Paralytic Hand

Tetraplegia - Concept

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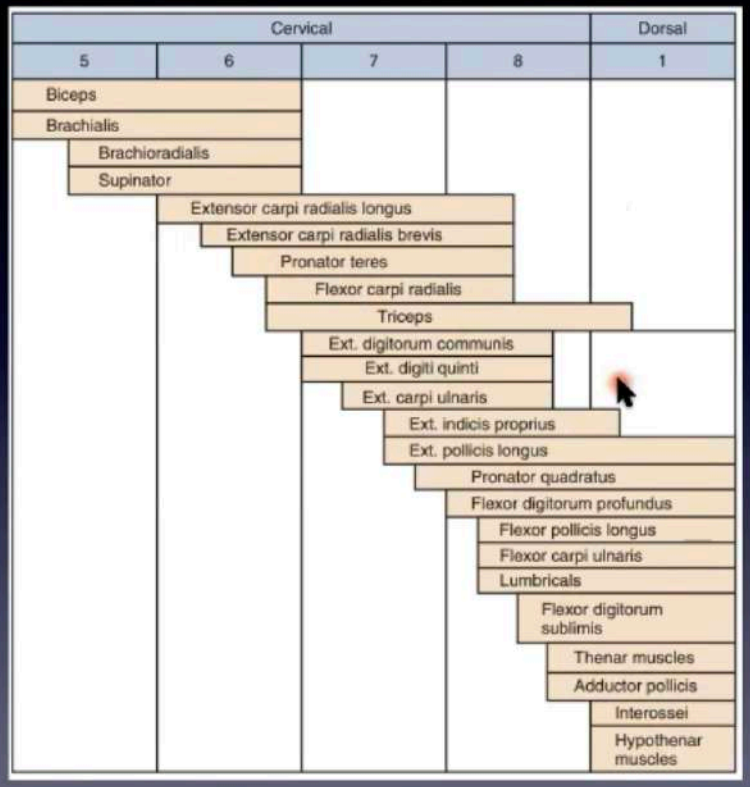
Spinal cord injury

- **Is different from injury of** central nervous system , brachial plexus or peripheral nerves .
-

tion; this concept means that the anterior horn cells in the spinal cord are arranged in a pattern from cephalad to caudad. Motor nuclei form longitudinal columns crossing several segmental levels, innervating peripheral musculature in a predictable manner.

Pattern seen is based on segmental innervation



spinal cord injury occurs, the motor nuclei cephalad to the injury will be functional; the motor nuclei at or caudad to the level of the injury will be nonfunctional.

Tetraplegia- pathogenesis

- Cervical spinal cord injury after fracture or dislocation
- Edema and hemmorhage subside in weeks then
- Repair and scar formation occurs

Metamere

- Area of spinal cord injury can vary in length and width known as metamere .

Nerve function

- Is normal - above injured metamere
- Is Absent - within injured metamere
- **Can be stimulated below injured metamere if LMN is uninjured .**

Muscle strength

- Is normal that are innervated above level of injury
- Flaccid or spastic that innervated below level of injury
- May improve in **years** that are innervates at level of injury

cases up to 24 months after injury. All upper limb muscles with an initial strength of grade 1 improved to at least grade 3 by 1 year after injury, with the exception of the triceps. If a muscle's strength was grade 2 or better at 1 month after injury, the median time for full recovery was 6 months.

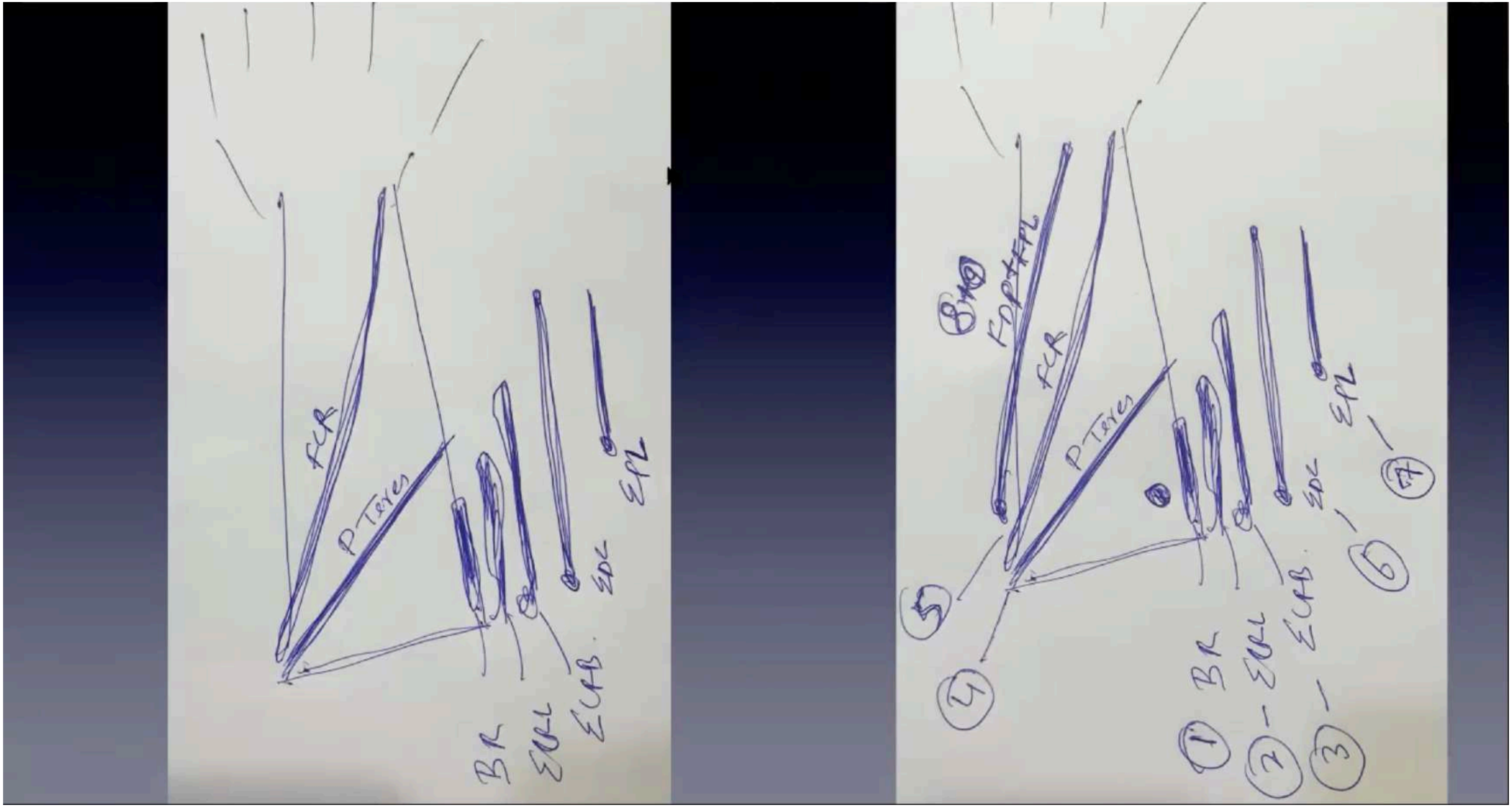
Classification

- There is **little correlation** between skeletal level of injury and spinal cord lesion - it is asymmetric - unusual pattern of spared sensory and motor power.

- That's why useful classification is **based on SPARED FUNCTION**

Classification
Based on number of functioning muscles

(Table 37.2). The International Classification for Surgery of the Hand in Tetraplegia characterizes the most common patterns of presentation, based on the number of functional muscles below the elbow. A muscle is defined as functional if it demonstrates grade 4 or better strength by manual muscle testing.



