Nerve Transfer Surgery to Improve Hand Function in Spinal Cord Injury: Multidisciplinary Evaluation and Management

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Disclosures

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- Consultant on current Missouri Spinal Cord Injury Research Project (MO SCIRP) grant.
Outline

- Case Presentation
- Background
- Patient Evaluation and Management
- Surgery and Intraoperative Technique
- Post-surgical Rehabilitation
- Results
- Future Directions
- Summary
Early Impressions...

10 months after surgery (brachialis to FCR and AIN)
3 years out from nerve transfers...

Patient notes that better use of hand has led to improve upper body strength overall—a ‘vicious’ cycle
Learning Objectives

- Describe the proper evaluation of patients with cervical level spinal cord injury (SCI) for possible nerve transfer surgery to improve upper extremity function.
- Explain the physiology and surgical principles of the brachialis to anterior interosseous nerve transfer to restore volitional prehension in patients with a C6 or C7 motor level SCI.
- Begin to discuss the barriers to surgical care for patients with cervical SCI.
Case Example—what is a nerve transfer for SCI?
21-year-old right handed male student
7/3/11 fracture dislocation C6 on C7 (MVA)
S/P trach, spinal fusion, IVC filter, suprapubic catheter, clavicle fracture treated non-operatively
Now:
- Neurologic status has stabilized; moderate spasticity
- RUE more functional than LUE
- Would like to feed self/write without assist devices
- Would like to do transfers independently and self-catheterize
- Plans to return to college; PT school
Functional Exam
# TABLE I

International Classification of the Hand in Tetraplegia

<table>
<thead>
<tr>
<th>Group</th>
<th>Motor Characteristics</th>
<th>Description of Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No muscle below elbow suitable for transfer</td>
<td>Flexion and supination of the elbow</td>
</tr>
<tr>
<td>1</td>
<td>Brachioradialis</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Extensor carpi radialis longus</td>
<td>Extension of the wrist (weak or strong)</td>
</tr>
<tr>
<td>3</td>
<td>Extensor carpi radialis brevis</td>
<td>Extension of the wrist</td>
</tr>
<tr>
<td>4</td>
<td>Pronator teres</td>
<td>Extension and pronation of the wrist</td>
</tr>
<tr>
<td>5</td>
<td>Flexor carpi radialis</td>
<td>Flexion of the wrist</td>
</tr>
<tr>
<td>6</td>
<td>Finger extensors</td>
<td>Extrinsic extension of the fingers (partial or complete)</td>
</tr>
<tr>
<td>7</td>
<td>Thumb extensor</td>
<td>Extrinsic extension of the thumb</td>
</tr>
<tr>
<td>8</td>
<td>Partial digital flexors</td>
<td>Extrinsic flexion of the fingers (weak)</td>
</tr>
<tr>
<td>9</td>
<td>Lacks only intrinsics</td>
<td>Extrinsic flexion of the fingers</td>
</tr>
</tbody>
</table>
The dilemma—improve function with minimal downtime.
Simplistically—can we do this?:
Background
Scope of Problem:

- Spinal Cord Injury—¼ million people living with SCI IN U.S. and ½ are at cervical level
- Profound effect on upper extremity/hand function
- Options to improve function exist—but adaptation/use of these treatments is limited
Why is this population underserved?

Some factors:

- Lack of relationship between treating team and hand surgeons
- Surgeons lack familiarity/experience/training
- Patient gap in information?
- Traditional surgery (tendon transfers/tenodesis) requires significant limitation on activity (splints/non-weightbearing/etc.)
- Logistics (OR facility, post-op care, etc.)


As a hand surgeon I am more used to...
But what can be done to improve function?

- “To Those Who Have Nothing a Little is a Lot”. Sterling Bunnell, MD.

- Or as one of my patients said: “For the first time, when I dropped a noodle on my chest, I was able to pick it off.”

Summary: subtle changes; priority to not downgrade function, improve function and quality of life…
Traditional Surgery in cervical SCI

Tendon transfers to improve hand function:

- Example: brachioradialis to thumb flexor tendon transfer
- Require post-op immobilization (4-6 weeks cast), non-weight bearing
- Requires motor re-training
- Biomechanical issues
- Improves crude pinch (thumb against hand)—doesn’t give prehension
New area—nerve transfers

What are Nerve transfers?

