NEURO INSTITUTE

Continuing Education for Rehabilitation Professionals

Upper Extremity Restoration in Spinal Cord Injury

Ann Vasile, MD

NeuroRestorative's COVID-19 Response

We are committed to protecting the health and safety of the individuals we serve, our staff, and the community. Our services are considered essential, and we are taking precautions to minimize disruption to services and keep those in our care and our team members safe. In some programs, that has meant innovating our service delivery model through Interactive Telehealth Services. We provide Interactive Telehealth Services throughout the country as an alternative to in-person services. Through Interactive Telehealth Services, we deliver the same high-quality supports as we would in-person, but in an interactive, virtual format that is HIPAA compliant and recognized by most healthcare plans and carriers.

You can learn more about our COVID-19 prevention and response plan at our Update Center by visiting **neurorestorative.com**.

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What we will cover

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- Understand the Neurologic exam —
- American Spinal Injury Association vs International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)
- Identify potential candidates for surgical reconstruction of paralysis Understand the difference between a tendon and nerve transfer
- Understand improved functional potential outcomes of surgical reconstruction for the paralyzed

Neurologic Classification of Spinal Cord Injury

- Formerly known as ASIA—American Spinal Injury Association
- *International standards for neurological classification of SCI*
- Key muscles and sensory levels to identify neurologic level of injury

Definitions

Tetraplegia: impairment cervical—arms, legs, trunk, pelvic organs

Paraplegia: impairment T, L or S—trunk, leg, pelvic organs; includes conus medullaris and cauda equina

Tetraparesis and paraparesis: use discouraged, describes incomplete

Incomplete injury:

- Preservation of any sensory or motor function below NLI that includes sacral segments
- Sensory “sacral sparing” S4-5 for deep anal pressure, light touch or pin-prick on rectal exam
- Motor sacral sparing includes voluntary contraction external anal sphincter on rectal exam

Complete injury:

- Absence sensory and motor in lowest sacral segments S4-5, no “sacral sparing”

Upper Extremity Key Muscles

C5: elbow flexors (biceps, brachialis)

C6: wrist extensors (ECRL and ECRB)

C7: elbow extensors (triceps)

C8: finger flexors to middle finger (FDP)

T1: small finger abductor (ABD)

Muscle Grading

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0 = Total paralysis

1 = Palpable or visible contraction

2 = Active movement, full ROM with gravity eliminated

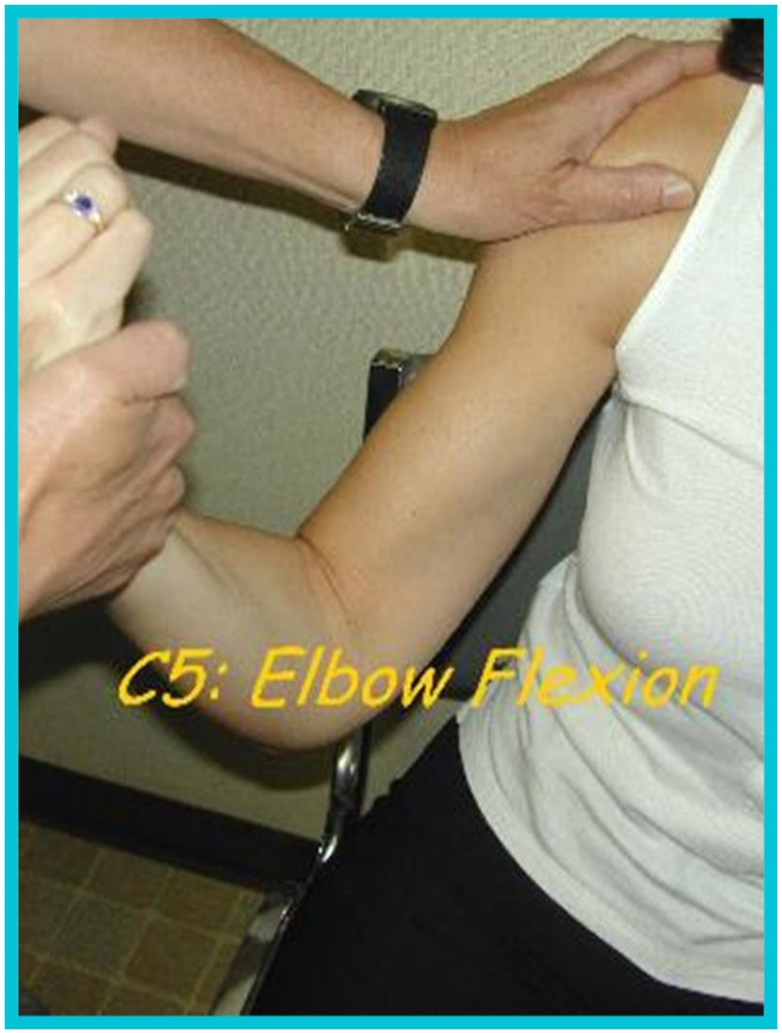
3 = Active movement, full ROM against gravity

4 = Active movement, full ROM against gravity and moderate resistance

5 = (Normal) active movement, full ROM against gravity and sufficient resistance to be considered normal

NT = not testable (due to immobilization, severe pain amputation, contracture)

C5



C6

C7

C8

T1

Lower Extremity Key Muscles

L2: hip flexors (iliopsoas)

L3: knee extensors (quad)

L4: ankle dorsiflexors (tib ant)

L5: long toe extensors (EHL)

S1: ankle plantar flexors (gastroc, soleus)

