UE Peripheral Nerve Surgery and Postoperative Management

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ASHT International Committee
Virtual Education Series

American Society of Hand Therapists™

Objectives

- Discuss current evidence for post-op protection and mobilization.
- Recognize the indications for nerve grafts, primary nerve repairs and nerve transfers and the postoperative therapy approaches for each.
- Identify critical timelines in post-op management of nerve repairs.
- Develop a treatment plan for sensory and motor recovery following nerve repair.

Surgery Options for Peripheral Nerve Lacerations

- Direct end to end repair
  - Primary within the first few days following injury
  - Secondary - one week or more following injury
- Nerve graft
- Conduit (nerve tube)
- Nerve transfer

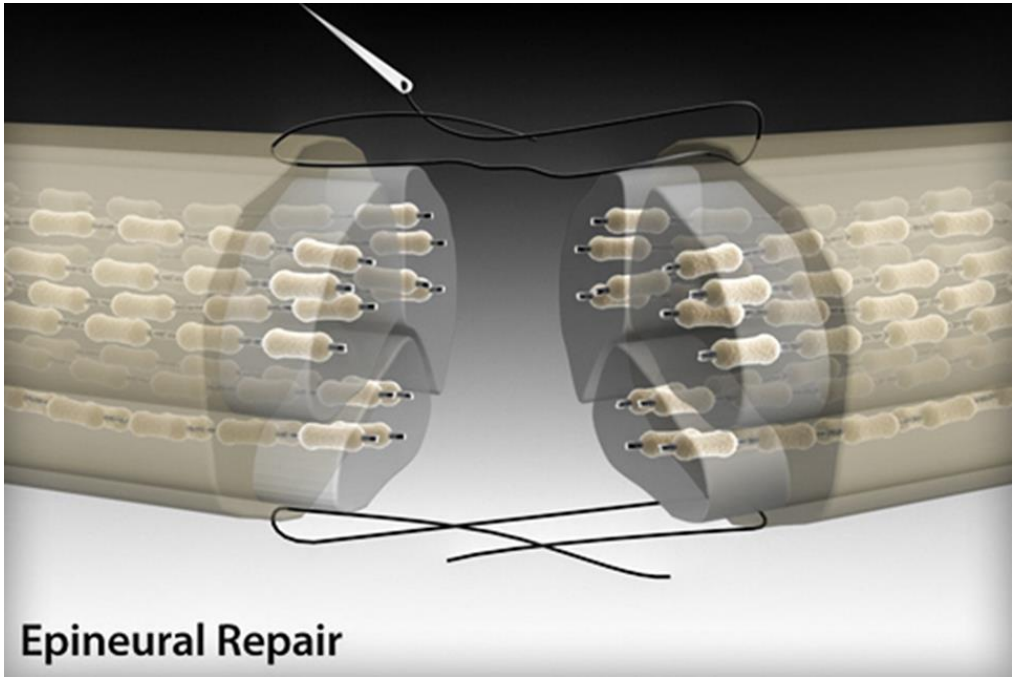
Prognostic Factors

- Degree of injury (less severe is better)
- Level of injury (more distal is better)
- Type of nerve (mixed nerve is worse)
- Age (younger is better)
- Mechanism of injury (injury in continuity is better than complete)
- Timing of repair (immediate repair is better)

Direct Repair

Indications

- Sharp lacerations without ragged edges allowing for minimal trimming and repair without tension



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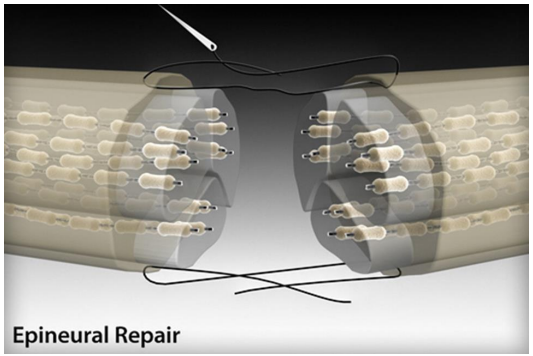
Direct Repair

Technique :

Preparation – The nerve ends are prepared to obtain normal, visible ends without necrotic tissue.

- The nerve ends are mobilized and brought together
- Tensionless repairs have shown to have better outcomes
- Extensive intrafascicular dissection is avoided
- Rotational alignment as able
- Epineural repair: Sutures through the epineurium only
- Sometimes individual fasciscular groups are identified for attachment (group fascicular nerve repair)
    - Preferred for larger nerves where sensory and motor fibers can be repaired separately


Epineural Repair

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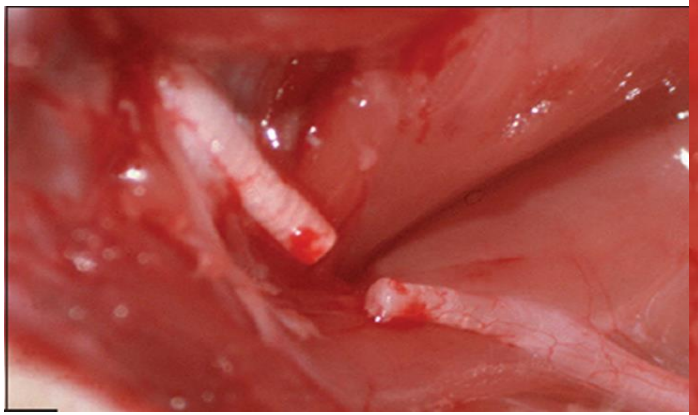
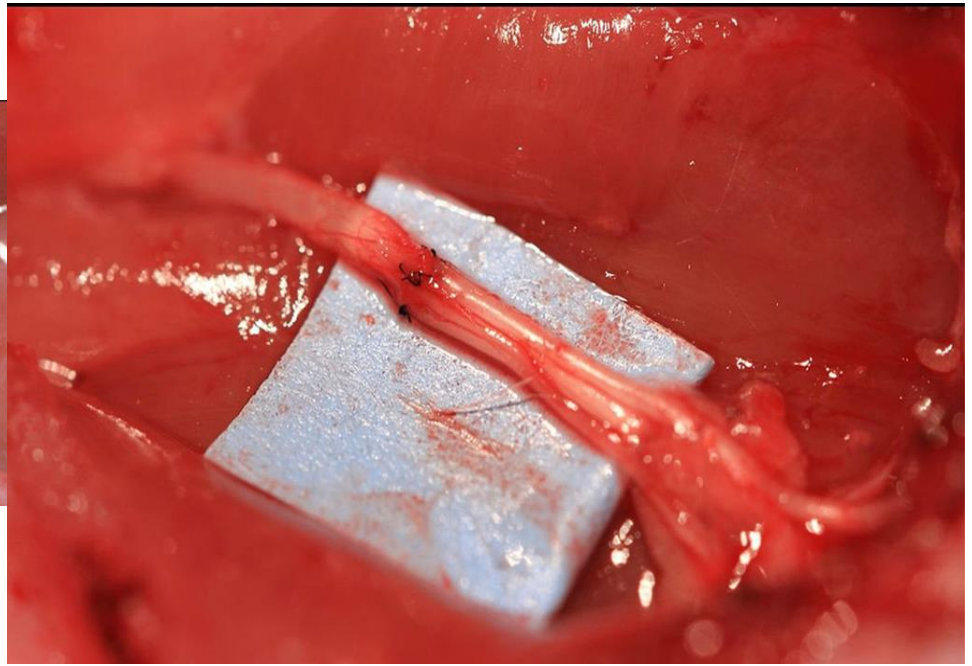
Direct Repair