• Robbing Peter to pay Paul…
• Take something that is working and re-wire into something that is not
• In SCI that means restoring volitional control to muscles by stealing from redundant muscles that they can still control—example:
  – Take an extra elbow flexor
  – Give back finger function
Nerve transfers in general

*Nerve* transfers:

• Used to treat peripheral nerve injury (example brachial plexus)

• Key differences:
  
  – In peripheral nerve, TIME=MUSCLE (if the nerve is cut, you must reinnervate within 1 year before muscle becomes unresponsive)
  
  – In SCI, muscle below injury is ‘kept alive’, need to restore control over that nerve/muscle unit (nerve transfer allows that—surgeon creates the peripheral nerve injury by cutting and re-splicing nerve—so need to find a working nerve to steal that is near to the muscle you need it to grow back to)
  
  – Some SCI patients DO have ‘peripheral or direct LMN’ injuries too
Nerve transfers in SCI

- Surgery is done on nerve in the arm (not spinal cord)
- RE-routing of nerves under volitional control
Nerve transfers in SCI

- Examples: brachialis to AIN/FCR, supinator to ECU, deltoid to triceps, others...
- No immobilization; minimal post-op activity limitations
- Requires time to regenerate down new path and do motor re-training
- No biomechanical issues and maybe more options…better function?
How we came to do the brachialis to AIN nerve transfer in patients with cervical spinal cord injury:

• Question 1: Is brachialis (elbow flexor expendable)?
• Question 2: How can we get hand function back?
1985

Sensory nerve transfers in paraplegic...


Medial antebraoral cutaneous-lateral femoral cutaneous neurotization to provide sensation to pressure-bearing areas in the paraplegic patient.

Mackinnon SE, Dellon AL, Patterson GA, Gruss JS.

Abstract
Although rotation of musculocutaneous flaps can achieve closure of pressure sores, these insensitive flaps in the paraplegic or quadriplegic contribute to recurrent ulceration. This report suggests a method of reinnervating the territory of the lateral femoral cutaneous nerve (the tensor fascia lata musculocutaneous flap) using the medial antebraoral cutaneous nerve of the forearm. This neurotization procedure has restored sensibility to the area of the healed pressure sore.

PMID: 4083708 [PubMed - indexed for MEDLINE]
Jumping the Gap in Spinal Cord Injury

2005

Mackinnon, SE

Double fascicular nerve transfer...


Results of reinnervation of the biceps and brachialis muscles with a double fascicular transfer for elbow flexion.

Mackinnon SE, Novak CM, Mykahn TM, Tuna TH
Division of Plastic and Reconstructive Surgery, Washington University School of Medicine, St. Louis, MO 63110, USA.

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Abstract

PURPOSE: To report the results of a surgical technique of nerve transfer to reinnervate the brachialis muscle and the biceps muscle to restore elbow flexion after brachial plexus injury.

METHODS: Retrospective review was performed on 6 patients who had direct nerve transfer of a single expendable motor fascicle from both the ulnar and median nerves directly to the biceps and brachialis branches of the musculocutaneous nerve. Assessment included degree of recovery of elbow flexion and ulnar and median nerve function including pinch and grip strengths.

RESULTS: Clinical evidence of reinnervation was noted at a mean of 6.5 months (SD, 1 mo; range, 3.5-7 mo) after surgery and the mean follow-up period was 20.5 months (SD, 11.2 mo; range, 13-43 mo). Mean recovery of elbow flexion was 110.2°. Postoperative pinch and grip strengths were unchanged or better in all patients. No motor or sensory deficits related to the ulnar or median nerves were noted and all patients maintained good hand function. No patients required additional procedures to further improve elbow flexion strength.

CONCLUSIONS: Transfer of expendable motor fascicles from the ulnar and median nerves successfully can reinnervate the biceps and brachialis muscles for strong elbow flexion. The reinnervation of the brachialis muscle, the primary elbow flexor, as well as the biceps muscle provides an additional biomechanical advantage that accounts for the excellent elbow flexion strength obtained using this technique. Direct coaptation of the nerve fascicles was performed without the need for nerve grafts and there was no functional or sensory donor morbidity.
Remember there are 3 muscles that flex the elbow:
  - Biceps
  - Brachialis
  - Brachioradialis
For patients with brachial plexus and peripheral nerve injury.

