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September 3-6, 2023
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Functional Restoration of the Upper Extremity in Persons with Tetraplegia

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Academy of Spinal Cord Injury Professionals, Inc.™
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Disclosures

- None

Introduction

- 59% of spinal cord injuries occur at the cervical level
- Upper extremity functional recovery is an important goal for persons with tetraplegia
  - ~50% rank it the #1 priority (Anderson, 2004)
  - >75% expected important or very important improvement in QOL with increased hand function (Snoek, 2004)
- Surgical reconstruction can be an effective approach to restoring function

History

- Dr. Sterling Bunnell – 1949

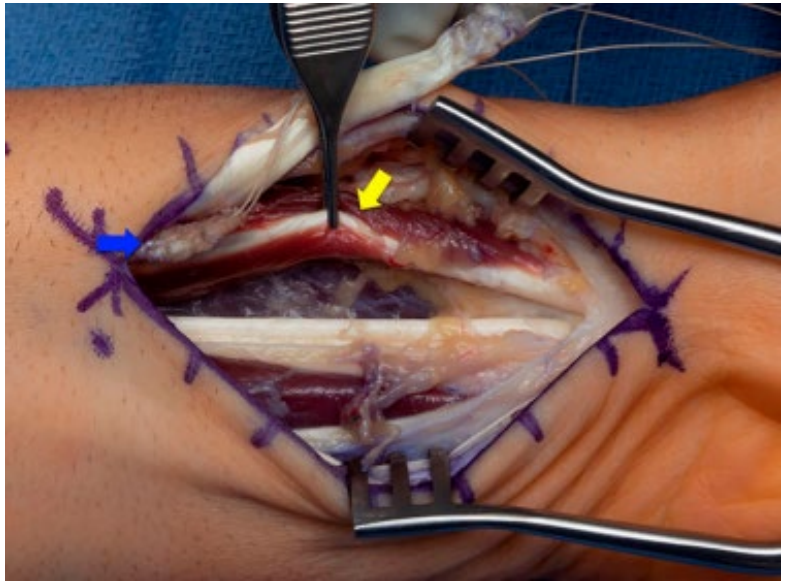
Green SA, 2016

- Drs. Walter Lamb, Marco Zancolli, and Torsten Moberg – 1960s-1970s

- Dr. Benassy - 1965

Types of Procedures

- Tendon transfer



Cantwell SR and Rhee PC, 2020

Types of Procedures

- Tendon transfer
- Tenodesis

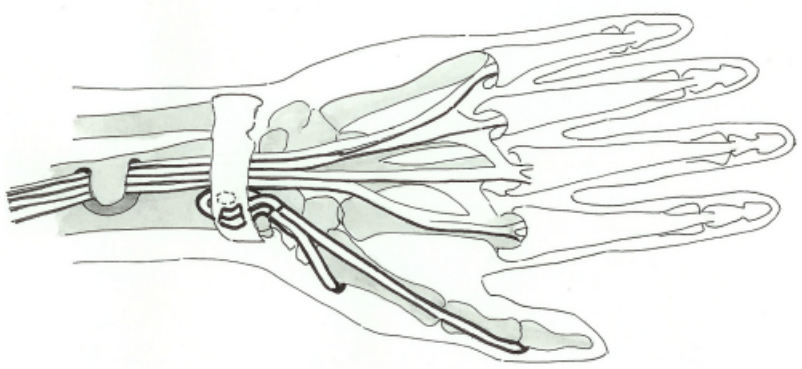
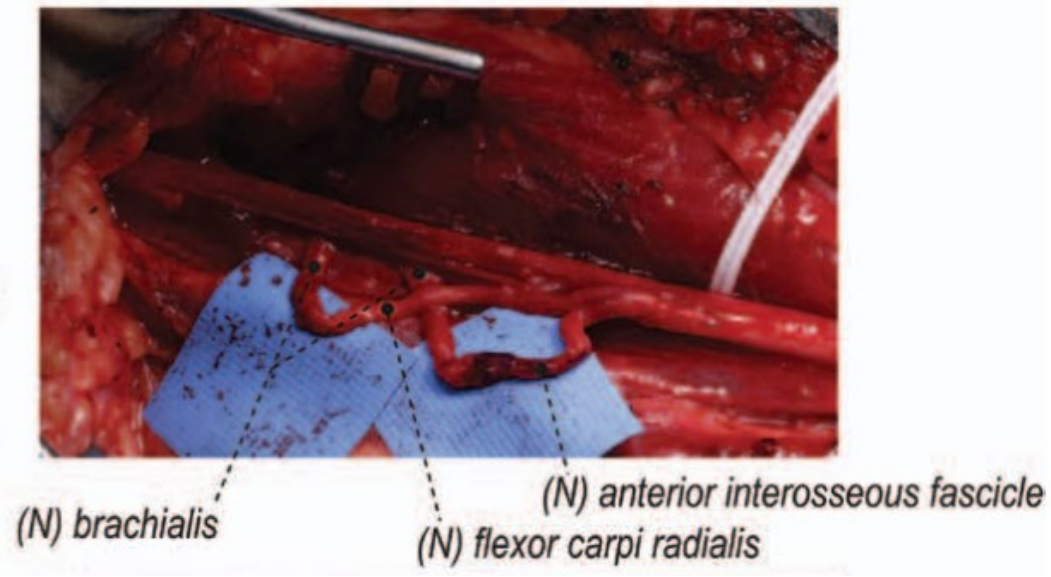