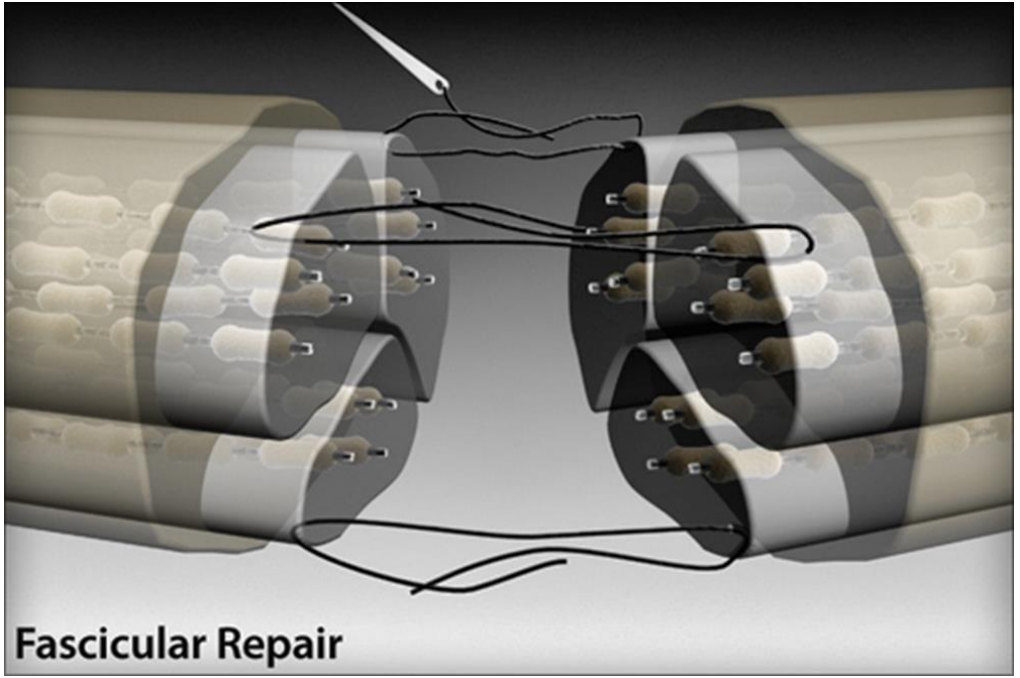


Wikipedia.com

Direct Fascicular Repair

Indications

- Larger, more proximal nerves



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Direct Nerve Repair Postoperative Management

01	Protect Repair	• Place repaired nerve on slack • Orthosis 2-3 weeks
02	Reduce edema	• Rest • Ice/Cold packs post operative • Elevation
03	Education	• Protection of repair • Range of motion to uninvolved joints • Edema control

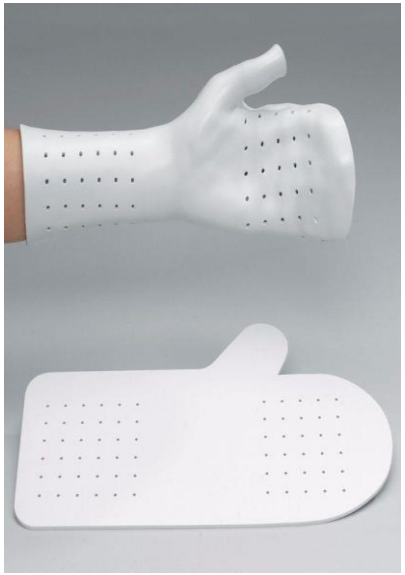
Direct Nerve Repair Postoperative Management

Median or ulnar nerve: dorsal blocking orthosis with wrist 30° deg flexion

L. Klein, 2022

*If finger flexors involved

Radial nerve: volar orthosis with wrist and digit extension



performancehealth.com

Benik.com

Direct Nerve Repair Postoperative Management

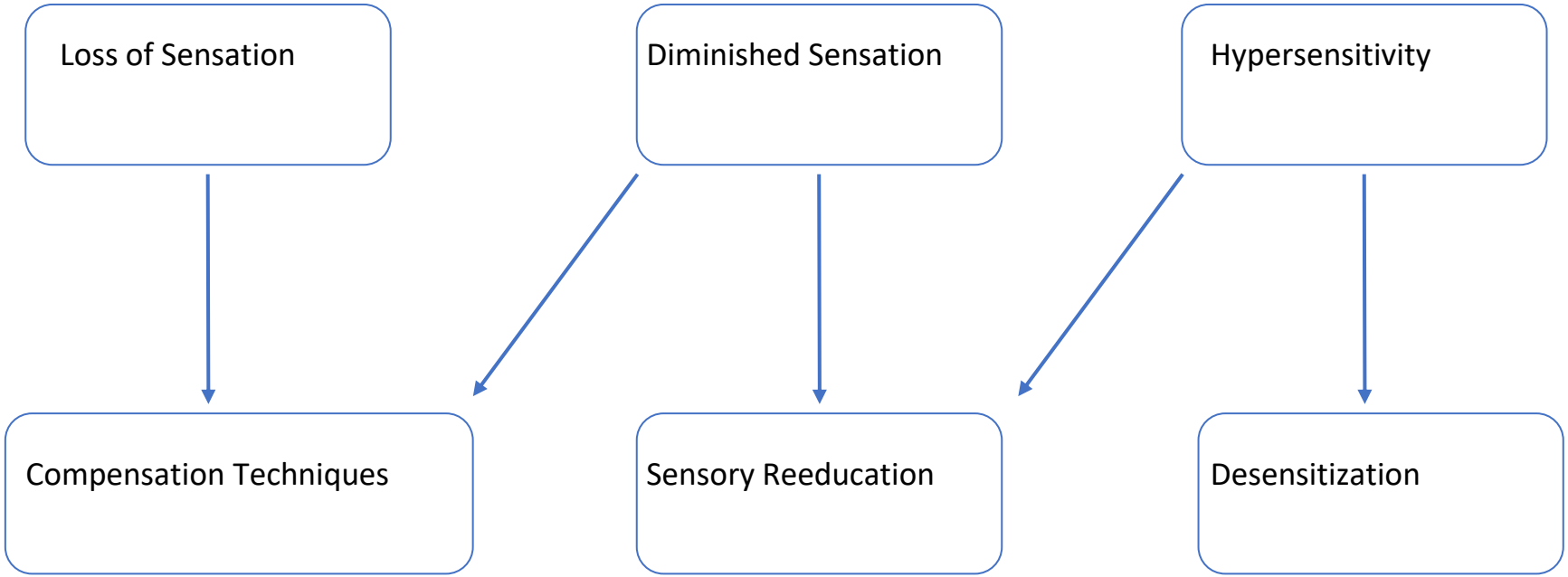
3 weeks:

- A/PROM: Begin by moving individual joints before composite motion; as composite motion may place tension on the nerve repair
  - Treatment for stiffness and tendon adhesions while protecting nerve repair
  - Use modalities to precondition tissue prior to ROM (e.g. hot pack or paraffin)
- Monitor motor and sensory recovery
- Orthosis to prevent deformity (PRN)
- Scar and edema management
  - Avoid aggressive scar massage directly over nerve repair
- Sensory reeducation/desensitization

Motor Recovery

- Prior to motor recovery: Protect from overstretch and deformity with appropriate orthosis/positioning
  - Ulnar nerve: anticlaw orthosis
  - Radial nerve: Wrist/finger extension or wrist synergistic orthosis
  - Median nerve: Thumb abduction
- When reinnervation begins:
  - Start with short exercise sessions
    - Gravity eliminated with assistance
  - Progress to place and hold
    - Midrange isometric contraction with slow-onset muscle contraction (10–15 second holds)
  - Active movement against gravity
  - Bilateral motion to assist with relearning motor patterns
  - Obtain good motor control prior to advancing resisted exercise

Sensory Recovery



Updated Sensory Reeducation Supports a Multisensory, Phased Approach

I = Immediately post injury/repair

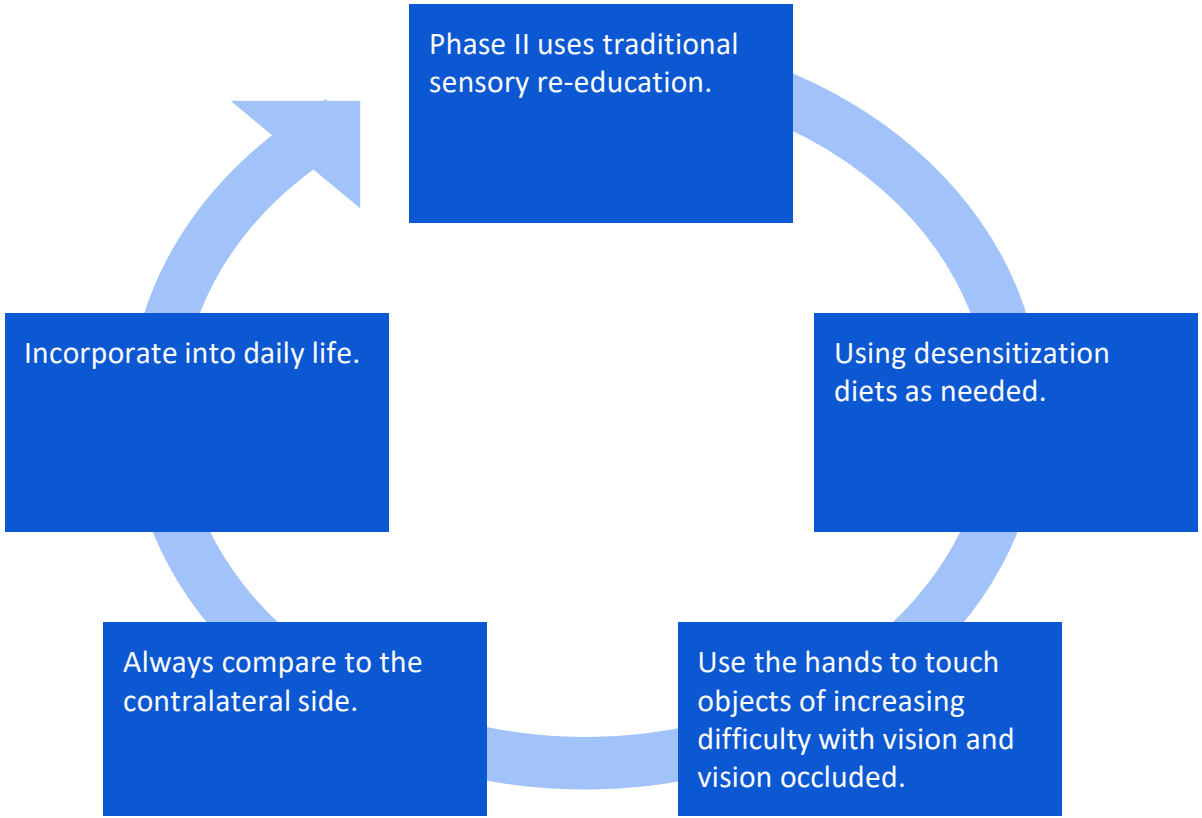
- Silent period
- Other areas expand/invade the silent area
- Goal is to minimize this, maintain area for correct sensory input
- ***Rationale = By time traditional sensory re-ed is started, incorrect reorganization of the brain is present and may not be correctable***

II = After reinnervation (3-4 months post)

II = After reinnervation (3-4 months post)

- Traditional sensory reeducation
- Application of forearm anesthesia (?)
- Distorted representation in brain
- Reorganize/Relearn
- Based on vision guiding touch and higher cortical functions

Phase II Begins When Some Sensation is Present.



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Digital Nerve Direct Repair Postoperative Management

Orthosis: Traditionally, use a finger length or hand based dorsal blocking orthosis to keep repair on slack with 20-30 deg flexion or as directed by surgeon

L. Klein 2018

Digital Nerve Direct Repair Postoperative Management

2 options, varies by surgeon

1. Immediate active, gentle passive flexion from dorsal blocking orthosis
   - Emphasize flexor tendon gliding to avoid adhesions

L. Klein 2015

2. Immobilize for 3 weeks
   - Treatment for stiffness and flexor tendon adhesion

Evidence Supporting No Immobilization Following Digital Nerve Repair

Vipond, Taylor, Rider

Postoperative Splinting for Isolated Digital Nerve Injuries in the Hand- Vipond, Taylor, Rider Journal of Hand Therapy Volume 20, Issue 3, July–September 2007, Pages 222–231

26 subjects, half 3 wks in orthosis, other half no orthosis: no difference at 6 months

Clare, de Haviland Mee, Belcher

Rehabilitation of digital nerve repair: is splinting necessary?

