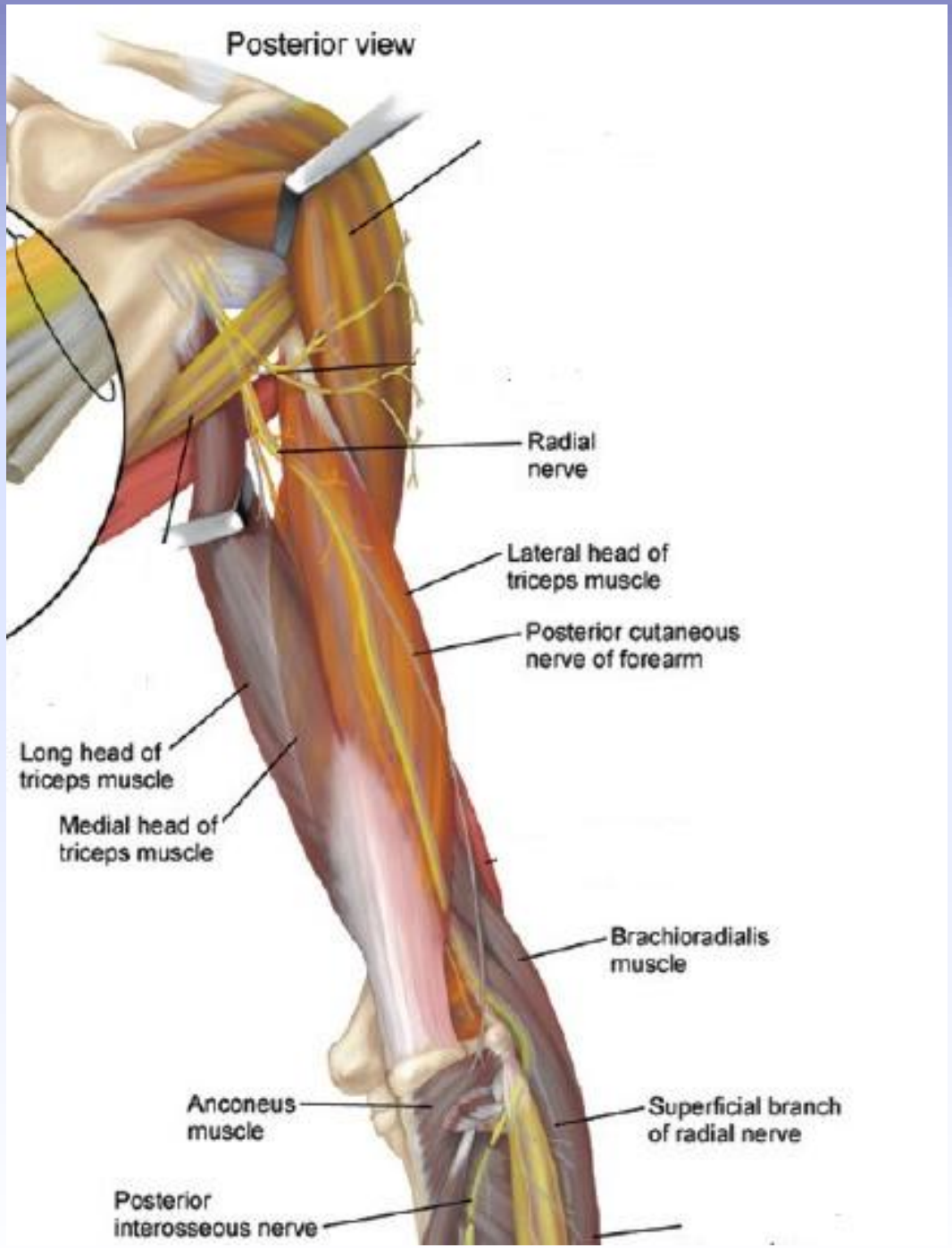
- BREAK-
- Repair and reconstruction of the radial nerve.

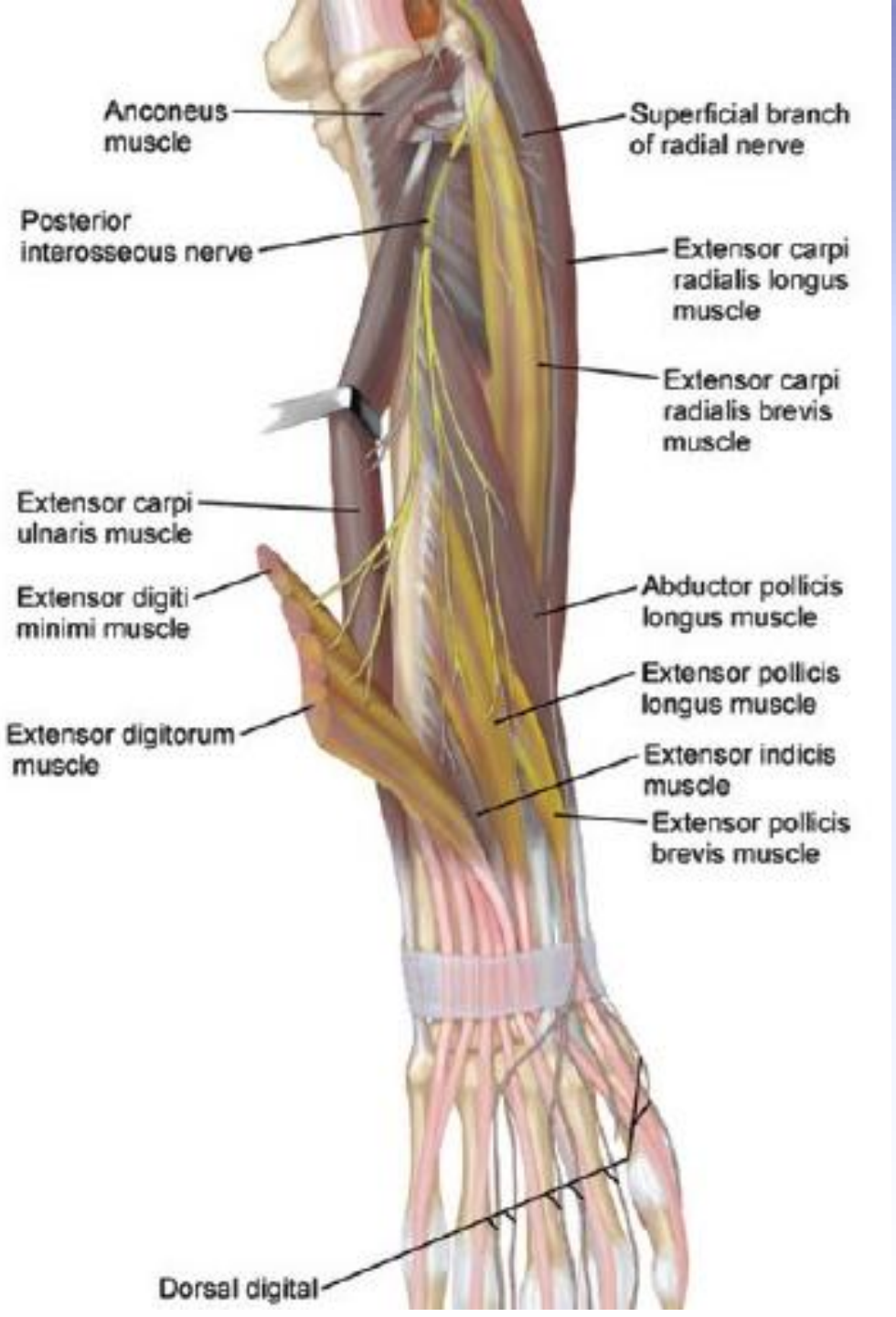


Radial Nerve



Brown JM. Nerve transfers in tetraplegia I: Background and technique. Surg Neurol Int. 2011;2:121.


Posterior view
Radial nerve
Lateral head of triceps muscle
Posterior cutaneous nerve of forearm
Long head of triceps muscle
Medial head of triceps muscle
Brachioradialis muscle
Anconeus muscle
Superficial branch of radial nerve
Posterior interosseous nerve


Anconeus muscle
Superficial branch of radial nerve
Posterior interosseous nerve
Extensor carpi radialis longus muscle
Extensor carpi radialis brevis muscle
Extensor carpi ulnaris muscle
Extensor digiti minimi muscle
Abductor pollicis longus muscle
Extensor pollicis longus muscle
Extensor digitorum muscle
Extensor indicis muscle
Extensor pollicis brevis muscle
Dorsal digital

The Radial Nerve

- Muscles innervated
  - Triceps, extensor carpi radialis and ulnaris, supinator, extensor pollicis
- Motor functions
  - Extension at all arm, wrist, and proximal finger joints below the shoulder; forearm supination; thumb abduction in plane of palm

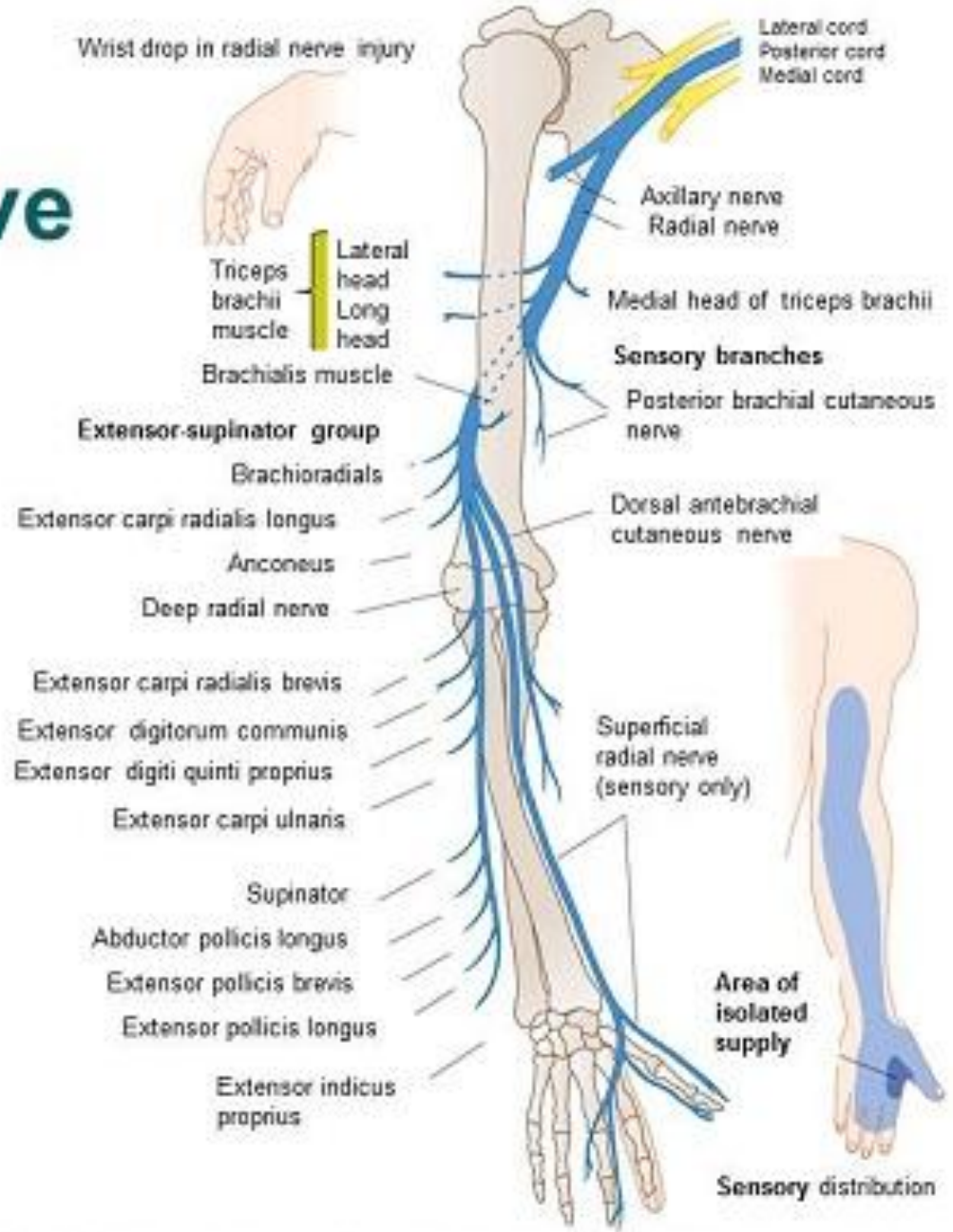


Figure 28-7. The radial nerve (C6-8; T1).In: Waxman SG. *Clinical Neuroanatomy*, 26th ed. http://www.accessphysiotherapy.com. Accessed May 10, 2011.