Classification

INTERNATIONAL CLASSIFICATION FOR SURGERY OF THE HAND IN TETRAPLEGIA			
Sensibility[†]	**Motor Group**[‡]	**Characteristics**	**Function**
O or Cu	0	No muscle below elbow suitable for transfer	
O or Cu	1	BR	Flexion and supination of the elbow
O or Cu	2	ECRL	Extension of the wrist
O or Cu	3[§]	ECRB	Extension of the wrist
O or Cu	4	PT	Pronation of the wrist
O or Cu	5	FCR	Flexion of the wrist
O or Cu	6	Finger extensors	Extrinsic extension of the fingers
O or Cu	7	Thumb extensor	Extrinsic extension of the thumb
O or Cu	8	Partial digital flexors	Extrinsic flexion of the fingers
O or Cu	9	Lacks only intrinsics	Extrinsic flexion of the fingers
O or Cu	X	Exceptions	

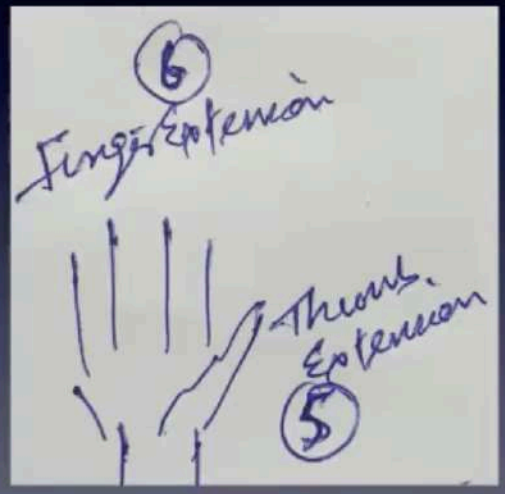
Pre operative Work up-1

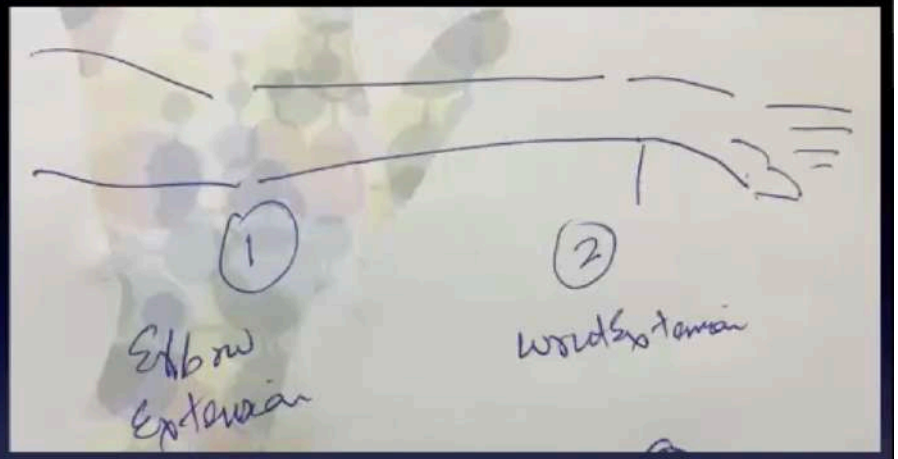
- **Grade the Strength of muscle below elbow**
- **BR**
- ECRL, ECRB
- PT ,FCR
- EDC, EPL
- FDS ,FDP, FPL

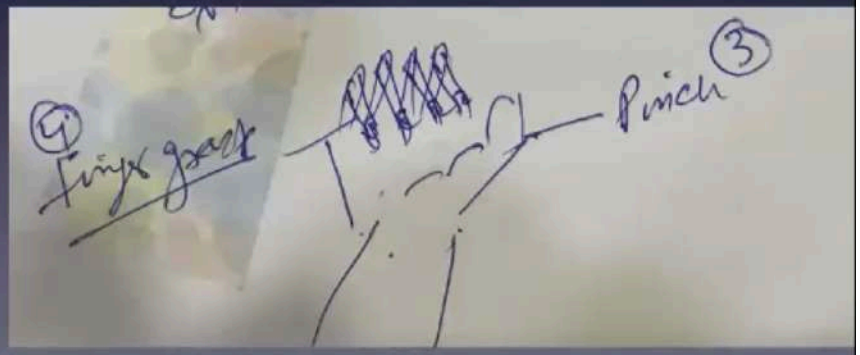
MUSCLE GRADING SYSTEM: UK MEDICAL RESEARCH COUNCIL	
Grade	**Description**
0	No contraction
1	Flicker or trace of contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against gravity and resistance
5	Normal power

Pre operative work up-2

- **Function the patient needs in priority**
- **Elbow extension**
- **Wrist extension**
- Thumb flexion [pinch]
- Finger flexion [grasp]
- Thumb extension , finger extension [release function]
- Intrinsic function of thumb and fingers







PREOPERATIVE WORK-UP: ASSESSMENT OF FUNCTIONAL NEEDS

What the Patient Needs	Muscles to Be Tested and Graded
Elbow flexion	Biceps, brachialis
Elbow extension	Triceps
Wrist extension	ECRL, ECRB, ECU
Wrist flexion	FCR, FCU
Finger extension	EDC, EIP, EDQ
Finger flexion	FDP, FDS
Thumb extension/ abduction	EPL, EPB, APL
Thumb flexion/opposition	FPL, APB, opponens, FPB
Intrinsics	Adductor pollicis, interossei, lumbricals

Pre operative Work up-3

- **Muscle available for transfer**
- **Bicep** - is available when Brachialis is grade > 4
- **BR** - is available when bicep is grade > 4
- **ECRL** - is available when ECRB is > grade 4
- **PT** - is usually avoided if FCR is available as pronator is important for pushing wheelchair .

Preoperative workup -4

- **Match the available muscles [tendon transfer]**
- And then
- Do Adjunct procedures for functional needs [Tenodesis , arthrodesis]

Indication and contra indication

CRITICAL POINTS: INDICATIONS AND CONTRAINDICATIONS FOR OPERATIVE INTERVENTION

Indications

- Cervical spine injury with upper limb partial paralysis.
- Stabilized motor recovery (12 months post injury).
- Functional deficits that can be improved with surgery.
- Medically stable (blood pressure, bowel and bladder function).
- Infection free (decubitus ulcers, bladder).
- Full passive range of motion.
- Realistic goals with good motivation and desire.
- Personal and social stability to carry out rehabilitation and staged procedures (if necessary).

Contraindications

- Spasticity.
- Contractures.
- Chronic pain problems.
- Psychological instability.

Types of operation

- Tendon transfer
- Adjunct procedure - Tenodesis , Arthrodesis

Priority of function by tendon transfer and remaining rest by adjunct procedure

- First for wrist extension
- Then for pinch
- Then fro grasp
- Finally for release function

When transfer option exhausted Remaining function is through

- Tenodesis
- And arthrodesis

Principle of tendon transfer

- Flexibility of joint
- Availability , excursion , direction of pull, soft tissue bed

Tenodesis

- Is defined as movement of one joint produced by motion of other joint [usually proximal joint]
- **Wrist is never fused - tenodesis effect will be lost**
- Tenodesis should be done before tendon transfer

Common tenodesis technique

- For thumb flexion and extension
- For finger flexion and extension
- For intrinsic function
- Disadvantage - weak pinch or grasp

Passive tenodesis

- Tenodesis effect can be enhanced surgically without the need to transfer active muscle
- Anchor the paralysed tendon proximal to wrist to decrease effective tendon excursion and increase digital movement with wrist motion

Arthrodesis

- Is useful in thumb to make multiarticular thumb stable and easier to control .
- Pip joint fusion of index finger is useful to stabilise the digit and useful pinch

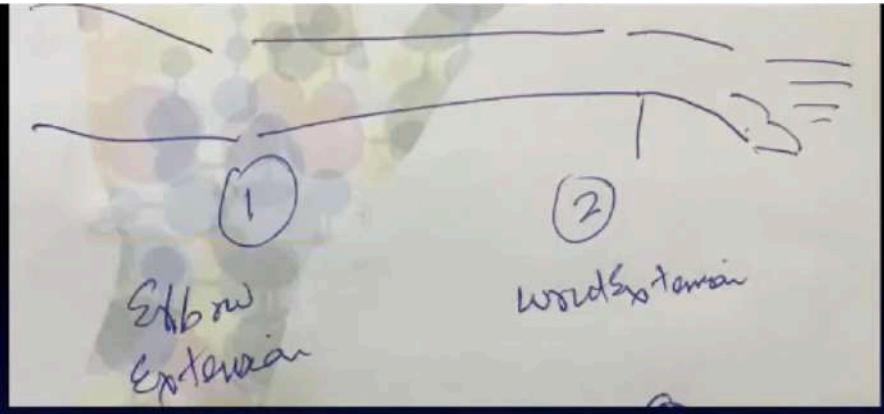
Worksheet - Sample patient

SAMPLE WORKSHEET FOR PREOPERATIVE PLANNING: C7 FRACTURE (GROUP 5)