2007

Brachialis to anterior interosseous nerve transfer...
Can this work to help restore hand function in patients with cervical spinal cord injury and upper extremity dysfunction?
2010

Case of brachialis to AIN nerve transfer in a spinal cord injury...
In SCI, unlike peripheral nerve injury, the cell body to muscle connection is often intact...
So we can do a nerve transfer (in the arm) to restore new volitional function:
A metaphor for the Brachialis to AIN Nerve Transfer in a tetraplegic person

Divert power from one outlet on 3rd floor to one on second floor.

Elbow function

thumb and index finger function

POWER ON

POWER OUT
In summary: Excellent possibilities for restoring function without significant down time

Caveats include:
• Limited knowledge of what will/won’t work
• Careful to not do too much at once
• Do not downgrade function (elbow flexion, pronation, tenodesis)
• Save a back-up plan
• It takes a long time to see the outcome; patience is key!

Build on what we know from traditional surgeries: Bunnel, Moberg, Lamb, Hentz, House, Zancolli
Other work on nerve transfer in SCI: Friden, Bertelli, etc.
So what did we do?:

Our approach Washington University in Saint Louis
Division of Plastic Surgery

Plan to offer nerve transfers to improve function in cervical SCI:

• Bring nerve transfers from our peripheral nerve injury patient population to patients with cervical SCI
• Key differences
• Safety first (*primum non nocere*)—must NOT downgrade function
• Multidisciplinary approach—comprehensive assessment with multiple practitioners input and multiple modalities of testing
The challenge—improve function with minimal downtime.
So how did we get to that plan?
Some of the TEAM:

- Physical Medicine and Rehabilitation—with subspecialty in SCI Medicine: Neringa Juknis, Rimma Ruvinskaya
- Plastic Surgery—Peripheral Nerve, Hand and Upper Extremity Surgical Team: Ida Fox, Kristen Davidge, Susan Mackinnon
- Hand Therapy: Lorna Kahn, Christine Novak
- PT/OT: Rebecca Hamm, Meredith Whitehead, Cassy Kubala
- Neurology/Electrodiagnostician: Craig Zaidman
- Anesthesiology
- Pre-operative/Introperative Nursing
- Post-operative in-house care team (step-down unit)
- Family/Caregivers
- Patient
Evaluation: Inclusion Criteria

- Cervical level spinal cord injury- with loss of (primarily) wrist and/or hand function
- Timing since spinal cord injury- minimum of 6-12 months, maximum 11 years?
- Condition of the upper extremities-
  - Baseline motor function (must have adequate expendable donor)
  - Joint stability
  - Range of motion- AROM and PROM
  - Spasticity
  - Contracture
- Assess current physical therapy/rehabilitation program
  - Access to physical therapy
  - Patient participation and compliance
- Other considerations
  - Social support
  - Financial support for perioperative care
  - Psychological well-being
Evaluation: Exclusion Criteria

- Age- < 18 years or > 50 years old? (others will be considered on case by case basis)
- Presence of co-morbidities-
  - Autonomic/hemodynamic instability
  - Pulmonary instability
  - Psychosocial status
  - Integumentary status- pressure sores
  - Urinary tract health- recurrent UTI
- Lack of suitable donor nerve
- Contractures
- Spasticity? (these transfers may help alleviate spasticity)
Nerve Transfers in Tetraplegia

Physical Therapy

EVALUATION
SUBJECTIVE HISTORY
- history of injury
- social situation/support
- pain
- goals
- work history/plans

PROM bilateral UE

MMT bilateral UE

SENSATION: SWM bilateral UE

QUALITATIVE GRASSP TEST
(prehension skill level)

QUANTITATIVE GRASSP TEST
Assess for joint contractures and limitations which may hinder progress following the nerve transfer

Address joint restriction preoperatively with ROM and splinting
MUSCLE TESTING

Complete manual muscle testing of bilateral upper extremities
- assess potential “donor” muscles
- confirm level of hand and arm strength deficits

COMPARISON OF ALL THREE ELBOW FLEXOR MUSCLES

**Biceps** tested in forearm supination
Palpate tendon

**Brachioradialis** tested in forearm neutral
Palpate muscle

**Brachialis** tested in forearm pronation
Palpate muscle by pinching beneath the biceps
SENSORY TESTING

Semmes Weinstein Monofilaments: test for the presence of touch sensibility
GRASSP TEST