Holstein-Lewis



- Distal 1/3 associated with entrapment of the radial nerve
- Up to 22% see radial nerve dysfunction
- 90% recover within 3-4 weeks
- 1-5cm of soft tissue b/w nerve and shaft of the radius
- Meta-analysis has shown equal incidence in transverse/spiral fx of middle or proximal 1/3

Treatment of Closed Humerus Fx

- Obvious Indication for exploration in open fx., penetrating injury, vascular injury, ipsilateral forearm fx or floating elbow
- Close fx. Controversial.
  - Most agree observation is recommended with NCS/EMG testing at 6 weeks and 3 months
  - 6-25% entrapped on early exploration
  - 20-42 % Lacerated
    - Some tout Ultrasound as helpful

Bodner G, Huber B, Schwabegger A, Lutz M, Waldenberger P. Sonographic detection of radial nerve entrapment within a humerus fracture. J Ultrasound Med. 1999;18(10):703e706.
Ljungquist KL, Paul M, Allan C. Radial Nerve Injuries. JHS. 2015: 40(1):166-172.

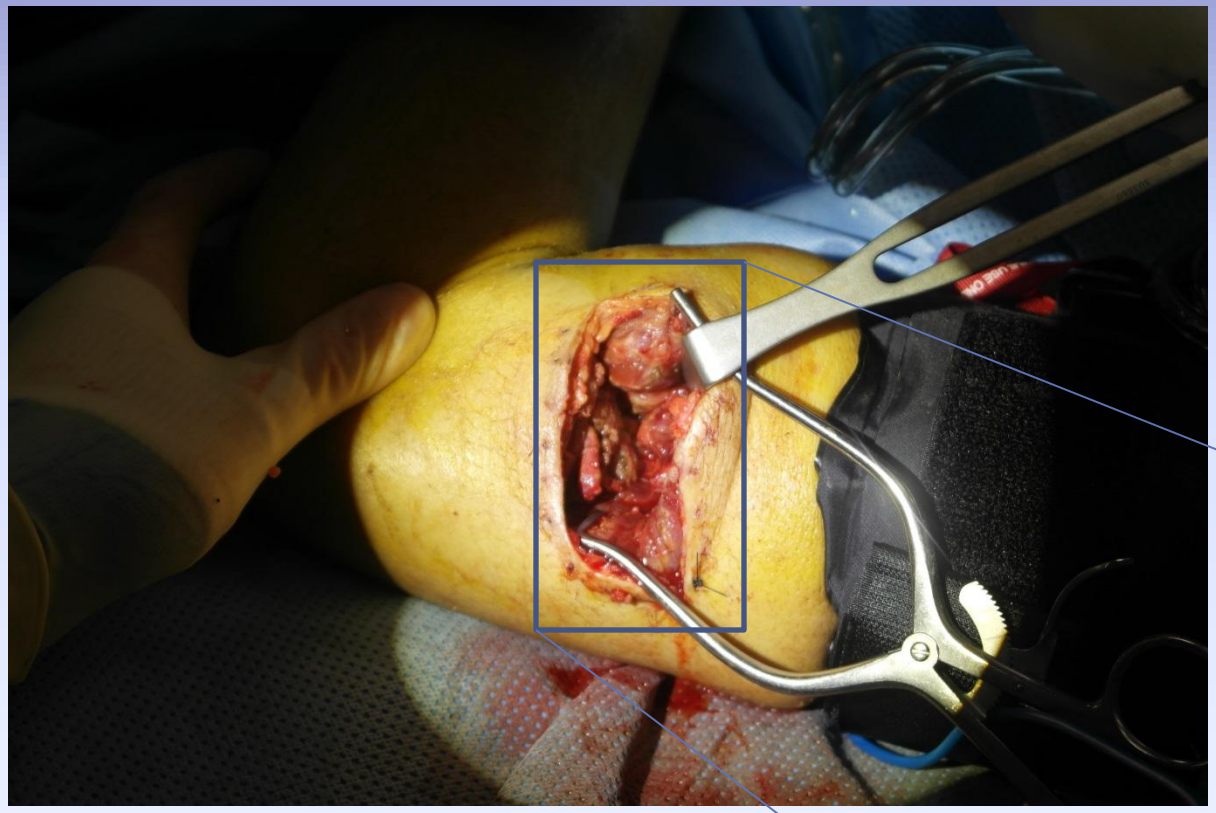
Algorithm for Closed Humeral Fx

- No operative intervention?
  - Adults: 6 weeks NCS/EMG
    - No Recovery: repeat at 12 weeks.
    - No Recovery: follow clinically until 5 – 6 months, if no clinical recovery then explore and graft versus transfers
  - Pediatrics:
    - Same except wait 9 months before surgical intervention

Mohler LR, Hanel DP. Closed fractures complicated by peripheral nerve injury. J Am Acad Othop Surg. 2006; 14(1): 32-37.

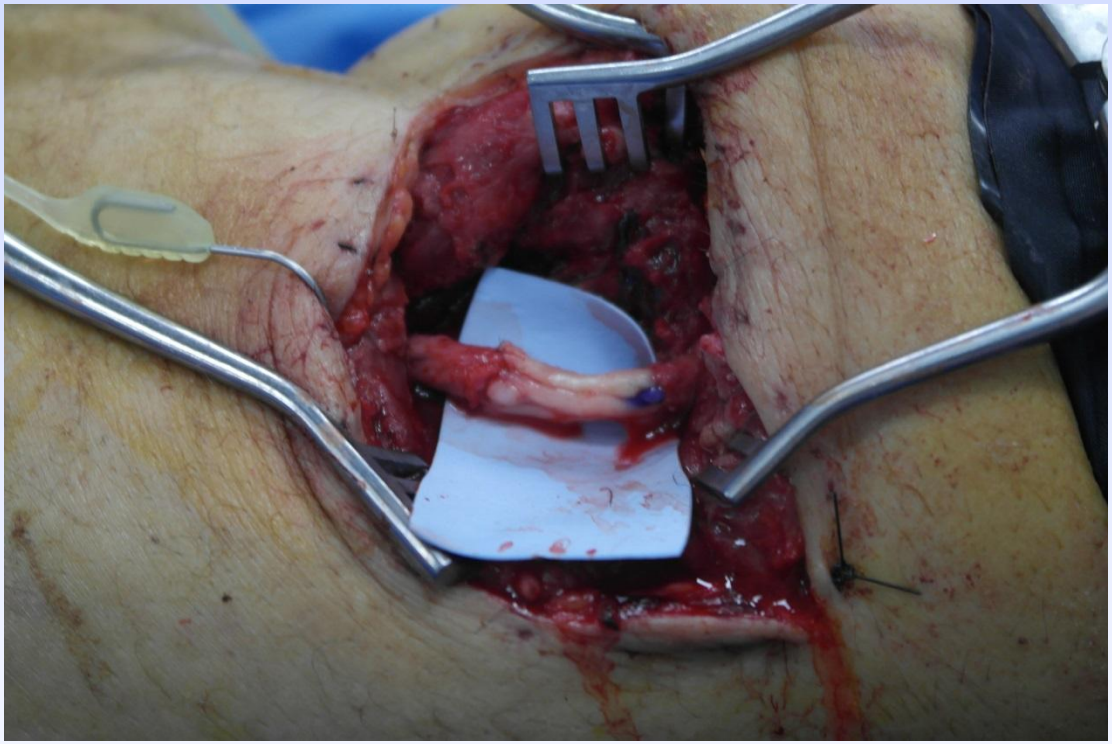
Open Humeral Fracture

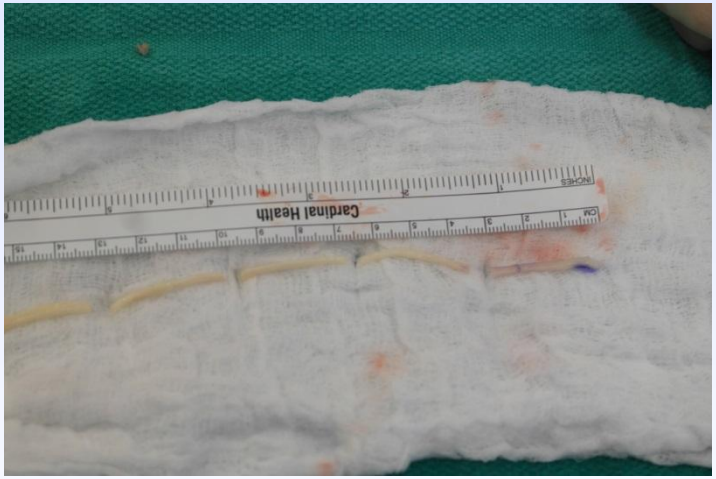
- High energy injury
  - SHOULD NOT ATTEMPT PRIMARY NEURORRHAPHY
  - GRAFT , GRAFT, GRAFT!!!