Muscles the Patient Has (Muscles Below Elbow with >Grade 4 Strength)	Functions the Patient Needs	Muscles Available to Transfer	Match of Available Muscles and Adjunct Procedures to Patient's Functional Needs	Surgical Plan
BR	Finger extension	BR	BR to FPL (thumb flexion)	Extensor phase (stage 1)
ECRL	Finger flexion	ECRL	ECRL to FDP (finger flexion)	EDC tenodesis
ECRB PT	Thumb extension and abduction	PT*	EPL tenodesis EDC tenodesis	EPL tenodesis CMC fusion
FCR	Thumb flexion and opposition (intrinsics)†		CMC fusion for thumb positioning	Flexor phase (stage 2) BR to FPL ECRL to FDP

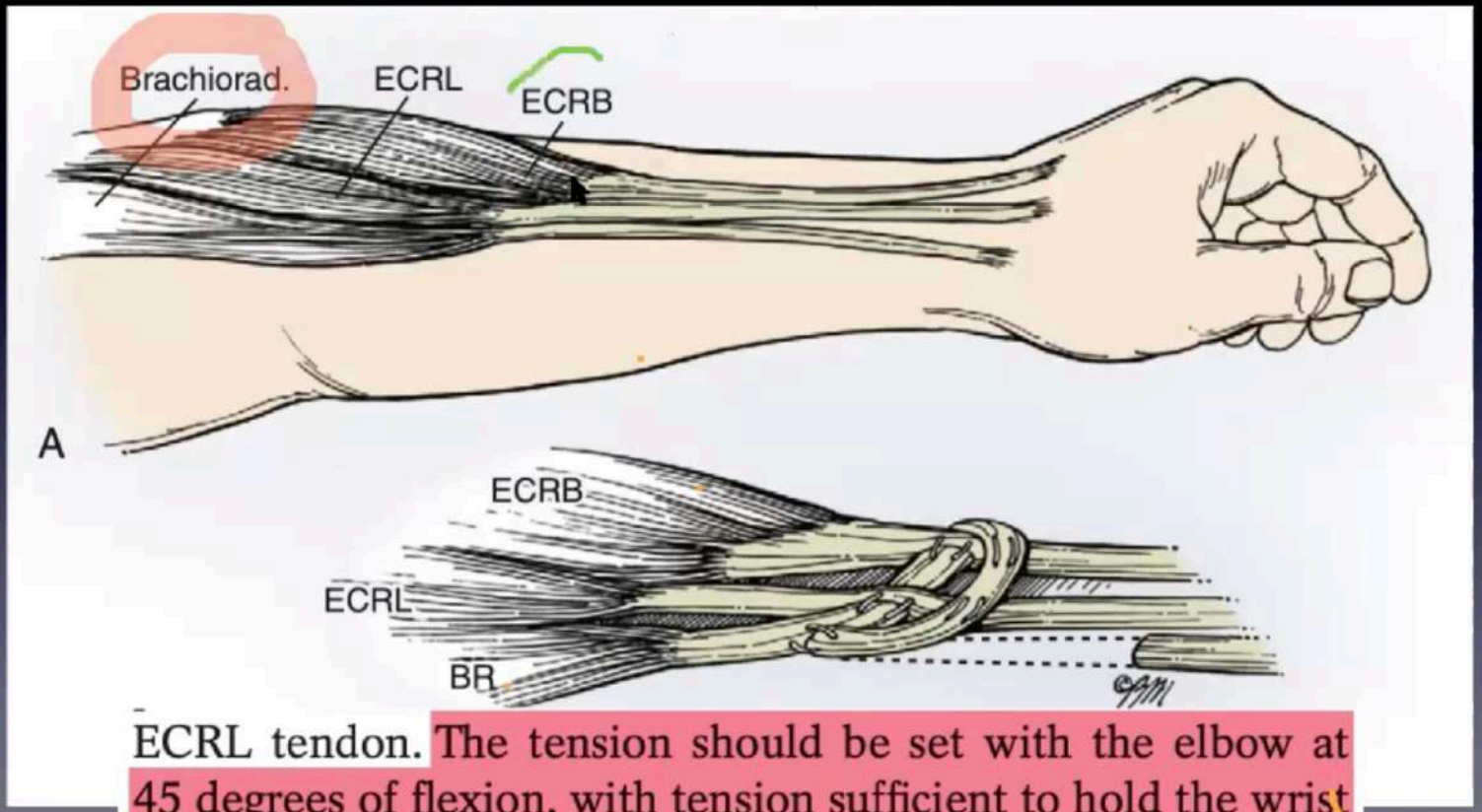
*PT can be used for transfer, but strength for manual wheelchair propulsion may be diminished, so it is not the first choice.
†Reconstruction of intrinsics may be necessary if joint imbalances exist.

Group 1 - Treatment
BR - good



- Tendon transfer for wrist extension - BR to ECRB
- Passive Tenodesis for lateral key pinch - Moberg pinch reconstruction
- arthrodesis of thumb cmc joint

BR to ECRB



ECRL tendon. The tension should be set with the elbow at 45 degrees of flexion, with tension sufficient to hold the wrist in 0 degrees. With the elbow flexed, the wrist should passively flex, and with the elbow extended, the transfer should tighten. Postoperatively, a long-arm cast is applied in the