The Journal of Hand Surgery: British & European Volume 29, Issue 6, December 2004, Pages 552–556

40 nerve repairs evaluated approx 20 months post repair – half immobilized, half not. Non splinted RTW significantly quicker

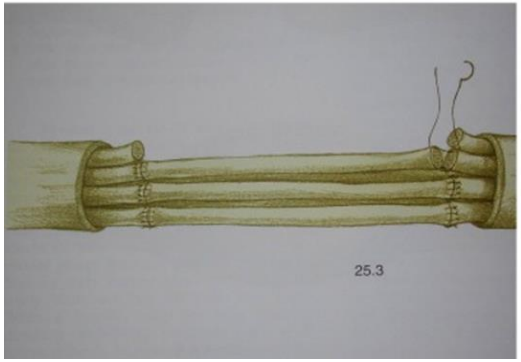
Conclude that, after repair of sharp, uncomplicated digital nerve divisions, splinting beyond the immediate postoperative period is at least unnecessary and may be deleterious

UE Peripheral Nerve Grafts

Indications

- Distance between the two nerve ends is too large to allow direct end-to-end repair
- Technique: Injured nerve ends are cut back until healthy fascicles are seen
  - The defect in the nerve is measured with all joints in maximum extension to minimize any tension during rehabilitation
  - The donor cables are cut to length (10-20% extra to allow for contraction) and inserted between the injured nerve ends and sutured
- Common donor nerves: Sural nerve for larger defects, lateral antebrachial nerve and the anterior branch of the medial antebrachial nerve

Nerve Grafts



Nerve Graft Postoperative Management

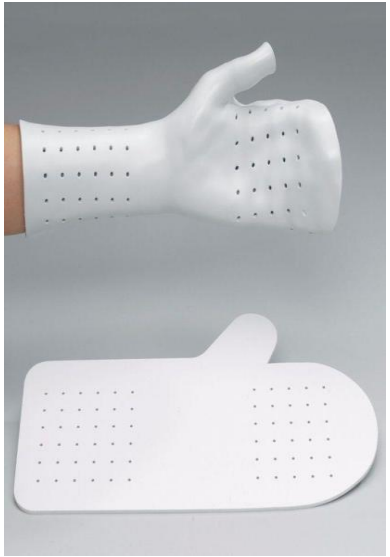
1. Protect repair - Place repaired nerve on slack with orthosis 7-10 days

Median or ulnar nerve: dorsal blocking orthosis with wrist 30° deg flexion

L. Klein, 2022

*If finger flexors involved

Radial Nerve: volar orthosis with digit and wrist extension



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Nerve Graft Postoperative Management

7-10 days post op:

- A/PROM
    - Allowed to move earlier than direct repair due to less tension on repair (Direct repair immobilized 2-3 weeks)
- Monitor motor and sensory recovery
    - Follow guidelines as described for direct nerve repair
- Orthoses for protection and to prevent deformity (PRN)
- Scar and edema management
- Sensory reeducation/desensitization
- Treatment for stiffness and tendon adhesions (PRN)

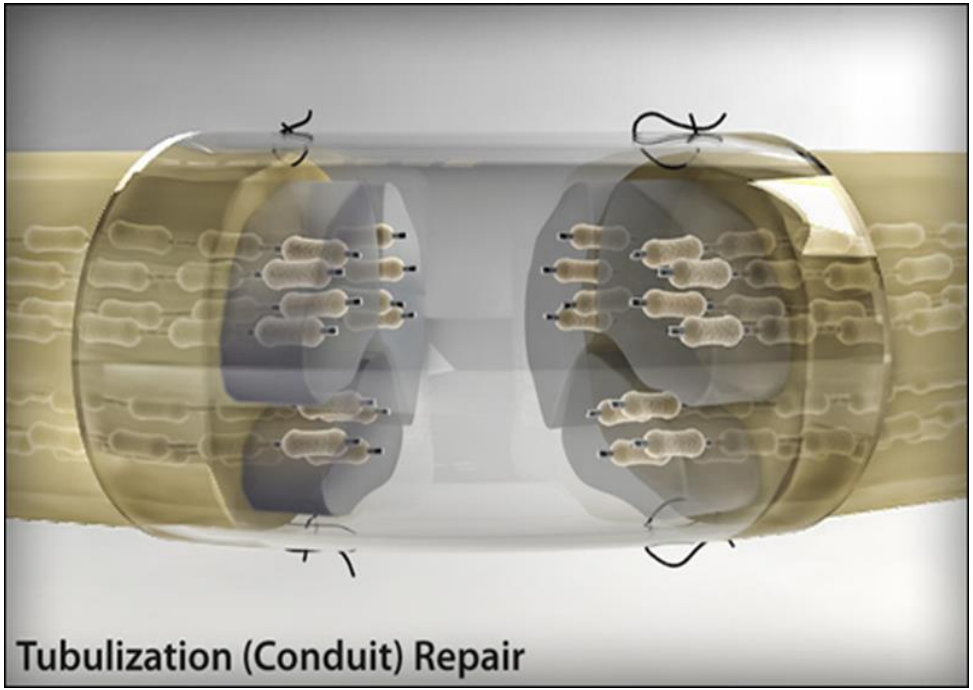
Nerve Conduit

Indications

- Most often used for nerve gaps of less than 3 cm involving small-diameter nerves such as digital nerves and radial sensory nerves

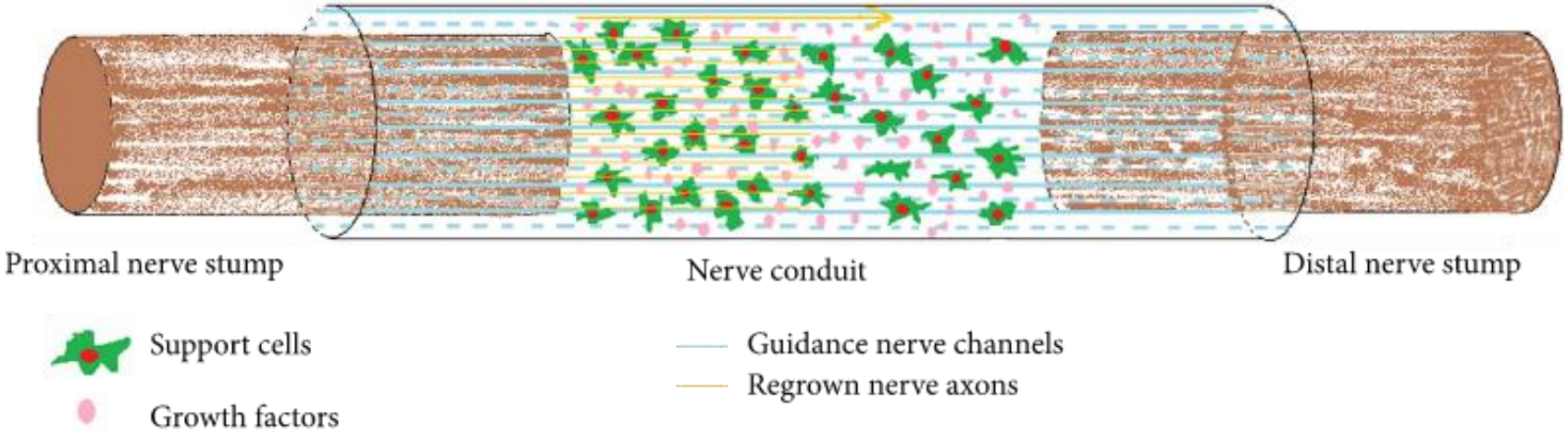
Limitations of Conduits in Peripheral Nerve Repairs