L2

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L3

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L4

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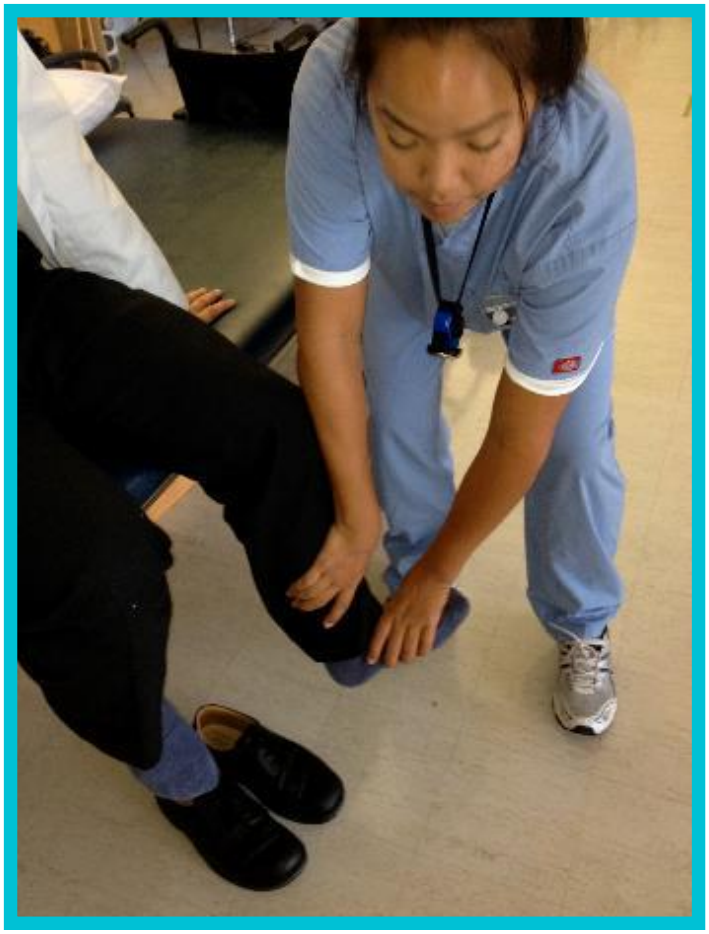

L5

S1

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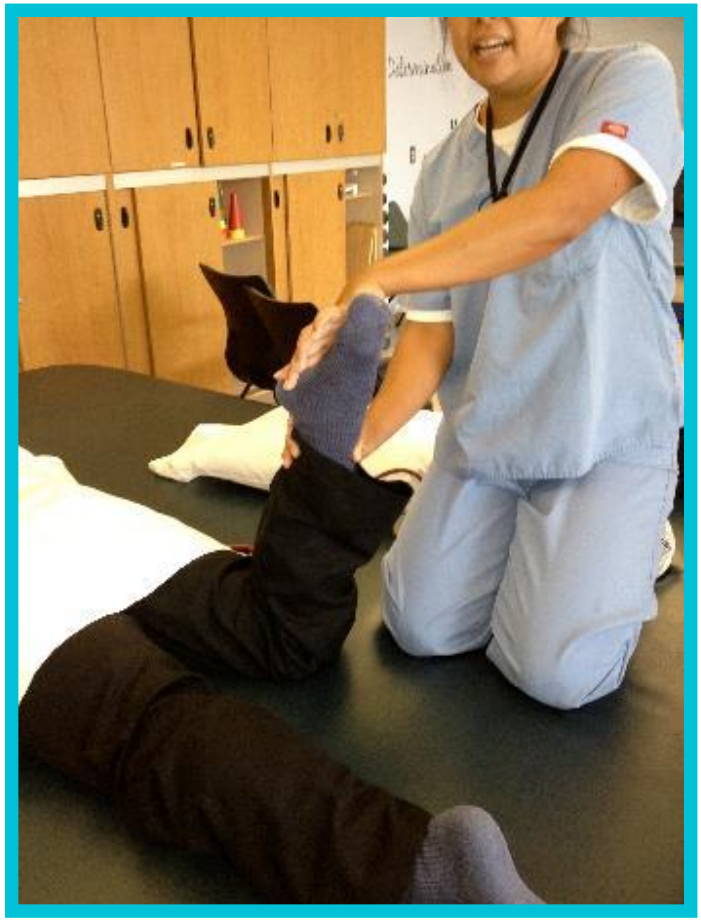

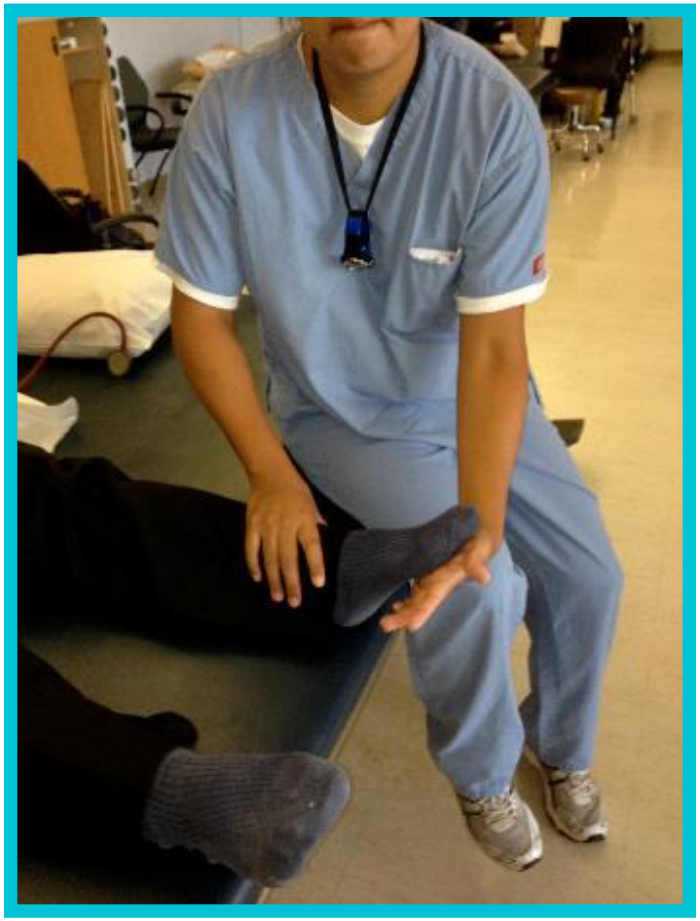

AIS Grading

ASIA A = Complete: no sensory or motor function is preserved in sacral segment S4-5