Cardinal Health




Cardinal Health

1



Via Christi HEALTH

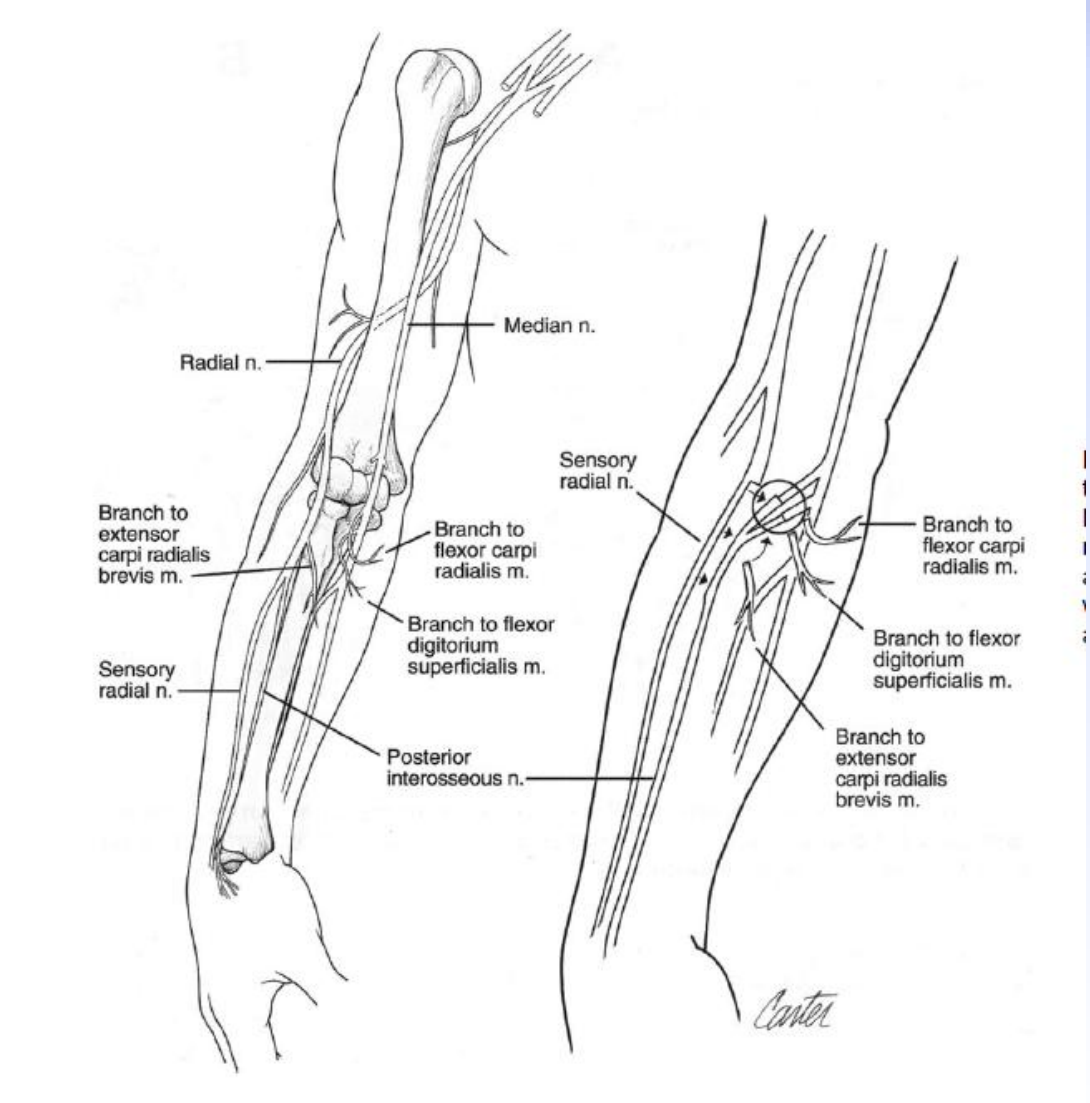


Outcomes of Radial Nerve Grafting

- Better than other Mixed Peripheral Nerves
  - PIN repair recovers better than Radial Nerve proper
  - 66% motor recovery versus 15%[1]

1. Roganovic Zpavlicevic G. Difference in recovery potential of peripheral nerves after graft repairs. Neurosurgery. 2006;59(3):621-633.

Nerve Transfers



- Median Nerve Redundant Branches
  - FDS
  - FCR
  - Palmaris Longus (if present)
- Synergism
  - FCR to EDC
  - FDS to ECRB

Weber RV, Mackinnon SE. Nerve Transfers in the upper Extremity. Journal for the American Society of Surgery of the Hand. *VOL. 4, NO. 3, Aug. 2004*

Radial Nerve Tendon Transfers

- Goal
  - Digit Extension (Radial Nerve)
  - Wrist Extension (radial nerve or PIN)
  - Thumb Extension (PIN)

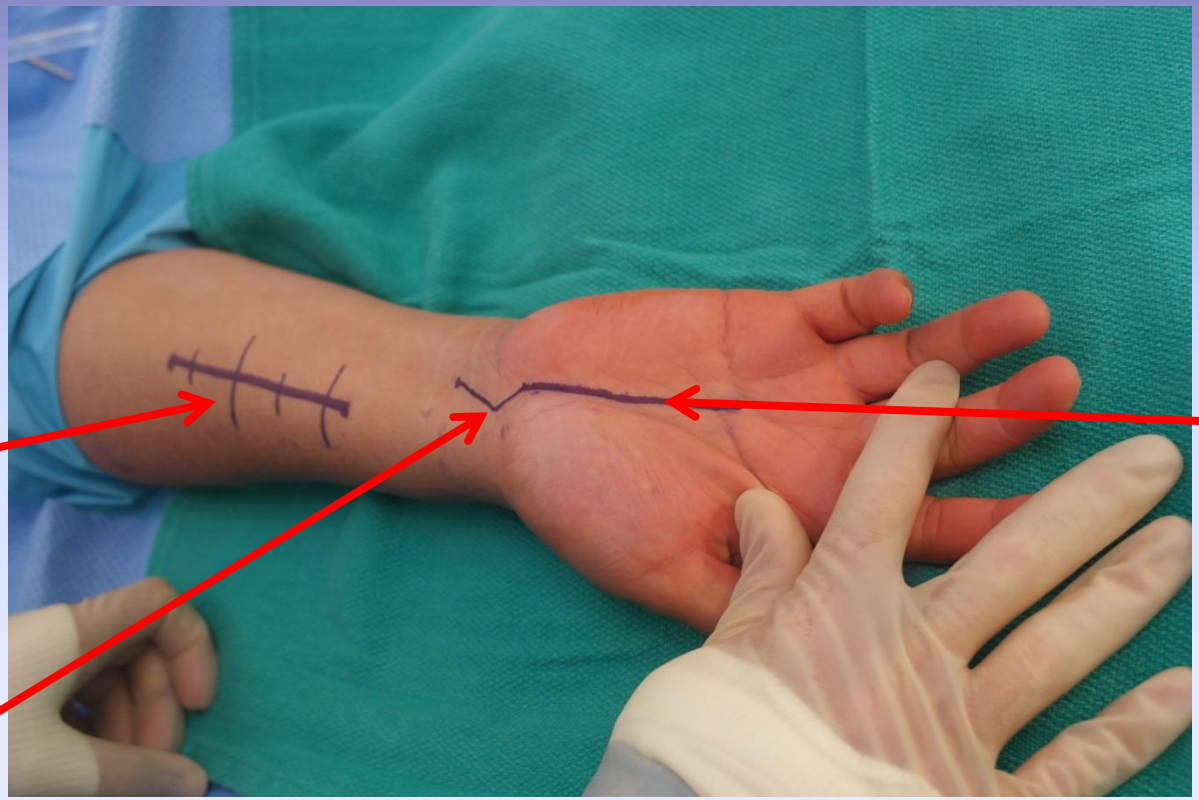
Table 31-6
BEST COMBINATIONS OF TENDON TRANSFERS FOR RADIAL NERVE PALSY

FCR Transfer (Starr,[76] Brand,[15] Tsuge and Adachi[84])
PT to ECRB
FCR to EDC
PL to rerouted EPL

Superficialis Transfer (Boyes[11]; Chuinard et al[24])
PT to ECRL and ECRB
FDS III to EDC
FDS IV to EIP and EPL
FCR to APL and EPB

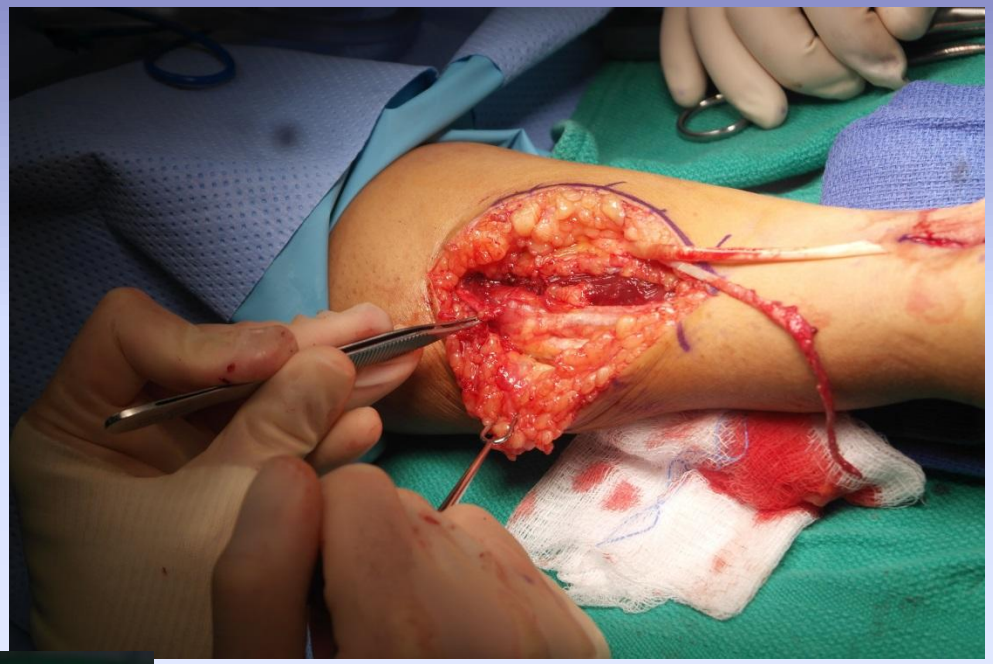
FCU Transfer
PT to ECRB
FCU to EDC
PL to reroute EPL

Green, David P. Green's Operative Hand Surgery. Vol. 1. Philadelphia, PA: Elsevier/Churchill Livingstone, 2005. Print.

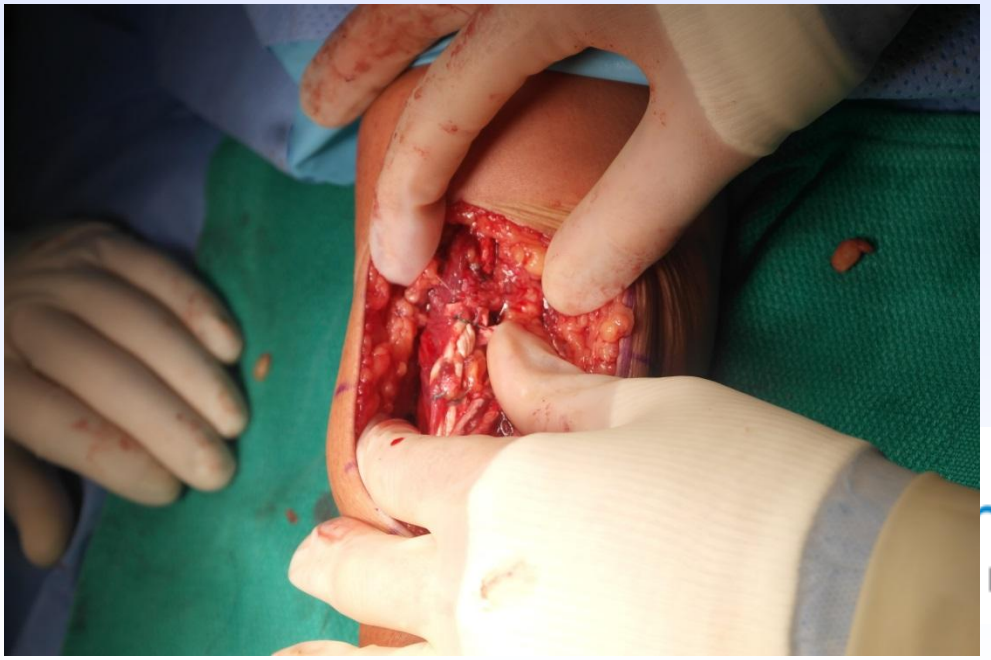




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HEALTH







Therapy for radial nerve palsy and subsequent rehab after treatment

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Radial Nerve

- The radial nerve has the best functional recovery, after repair, of all the nerves in the upper extremity (Adams and Wood, 1981; Burkhalter 1974).
- Average time to recovery has been reported as 7.5 months (Bevin, 1976)

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Testing for Radial Nerve Palsy

- Recall muscles that are innervated by the radial nerve:
  - Triceps
  - Brachioradialis
  - Supinator
  - Extensor muscles of the wrist
  - Extensor muscles of the fingers.