- STRENGTH: assess 10 key muscles of the upper extremity
- SENSATION: assess 6 points on the volar and dorsal aspect of each hand
- PREHENSION
  - QUALITATIVE PREHENSION: TO ESTABLISH WHICH COMPONENTS OF THE FINGER-HAND-FOREARM CAN BE ACTIVELY OR PASSIVELY POSITIONED TO ALLOW A GRASP FUNCTION AND IF THIS MOVEMENT IS WRIST DOMINANT
    1. cylindrical grip      2. tip to tip pinch      3. lateral key pinch
  - QUANTITATIVE PREHENSION: A TIMED TEST WITH PATIENT SEATED IN FRONT OF A TABLE. SIX TASKS ARE PERFORMED WITH EXAMINER OBSERVING TYPE OF GRASP PATTERN USED. SCORING IS BASED ON A 5 POINT SCALE AND PT MUST COMPLETE ONE COMPONENT OF A TASK TO ACHIEVE A ONE.
GRASSP TEST
QUANTITATIVE PREHENSION TESTING

SCORING: (max 1min and 15 seconds are allowed)
0 = the task cannot be completed at all
1 = the task cannot be completed (<50% of task)
2 = the task is not completed (50% or more of task)
3 = the task is conducted/completed using tenodesis or an alternative grasp other than the expected grasp
4 = the task is conducted using the expected grasp with difficulty (lack of smooth movement or difficult slow movement)
5 = the task is conducted w/o difficulties using the expected grasping pattern and unaffected hand function.

KEY PINCH

CYLINDRICAL GRIP

SPHERICAL GRASP

PENNIES/TIP TO TIP PINCH

PEGBOARD/TRIPOD PINCH
Evaluation: further work-up

- Check electrodiagnostics—Often see mixed injury
  - Want normal EMG of donors
  - Check for direct lower motor neuron cell body injury to recipients
  - Coexisting peripheral nerve injury—assessment of conduction of median and ulnar nerves, etc.

(nerve transfer ineffective if >1 year post-SCI if there is LMN injury—can we rescue muscles with combined injury with early intervention—area of future investigation?)

- Consider imaging
  - U/S to assess muscle quality—fatty replacement/fibrosis
## Example EMG study—not a good candidate for nerve transfer

<table>
<thead>
<tr>
<th>EMG Study</th>
<th>Fibrillations</th>
<th>MUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ins Act</td>
<td>PSW</td>
</tr>
<tr>
<td>Name</td>
<td>norm</td>
<td>1+</td>
</tr>
<tr>
<td>L. Brachioradialis</td>
<td>2+</td>
<td>norm to sev dec rec</td>
</tr>
<tr>
<td>L. Biceps Brachi.</td>
<td>norm</td>
<td>none</td>
</tr>
<tr>
<td>L. Brachialis</td>
<td>inc</td>
<td>2+</td>
</tr>
<tr>
<td>L. Triceps</td>
<td>inc</td>
<td>none</td>
</tr>
<tr>
<td>L. Supraspinatus</td>
<td>inc</td>
<td>none</td>
</tr>
<tr>
<td>L. Infraspinatus</td>
<td>inc</td>
<td>none</td>
</tr>
<tr>
<td>R. Brachioradialis</td>
<td>inc</td>
<td>2+</td>
</tr>
<tr>
<td>R. Brachialis</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>R. Biceps Brachi.</td>
<td>inc</td>
<td>2+</td>
</tr>
<tr>
<td>R. Triceps</td>
<td>norm</td>
<td>none</td>
</tr>
<tr>
<td>R. Supraspinatus</td>
<td>norm</td>
<td>2+</td>
</tr>
<tr>
<td>R. Infraspinatus</td>
<td>norm</td>
<td>mild to mod red rec</td>
</tr>
</tbody>
</table>

**Notes:**
- mod to sev dec rec
- sev red rec
- no mups
- sev dec rec
- moderate to severe decreased recruitment
- moderate to severe reduced recruitment
- single mup, sev red
- patchy mild to severe
Management

Evaluation: take home points

• Want biologic, psycho, and social stability
  – As edema resolves, reconditioning occurs can see improved function
  – Mentally ready?, realistic expectations?, post-operative help?