Fig. 2. Tenodesis of a long thumb extensor (EPL) and common fingers extensors (EDC).

Cizmar I, et al. 2006

Types of Procedures

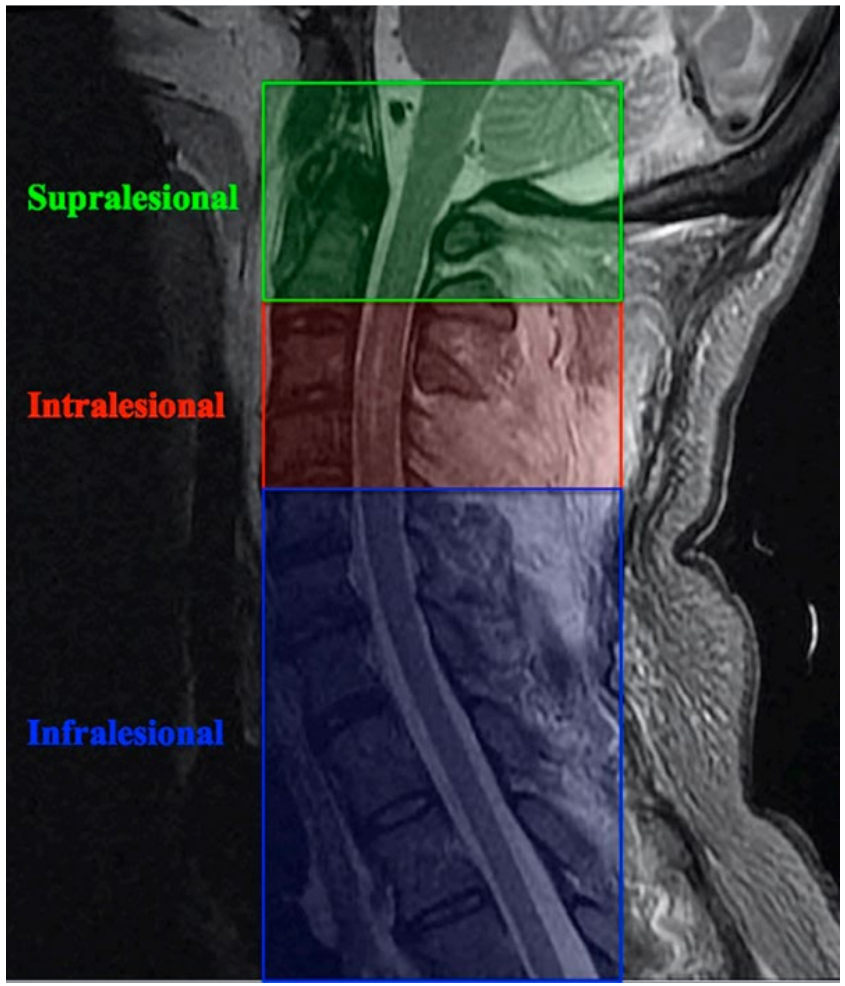
- Tendon transfer
- Tenodesis
- Arthrodesis
- Nerve transfer