ASIA B = Sensory Incomplete: sensory, but no motor function is preserved below the neurologic level and includes sacral segments S4-5, AND no motor function is preserved more than three levels below the motor level on either side of body

ASIA C = Motor Incomplete: motor function is preserved below the neurologic level and more than half of key muscles below single neurologic level of injury have muscle grade less than 3

ASIA D = Motor Incomplete: motor function is preserved below neurologic level and at least half or more key muscles below NLI have muscle grade of 3 or greater

ASIA E = Normal: if sensation and motor function are grade as normal in all segments, and the patient had prior deficits (someone without SCI does not receive ASIA grade)

AIS Grading

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INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI)

ASIA American Spinal Injury Association — ISCOS International Spinal Cord Society

Patient Name _____ Date/Time of Exam _____

Examiner Name _____ Signature _____

RIGHT	MOTOR KEY MUSCLES	SENSORY KEY SENSORY POINTS Light Touch (LTR)	Pin Prick (PPR)	SENSORY KEY SENSORY POINTS Light Touch (LTL)	Pin Prick (PPL)	MOTOR KEY MUSCLES	LEFT
	C2					C2	
	C3					C3	
	C4					C4	
Elbow flexors	C5					C5	Elbow flexors
Wrist extensors	C6					C6	Wrist extensors
Elbow extensors	C7					C7	Elbow extensors
Finger flexors	C8					C8	Finger flexors
Finger abductors (little finger)	T1					T1	Finger abductors (little finger)
	T2					T2	
	T3					T3	
	T4					T4	
	T5					T5	
	T6					T6	
	T7					T7	
	T8					T8	
	T9					T9	
	T10					T10	
	T11					T11	
	T12					T12	
	L1					L1	
Hip flexors	L2					L2	Hip flexors
Knee extensors	L3					L3	Knee extensors
Ankle dorsiflexors	L4					L4	Ankle dorsiflexors
Long toe extensors	L5					L5	Long toe extensors
Ankle plantar flexors	S1					S1	Ankle plantar flexors
	S2					S2	
	S3					S3	
	S4-5					S4-5	
RIGHT TOTALS (MAXIMUM)		(50)	(56)	(56)	(56)	(50)	LEFT TOTALS (MAXIMUM)

UER (Upper Extremity Right)

UEL (Upper Extremity Left)

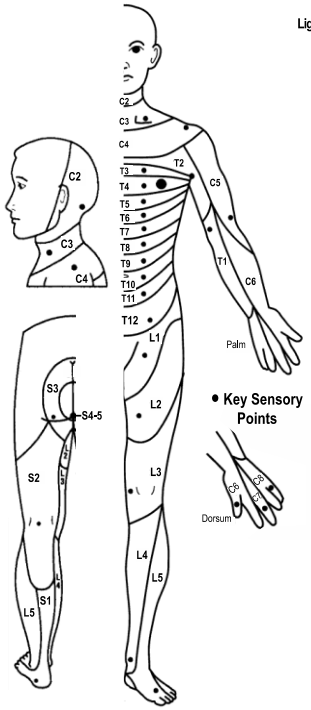
LER (Lower Extremity Right)

LEL (Lower Extremity Left)

Comments (Non-key Muscle? Reason for NT? Pain?):

(VAC) Voluntary anal contraction (Yes/No) ☐

(DAP) Deep anal pressure (Yes/No) ☐



MOTOR (SCORING ON REVERSE SIDE)

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
5* = normal corrected for pain/disuse
NT = not testable

SENSORY (SCORING ON REVERSE SIDE)

0 = absent — 2 = normal
1= altered — NT = not testable

MOTOR SUBSCORES

UER ☐ + UEL ☐ = UEMS TOTAL ☐ (MAX (25) (25) (50))

LER ☐ + LEL ☐ = LEMS TOTAL ☐ (MAX (25) (25) (50))

SENSORY SUBSCORES

LTR ☐ + LTL ☐ = LT TOTAL ☐ (MAX (56) (56) (112))

PPR ☐ + PPL ☐ = PP TOTAL ☐ (MAX (56) (56) (112))

NEUROLOGICAL LEVELS (Steps 1-5 for classification as on reverse)

	R	L
1. SENSORY		
2. MOTOR		

3. NEUROLOGICAL LEVEL OF INJURY (NLI) ☐

4. COMPLETE OR INCOMPLETE? ☐
Incomplete = Any sensory or motor function in S4-5

5. ASIA IMPAIRMENT SCALE (AIS) ☐

(In complete injuries only) **ZONE OF PARTIAL PRESERVATION** Most caudal level with any innervation