4 steps of Moberg passive key pinch

IP joint k wire ,
MP joint tenodesis by EPB,
FPL tenodesis
A1 pulley release

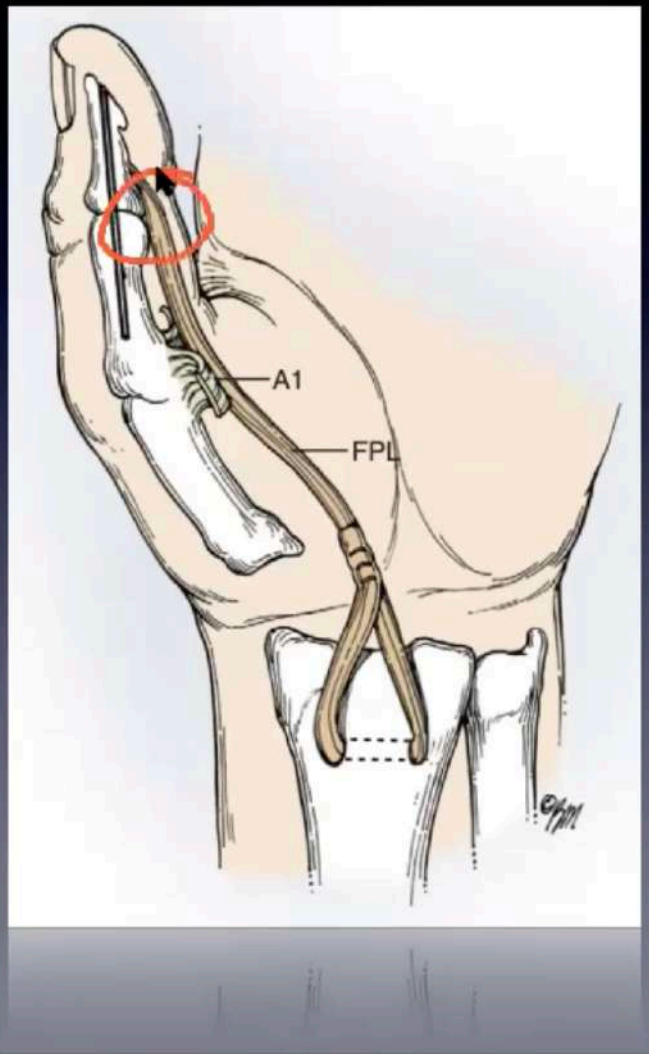


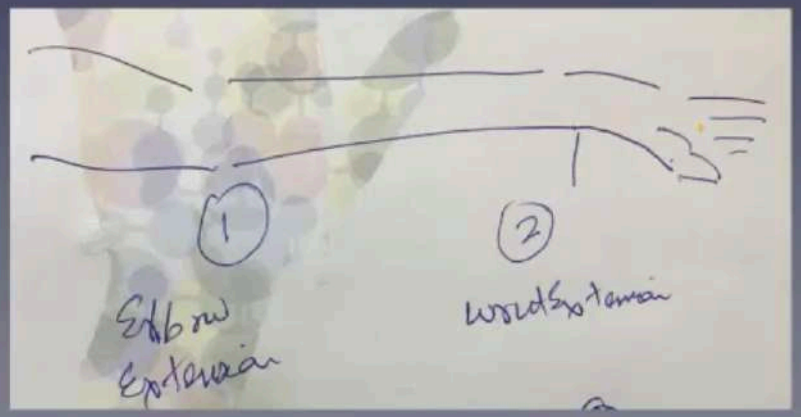
Figure 37.7 The classic Moberg passive key pinch reconstruction includes FPL tenodesis to the radius at the proximal edge of the pronator quadratus and Kirschner wire fixation of the IP joint to prevent premature flexion (Froment's sign). Additional optional steps include A1 pulley release to increase FPL torque at the MP joint and fixation of the EPB to the dorsal first metacarpal to avoid MP hyperflexion. This classic combination is seldom used because it has undergone many modifications, as described in the text. *(Copyright Elizabeth Martin.)*

Group 2 & 3
Muscle strength - ECRL & ECRB

- Mohammed method - Bean sign - visible groove between ECRL & ECRB suggest grade > 4 ECRL & ECRB
- Moberg method - Needle passed through muscle under local anesthesia and 5 kg weight hooked to wrist - suggest ECRB > 4 if able to bear 5 kg weight
- Allieu method PT action if present means - both ECRL & ECRB are grade > 4

Review of literature describe variety of operation for group 2 & 3

Author preferred treatment for both Group 2 & 3
is
House 's one stage active key pinch



Houser one stage

2	BR to FPL
	CMC fusion
	EPL tenodesis
	Option: split FPL tenodesis
3	BR to FPL
	CMC fusion
	EPL tenodesis
	Option: split FPL tenodesis

House 's one stage active key pinch

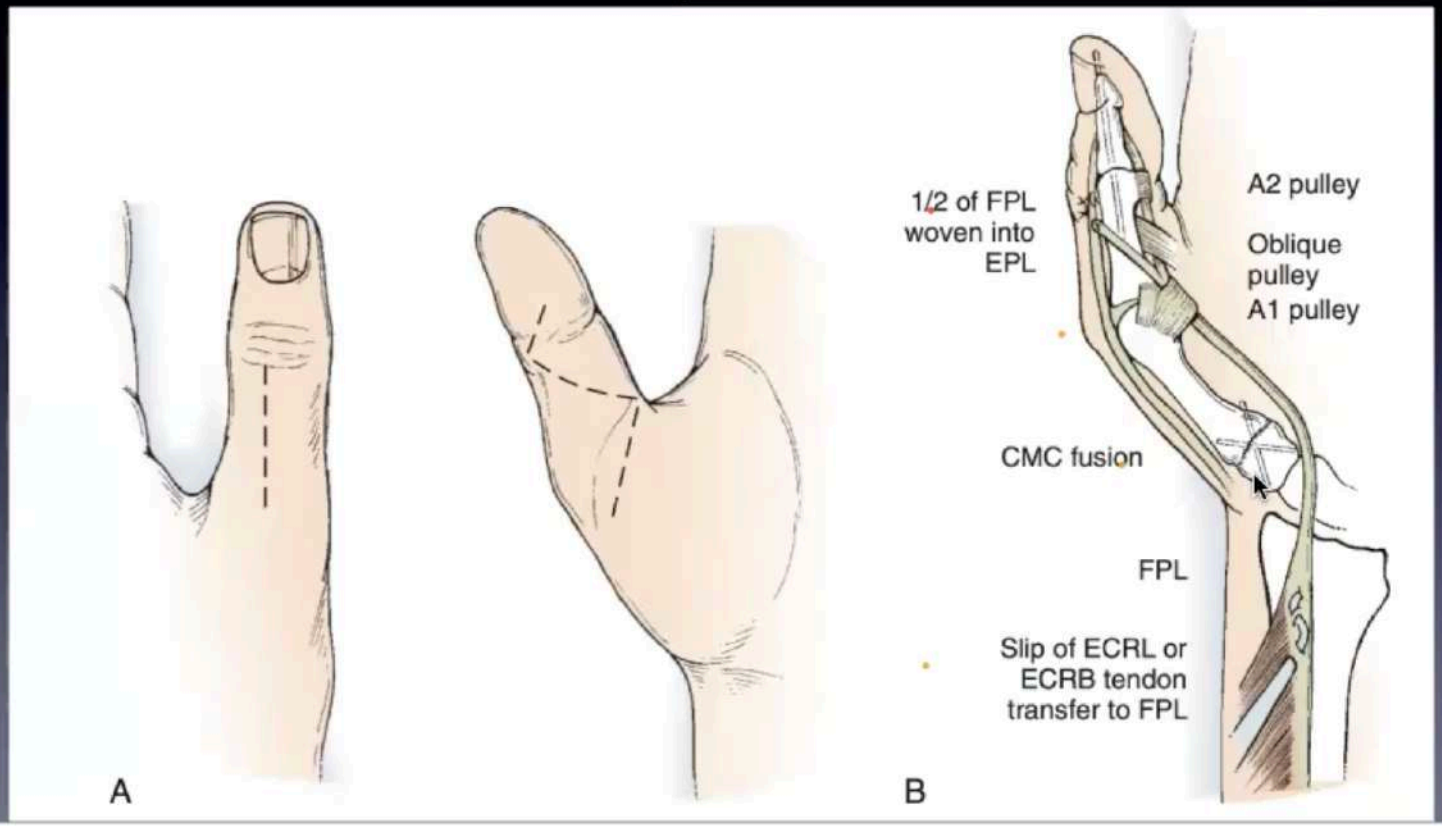
AUTHOR'S PREFERRED METHOD OF TREATMENT

To avoid the loss of wrist extensor strength, my preference is to treat patients in groups 2 and 3 identically—not transferring either the ECRL or the ECRB. For group 2 and 3 patients, I prefer House's one-stage active key pinch reconstruction[37] consisting of CMC fusion, BR to FPL tendon transfer, EPL tenodesis, split FPL transfer for stabilization of the thumb IP joint, and, if the index finger does not flex sufficiently to be a post for key pinch, a lasso procedure (see Table 37.6). Because most patients in groups 2 and 3 have adequate natural tenodesis and balance of the paralyzed fingers, reconstructive efforts are focused on the thumb.