Fox IC, et al. 2020

Guiding Principles of Tendon/Nerve Transfers

1. Supple joints/functional ROM
2. Sufficient inherent strength of donor muscle/sufficient motor axons
3. Donor excursion and force of contraction should be comparable to recipient
4. Synergy
5. Joint stabilization if transfer spans >1 joint
6. Straight line of pull
7. Donor should be unimportant or duplicative
8. Peripheral innervation of recipient should be intact (or acutely lost)



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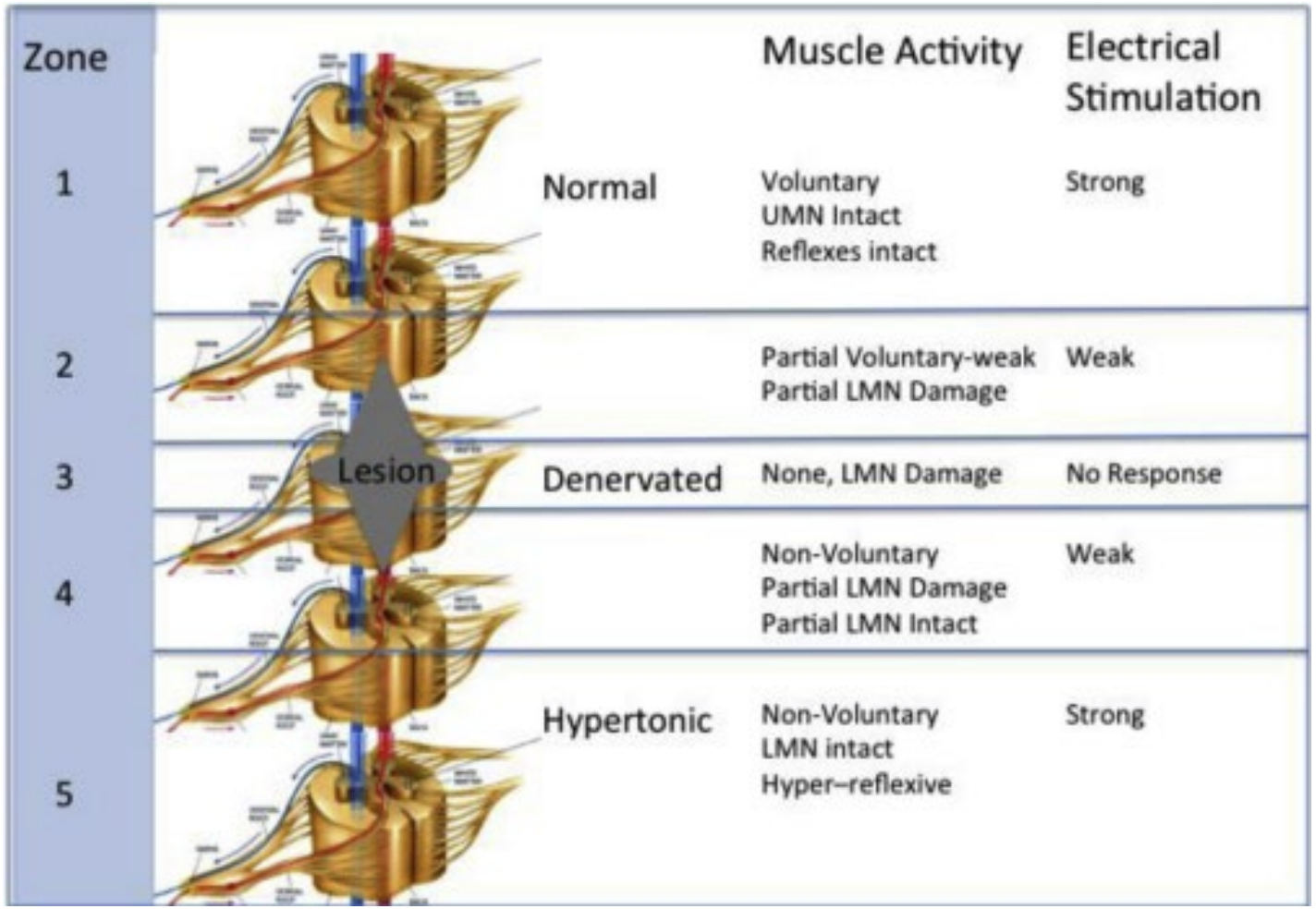