Amy M. Moore, Rahul Kasukurthi, Christina K. Magill, H Francis Farhadi, Gregory H Boorschel, Susan E. Mackinnon; Hand (NY). 2009 Jun; 4(2): 180-186.



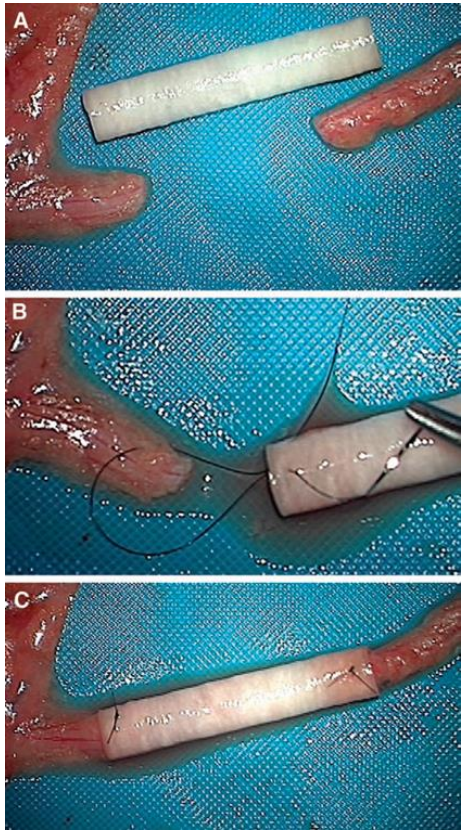
Nerve Conduit

Use of nerve growth factors, channels, guidance fibers



Muheremu A, Aiang A. Past, present and future of nerve conduits in the treatment of peripheral nerve inury. BioMed Research International Volume 2015 |Article ID 237507 https://doi.org/10.1155/2015/237507 Review Article | Open Access

Nerve Conduits to Repair Digital Nerve



S. Goldberg, L. Klein 2011

Nerve Conduit Postoperative Care

Taras J. 2016 (ref 16)

Digial Nerve Tension Free Postoperative Care

- 2-3 days post repair
  - No orthosis
  - Wrist neutral, short arc active motion of fingers
  - Gentle composite active flexion
  - Edema instruction
  - No functional use of hand for 4 weeks
- 2 Weeks post op
  - PROM
  - No dynamic orthosis
  - No Ultrasound
- 4 Weeks
  - Functional flexion

Median or Ulnar Nerve, or Digital Nerve with Tension

- Dorsal blocking orthosis:
  - wrist 0-30° flexion; P 45° flexion; IP's neutral
  - Removed for hygiene and exercise
  - AROM within orthosis
  - No Ultrasound
- 2 Weeks post op: begin therapy
  - Edema, wound/scar care
  - Protected PROM
  - Isolated joint and composite AROM with wrist held in flexion passively
  - Wrist ROM with digits relaxed
- 4 weeks: Discontinue protective orthosis
  - Orthosis to prevent deformity prn
  - No scar massage (6-8 weeks)
  - Silicone or gel pad if tolerated
- 6 weeks:
  - Composite digital and wrist ROM
  - Resistance

Nerve Transfers

Purpose:

Nerve transfer involves bringing an innervated donor nerve to a denervated target nerve to provide reinnervation to the target muscle or sensory end organ. When the donor nerve is closer to the target end organ, the nerve transfer will provide faster reinnervation and the opportunity for superior results with better sensorimotor function.

Indications

- Proximal nerve injury or delayed presentation where muscle atrophy and motor end plate degeneration will occur prior to reinnervation
- Large gap
- Brachial plexus injuries with root avulsion
- Type of injury with no proximal nerve stump

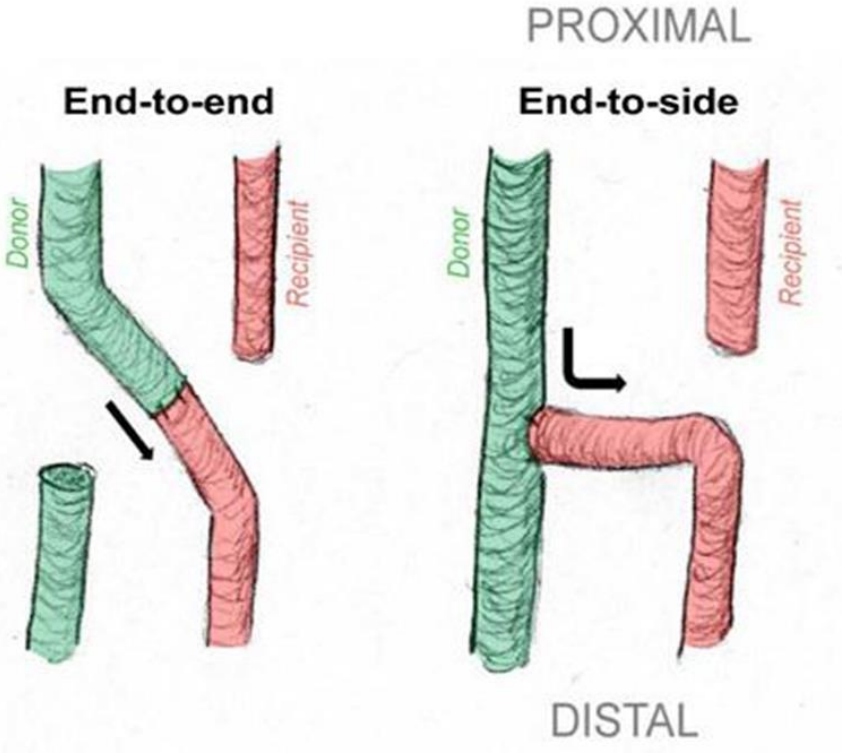
Nerve Transfers

- Types:
  - End-to-end
  - End-to-side
  - Reverse end-to-side or supercharge

Nerve Transfers

End-to-end nerve transfer: direct coaptation of the end of the donor nerve to the proximal end of the recipient nerve