	R	L
SENSORY		
MOTOR		

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REV 02/13

International Surgical Classification

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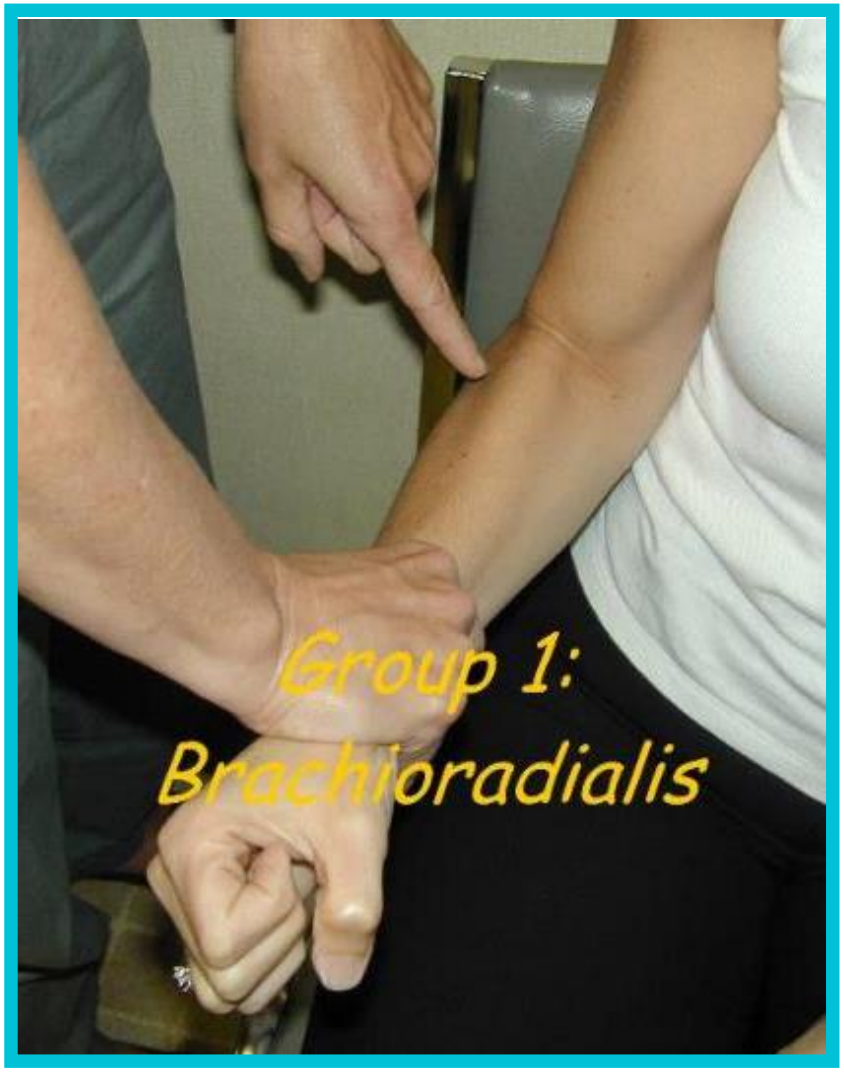
TABLE 1. *International Classification for Surgery of the Hand in Tetraplegia Edinburgh, 1978 (Modified-Giens 1984)*

Sensibility group	Motor characteristics	Description of function
0	No muscle below suitable for transfer	Flexion and supination of the elbow
1	BR	
2	ECRL	Extension of the wrist (weak)
3[a]	ECRB	Extension of the wrist (strong)
4	PT	Extension and pronation of the wrist
5	FCR	Flexion of the wrist
6	Finger extensors (partial or complete)	Extrinsic extension of the fingers
7	Thumb extensor	Extrinsic extension of the thumb
8	Partial digital flexors	Extrinsic flexion of the fingers (weak)
9	Lacks only intrinsics	Extrinsic flexion of the fingers
X	Exceptions	

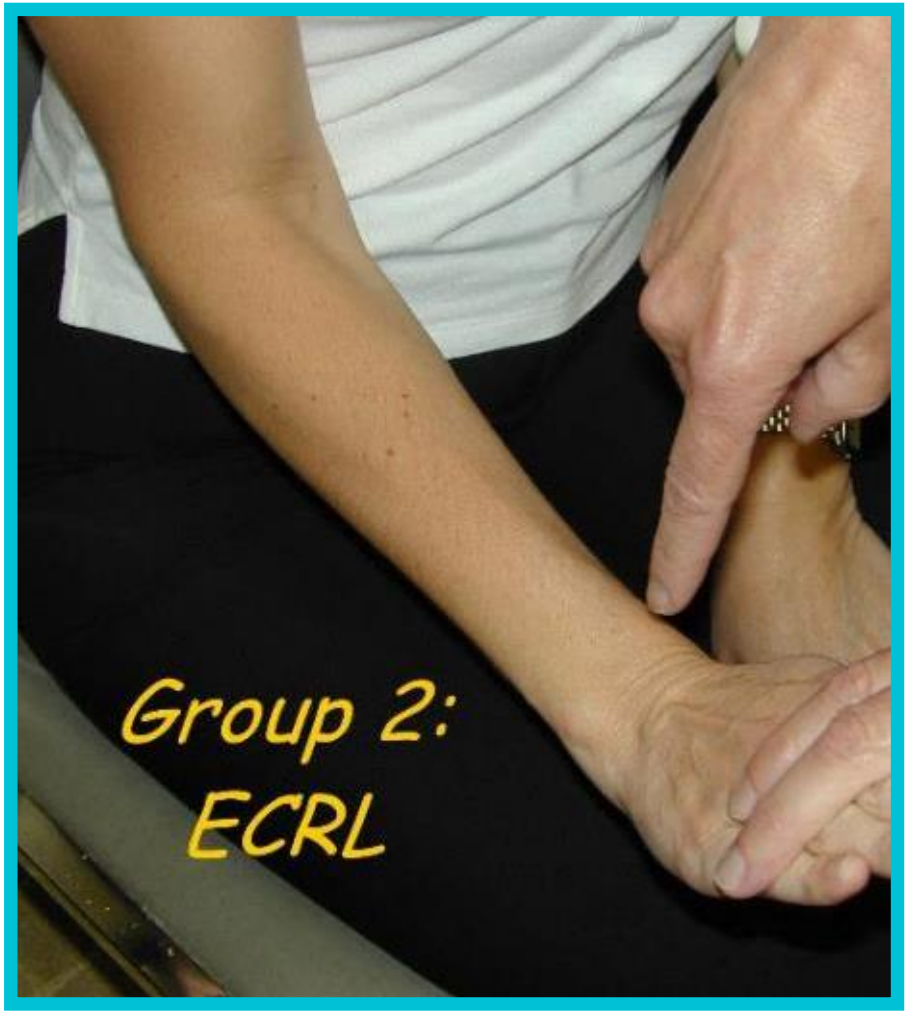
BR, brachioradialis; ECRL, extensor carpi radialis longus; ECRB, extensor carpi radialis brevis; PT, pronator teres; FCR, flexor carpi radialis.

[a] It is not possible to determine strength of ECRB without surgical exposure.