Bryden AM, et al. 2016

Examination

- Motor exam
- Sensation
  - 2-point discrimination of ≥10 mm
- ROM
- Spasticity
- Pain
- Function
- EMG/NCS
- Electrical stimulation

TABLE 1. Muscle Function According to Medical Research Council System

Muscle Strength Grade	Muscle Function
M0	No active range of motion, no palpable muscle contraction
M1	No active range of motion, palpable muscle contraction only
M2	Reduced active range of motion—not against gravity, no muscle resistance
M3	Full active range of motion, no muscle resistance
M4	Full active range of motion, reduced muscle resistance
M5	Full active range of motion, normal muscle resistance

Friden J and Gohritz A. 2015

Timing

- Considerations
  - After initial rehabilitation
  - Plateau in spontaneous recovery
  - Medical stability
  - Psychological stability
- Tendon transfer
  - Can be completed years after injury
- Nerve transfer
  - LMN damage: 6-12 months postinjury
  - Intact LMN: Less time-sensitive

Patient Selection

- Requires multidisciplinary assessment
- Ideal candidates
  - Emotional stability
  - Cognitively intact
  - Little to no spasticity/without contractures
  - No peripheral nerve/brachial plexus injury
  - Motivation and ability to participate in rehabilitation
  - Good social support
  - Realistic expectations

Preparing for Surgery

- Establish goals, expectations, and understanding of surgery
- Strengthen donors and improve passive ROM

What is typically the first priority in upper extremity reconstruction?

a) Wrist extension
b) Elbow extension
c) Lateral pinch
d) Palmar grasp

What is typically the first priority in upper extremity reconstruction?

~~a) Wrist extension~~

b) Elbow extension

~~c) Lateral pinch~~

~~d) Palmar grasp~~

Priorities in Functional Restoration

#1 Elbow extension

#2 Wrist extension

#3 Lateral pinch and release

#4 Palmar grasp and release

Surgical Algorithms

- Injury level
- Hand dominance
- Patient preference
- Functional goals
- Surgeon preference and experience

International Classification of Surgery of the Hand in Tetraplegia (ICSHT)

Sensibility O or OCu Group	Motor characteristics Lowest muscle grade ≥ 4	Description Motor function
0	No muscle below elbow	Flexion and supination of elbow
1	Brachioradialis	Flexion and rotation to neutral position of forearm
2	Extensor carpi radialis longus	Extension of wrist (weak)
3	Extensor carpi radialis brevis	Extension of wrist (strong)
4	Pronator	Pronation of forearm
5	Flexor carpi radialis	Flexion of wrist
6	Finger extensors	Extrinsic extension of digits
7	Thumb extensors	Extrinsic extension of thumb
8	Partial digital flexors	Extrinsic flexion of fingers (weak)
9	Lack only intrinsic	Extrinsic flexion of fingers
10 =X	Exceptions	

Dahlgren A, 2008

What is the lowest ICSHT group that has a wrist extensor available for transfer?

a) 1
b) 2
c) 3
d) 4
e) 5

What is the lowest ICSHT group that has a wrist extensor available for transfer?