For group 3
Alternate option is
Zancolli two stage reconstruction
First Tenodesis and arthrodesis then tendon transfer

- **Stage I [tenodesis and arthrodesis]**
  - Extensor tenodesis of thumb and fingers
  - Intrinsic tenodesis to reduce digital clawing
  - IP joint fusion thumb

Other option for group 3
Split FPL tenodesis



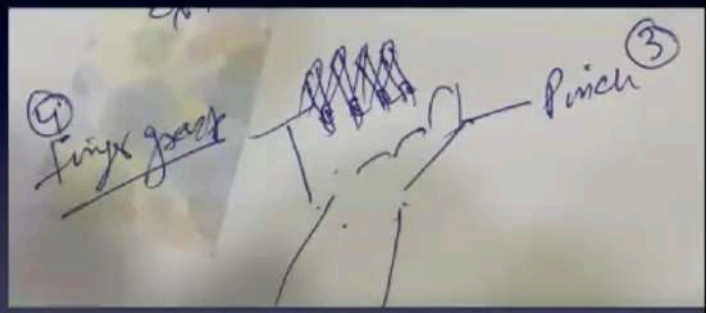


Figure 37.10 Split FPL distal tenodesis. **A,** Dorsal and palmar incisions. **B,** Transfer of the radial half of the FPL to the EPL improves thumb intrinsic balance by stabilizing the MP and IP joints, providing more effective lateral pinch.[66]

Grade 4 & 5

- **Good power in BR, ECRL ,ECRB and PT [group 4], [FCR [group 5]**
- Lass than grade 4 power below elbow [FDS FDP, FPL]

Author preferred treatment

4 and 5	House two stage:
	Extensor phase
	EDC tenodesis (*option:* BR to EDC)
	EPL tenodesis
	Options: CMC fusion, intrinsic tenodesis
	Flexor phase
	ECRL to FDP
	BR to FPL (*option:* PT to FPL)
	Options: adduction-opponensplasty (BR or PT with FDS graft), split FPL tenodesis, lasso procedure

Stage I

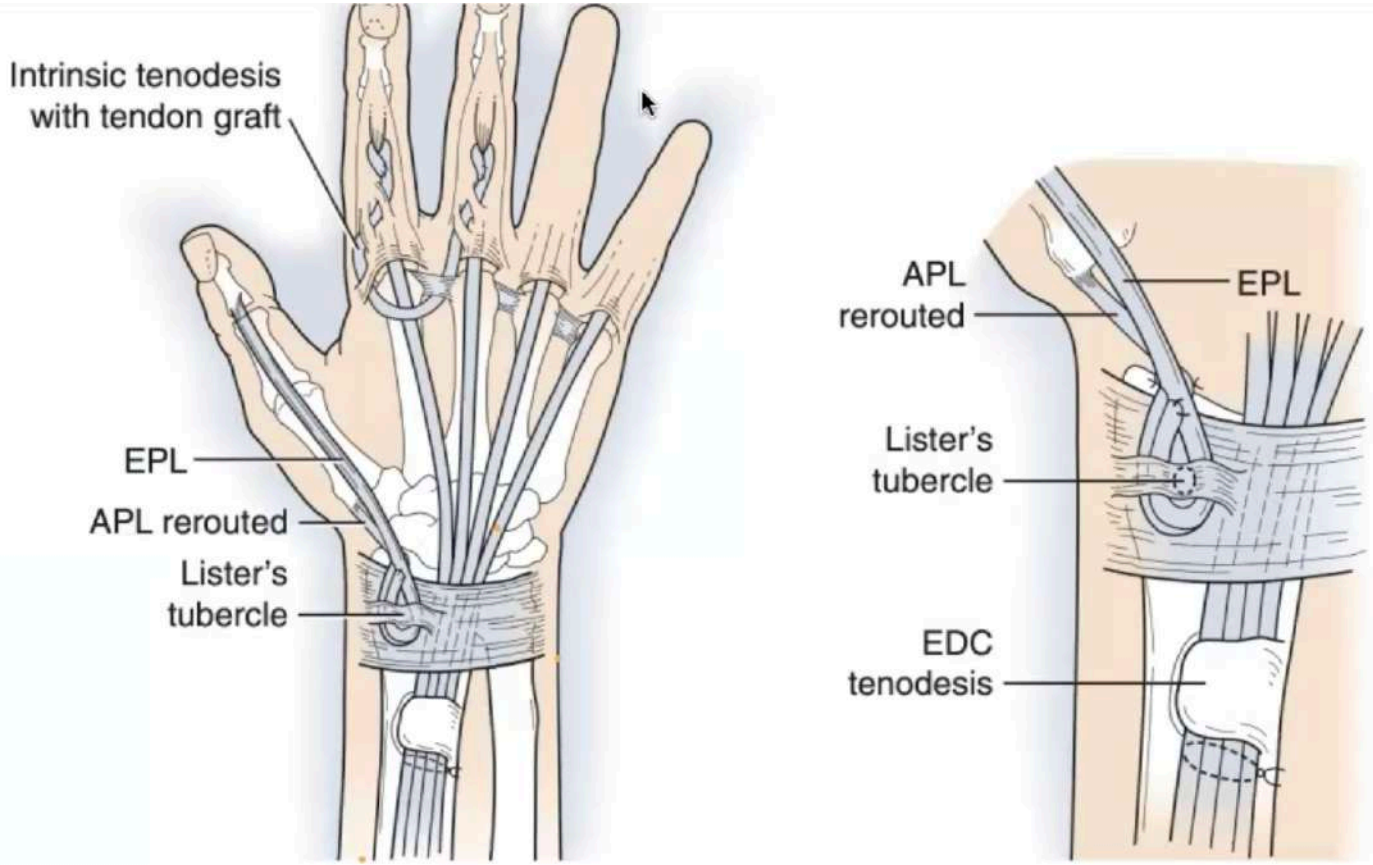


Figure 37.12 Stage 1 (extensor phase) of House's two-stage reconstruction for patients in group 5. **A,** Intrinsic tenodesis may be performed for inadequate IP extension. A free tendon graft is routed through the lumbrical canals, volar to the deep transverse metacarpal ligament and around the second metacarpal, and braided and sutured into the lateral bands and central slips of adjacent digits. The same technique can be used for the ring and little fingers (around the fourth metacarpal).[39] **B,** Tenodesis of the EDC is accomplished by fixation of the tendons into a "horseshoe window" in the distal radius with a heavy suture that also balances the relative tension of all four fingers. The EPL and APL (rerouted through the third dorsal compartment) are usually passed around Lister's tubercle and braided together to provide balanced thumb abduction and extension and sutured in a loop around the extensor retinaculum. *(Copyright Elizabeth Martin.)*

House stage II

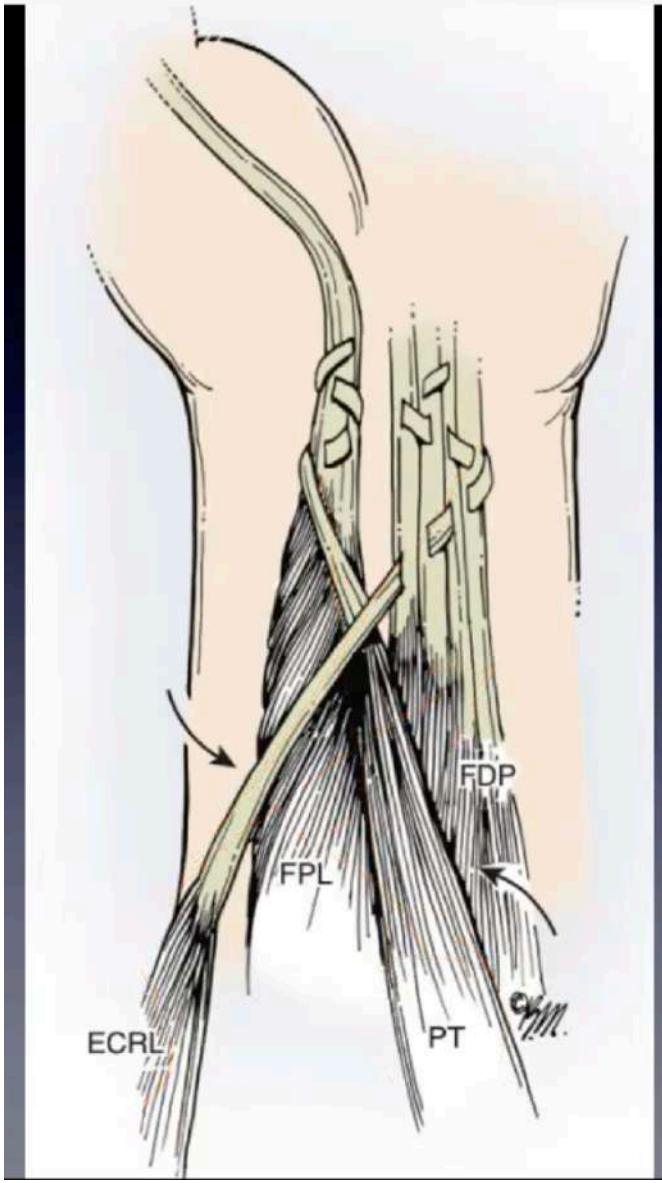
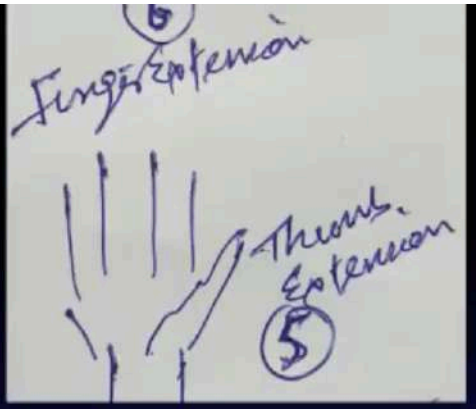


