Tendon Transfers for Nerve Palsies

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I. Introduction

Functional deficits after nerve injury are determined by the specific nerve involved and location of the injury.

Reconstruction of function after nerve injury is dependent on time from injury, presence of concomitant injuries (bone and soft tissue) and availability of donors (i.e. redundancy of function).

Definition: Tendon transfer – transfer of a functional muscle-tendon unit to replace a lost or missing muscle-tendon unit in order to restore motion or balance to the wrist and/or hand.

II. Principles

In order for successful return of function, certain principles should be considered:

- Tissue Equilibrium: Resolution of Wound Healing, Bony Union, and Correction of Contractures
  - Local tissue should be in optimal condition: soft, mobile, no evidence of induration
  - Full passive joint ROM is necessary preoperatively
    - This may require contracture releases, therapy and splinting
  - Avoid transfers across scar tissue and skin grafted areas.
  - Plan incisions to place tendon junctions beneath flaps rather than beneath incisions or scars

- Expendable Donor
  - Avoid downgrading function with unacceptable donor loss
  - Patients' needs vary for "priority"
  - Goal: maintain at least one wrist flexor (not PL alone), wrist extensor, extrinsic finger flexor and extensor.

- Adequate Strength
  - Goal: balance of power
  - Consider: lost muscle strength, donor muscle strength and remaining counterbalance strength
  - Force is proportional to muscle cross sectional area at resting length
  - Expect the muscle to lose one grade of strength after transfer

Muscle	Strength
Brachioradialis	2.0
FCU	2.0
FCR, ECRL, ECRB, ECU, PT, FPL, FDP (each), FDS (each)	1.0
EDC, EIP, EDQ	0.5
APL, EPB, EPL, PL	0.1
Interossei (combined)	2.7
Lumbricals (combined)	0.5

- Try to avoid using previously denervated muscle

- Appropriate Excursion
  - Tendon Excursion must match for function
  - Proportional to fiber length
  - Methods to Augment "effective" Excursion:
    - Tenodesis effect: Wrist flexion/extension gives up to 25mm

Wrist Flexors and Extensors	33 mm
Finger Extensors, FPL and EPL	50 mm
Finger Flexors	70 mm

- Straight line of Pull
  - Avoids loss of power and excursion

- One Tendon – One Function
  - Donor function will be dissipated and less effective if multitasking

- Synergism
  - Capitalize on Tenodesis and use muscles that commonly work together
  - Assists with postoperative rehab and retraining

III. Tendon Transfers for Specific Nerve Injuries

- **Radial Nerve Tendon Transfers**
- Distinguish High Versus Low Injury
  - High (Radial Nerve Proper): Triceps, Brachioradialis, ECRL
  - Low (Posterior Interosseous Nerve): Supinator, ECRB, EDC, ECU, EDM/Q, APL, EPL, EPB, EIP
    - i.e. Loss of finger extension at MP joints and Thumb IP extension

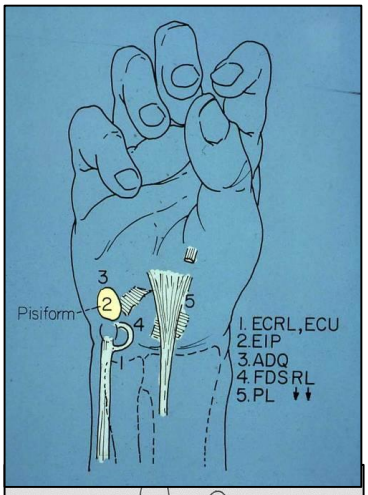
- Common Tendon Transfers: Brand, Jones, Boyes

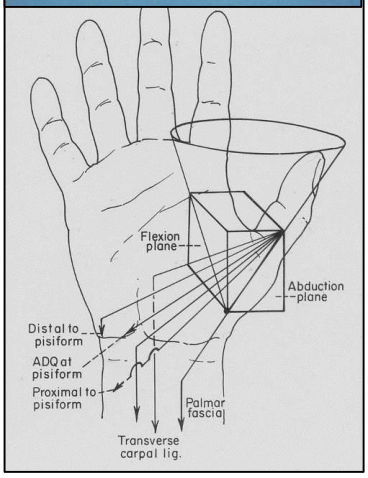
- Brand (most common)
  - Wrist Extension: PT to ECRB
  - Finger Extension: FCR to EDC
  - Thumb Extension: PL to EPL
  - Perform transfers in sequence: wrist, fingers then thumb
  - Include EDM if EDC to small finger is diminutive