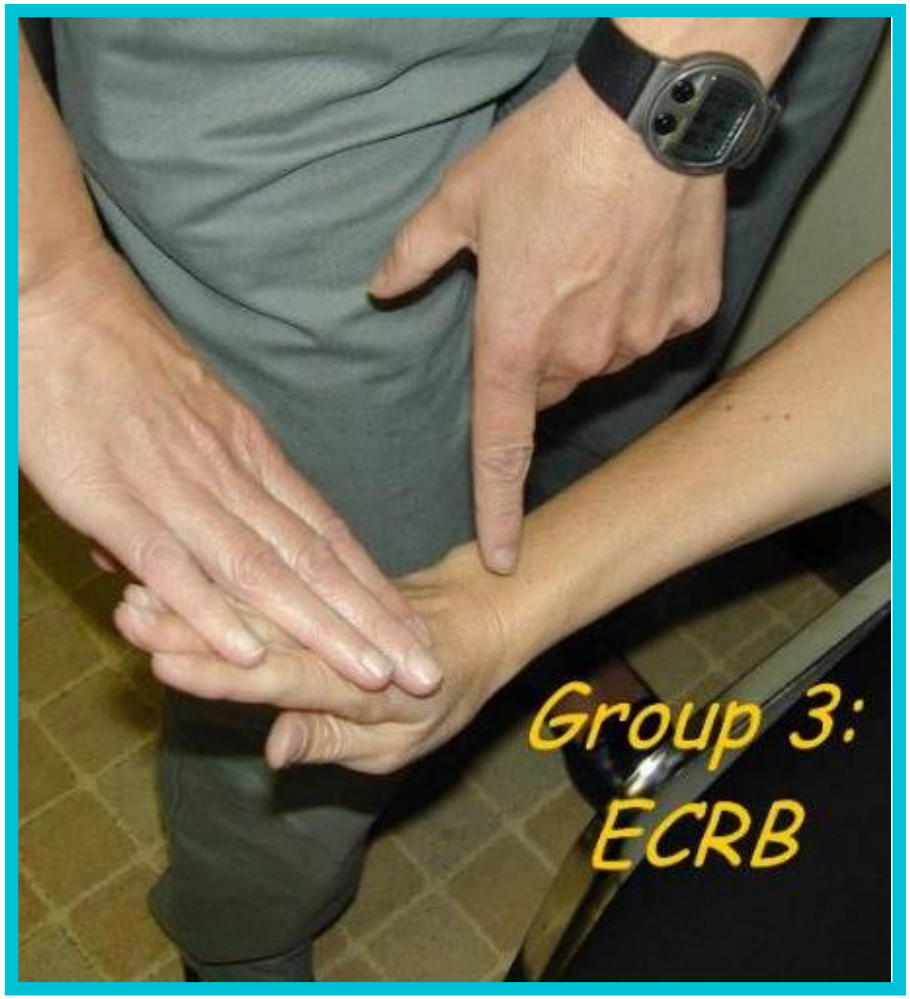
Brachioradialis



ECRL



ECRB



Pronator Teres

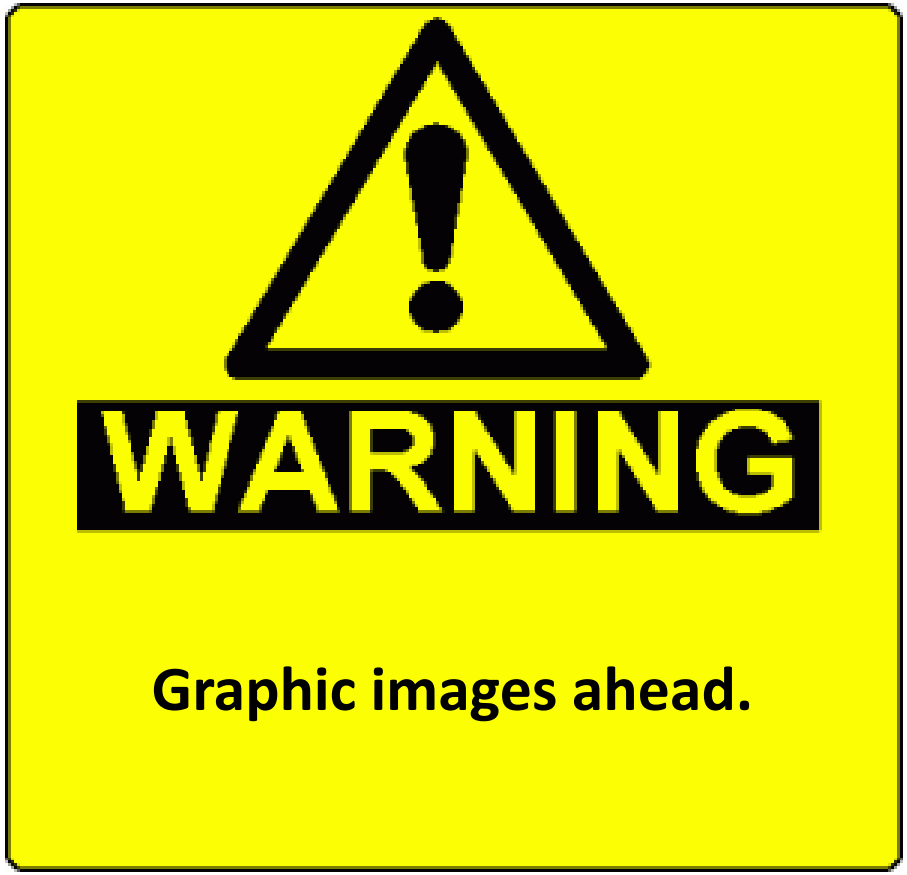
FCR

Finger Extension

Finger Flexors

Finger Flexors

Most patients with tetraplegia prefer restoration of hand function over all other functions, including bowel, bladder, and sexual functions.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Graphic images ahead.