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Testing for Radial Nerve Palsy

- Inability to *simultaneously* extend the wrist and fingers (drop wrist).
- Inability to simultaneously radially abduct the extended thumb
- Proximal radial nerve injuries at elbow and above will present with motor and sensory impairments

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Sensibility Testing of Radial Nerve

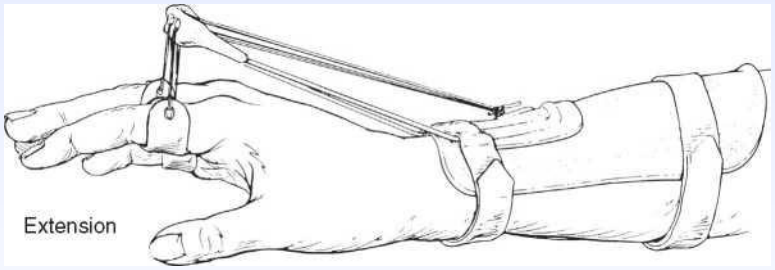
- **Sensation testing**
  - Tinel's sign- assessed by percussion from distal to proximal along the nerve trunk
  - Sharp/dull discrimination
  - Semmes-Weinstein monofilament test
  - Two-point discrimination (static and moving)
    - Normal: <6 mm
    - Fair: 6-10 mm
    - Poor: 11-15
    - Protective: one point perceived
    - Anesthetic: no points perceived.
  - Moberg Pick-up Test

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Treatment for Radial Nerve compression palsy

- **<u>Proximal Radial</u>**
  - Regions compressed:
    - Lateral or long head of triceps
    - Lateral intermuscular septum
    - Spiral groove of humerus
  - Deformity:
    - Wrist and hand extensor weakness (early)
    - Dropped wrist and hand (late)
  - Splint and recommendations:
    - Wrist support – early
    - Outrigger splint to assist wrist, finger and thumb extension- late





"Splint to rest- allow to heal- glide nerve" Lastayo P 2001, AAHS Quarterly Surgery and Rehab of the Hand, Philadelphia meeting 2008

Treatment for Radial Nerve compression palsy

- **Radial Tunnel**
  - Regions compressed:
    - RadioHumeral joint fascia
    - ECRB
    - Supinator
  - Deformity:
    - Pain only
  - Splint and recommendations:
    - Dorsal wrist splint
    - Avoid wrist extension and supination.



"Splint to rest- allow to heal- glide nerve" Lastayo P 2001, AAHS Quarterly Surgery and Rehab of the Hand, Philadelphia meeting 2008

Treatment for Radial Nerve compression palsy

- **PIN**
  - Regions compressed:
    - Radial head
    - Arcade of Frohse (prox supinator)
    - Distal margin of Supinator
  - Deformity:
    - Loss of MP ext, fingers and thumb ext
    - Loss of ECRB/L
  - Splint and recommendations:
    - Muenster to limit rotation
    - Extention tenodesis splint for MP ext assist
    - Avoid repetitive pro/sup
    - Radial nerve glove
    - Stretch supinator



"Splint to rest- allow to heal- glide nerve" Lastayo P 2001, AAHS Quarterly Surgery and Rehab of the Hand, Philadelphia meeting 2008

Radial Nerve Splinting

- <u>Why splint for Radial nerve?</u>
  - Loss of wrist extension: increases risk of overstretching wrist extensors→
  - Increased resting MCPJ extension→
  - Increasing tension placed on EDC→
  - Resulting in shortening of collateral ligaments and, if unrelieved, will lead to contracture of the MCPJ's

Via Christi HEALTH


via youcandomore.net

Treatment for Radial Nerve palsy

- Pearls:
  - When associated with extensor tendon repairs, the guideline for extensor tendon repairs should be followed.
  - Non-dominant: consider static splint
  - Nighttime splint: static wrist immobilizer
  - Splint compliance is determined by ensuring
    - Splint functionality (too bulky?)
    - Cosmetically acceptable

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Treatment for Post-op Radial Nerve repair

- Acute stage (1-3 weeks)
  - Splinting options:
    1. maintained in intraoperative cast
    2. Forearm based, static, wrist extension splint (wrist in 0-30°). If repair is tight, increased extension is necessary
    3. High radial nerve injuries (proximal to elbow): also immobilize elbow in 90° for 3 weeks
  - Exercise: Hourly active flex and active-assisted extension of digits only
  - Edema: position forearm in elevation when sitting/ sleeping
  - Instruction: single arm use only, maintain ROM of elbow/ shoulder regularly

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Treatment for Post-op Radial Nerve repair

- <u>Week 3</u>
  - Complete a functional and sensory assessment

At forearm level	Results in
ECU	Loss of ulnar wrist ext
EDM, EI, EDC	Loss of MCPJ ext
AbdPL, EPB, EPL	Loss of thumb radial abd and ext

At elbow level (see above plus)	Results in
Supinator	Weakened supination
ECRL & ECRB	Loss of ulnar and radial wrist ext

Proximal to elbow (see above plus)	Results in
Brachioradialis	Weakened elbow flex

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Treatment for Post-op Radial Nerve repair

- Week 3
  - Splinting options:
    1. At night- continue volar forearm-based night resting splint
    2. Day- fabricate low-profile dynamic MCPJ ext splint (forearm based if prox to wrist, hand-based if PIN only)
    3. Gradually wean wearing time of splint or consider discarding sections of the dynamic splint as recovery occurs.
  - Exercise:
    - Maintain passive ext of long flexors
    - Active flex of individual joints (avoid composite wrist and finger flex until week 8)
    - Active/ passive thumb palmar and radial thumb abd and thumb ext to maintian thumb web space
    - Commence nerve gliding

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Treatment for Post-op Radial Nerve repair

- Week 3 (continued)
  - Scar management
    - Begin once wound is closed
  - Desensitization/ sensory re-education
    - Begin with localization of moving touch using light and deep pressures over the involved area. Once perceived→ upgrade to recognizing of shapes (starting with large objects and moving on to smaller objects) and discriminative sensation of different textures.

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Treatment for Post-op Radial Nerve repair

- Week 6 +
  - <u>Splinting options:</u>
    - Continue with dynamic extension splint or wrist extension splint/ wrist brace to promote function.
  - <u>Exercises:</u>
    - Initiate gentle passive ROM of wrist and digits (if ext tendons are associated, passive flex should be delayed until week 10)
    - Begin resisted exercises
      - Putty strengthening program
      - Progress to activities requiring a stable wrist /digit extension.

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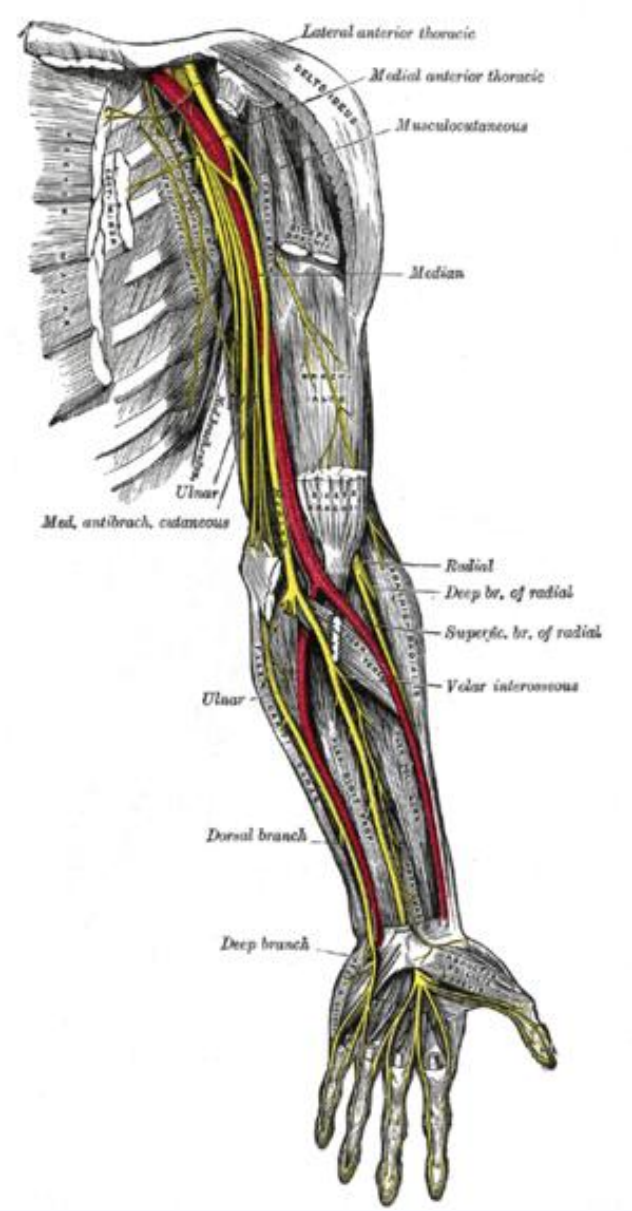
- BREAK:
  - Repair and reconstruction of the ulnar nerve. DR:L

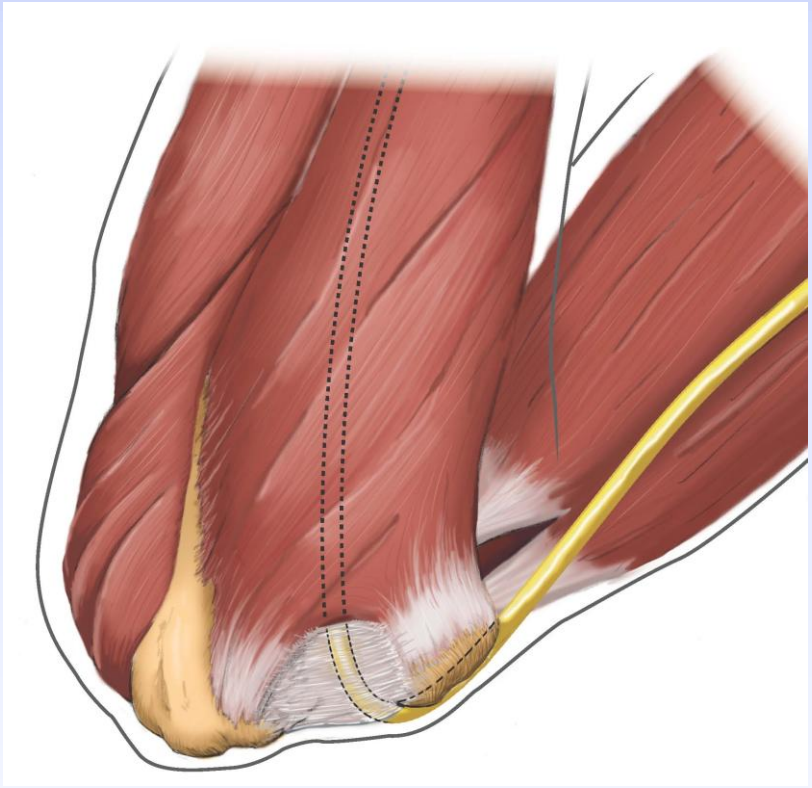
Ulnar Nerve

- Most frequent major peripheral nerve injury in hospitalized patients .
- Early repair is paramount for any recovery
- Results much less desirable than other nerves

Lad SP, Nathan JK, Schubert RD, Boakye M. Trends in median, ulnar, radial, and brachioplexus nerve injuries in the United States. Neurosurgery. 2010;66(5):953e960.