- Jones
  - Wrist Extension: PT to ECRB
  - Finger Extension: FCU* to EDC
  - Thumb Extension: PL to EPL
  - Reluctance to use FCU since it is the most powerful wrist flexor
  - FCU is critical in "hammering" and "dart throwing" motion

- Boyes
  - Wrist Extension: PT to ECRB
  - Thumb/Finger Extension*:
    - FDS (ring) to EIP/EPL
    - FDS (long) to EDC/EDM
    - FDS taken through IOM

- **Median Nerve Tendon Transfers**
- Distinguish High Versus Low Injury
  - High: PT, FCR, FDP,PL, FDS, FPL, PQ, ABP, OP, superficial head of FPB, Lumbricals I, II
    - Functions to Restore: Finger flexion, Thumb Flexion and Opposition
  - Low: Opposition (ABP)





- Low Injuries Most Common: Restoration of Opposition
  - Restores prehensile pinch and grasp
  - Vector of pull: Pisiform
  - Insertions: APB tendon, APB/EPL

- Options for Opponensplasty
  - FDS Ring (Royle-Thompson/Bunnell)
  - EIP (Zancolli, Burkhalter)
  - ADM (Huber)
  - PL (Camitz)
  - Other Less common options: ECU, APL, FCR, ECRL

- High Median Nerve Palsy
  - Loss of intrinsic and extrinsic function
  - Finger Flexion, Thumb Flexion and Opposition
    - No need to address loss of FCR and PL if ulnar function intact
- Smith and Hastings(1980)
  - EIP to APB
  - BR to FPL (thumb IP arthrodesis for stability)
  - FDP tenodesis (side to side, powered by ulnar)
- Burkhalter (1974)
  - EIP to APB
  - BR to FPL
  - ECRL to FDP (index and middle)
- Boyes (1970)
  - ECU (with graft) to thumb prox phalanx
  - BR to FDP (index and long)
  - ECRL or B to FPL
- Brand (1975)
  - ECU (with graft) to Prox Phalanx thumb
  - FDP tenodesis

- ECRL to FPL
- FCU split to FCR and FCU for wrist balance

❖ Others less common (Goldner)

❖ **Ulnar Nerve Tendon Transfers**

❖ Multiple Signs Associated with Ulnar Nerve Palsy

Signs and Tests for Ulnar Nerve Palsy

Eponym	Description
Froment's sign[7]	Hyperflexed thumb IP with attempted pinch
Jeanne's sign[8]	Thumb MP hyperextension with attempted pinch
Duchenne's sign[12]	MP hyperextension and IP flexion of ring and small fingers
Masse's sign[36]	Flattening of metacarpal arch (inability of the hand to cup water)
Wartenberg's sign[15]	Abducted small finger
Egawa sign[5]	Inability to abduct/adduct fingers with MP flexion
Andre-Thomas sign[37]	Flexion of wrist with attempted IP extension (patients attempt to use tenodesis to increase IP extension)
Pollock sign[5]	Inability to flex distal interphalangeal joint of small finger (typically absent with low ulnar nerve palsy)
Bouvier maneuver[13]	Ability to extend to IP joint of the fingers with the MPs flexed; lost with MPs hyperextended
Earle-Vlasou sign[38]	Inability to cross middle finger over index finger
Mumenthaler's sign[39]	Loss of dimple along ulnar border of hand with abduction of the small finger (related to absent function of palmaris brevis)
Bunnell's sign[11]	Thumb no longer pinches against index to make an "O"
Other	
Confrontational testing[40]	Abductor digiti minimi strength test; patient holds palms in front of face, places small finger ulnar tips together, and pushes; asymmetry is positive test
Index finger abduction	Flex index finger 30° and abduct; palpate 1st dorsal interosseous muscle

Goldfarb et al. JHS 2003

❖ Distinguish between High Versus Low Injury
- Low: Loss of power pinch, claw deformity – decreased hand strength and loss of coordinated hand/finger activity, loss of fine motor control
  - Interossei, Lumbricals (small and ring), Adductor pollicus, Hypothenar Muscles (FDM/Q, AbDM, ODM)
- High: Loss of extrinsic finger flexion to small and ring(FDP) and ulnar wrist flexion (FCU) and Intrinsic function
  - Decreased power grip with up to 50% loss of grip strength in addition to low injury deficits

❖ Correction for Low Ulnar Nerve Palsy

❖ <u>Ulnar Claw Deformity def</u>: Hyperextension of MP joints (from pull of intact extrinsic extensors) and Flexion of IP joints (from pull of intact extrinsic flexors) due to paralysis of interosseous muscles of all fingers and ulnar innervate lumbricals to ring and small fingers.
- Ring and small finger are most affected but all four fingers can be impacted.
- Low injuries result in more dramatic clawing with extrinsic flexors (FDP) intact.
- Results in loss of coordinated grasp with DIP joint flexion followed by PIP then MP joint flexion.