a) ~~1~~

b) ~~2~~

c) 3

d) ~~4~~

e) ~~5~~

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Dahlgren A, 2008

TABLE 5. Surgical Algorithms According to International Classification

IC Group	Recommended Surgical Procedure
0	• Abducted shoulder (anterior deltoid muscle transfer) • Flexion contracture of the elbow (biceps tendon Z-tenotomy) • Supinated but not contracted forearm (Zancolli biceps rerouting—check the presence of supinator muscle) • Fixed supination contracture—osteotomy of radius
1	• BR-to-ECRB for active wrist extension • Moberg's key pinch procedure • ELK procedure
2	• BR-to-FPL (active key pinch) • CMC 1 fusion • ELK procedure • EPL tenodesis to dorsal forearm fascia
3	• BR-to-FPL • ECRL-to-FDP 2-4 • ELK procedure • House intrinsic procedure • CMC 1 fusion • EPL-tenodesis
4	• BR-to-FPL • ECRL-to-FDP 2-4 • ELK procedure • House intrinsic procedure • CMC 1 fusion • EPL-tenodesis
5	• BR-to-FPL • ECRL-to-FDP 2-4 • ELK procedure • House intrinsic procedure • CMC 1 fusion • EPL-tenodesis
6	• BR-to-FPL • ECRL-to-FDP 2-4 • ELK procedure • House intrinsic procedure • EDM-to-APB transfer • EDC-to-EPL
7	• BR-to-FPL • ECRL-to-FDP II-IV • ELK procedure (if required) • House intrinsic procedure • EDM-to-APB or EIP-to-APB
8	• BR-to-FPL • ECRB activated ADDP • Opponensplasty (EIP, EDM, FCU) • Active Zancolli lasso procedure (ECU) • House intrinsic procedure
9	• House intrinsic procedure
10	• Pathological postures (MP joints fixed in hyperextension, lack of any functioning intrinsic muscles, wrist fixed either in flexion or extension, etc.) • Release of contracted muscles, joint capsules, tendon lengthenings

Fridén J and Gohritz A, 2015

Restoration of Elbow Extension

- Tendon transfers
  - Posterior deltoid → triceps
    - Requires bridging tissue graft
  - Biceps → triceps
- Nerve transfers
  - Teres minor motor branch → triceps motor branch
  - Branch to posterior deltoid → triceps
  - Brachialis nerve → triceps

FIGURE 1: A woman with C6 tetraplegic who has regained the ability to shake hand after posterior deltoid to triceps reconstruction and subsequent single-stage grip reconstruction—a good example for enhanced independence and communication.

Fridén J and Gohritz A, 2015

Phases of Pinch/Grasp

- Object acquisition
- Pinch/grasp
- Hold/manipulate
- Release

Restoration of Wrist Extension/Passive Grasp

- Tendon transfers
  - BR → ECRB (Group 1)
    - +FPL to radius tenodesis (Moberg)
    - +EPL Loop Knot (ELK) procedure
- Nerve transfers
  - Brachialis motor nerve → ECRL (Groups 0-1)
    - +Moberg

Restoration of Active Grasp

- Tendon transfers
  - BR → FPL (Groups 2-8) – Lateral pinch
  - PT → FPL (Group ≥5) – Lateral pinch
  - ECRL → FDP (Groups ≥3) – Palmar grasp
- Nerve transfers
  - Brachialis motor nerve → AIN

Restoration of Finger Extension

- Tenodesis
  - EPL tenodesis to forearm fascia (Groups 2-4)
  - EDC to dorsal retinaculum (Groups 2-4)
  - EPL to EIP or EDC (Group 6)
- Tendon transfers
  - PT → EPL, EDC, APL (Group 5)
  - BR → EDC and/or FPL (Group 5)
  - EDM → APB (Group 6)
- Nerve transfers
  - Supinator motor nerve → PIN

Restoration of Intrinsics

- Intrinsic minus positioning
- Zancolli lasso procedure
  - FDS divided distal to A1 pulley and sutured to itself
  - Flexion moment across MCPs
- House reconstruction
  - Involves tendon graft through lumbrical canals, around metacarpal neck, and secured to radial lateral bands
  - Reciprocal PIP and MCP extension/flexion

Post-Operatively

Tendon Transfer

- Traditionally, immobilization in splint/cast x1-4 weeks
  - Some surgeons now recommending early active mobilization
- Therapy after cast removal
  - Protective splinting, scar mobilization, active ROM
  - Light activities allowed at 8 weeks
  - Can resume most activities at 12 weeks
  - Strengthening