Ulnar Nerve


Lateral anterior thoracic
Medial anterior thoracic
Musculocutaneous
Median
Ulnar
Mal. antibrach. cutaneous
Radial
Deep br. of radial
Superfic. br. of radial
Volar interosseous
Ulnar
Dorsal branch
Deep branch

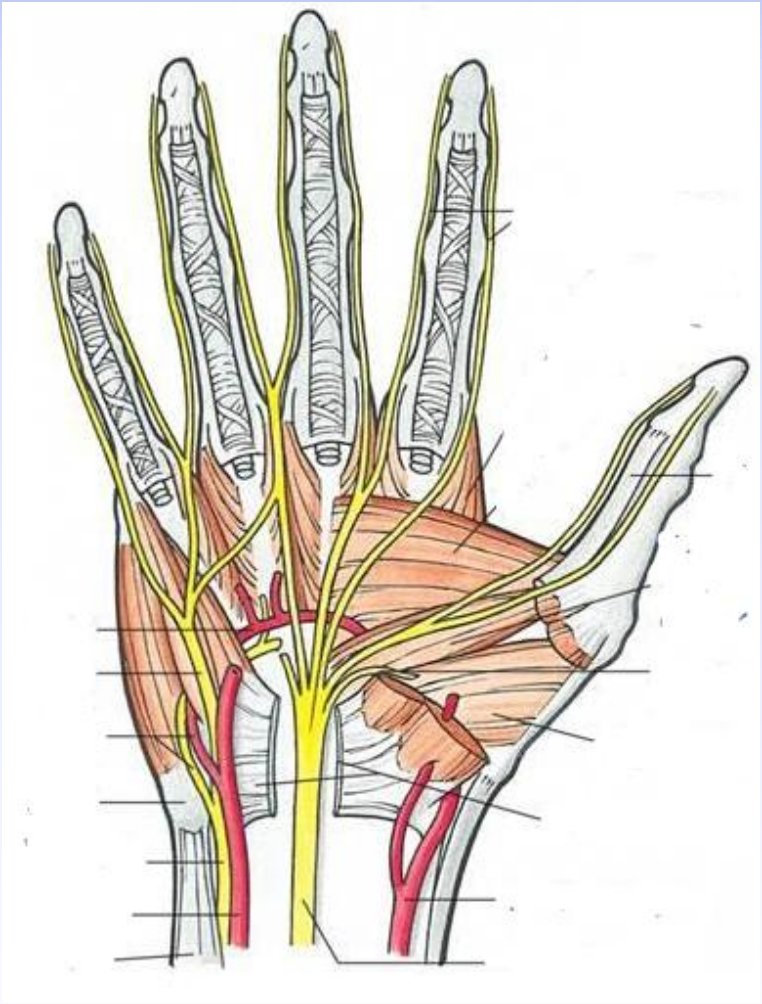




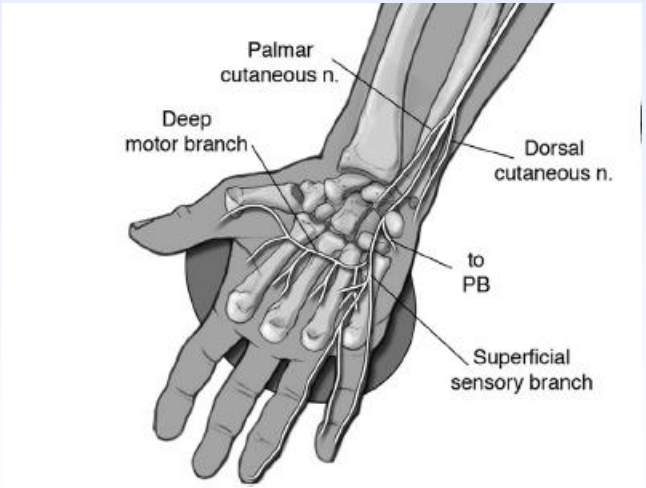
Ulnar Nerve

- Flexor Carpi Ulnaris
- Flexor Digitorum Profundus (ring,small)

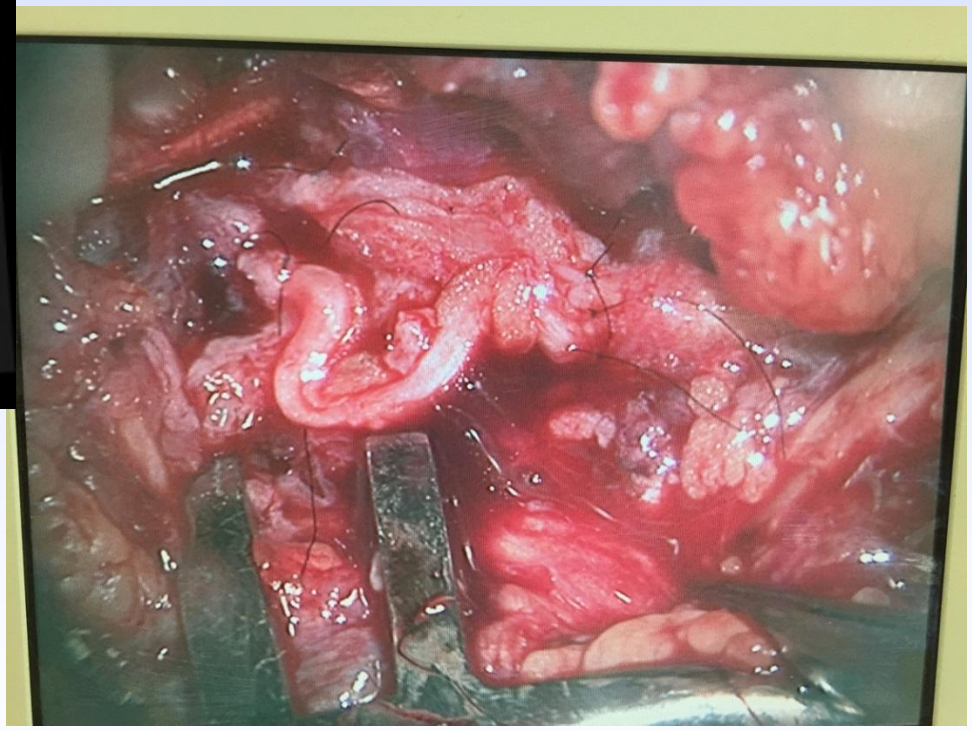
Ulnar Nerve



- Opponens digiti minimi
- Abductor digiti minimi
- Flexor digiti minimi brevis
- Palmar and Dorsal Interossei
- Adductor Pollicis
- Flexor Pollicis brevis (deep head)