End-to-side nerve transfer: coaptation of the proximal end of the recipient nerve to an epineural window in the side of an intact and functioning donor nerve



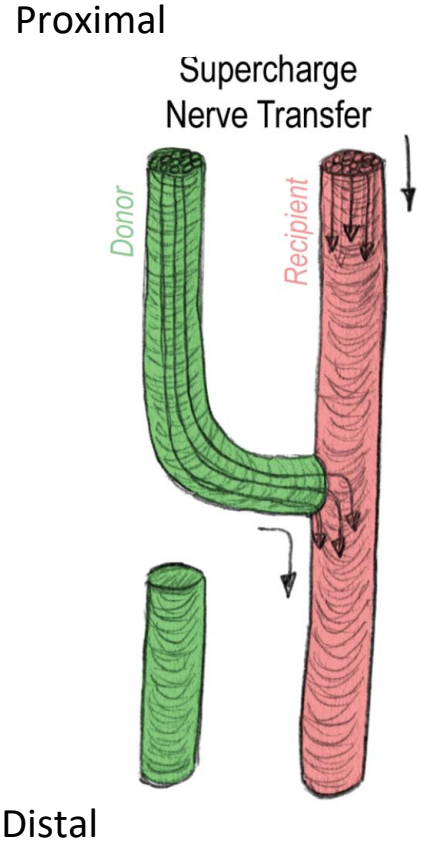
Peripheral Nerve Surgical Research Laboratories
Pnsrl.wustl.edu
Courtesy of Susan Mackinnon

Nerve Transfers

Reverse end-to-side or supercharge nerve transfer: Donor nerve is coapted to the side of an injured nerve to rapidly innervate and support end organs while allowing for additional reinnervation after a proximal repair at the injury site.

Used when there has been a more proximal injury or repair that would not likely reach the muscle before the motor end plates degeneration

Allows faster innervation of target tissue while still regenerating proximally



Peripheral Nerve Surgical Research Laboratories
Pnsrl.wustl.edu
Courtesy of Susan Mackinnon

Nerve Transfers

Consider what is lost compared to what is gained

Donor nerves: Used when there are other muscles available that can do the action

Examples: Nerves to ECRB (ECRL available)

Brachialis (Biceps, coracobrachialis available)

FDS (FDP available)

Terminal AIN to pronator quadratus (pronator teres available)

Recipient: To regain critical motions, when no other muscle is present to do the action

Distal examples: Nerves for pronation if both pronators out, FPL, FDP, EDC, EPL, lumbricals and interossei

Number of options available

Nerve Transfers

Numerous transfers have been described, but there are a handful of transfers for which there is strong clinical evidence

Shoulder abduction and external rotation: Nerve to spinal accessory transferred to suprascapular nerve, nerve to medial triceps branch transferred to axillary nerve

Elbow flexion: Ulnar nerve fascicle to flexor carpi ulnaris transferred to biceps branch and median nerve fascicle to FDS transferred to brachialis branch of the musculocutaneous nerve

Ulnar intrinsic function: Distal anterior interosseous nerve to pronator quadratus transferred to ulnar motor branch

Rinker B. Nerve Transfers in the Upper Extremity: A Practical User's Guide. Ann Plast Surg. 2015 Jun;74 Suppl 4:S222-8. doi: 10.1097/SAP.0000000000000373. PMID: 25978554.

Specific Peripheral Nerve Transfer Examples

Source of next 3 slides:

Plastic and Aesthetic Research

Nerve transfers of the forearm and hand

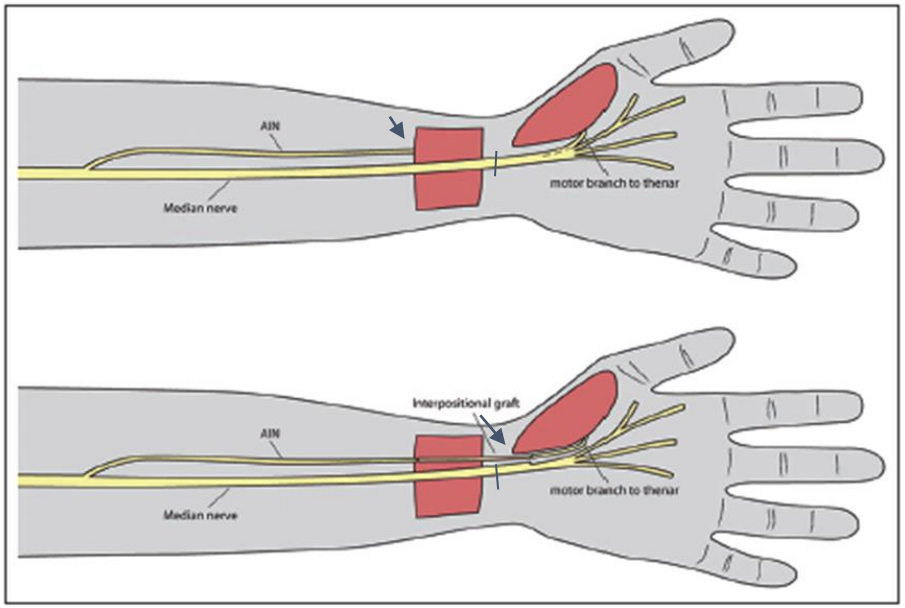
Paolo Sassu, Katleen Libberecht, Anders Nilsson

Date of Web Publication 15-07-2015

DOI:10.4103/2347-9264.160887

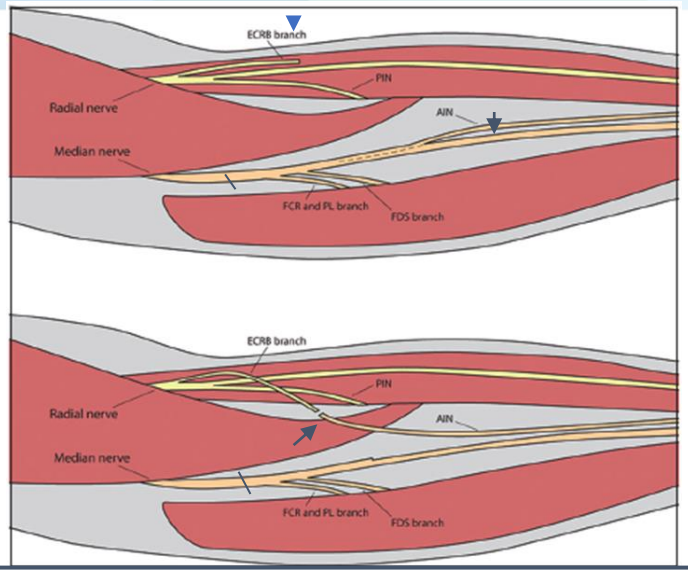
Open access online journal

Nerve Transfers for Median Nerve Deficit



Distal median nerve deficit

Transfer of the terminal branch of the anterior interosseous nerve to the motor branch to the thenar muscles, using an interpositional graft.