Figure 37.13 Stage 2 (flexor phase) of House's reconstruction includes both ECRL to FDP tendon transfer and PT to FPL tendon transfer. Another option would be ECRL to FDP and BR to FPL tendon transfers.[39] *(Copyright Elizabeth Martin.)*

Group 6

- **Good wrist extensor [BR, ECRL, ECRB , PT , FCR , EDC]**
- Absent EPL
- Absent Intrinsic

Group 6
Author preferred treatment



ECRL to FDP
BR to FPL (*option:* PT to FPL)
EPL tenodesis (*option:* EPL to EDC)
Options: CMC fusion or adduction-opponensplasty (BR or PT with FDS free graft), split FPL tenodesis, lasso procedure (BR or PT to FDS)

Group 7

- Good wrist extensor [BR, ECRL, ECRB , PT ,FCR ,EDC, EPL]
- Absent Intrinsic

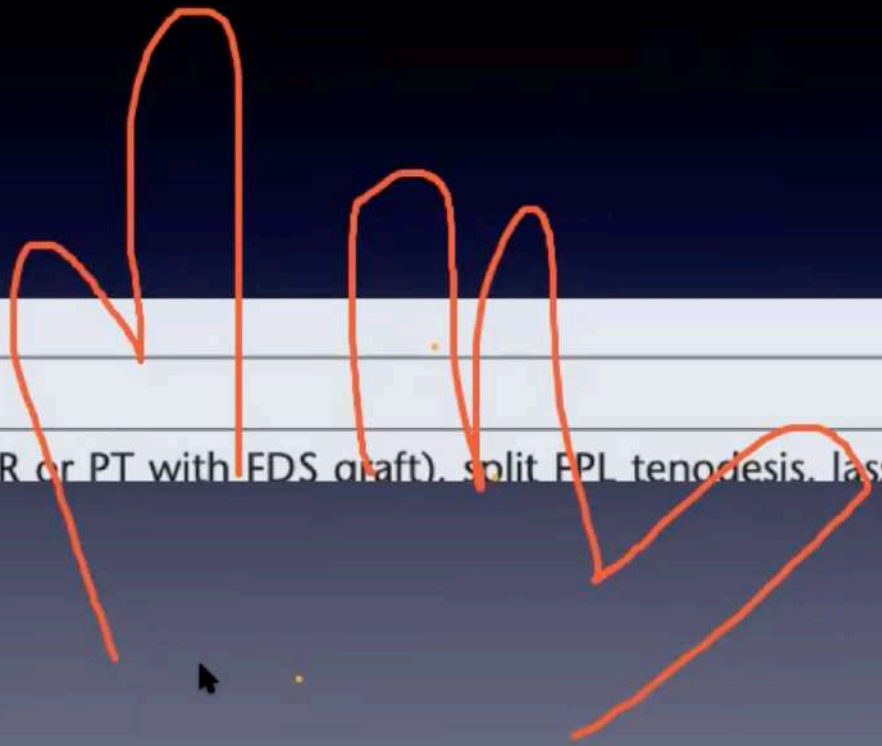
Group 7 - treatment

- Thumb opponensplasty in one side and cmc fusion on other side

Group - 8
Absent FDS power
Lack grade 4 power of long flexor of digits - FDP, FPL
Lack intrinsic

- **Radial side finger flexor - FDP** [thumb , index middle finger] weaker than little and ring finger
- Absent FDS
- Absent Intrinsic

Group 3
Author preferred treatment



FDP side to side
BR to FPL
Options: opponensplasty (BR or PT with FDS graft), split FPL tenodesis, lasso procedure (BR or PT to FDS)

Group 9

- Good finger flexor lead to IP flexion
- Absent intrinsic lead to clawing of finger
- Pip central slip deficiency lead to finger flexion at IP joint of digits

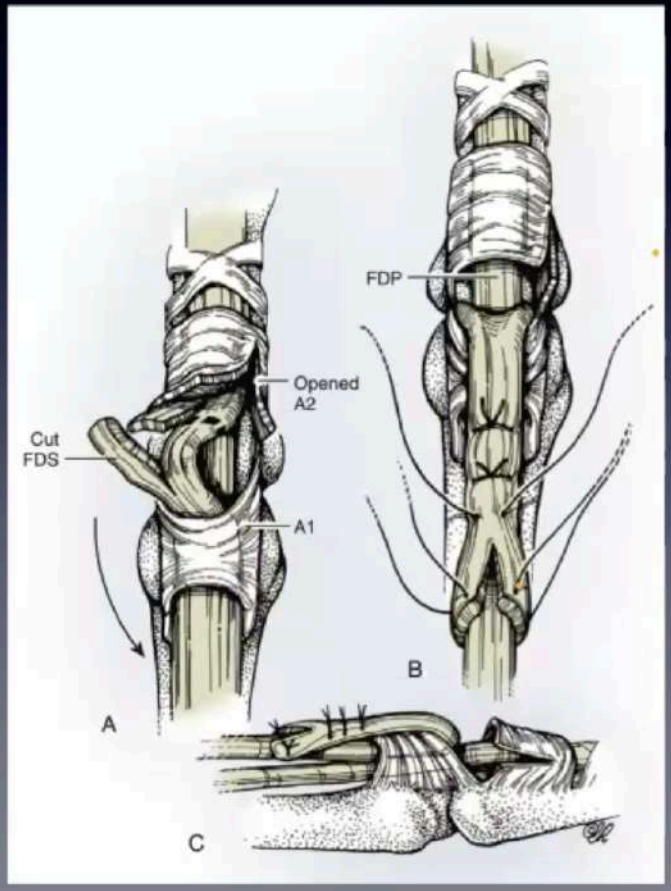
Group 9- treatment

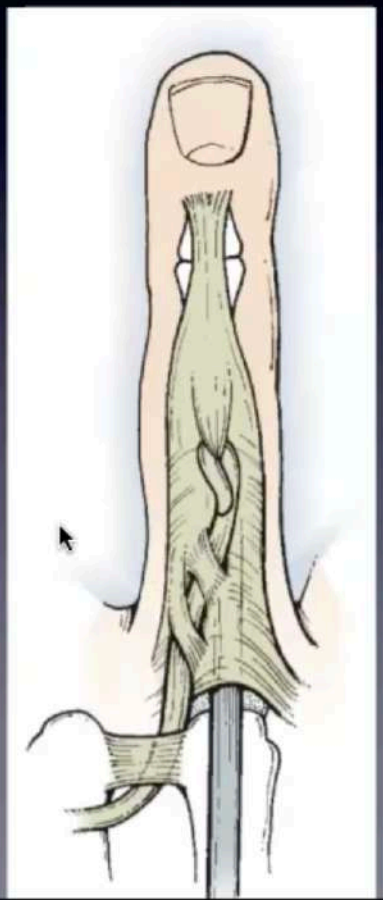
Like low median and ulnar clawing

- Split FPL transfer for thumb IP flexion
- Single stage intrinsic reconstruction - zancolli lasso using FDS
- Central slip tenodesis for central slip deficiency

- Hyperflexion of the thumb IP joint (Froment's sign): treated with split FPL transfer.
- Clawing of the digits with MP hyperextension of the fingers and PIP flexion with early digital "roll-up": treated with Zancolli passive or active lasso procedure.
- PIP flexion deformity due to central slip deficiency: treated with intrinsic tenodesis.