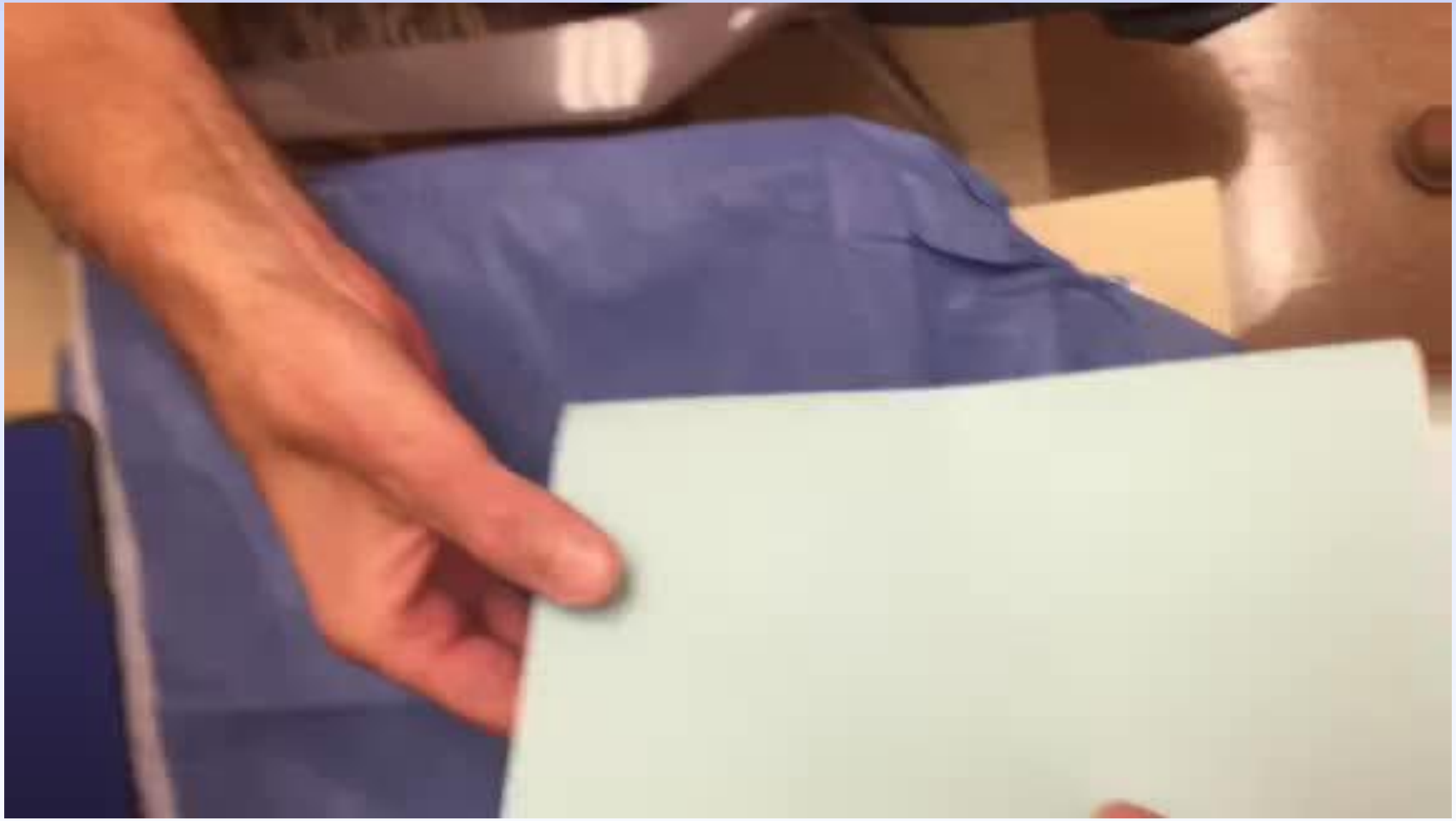




Ulnar Nerve Motor Grafting

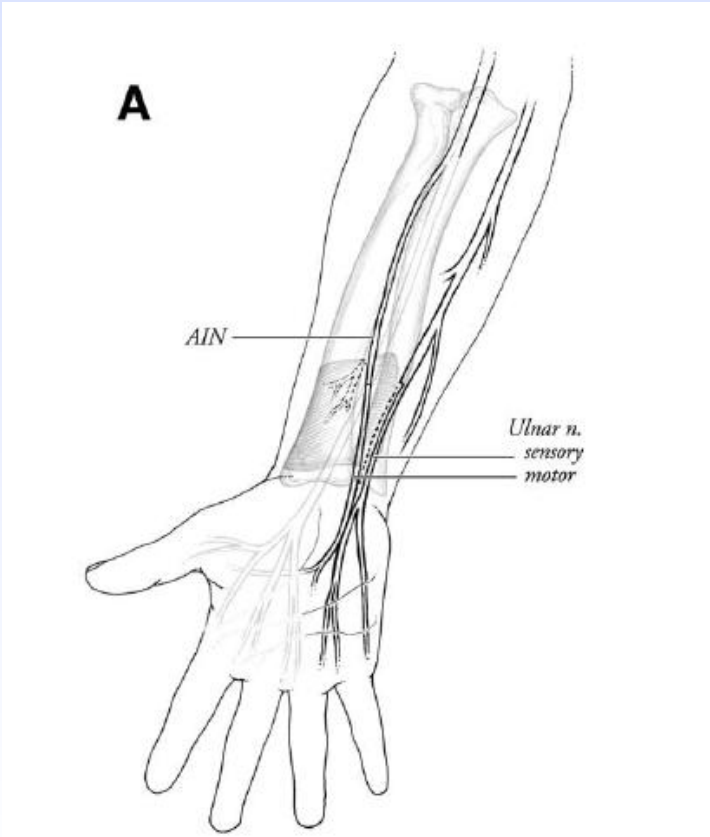


Ulnar Nerve Grafting Motor Branch

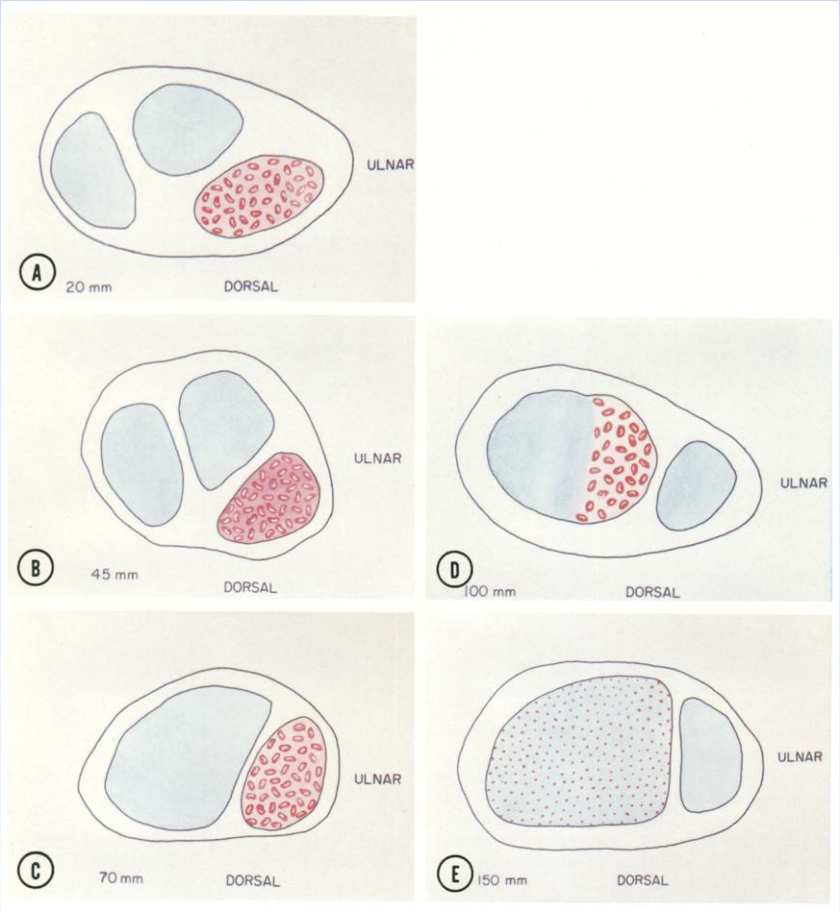


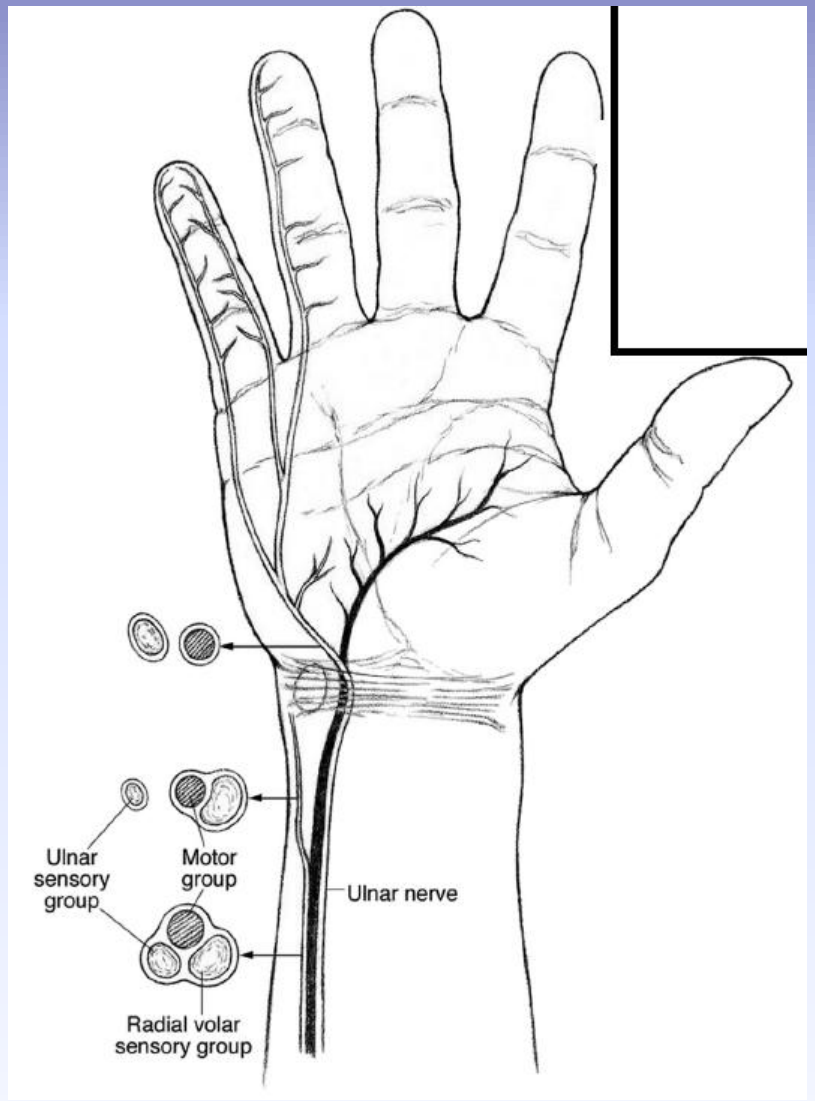
Nerve Transfer

- AIN to Ulnar Nerve
  - Terminal branch for the AIN supplies the Pronator Quadratus



Weber RV, Mackinnon SE. Nerve Transfers in the upper Extremity. Journal for the American Society of Surgery of the Hand. VOL. 4, NO. 3, Aug. 2004

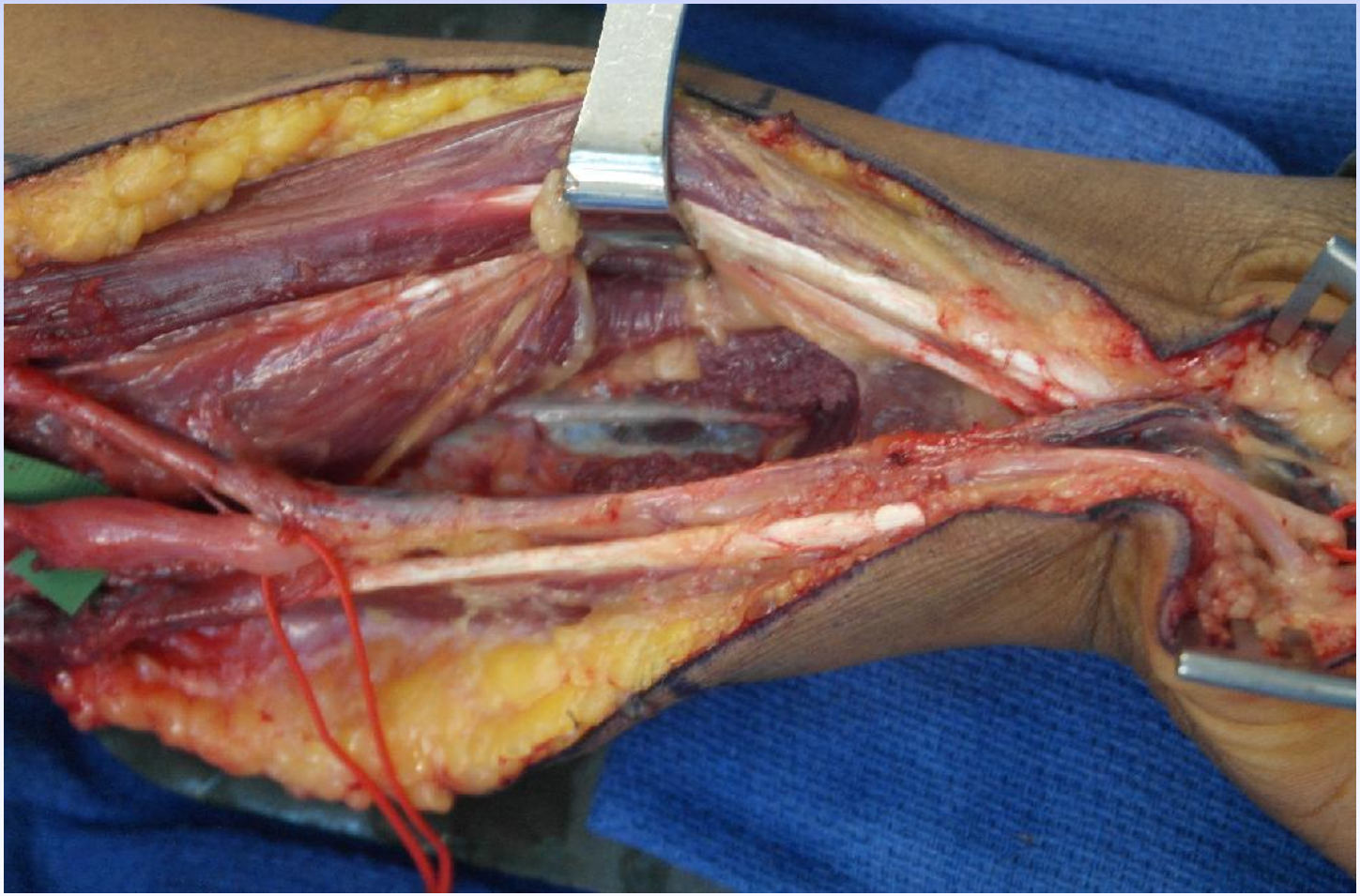




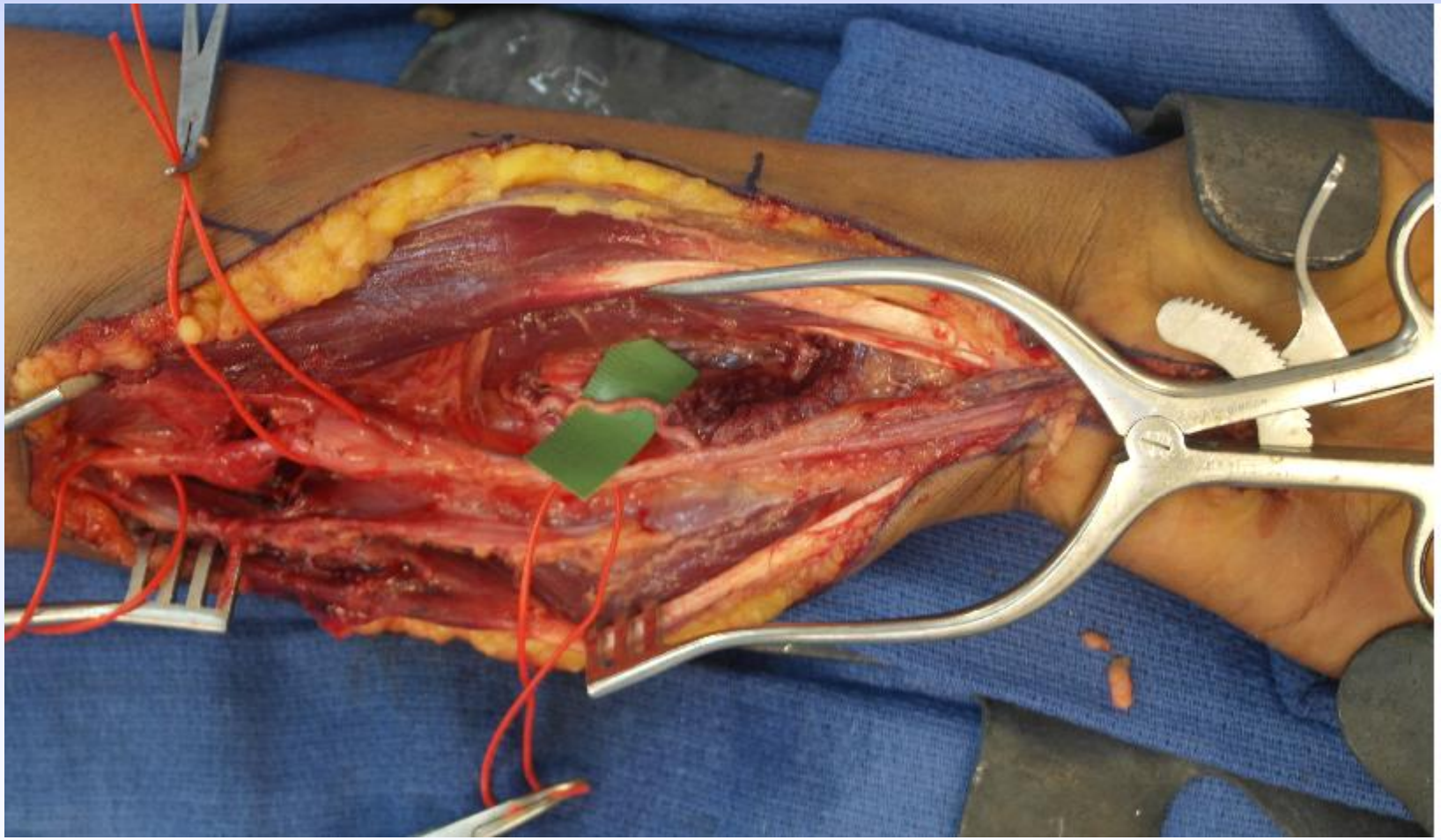
Surgical significance of the motor fascicular group of the ulnar nerve in the forearm. Chow JA, Van Beek AL, Meyer DL, Johnson MC. JHS, Vol. 10, Issue 6, p867–872