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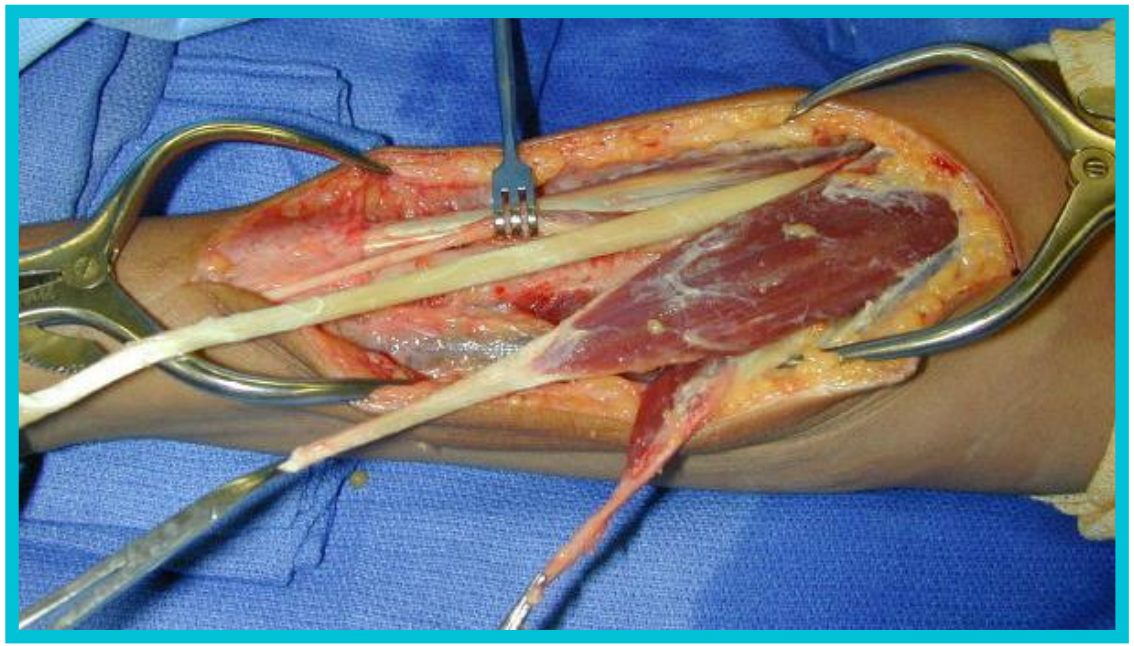
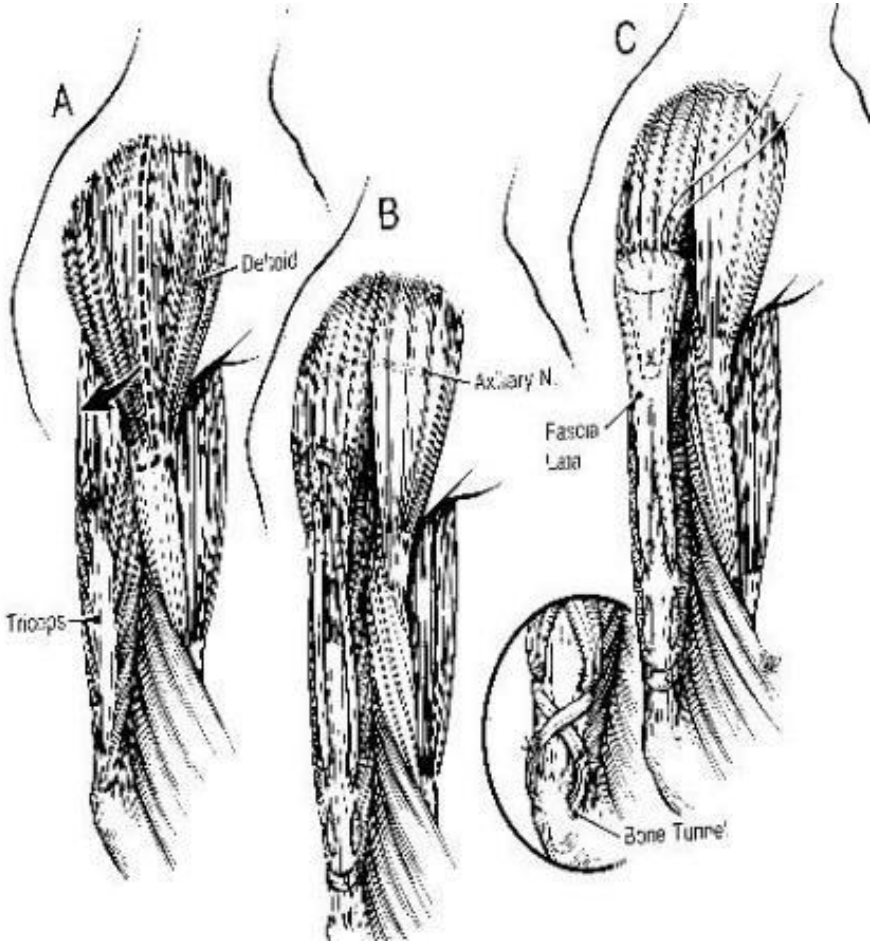


Deltoid to Triceps Transfer

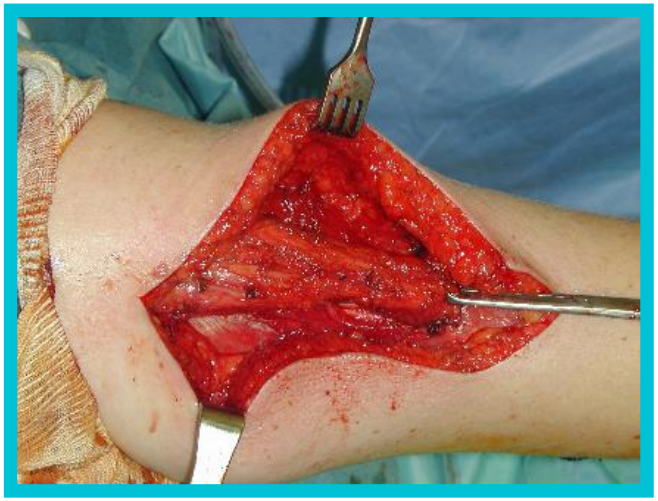
Elbow extension should be provided first when needed