Group - 9
Zancolli lasso using fds
Central slip tenodesis with free graft





Group 0
Lack elbow extension

- Active elbow extension is useful
- Assist patient in reaching object above shoulder level
- Improve driving ability
- Wheel chair propulsion and independent transfer
- Permit pressure relief
- Active elbow motion allow BR tenodesis effect for hand reconstruction

- Bicep and deltoid are innervated at higher level than tricep
- Brachialis muscle strength should be >grade 4 to allow bicep transfer to tricep

Bicep , Brachialis muscle strength

testing is performed, testing elbow flexion, attempting to isolate the brachialis by supinating the forearm, and allowing relaxation of the biceps. This can be verified by palpating the groove between the more tubular biceps anteriorly and the flatter brachialis posteriorly to differentially test strength. In

level (C5-6). If the patient has strong wrist extension, the spinal cord lesion should be below C6, sparing the biceps, brachialis, supinator, and wrist extensors, but above the innervation of the paralyzed triceps. Such findings on clinical examination verify that transfer of the biceps will not lead to a functional loss. Electromyography is generally not necessary as part of the routine evaluation.

Group 0
Lack elbow extension

- Bicep to tricep tendon transfer - preferred than posterior deltoid to tricep

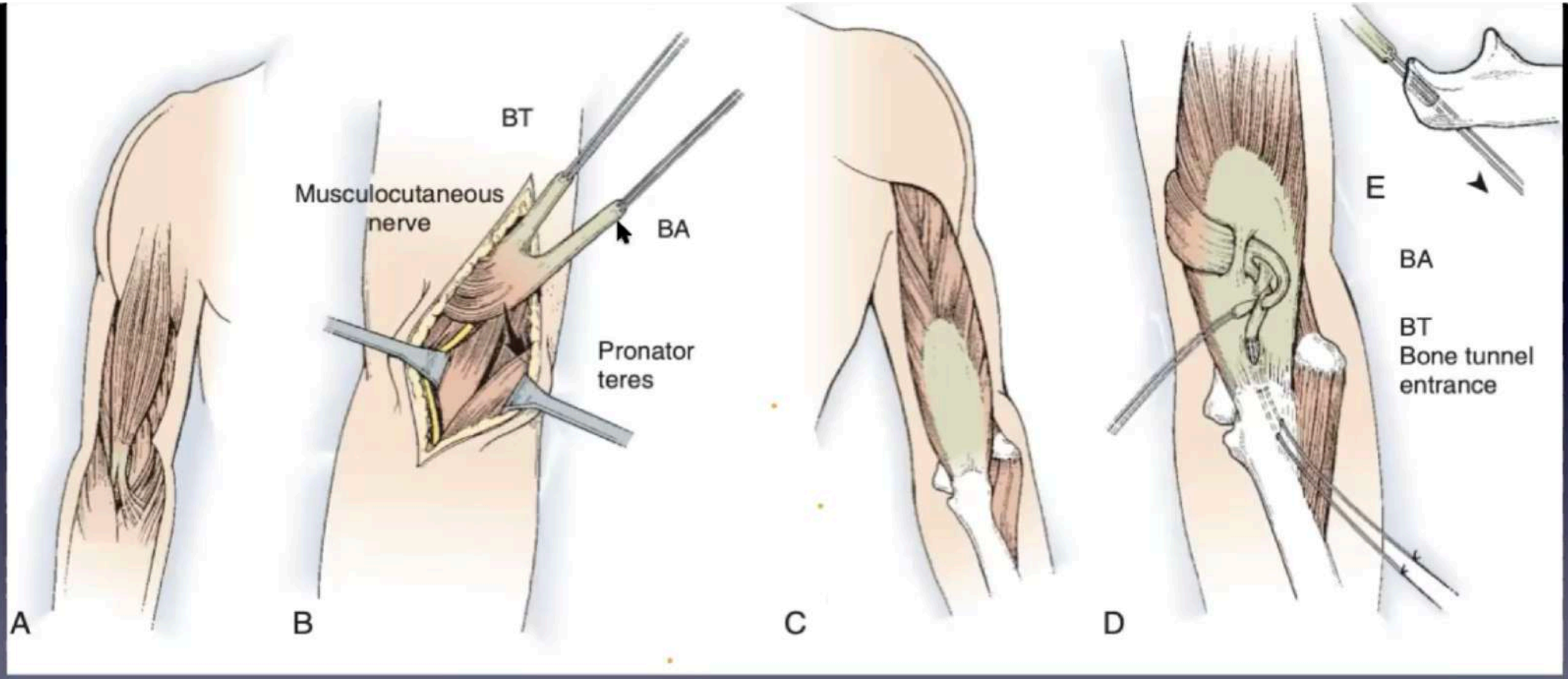


Figure 37.2 Biceps to triceps transfer. **A** and **B**, The biceps tendon (BT) and bicipital aponeurosis (BA; lacertus fibrosus) are released, and the muscle belly is mobilized proximally through an anterior incision. **C** and **D,** The biceps is rerouted medially around the arm in the subcutaneous plane and inserted by braiding the tendon "tails" into the triceps tendon. **E**, Direct insertion of the biceps tendon into a bone tunnel in the olecranon, with heavy sutures tied over bone. This provides strong fixation, permitting relatively early mobilization.

Option - Deltoid to tricep

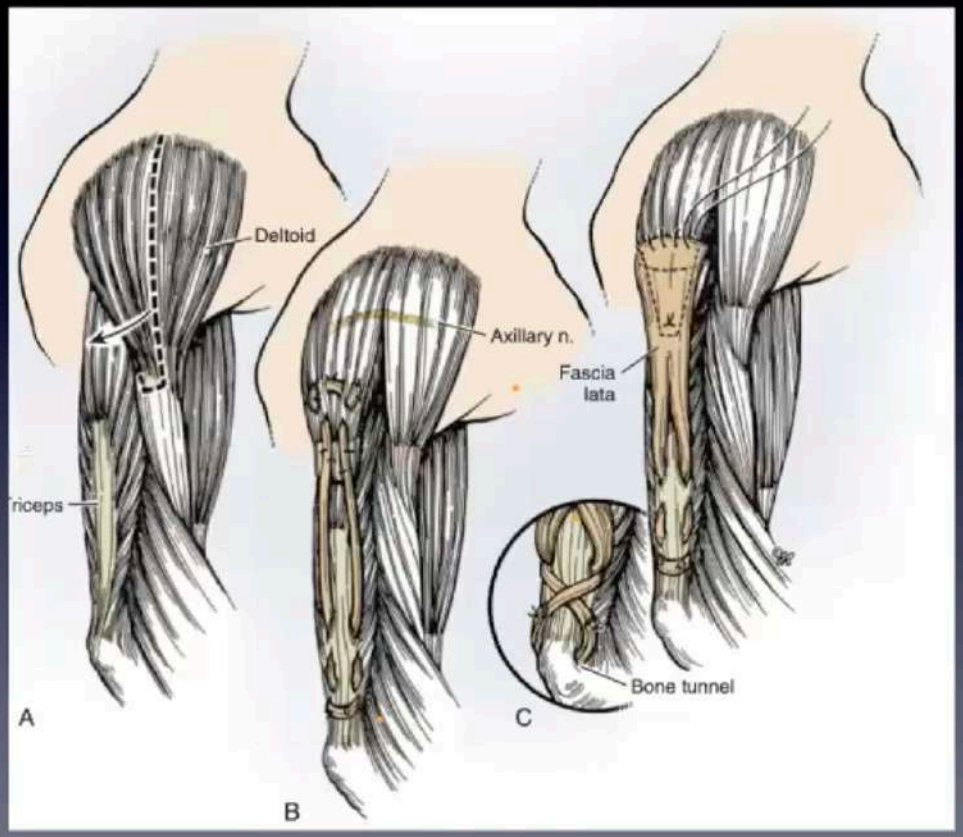


Figure 37.3 Deltoid to triceps transfer.[61] **A,** The posterior border of the muscle belly is isolated, preserving as much of the tendinous insertion as possible. **B**, Tendon grafts are laced into the distal end of the deltoid muscle belly and triceps aponeurosis. **C**, Fascia lata is used rather than tendon grafts. Direct insertion into the olecranon through a bone tunnel can be performed with either type of graft. *(Copyright Elizabeth Martin.)*