❖ <u>Physical Exam</u>
- Assess motion, both active and passive, of all joints.

- Identify contractures.
- Identify any other concomitant nerve injuries.
- Bouvier's maneuver – test the integrity of central slip and lateral bands (function of the PIP joint) by blocking MP in flexion and testing extension of PIP and DIP joint.
  - If full active extension of PIP and DIP joint intact then normal function of extensor apparatus is preserved.
  - If full extension of PIP and DIP with MP blocking (POSITIVE TEST) – then static procedures are possible to correct hyperextension of MP joint
  - If PIP remains flexed with MP blocked (NEGATIVE TEST) – then dynamic tendon transfer is needed to extension of PIP joint.

❖ Surgical Options for Anti-Claw

❖ <u>Static Techniques:</u> Prevent hyperextension of MCP joint
- Bony blocks on the dorsum of MC head
- MP joint capsulodesis with volar plate advancement
- Bunnell flexor pulley advancement to create bowstringing of flexor tendon
- Tendon graft sutured to the deep transverse intermetacarpal ligament

❖ <u>Dynamic Techniques:</u> Prevent hyperextension of MP joint and also have ability to extend PIP joint by inserting onto lateral bands.
- 3 main types:
  - Dynamic tenodesis – tendon is looped through the extensor retinaculum, along the lumbricals, and inserted into lateral bands
  - Dynamic procedures using digital flexors
  - Dynamic procedures using wrist motors (ECRB, ECRL or FCR)

❖ See Table 4 for specifics (see below)

❖ Restoration of Power Pinch
- Smith Transfer: ECRB to Adductor Pollicus (AP) with graft
- FDS ring to AP
- APL to FDI with graft
- EIP to AP

❖ Finger Flexion
- FDP side to side tenodesis

Table 4
Dynamic procedures for correction of claw deformity

Technique	Description	Comments
Dynamic Tenodesis		
Wrist tenodesis (Fowler and Tsuge)	Free tendon graft attached to central extensor retinaculum and passed from dorsal to palmar, deep to DTML and inserted into lateral bands	Tenodesis loosens with time
Extrinsic Finger Flexors		
Flexor digitorum superficialis (modified Stiles-Bunnell)	Middle-finger FDS split into 4 slips, routed through lumbrical canal of each finger volar to the DTML, sutured to the lateral band of the extensor apparatus	Modified several times. PIP and DIP extension lag can occur in donor finger
Modifications of insertion sites Lateral band (Stiles, Bunnell) Phalangeal insertion (Burkhalter) Pulley insertion (Riordan, Zancolli) Interosseous insertion (Zancolli, Palande)		
Finger-Level Extensors		
Extensor indicis proprius and extensor digiti minimi (Fowler)	EIP and EDM tendons are transferred to lateral bands of dorsal apparatus	May produce excessive tension in extensor apparatus (intrinsic-plus deformity) and reverse metacarpal arch. Does not add grip strength
Wrist-Level Motor Transfers		
Dorsal route ECRB (Brand)	ECRB lengthened by free tendon graft (split into 4 tails); passed through intermetacarpal spaces, deep to DTML and attached to radial lateral bands MF, RF, SF, and ulnar lateral band IF	Does not improve metacarpal arch or grip strength. ECRL also used
Flexor carpi radialis (Riordan)	Flexor carpi radialis is augmented with free tendon graft brought around the forearm and then routed in similar fashion as described above by Brand	Removes FCR, strong wrist flexor
Flexor route ECRL (Brand)	Free tendon graft is passed through the carpal tunnel (split into 4 tails), and ECRL is used as the motor and brought around the forearm to the volar side	Uses free tendons for length (adhesions), Requires extensive therapy postoperatively, possible crowding of carpal tunnel can occur

Abbreviations: DTML, deep transverse metacarpal ligament; ECRB, extensor carpi radialis brevis; ECRL, extensor carpi radialis longus; EDM, extensor digitorum minimi; EIP, extensor indicis proprius; FCR, flexor carpi radialis; IF, index finger; MF, middle finger; RF, ring finger; SF, small finger.

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