Nerve Transfer

- Partial weight bearing and ADLs 1-2 weeks
- Full activity at 2-4 weeks
- Hand therapy at 1 month post op
  - Donor muscle activation
  - Neuromuscular re-education
  - Strengthening

Potential Complications

- Tendon rupture
- Stretching of tendon transfers and tenodeses over time
- Nerve transfer failure

Outcomes

- ↑ Functional independence
- ↓ Need for orthoses
- ↑ QOL
- ↑ Self-image and confidence

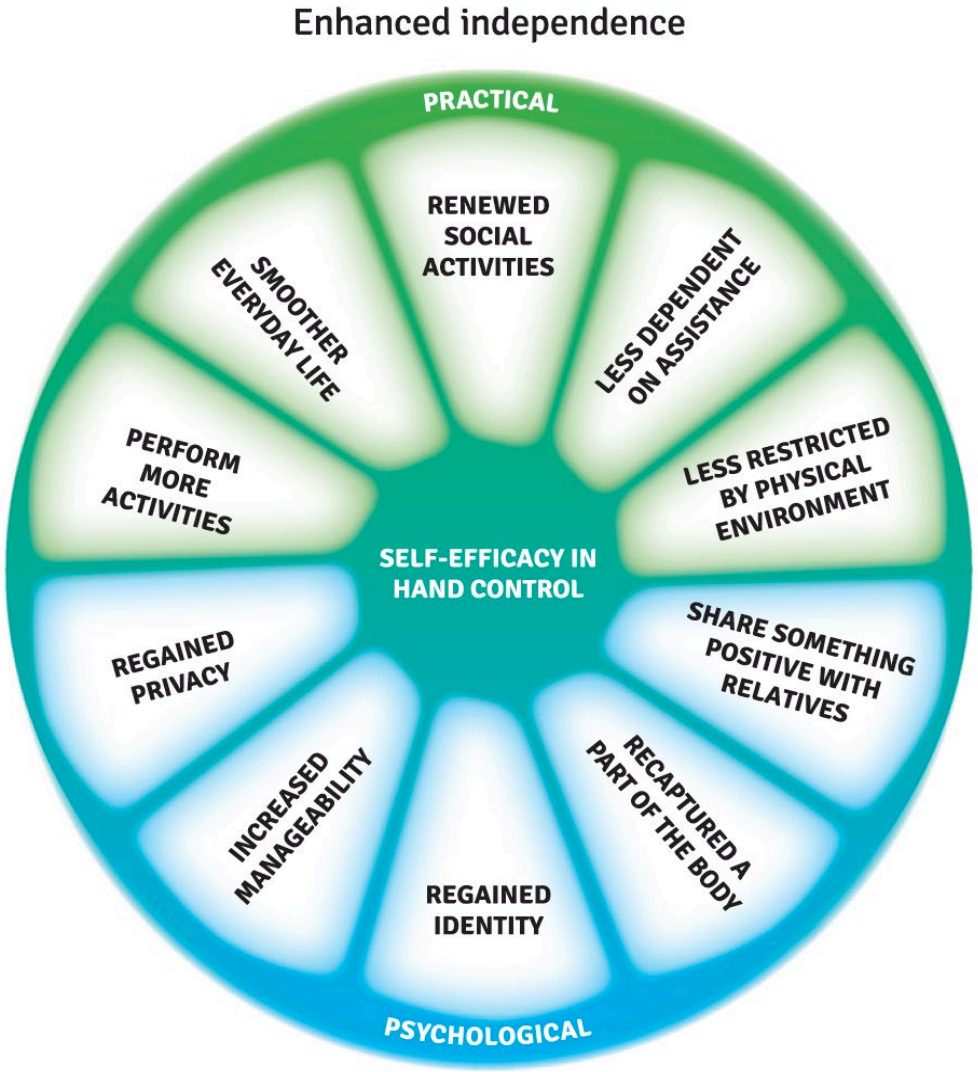

Figure 1. Aspects of the enhanced independence experienced after grip reconstruction.

Wangdell J, et al. 2013

THANK YOU!

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