The transfer is tensioned to allow 60 to 90 degrees of elbow flexion passively. The lacertus fibrosus is then interwoven through the biceps to triceps weaves to further secure the tendon weave. Postoperatively, the elbow is placed in about 30 degrees of flexion in a long-arm cast for 4 weeks. A flexion block splint (hinged elbow orthosis) is then used full time, and 15 degrees of flexion is added each week until

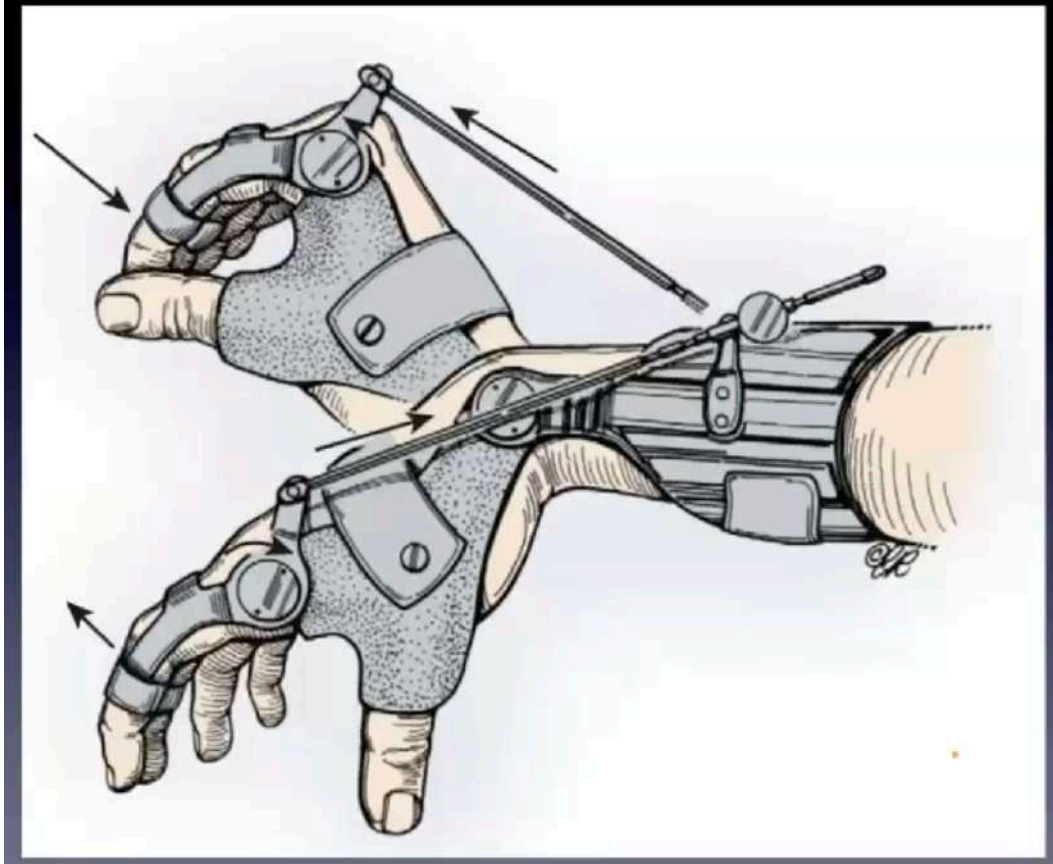


Figure 37.5 The wrist-driven flexor hinge splint uses the principle of synergistic action. As the wrist is extended, the fingers are flexed to bring them into contact with the thumb, which is fixed. As the wrist is flexed, the fingers are extended. *(Courtesy of T. Engen, MD. Copyright Elizabeth Martin.)*

Forearm pronation

FOREARM PRONATION

Pronation is important to patients who have only active wrist extension (groups 2 and 3). These patients use the automatic or tenodesis effect for grasp, but if the hand cannot be pronated, gravity cannot be used to provide a tenodesis effect for digital extension and release. Those patients using a tenodesis brace need pronation for the same reason.

Zancolli produced pronation by converting the biceps into a forearm pronator (Figure 37.4). He rerouted the tendon around the radius, converting the biceps from a supinator to a pronator.[89]

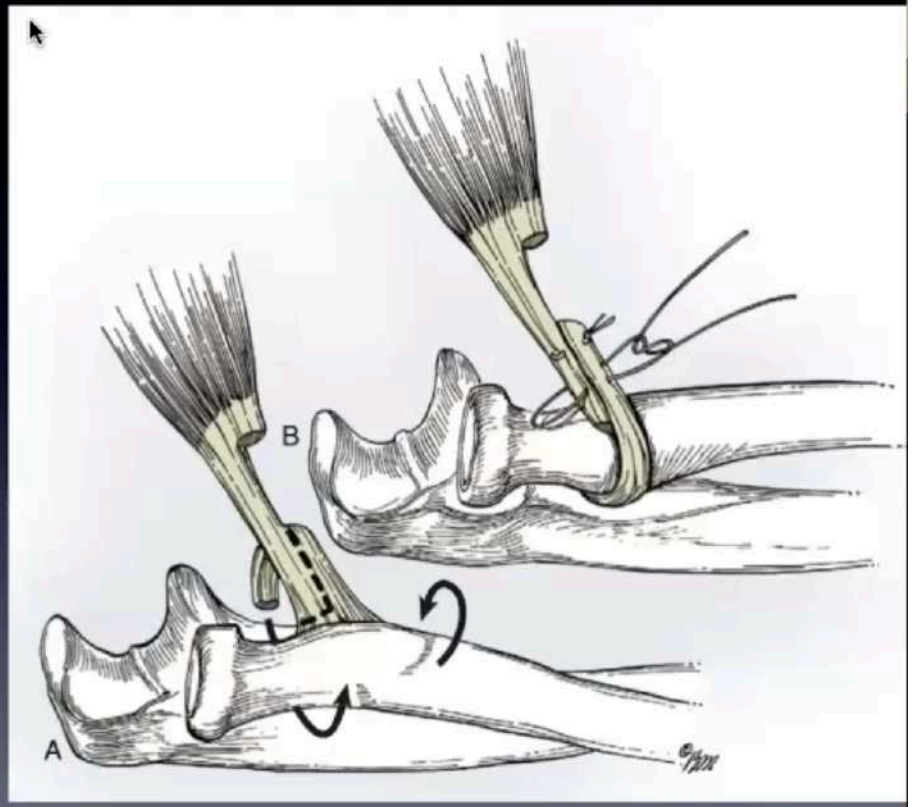


Figure 37.4 Zancolli's method for rerouting the insertion of the biceps tendon to provide pronation of the forearm. Half the tendon is passed behind the neck of the radius **(A)** and then sutured into the remaining biceps tendon **(B)**.[91] *(Copyright Elizabeth Martin.)*

Neuroprosthesis system
Stimulator - Receiver
Indication

The neuroprosthesis is indicated for tetraplegic patients for whom standard surgical procedures or orthotic devices cannot provide useful improved function or who have

This technology takes advantage of paralyzed muscles that are no longer under cortical control (due to spinal cord injury) but have intact spinal reflex arcs. The anterior horn

below the level of the direct spinal cord injury. These muscles can be stimulated to contract with relatively weak electrical

currents. Muscle signals, nerve signals, or volitional movements (above the level of spinal cord injury), typically from the contralateral shoulder or neck, are used to control the device.

Neuroprosthesis system
Stimulator - Receiver

- System - Stimulate the electrode attached to desired muscle to achieve specific function of hand grasp and release
- If desired muscle cannot be stimulated then do
- tendon transfer to the that desired muscle and system will stimulate the the donor muscle that will act on non stimulate muscle indirectly to achieve desired function of hand grasp and release .