Most useful and reliable procedure

Allows elbow to be extended in space



Deltoid to Triceps Transfer



Six Months After PD to Triceps Transfer

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Biceps to Triceps Transfer

Elbow extension should be provided first when needed

Most useful and reliable procedure

Allows elbow to be extended in space

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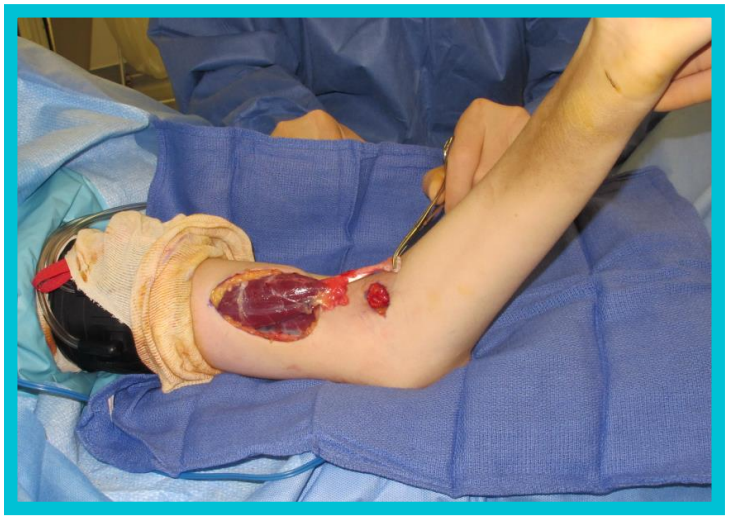

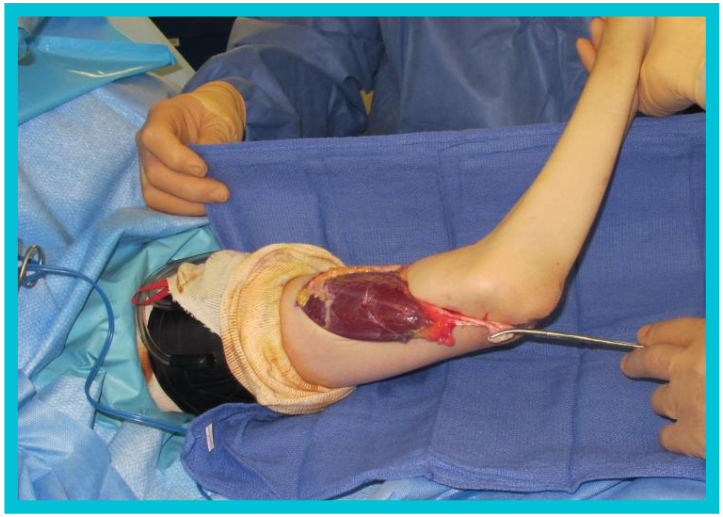

Post-Op Biceps to Triceps Transfer

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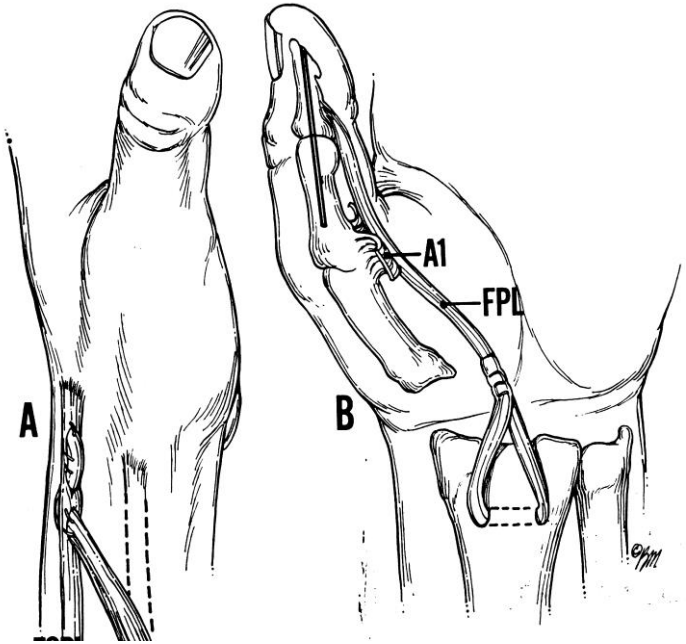
Moberg's "Key Grip Procedure"

- Simplest hand grip reconstruction
- Active wrist extension converted into thumb key pinch (tenodesis)
- Weak thumb pinch gained
- Complications include stretching out of tran