Via Christi HEALTH

Nerve Transfers



Nerve Transfers

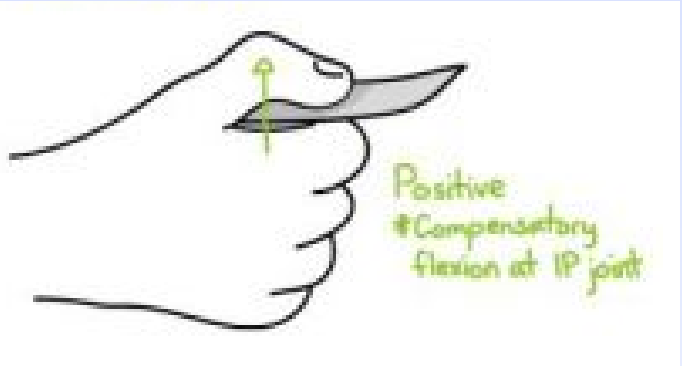


Tendon Transfers for Ulnar Nerve Palsy

- Goals
  - Restore Thumb Adduction, Index Abduction, MP function of the digits

Thumb Adduction

- Loss of Adductor Pollicis leads to deficiency in pinch strength
- Possible tendon transfers
  - ECRB
  - FDS II



Adductorplasty

- Transverse incisions made to harvest ECRB
- Withdrawn from extensor retinaculum



Adductorplasty

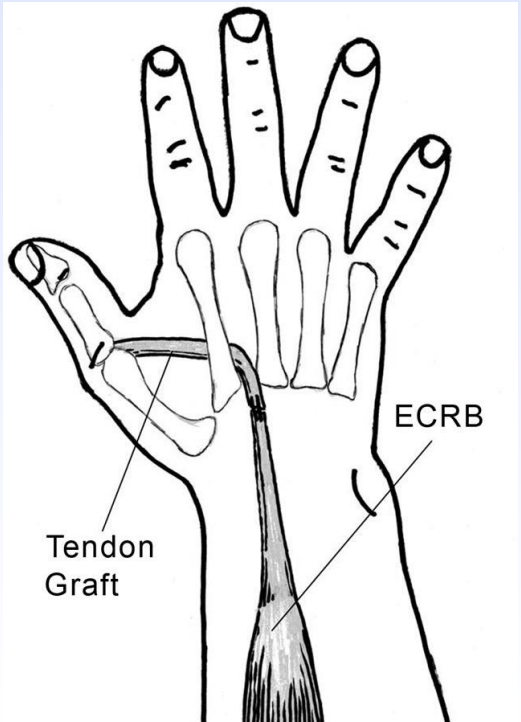
- ECRB lengthened
- Routed through metacarpal space



Adductorplasty

- Tendon routed around, volar to 2nd MC
- Inserted to thumb MCP
- Between add pollicis, 1st dorsal interosseous





Index Abduction

- APL slip or Brachioradialis transferred to 1st DI
- Provides 1st dorsal interosseous function



Bouvier's Test

- Evaluates extensor hood integrity
- Delineates simple from complex claw deformities
- Surgical implications
  - Transfer will correct MCP ext
    - Simple = insert P1 or A1 pulley
    - Complex = insert lateral bands

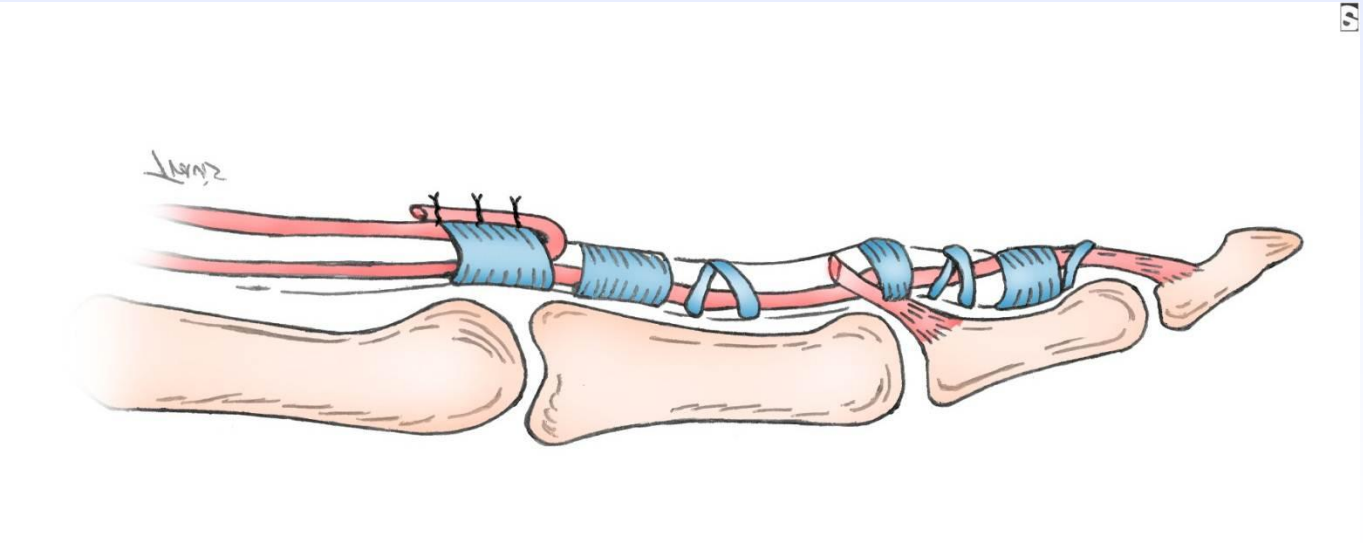
- Simple (+Bouvier's)
  - Corrected MCP extension
  - Allows for IP jt to extend actively (extrinsic extensors)
  - Good extensor apparatus

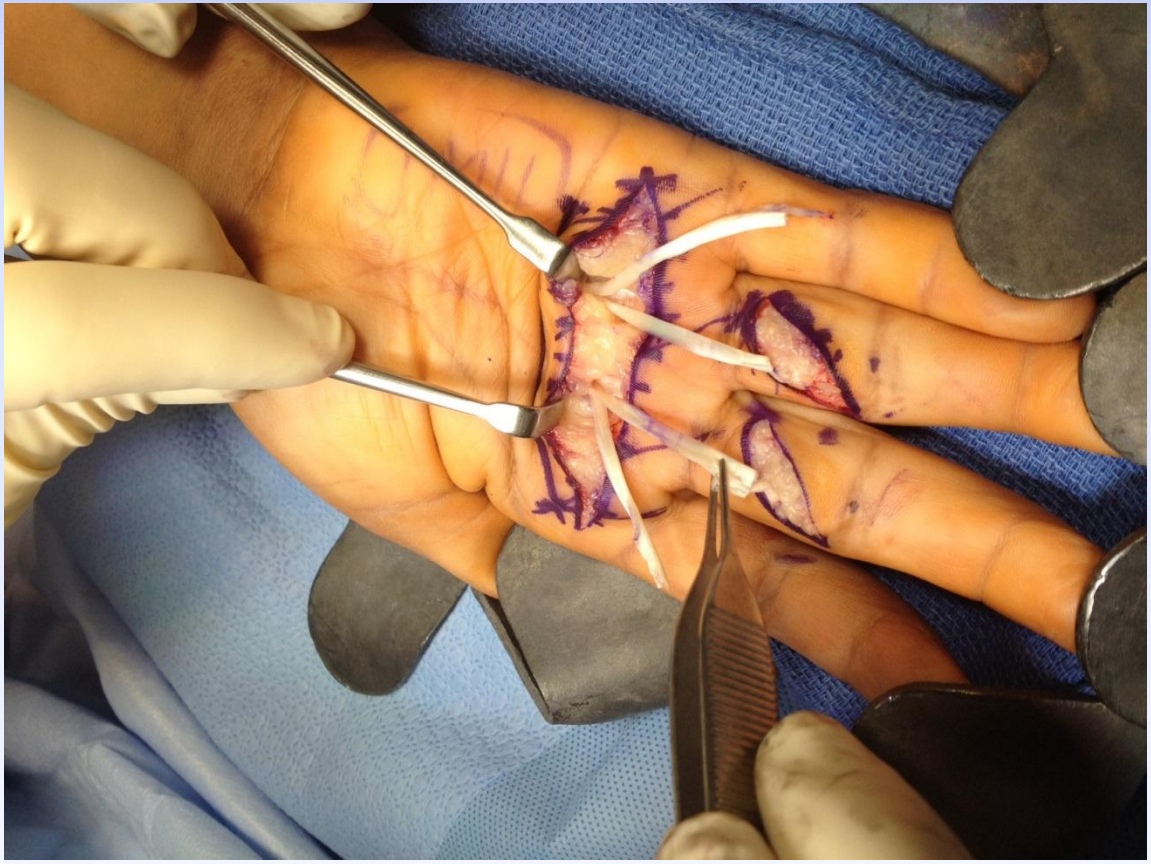
- Complex (-Bouvier's)
  - MCP extension
  - IP jts UNABLE to extend
  - Insufficient extensor apparatus



Zancolli Lasso Transfer

- FDS released
- Delivered through A2 pulley
- Sewn over A1 pulley to itself
- Corrects MCP claw deformity



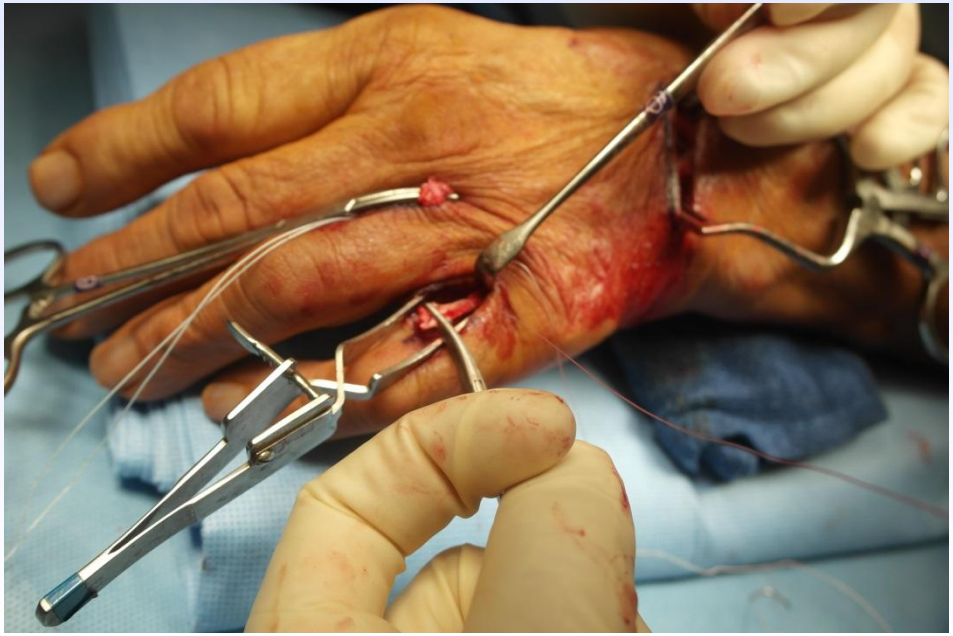












Therapy for ulnar nerve palsy and subsequent rehab after treatment

- Assessment- low lesion
  - Intrensic atrophy
  - Hypothenar eminence atrophy
  - Clawing of 4th and 5th digits
  - Wartenberg's sign (abd of 5th digit



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Therapy for ulnar nerve palsy and subsequent rehab after treatment

- Assessment – high nerve lesion

  *Same presentation as with low lesion, plus the following:

  – Clawing less evident due to paralysis of FDP
  – Atrophy of medial aspect of upper forearm.