High median nerve deficit

Transfer of the motor branch to extensor carpi radialis brevis to the anterior interosseous nerve.

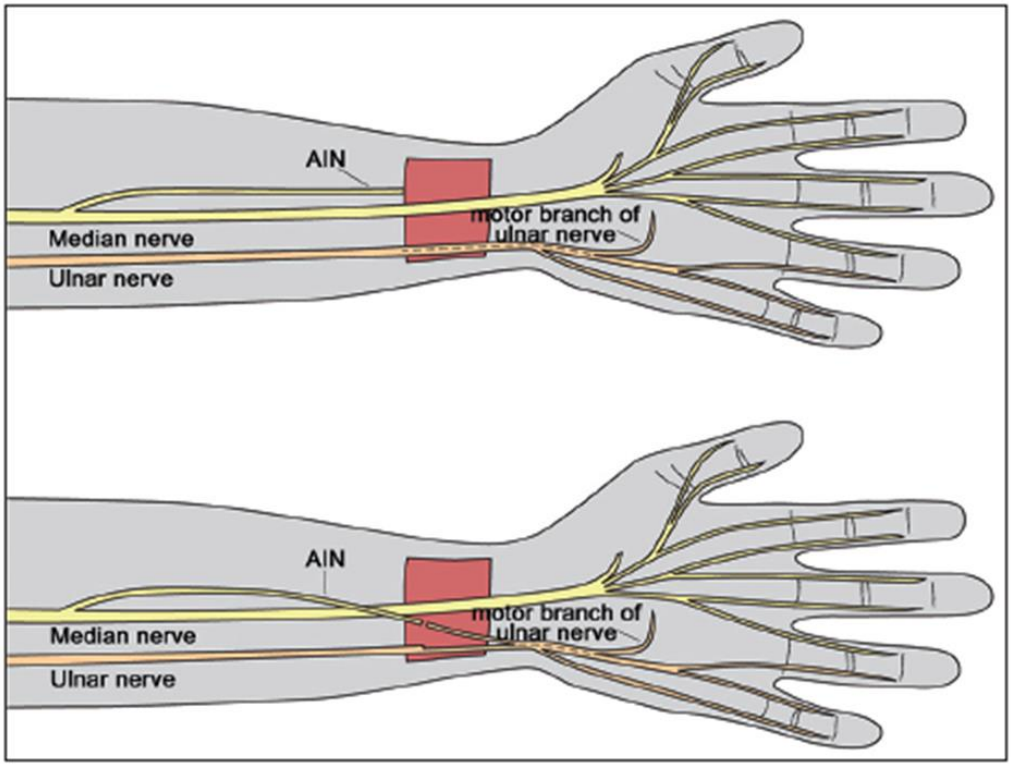
*If pronator teres also out, would need transfer such as ECRB branch to PT, brachialis branch to AIN

Nerve Transfer for Ulnar Nerve Deficit

Ulnar nerve deficit

- Loss of interossei, ulnar lumbricals results in claw deformity

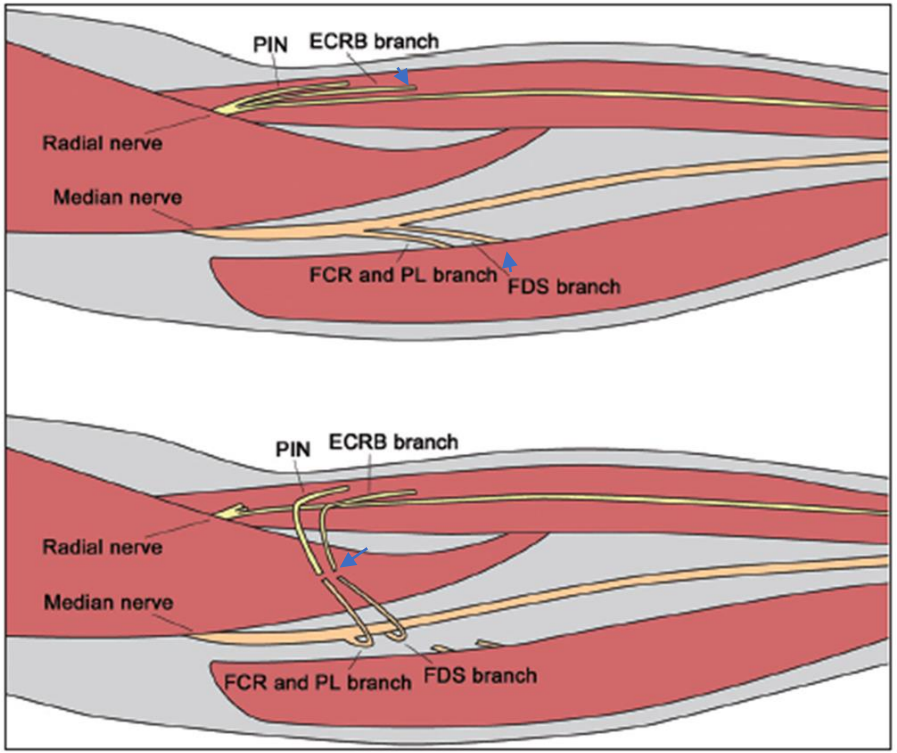
Transfer of the terminal branch of the AIN (median nerve branch to pronator quadratus) to the motor branch of the ulnar nerve



Nerve Transfer for Radial Nerve Deficit

Transfer of the motor branch to FDS to the ECRB for wrist extension

Transfer of the motor branches to FCR and palmaris longus muscle to the PIN (all extrinsic digit extensors)



Nerve Transfer Rehabilitation Concepts

"In the early period following nerve transfer and muscle reinnervation, contraction is initiated by "contraction" of the donor muscle. This will utilize the previous motor patterns and cortical maps to produce muscle contraction. Until new recruitment patterns are recognized and established, initiation of the intended muscle action requires contraction of the muscle from the donor nerve. To assist in the relearning of new motor patterns, bilateral muscle contractions (of the donor and recipient muscles) using input from the uninjured side will provide feedback and cortical input of a similar normal motor pattern."

Nerve Transfer Example - AIN to Ulnar Nerve

"In cases of an anterior interosseous nerve (AIN) to deep motor branch of the ulnar nerve transfer, patients are asked to perform a pinching action while simultaneously performing pronation. Once the new motor pattern is established intrinsic ulnar nerve motor patterns will be performed independent of forearm pronation. As the muscle control and strength increase, discriminatory and dexterity exercises and tasks are incorporated into the rehabilitation program."