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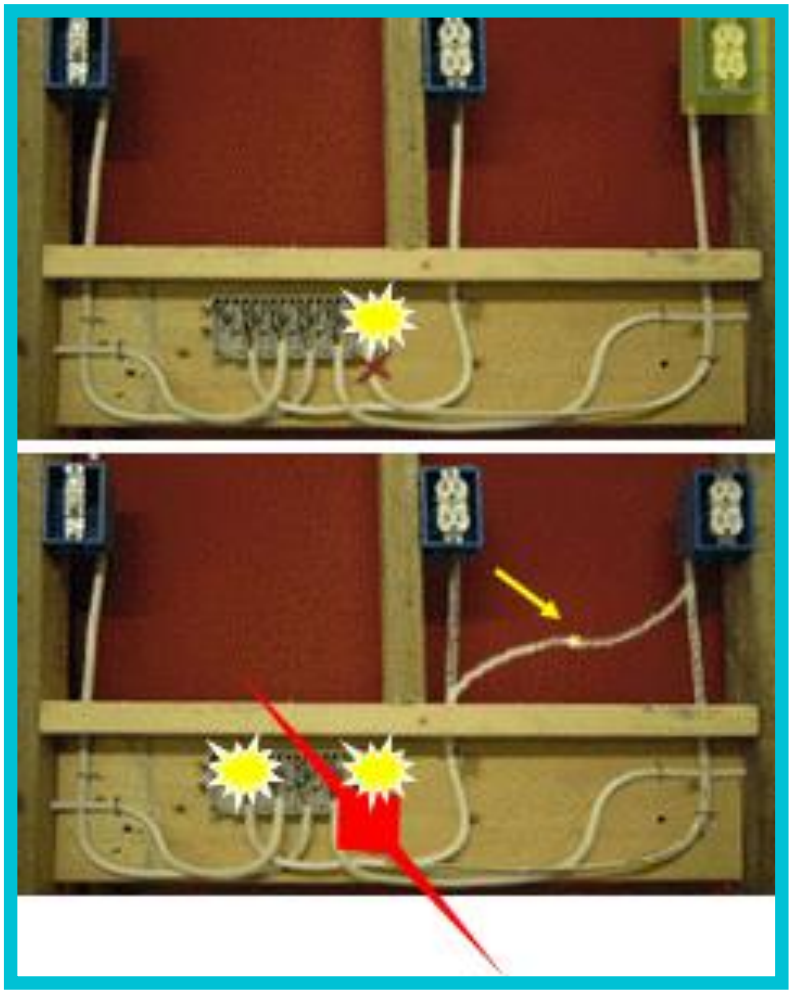
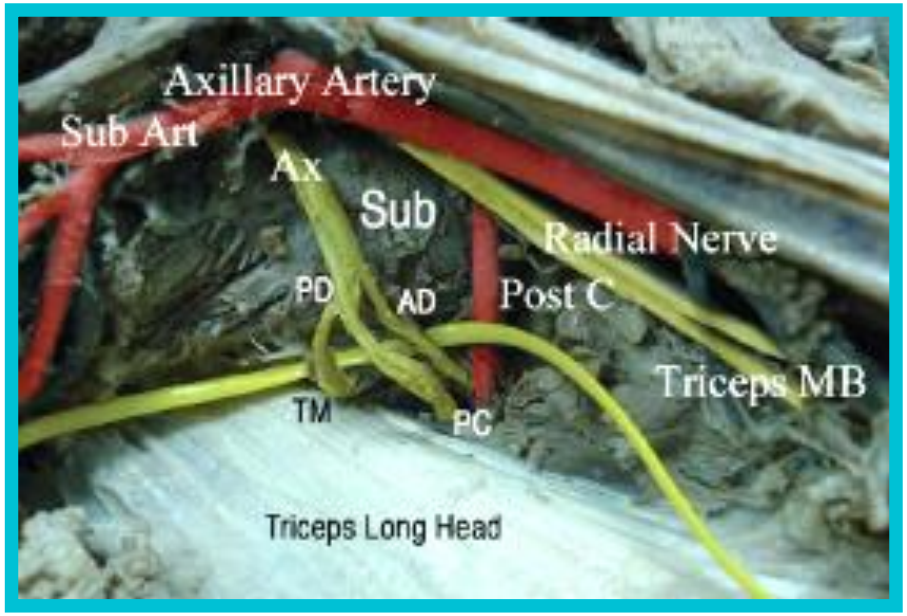
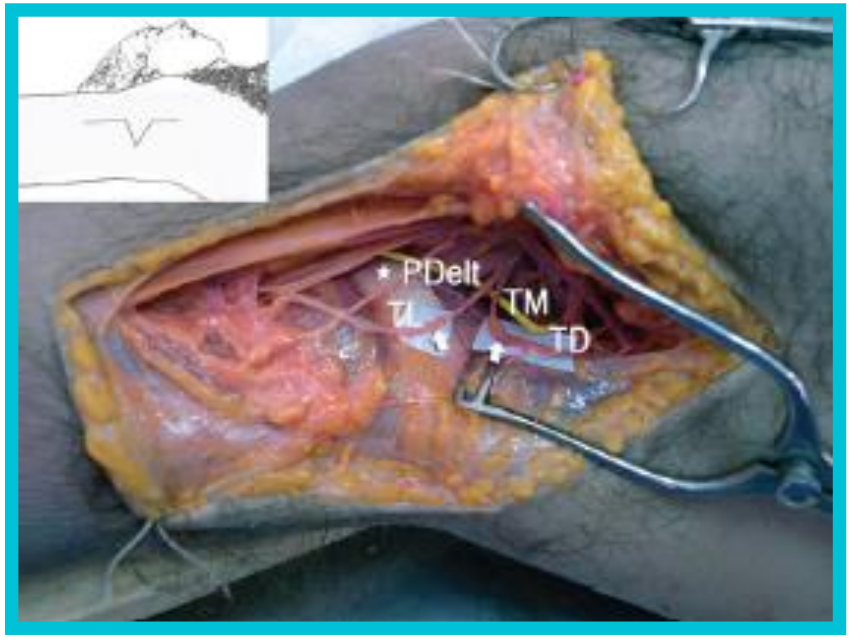
Nerve Transfers

- Trivial or redundant motor units are surgically redistributed to reconstruct a critical missing function.
- Provides a fresh axon source
- Donors with pure motor or sensory function may be utilized
- Can reduce denervation time
- Neural plasticity over time can provide normal interpretation of cues initiating movement




Axillary Artery
Sub Art
Ax
Sub
Radial Nerve
PD
AD
Post C
Triceps MB
TM
PC
Triceps Long Head


PDelt
TL
TM
TD

Summary

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Distal transfer

Results

- Tendon results immediate and increased certainty of outcome
- Nerve results can take up to nine months or greater and decreased certainty of outcome
- Tendon may have more restrictions/bracing post-op
- Nerve has minimal restrictions/bracing post-op
- Therapy approximately the same

References

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"If you have nothing, a little is a lot."

- Sterling Bunnel, MD