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Testing for Ulnar nerve palsy

- Recall muscles that are innervated by the ulnar nerve:
  - Flexor carpi ulnaris
  - RF/SF FDP
  - Adductor pollicis
  - Interossei muscles

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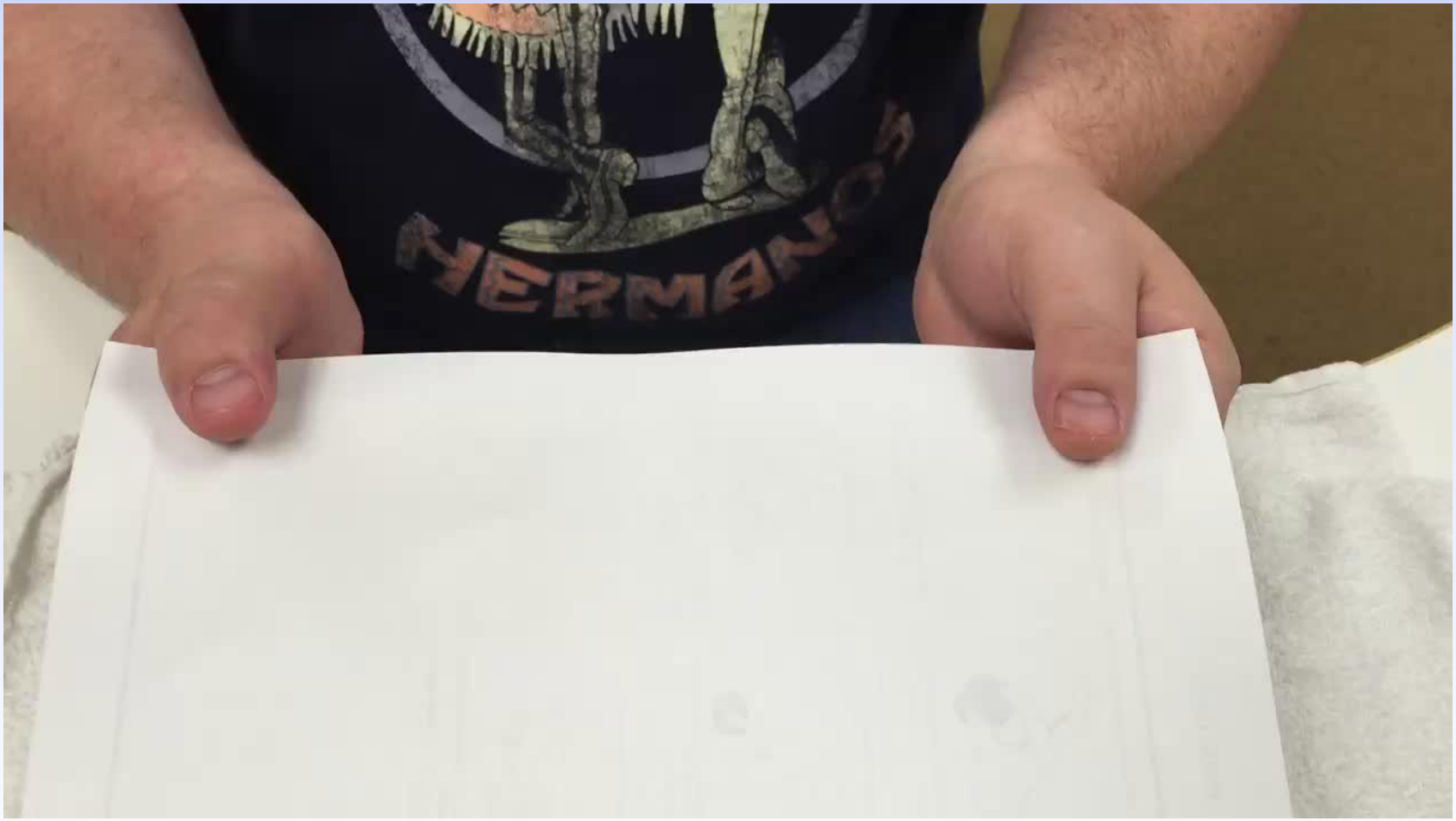
Testing for Ulnar Nerve Palsy

- **<u>Thumb Adduction</u>**:
  - place and hold against palm. (asking pt to add thumb from abducted position could lead to substitution by APB, EPL, FPL
  - Froment's sign
  - Jeanne's sign





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HERMANOS

Testing for Ulnar Nerve Palsy

- IPJ Extension
  - Bouvier's test: hyperextension of RF/ SF MCPJ is prevented and pt asked to extend finger
- Finger adduction
  - Test 5th finger on flat surface (to prevent finger flexor substitution). + Wartenberg's Sign (inability to adduct the 5th digit)
- Finger abduction
  - Test MF radial and ulnar abduction on flat surface (to eliminate EDC compensation
  - Ulnar paradox: higher the lesion, the less the claw
  - Martin-Gruber anastomosis: median nerve fibers ultimately innervate the intrinsic hand muscles



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Treatment for Ulnar nerve compression palsy

- **<u>Ulnar Cubital Tunnel:</u>**
  - Regions compressed:
    - Intermuscular Septum
    - Arcade of Struthers
    - Medial Epicondyle
    - Arcuate ligament
    - FCU
  - Deformity:
    - Abduction of small finger (early)
    - Claw hand (late)
  - Splint and recommendations:
    - Buddy tape small to ring – early
    - Medial elbow pad- day
    - Elbow and wrist support splint – night (elbow between 30-60°, wrist neutral)
      - Towel splint
    - Anti-claw splint – late
    - Encourage work with elbow flex < 90°



"Splint to rest- allow to heal- glide nerve" Lastayo P 2001, AAHS Quarterly Surgery and Rehab of the Hand, Philadelphia meeting 2008

Therapy for Ulnar Nerve Palsy

- **Compression**:
  - Buddy tape small to ring – early
  - Medial elbow pad- day
  - Elbow and wrist support splint – night (elbow between 30-60°, wrist neutral)
    - Towel splint
  - Anti-claw splint – late
  - Encourage work with elbow flex < 90°

Via Christi HEALTH



Treatment for Post-op Ulnar nerve repair

- Acute stage (1-3 weeks)
  - Splinting :
    - Immobilization of the wrist in neutral and MCP joints of ring and little in 70° flexion
    - In order to allow flexion of digits, consider replacing the surgical cast with a thermoplastic forearm based dorsal blocking splint
  - Exercise:
    - Active assisted ROM of digits only, wrist immobilized
  - Edema:
    - position forearm in elevation when sitting/ sleeping
  - Instruction:
    - single arm use only, maintain ROM of elbow/ shoulder regularly

WHAT-OCT-018; Guideline for Therapy Intervention for Ulnar nerve Lesions and Neurapraxia

Via Christi HEALTH

Treatment for Post-op Ulnar nerve repair

- Weeks 3-6
  - Splinting :
    - Continue splinting at night time and in ‘at risk situations’
  - Exercise:
    - Active ROM of wrist can be introduced
    - Introduce nerve gliding exercises, avoid tension on the ulnar nerve.

WHAT-OCT-018; Guideline for Therapy Intervention for Ulnar nerve Lesions and Neurapraxia

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Treatment for Post-op Ulnar nerve repair

- Weeks 3-6
  - Scar management
    - Begin once wound is closed
  - Desensitization/ sensory re-education
    - Begin with localization of moving touch using light and deep pressures over the involved area. Once perceived→ upgrade to recognizing of shapes (starting with large objects and moving on to smaller objects) and discriminative sensation of different textures.

WHAT-OCT-018; Guideline for Therapy Intervention for Ulnar nerve Lesions and Neurapraxia

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Treatment for Post-op Ulnar nerve repair

- Week 6-8
  - Splinting
    - *Night*: splint in POSI to decrease the likelihood of fixed claw deformity.
    - *Day*: an anti-claw splint to little and ring: dorsal hand based blocking splint to prevent hyperextension of the MCP joints but allow full flexion.
  - Exercises
    - Gentle passive ROM of wrist and digits can be introduced. (If flexor tendons are associated passive extension should be delayed until 12 weeks post surgery!)



WHAT-OCT-018; Guideline for Therapy Intervention for Ulnar nerve Lesions and Neurapraxia

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Treatment for Post-op Ulnar nerve repair

- Post splint removal:
  - Carry out a functional and sensory assessment of the hand. The following deficits can be expected:
    - Clawing of little and ring
    - Loss of arches of the hand and wastage of hypothenar eminence
    - Loss of thumb adductor
    - Wastage of the web spaces
    - At forearm level there will also be a weak wrist flexion and loss of ulnar deviation of the wrist. The clawing may be less if the laceration is at elbow level.
    - **Functional loss**:
    - o Decreased power in all grips
    - o Loss of writing grip due to loss of thumb adduction
    - o Inability to adduct and abduct the digits
    - **Sensory loss:** hypothenar eminence, volar ring and little. At elbow level the dorsal ulnar surface of the hand will be affected.

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Treatment for Post-op Ulnar nerve repair

Reinforce importance of protection of the ulnar side of the hand from harm by sharp or hot objects

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Treatment for Median nerve compression palsy

- **<u>Proximal Median:</u>**
  - Regions compressed:
    - Ligament of Struthers
  - Deformity:
    - Hand weakness, loss thumb webb
    - Ishemic attacks
  - Splint and recommendations:
    - Webb spacer (late)
    - Avoid overhead work
    - LAS to rest



"Splint to rest- allow to heal- glide nerve" Lastayo P 2001, AAHS Quarterly Surgery and Rehab of the Hand, Philadelphia meeting 2008

Treatment for Median nerve compression palsy

- **<u>Pronator Syndrome:</u>**
  - Regions compressed:
    - Lacertus Fibrosis of biceps
    - Pronator
    - FDS
  - Deformity:
    - Hand weakness, loss thumb webb
  - Splint and recommendations:
    - Muenster to limit rotation
    - Avoid repetitive pronation/ supination
    - Stretch pronator



"Splint to rest- allow to heal- glide nerve" Lastayo P 2001, AAHS Quarterly Surgery and Rehab of the Hand, Philadelphia meeting 2008

Treatment for Median nerve compression palsy

- **AIN:**
  - Regions compressed:
    - Pronator
    - FDS
  - Deformity:
    - Loss of thumb IP and index DIPJ flex
  - Splint and recommendations:
    - Muenster to limit rotation
    - Maintain distal joint mobility



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