• Examine Left and Right carefully
  – Often see differences
  – Don’t be tricked by use of gravity/spasm or other compensatory moves
  – Watch how they use their hands/ask what they want
  – Assess putative donors/recipients
    • Elbow flexion via Biceps vs Brachialis vs Brachioradialis
    • Assess wrist extension (radial extensors only?), FCR, PT
    • PROM ok?
## Surgeries Done

<table>
<thead>
<tr>
<th>Patient #/Side</th>
<th>Age (years)</th>
<th>Time Since SCI (years)</th>
<th>Nerve Transfer(s) Done</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Left</td>
<td>22</td>
<td>1</td>
<td>Brachialis to AIN</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brachialis to FCR/FDS</td>
<td></td>
</tr>
<tr>
<td>1-Right</td>
<td>22</td>
<td>1</td>
<td>Brachialis to AIN</td>
<td>Minor -Hypesthesia thumb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brachialis to FDS</td>
<td></td>
</tr>
<tr>
<td>2-Right</td>
<td>31</td>
<td>10</td>
<td>Brachialis to AIN</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brachialis to FCR</td>
<td></td>
</tr>
<tr>
<td>3-Left</td>
<td>15</td>
<td>3</td>
<td>Exploration-no transfer done</td>
<td>Insufficient donors available</td>
</tr>
<tr>
<td>4-Left</td>
<td>47</td>
<td>&lt;1 (7 months)</td>
<td>Brachialis to AIN/FCR</td>
<td>Major Systemic - Urosepsis (1 week post-operatively)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deltoid to Triceps</td>
<td></td>
</tr>
<tr>
<td>5-Right</td>
<td>22</td>
<td>1.5</td>
<td>Brachialis to AIN</td>
<td>Minor - Seroma (drained in office)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Supinator to ECU</td>
<td></td>
</tr>
<tr>
<td>6-Right</td>
<td>28</td>
<td>12</td>
<td>Brachialis to AIN</td>
<td>Major Systemic - Prolonged stay due to concern for urinary tract infection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brachialis to FCR</td>
<td>Minor - Paresthesia thumb</td>
</tr>
<tr>
<td>7-Right</td>
<td>34</td>
<td>12</td>
<td>Brachialis to AIN/FDS</td>
<td>None</td>
</tr>
</tbody>
</table>
Surgical Plan

- **Left Side**
  - Brachialis (1\textsuperscript{st} branch) to AIN
  - Brachialis (2\textsuperscript{nd} branch) to FCR/FDS (median nerve motor component fascicle)
  - Exclusion of PT (volitional control) thenar fascicles (too far), sensory fascicles (wasteful)

- **Right Side**
  - Brachialis (1\textsuperscript{st} branch) to AIN
  - Brachialis (2\textsuperscript{nd} branch) to FCR/FDS (median nerve motor component fascicle)
  - Transfer to FCR/FDS was done end to side to avoid downgrading volitional existing FCR function
  - Exclusion of PT (volitional control) thenar fascicles (too far), sensory fascicles (wasteful)
Surgical Technique
Brachialis nerve branches to AIN and FCR nerve

(N) medial antebrachial cutaneous
(N) brachialis
(N) pronator teres
(N) median
(N) thenar
(N) anterior interosseous
(N) FCR/PL/FDS
(N) sensory component
Surgical Technique

Brachialis Stimulation
Recipient Nerve Stimulation
Surgical Technique

Nerve Transfers Done
### Traditional Tendon Transfers:

<table>
<thead>
<tr>
<th>SCI level</th>
<th>Missing function</th>
<th>Reconstructive options</th>
</tr>
</thead>
</table>
| High (C5) | Elbow extension  | 1. Deltoid to triceps tendon transfer  
|           |                  | 2. Biceps to triceps tendon transfer |
|           | Wrist extension  | BR to ECRB or ECRL tendon transfer |
|           | Pinch            | 1. FPL tenodesis to distal radius  
|           |                  | 2. Thumb IPJ fusion |
| Mid (C6-7)| Pinch            | Thumb:  
|           |                  | 1. BR to FPL tendon transfer  
|           |                  | 2. PT to FPL tendon transfer  
|           |                  | 3. FPL tenodesis  
|           |                  | 4. Thumb fusion |
|           | Thumb:           | Index finger:  
|           |                  | ECRL to FDP Index tendon transfer |
|           | Grasp            | ECRL to FDPs of all digits tendon transfer |
|           | Wrist flexion    | 1. Gravity  
|           |                  | 2. PT to FCR tendon transfer |
|           | Finger extension | 1. EDC tenodesis to radius  
|           |                  | 2. BR to EDC tendon transfer |
|           | Thumb extension  | 1. EPL tenodesis to radius  
|           |                  | 2. Side-to-side transfer of EPL to EDC |
|           | Intrinsics       | Zancolli anti-claw lasso |
| Low (C8)  | Intrinsics       | 1. Opponensplasty  
|           |                  | 2. Zancolli anti-claw lasso |
## Summary of Surgical Options

### Novel use of Nerve Transfers

<table>
<thead>
<tr>
<th>SCI level</th>
<th>Missing function</th>
<th>New Reconstructive options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong> (C5)</td>
<td>Elbow extension</td>
<td>Deltoid to triceps nerve transfer?</td>
</tr>
<tr>
<td></td>
<td>Wrist extension</td>
<td>Brachialis to ECRB nerve transfer</td>
</tr>
<tr>
<td><strong>Mid</strong> (C6-7)</td>
<td>Pinch</td>
<td>Brachialis to AIN nerve transfer</td>
</tr>
<tr>
<td></td>
<td>Wrist flexion</td>
<td>Brachialis (2&lt;sup&gt;nd&lt;/sup&gt; branch) to FCR nerve transfer?</td>
</tr>
<tr>
<td></td>
<td>Other options</td>
<td>Use of BR, Supinator, ECRB as donors?</td>
</tr>
</tbody>
</table>
Further Surgical Refinement

• Double check exam intra-operatively as well
  – Confirm donor—are biceps and brachialis both OK?
  – Confirm recipient—do recipient muscles, when stimulated, produce some motion?

• First do no harm
  – Abort surgery if there is any possibility that function will be downgraded
  – Case example:
    • C5 motor level
    • Patient with very weak deltid 2/5, somewhat weak elbow flexion 4-/5
    • Goal: restore wrist extension (and hand use via tenodesis) by brachialis to ECRL transfer*

Stimulation of Functional Donor Nerve

Stimulation of *Functional* Brachialis Nerve (*Donor*)
Retrospective Case Review of Aborted Nerve Transfer

Stimulation of Musculocutaneous Nerve (Donor) – Video #1
Peri-Op: take home points

• Surgery
  – Short acting paralytic
  – No tourniquet
  – Internal Topography
  – *Intra-operative Stimulation (everything motor stimulates)***
  – Figure out donors/ recipients—make sure OK to use—before you cut

• Post-operative
  – Specialty bed
  – Non-circumferential dressings
  – Watch for autonomic dysreflexia (hypertension response to stimuli)

• Therapy…

***This is the KEY difference versus traditional *peripheral* nerve injury nerve transfer surgery***
Nerve Transfers in Tetraplegia

Rehabilitation
Timeline for Rehabilitation

- **Pre-op:**
  - Evaluation and consult with team

- **2-4 weeks post-op:**
  - Evaluation and patient education/initiation of motor re-education program

- **Monthly visits:**
  - Check for compliance, monitor progress/signs of early return and address any issues relating to PROM that may interfere with progress
  - Encourage task oriented repetitive movement exercises

- **Once trace movement is noted:**
  - Frequency of visits is increased until adequate control of motion is achieved; 3+/5
  - No resistance training until at least a grade 3-/5 is achieved

- **Once plateau is reached:**
  - Decrease frequency of visits with a strong home program

- **Follow 18-24 months**
First Therapy Visit
2-4 weeks post-op

1. **patient education**
   - anatomy of the transfer
   - general guidelines for motor re-education
   - timelines and expectations
grade 0 = no volitional muscle contraction

grade 1 = trace muscle contraction

grade 2 = full movement with gravity lessened positioning

grade 3 = full movement against gravity

grade 4 = able to move against gravity and take some resistance

grade 5 = able to take full resistance without movement
Rehabilitation Instructions for Nerve Transfers

Date of Surgery:

General Advice:
1. Practice donor exercise often
2. Practice combined motions frequently for short periods/low reps
3. Respect fatigue; stop and try again later
4. more is more when it comes to donor ms contractions!
5. Be patient! This will take a long time!