Novak C, von der Heyde R. 2015(13)

Donor Activation Focused Rehabilitation Approach - DAFRA

Kahn, Moore 2016

3 Phases

- Early- recipient is 0/5
- Middle - recipient is ⅕, often starts with a twitch, muscle and tendon activity can be palpated
- Late Phase- recipient is ⅗, resisted exercises, may take as long as 2-3 years to achieve functional strength

Early Phase

Begins 10-14 days post op

Early:

- Education on donor nerve muscles vs recipient and motion for each
- Timeline from 0/5 to 1/5 is generally 1” per month, starts with a twitch
- Flood donor nerve muscles with frequent (10-20x per hour) high reps/low resistance exercises to encourage neural activation and growth (more is more), mentally practice recipient action (>30% neuron fire during imagery)
- Maintain PROM - Proper positioning with muscle at ideal length to avoid overstretch or shortening using orthotics, sling, other positioning
- Once patient is able to perform HEP, decrease frequency to 1x monthly until recipient activation is present. Save visits for later phase when recipient muscle is ready for rehab.
- Look for exercises that can be easily done at home without special equipment

Middle Phase - Begins When Twitch is Felt

- Monitor for recipient activation, begins with a twitch
  - Start with AA, gravity eliminated
  - Supine, sidelying, prone for shoulder/elbow nerve transfers, advance to dowel exercises
- Continue PROM
- EMG- trigger muscle stimulation
- Continue donor flooding exercises for several months
- Prior to muscle strength ⅗, avoid fatigue of the recipient muscle
- Biofeedback- goal is 50% of MVC (maximal voluntary contraction)

Middle Phase, continued

- Strong resistance to donor with A/A to recipient
  - Exercise donor and recipient simultaneously until recipient is 3+/5; could be 12 months post op
  - Exercises in pool for shoulder/elbow nerve transfers when strength has progressed to ⅖
  - Place and hold when strength is 2+ to 3-/5
- Keep in mind:
  - If entire donor nerve is taken, no return is expected in donor in supplied muscle
  - Because there are fewer motor nerve fibers than originally, the end point of strength will vary and may take >2 years
  - Do not overwhelm the recipient muscle, minimize muscle fatigue

Late Phase Begins When Strength ⅗ is Achieved

- Start weights and band at 3 or 3+/5
  - Attempts before this result in fatigue, pain and frustration
  - Best to avoid excessive fatigue
- Review expectations and timelines with the patient (as much as 2-3 years)
- We are also treating the psychosocial aspects of these life- changing injuries
- No consensus in the literature about NMES
  - Important to avoid fatigue
  - Biofeedback may be helpful, esp if there is difficulty activating the recipient independent of the donor

Case Study: Direct Repair Median Nerve Combined with Flexor Tendon Repairs at Wrist

39 year old male (young, strong, healthy - advance cautiously)

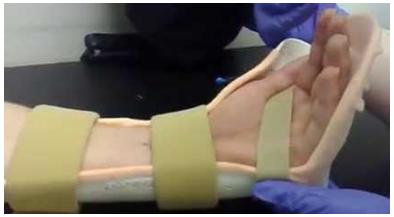
Cutting tile to help a friend, a piece of tile broke off, lacerating volar wrist

Partial lacerations to FPL, FDS to middle and ring fingers

Full laceration of median nerve, palmaris longus

Primary repair 1/11/22

<u>6 days post op</u> referred to therapy for fabrication of dorsal blocking orthosis with wrist in 20 deg flexion, MP's flexed, IP's extended (fingers & thumb included due to flexor tendon repairs



Exercises in therapy and at home:

Thumb passive flexion and place and active hold flexion

Fingers passive and true active flexion to ½ fist

IP extension to hood of dorsal blocking orthosis

No wrist extension

L. Klein 2015

Treated 1x/week with above exercises: Once sutures out, used heat with tie down to digits for stiffness, attained full PROM within 2 weeks

Difficulty from beginning with active hold IP flexion of thumb

Higgins A, Lalonde D. Flexor Tendon Repair Postoperative Rehabilitation: The Saint John Protocol. *PRS Global Open.* 2016

2 weeks post op:

- Initiated education for sensory loss
- Expectations for recovery of nerve function
- Periodic sensory assessment
- Scar management: Gentle massage
- Passive thumb abduction to prevent deformity

L. Klein 2022

HEP2go Therapeutic Exercise

3.5 weeks post op:

Remove orthosis for exercise of gentle active composite flexion and extension of digits *(still no wrist extension)*

	MP	PIP	DIP
Index	65	65	35
Middle	60	75	55
Ring	45	85	50
Small	60	90	45
Thumb	55 MP	5 IP	

Full passive flexion, limited IP flexion indicates adhesions of FDP to index and FPL to thumb: Focused on addressing flexor tendon gliding

4 weeks post op:

- Added very gentle active wrist extension
  - Wrist ROM -15° extension to 45° flexion
- Orthosis between exercises
- Tinel's in proximal palm
- Hypersensitive palm: Desensitization

5.5 weeks: Wrist AROM 17° extension, 48° flexion, 20° RD, 15° UD

7 weeks: MD "Increase activities very gradually"

8 weeks: Wrist extension 36°, flexion 45°

- Still no pull through of FPL in composite flexion (65° MP, 0° IP)
  - Began gentle manual resistance of thumb IP flexion
- Added passive wrist extension
- Initiated very light gripping
- Tinel's advancing distally
- Digits still numb

L. Klein 2022

9.5 weeks: Wrist extension 49°, flexion 50°, RD 20°, UD 25°

Thumb composite flexion: 70° MP, 40° IP (composite flexion)

10.5 weeks: Advanced strengthening

Baseline grip right 148#, left 30#

Pinch testing deferred (FPL repair)

11.5 weeks post op: “Buzzing in fingers”, no thumb abduction/opposition, weak but improving

Wrist extension 60 deg, flexion 56 deg, RD 25 deg, UD 30 deg

Digit motion

	MP	PIP	DIP
Index	+12-85	0-92	0-60
Middle	+15-85	0-105	0-65
Ring	+20-80	+20-110	-10-54
Small	+20-80	0-100	0-60
Thumb	MP 0-75	IP 0-30 (60 with blocking)	

Advanced to home program with reassessment 6 months

Case Study Takeaways

- Educate on early protection of repair postoperatively
  - Recognize differences between patients (fearful or aggressive) and modify approach/advancement
- Recognize potential for flexor tendon adhesions with any volar surgery
- Recognize potential for stiffness following any immobilization period and treat accordingly, with appropriate protection of repaired structures
- Educate regarding sensory loss and expectations
- Monitor motor recovery, educate regarding expectations
- Protect numb areas, desensitize as recovery occurs

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Thank You!

Questions?

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