Transfer #1:
___________________________nerve
(_______________________________________ muscle) to
___________________________ nerve
(_________________________________________________________muscles)

"Donor"= ____________________________ms
(____________________________________________________)

"Recipient " Muscle = ____________________________ms
(___________________________________________________________________
______________________________)

Exercise #1

Exercise #2:

1. patient education

sample instruction sheet

help the patient understand
the “donor” and the
“recipient “ muscles
Sample Instruction Sheet for Musculocutaneous to AIN nerve transfer

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Transfer:

Musculocutaneous nerve (Brachialis muscle) TO Anterior Interosseous nerve /AIN (FPL and FDP muscles)

“DONOR”= Brachialis muscle (bends the elbow)

“RECIPIENT”= Flexor Pollicus Longus muscle (bends the thumb)
and Flexor Digitorum Profundus muscle (bends the index and occasionally the long finger(s))
First Post-op Therapy Visit

2. Initiate “donor” muscle group activation exercises:
   repetitive elbow flexion/ hourly
First Post-Op Therapy Visit

3. Address scar/edema management and ROM as needed
First Post-Op Therapy Visit

4. Address any issues with joint restrictions/PROM
   Instruct in splinting prn and home program
Subsequent Therapy Visits

splinting to aid in donor activation exercise

musculocutaneous (brachialis) to AIN (FPL and FDP-index/long)

recipient muscles held in more optimal position for weak contraction

LENGTH TENSION CURVE
one month post op

- initiating light resistance w/ high frequency elbow flexion
Subsequent Therapy Visits

- advance home program as able
- when family member is available, instruction is given in passive recipient muscle exercises and place and hold
- light functional pinch activities are encouraged
Subsequent Therapy Visits

- monitor progress/ test for early return:
  resisted “donor” motion with isolated recipient muscle
  (resisted elbow flexion with isolated thumb and finger flexion)
Use of BTE (a computerized tool simulator) for repetitive functional training

- provides objective measures to track progress
- computer program motivates patient with visual and numerical feedback

functional tasks that require both donor and recipient muscle participation
This patient also received a nerve transfer for wrist flexion function
musculocutaneous/brachialis ms to median/FCR ms

5 months post op
training wrist flexion (recipient muscle) with elbow flexion (donor muscle) in gravity lessened positioning
5 months post op assessing pinch function

preoperatively pt was able to move 2 pegs in the allowed time of 1 minute 15 sec with 11 drops
initiate light resistance to finger and thumb flexor muscles when active strength approaches 3/5
7 months post op
wrist function
comparison of 1, 5 and 7 months post-op wrist and hand function

one month post

five months post

seven months post
additional potential nerve transfers for the tetraplegic patient

radial/supinator to PIN/finger extensors
14 months post-op

resisted “donor” supinator continues to make a more significant contraction of the recipient finger extensors in a patient who has not had as much motor re-education
Challenges

• Co-morbidities do exist in these patients

• Vulnerability
  – Health-wise
  – Downgrading any function of upper extremity is simply unacceptable
    • Be mindful of what you are ‘stealing’
    • Do not try and do too much at one time
    • Save a back up plan

But with a comprehensive, multidisciplinary approach, nerve transfers can safely be used to strengthen and expand the armamentarium of options to improve upper extremity function in patients with cervical SCI.
Take Away Points

• To better serve an underserved population
• *But be exquisitely mindful of not downgrading function*
• Nerve transfer in SCI--advantages:
  – Minimal post-op activity restrictions (still needs help for transfers, electric wheelchair for 2-4 weeks) (tendon transfers require weeks of casting and months of NWB)
  – Opens up more options (use of brachialis—can’t be used for tendon transfer)
  – Keeps the biomechanics
  – One nerve → more then one function?
Future Work

Questions

– How to pre-operatively evaluate donor and recipient muscles?
– Other options—shoulder, use of supinator donor, other uses of brachioradialis?
– What patients are not candidates?
– How can surgeries be combined to maximize results?
– Can we do early surgery for restoring triceps? (with multilevel or BP injury)

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What can we achieve with nerve transfer?

Pre-operatively

Early Post-Operatively (10 mo)

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