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Activity beats no activity and why more is better.

Rebecca Martin, OTR/L, OTD, CPAM, CKTP

Objectives

At the conclusion of the lecture, participants will

• …identify anticipated functional deficits by neurological level in patients with SCI.
• …select assessments appropriate for functional level and participation domain for patients with SCI.
• …discuss interventions designed for compensation, restoration, and recovery of function in SCI.
UPPER LIMB ORTHOSES

Algorithm for Prescription

[Flowchart image]

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Upper Limb Orthoses

- Better accepted when there is a clearly defined therapeutic program and functional gain.

- Low-temperature thermoplastic orthoses are fabricated by OTs, whose role is evaluating the need for orthoses, recommending devices and training in their use.

- The role of the certified orthotist is to recommend, design, fabricate, fit and follow up on definitive (long-term) upper limb orthoses that are constructed from durable metal and plastic alloys.

Goals for Orthotic Use

- Improve independence
- Increase ease of activity
- Increase spontaneity
- Improve temporal aspects of performance
- Maintain biomechanics of upper limb/ Contracture management (tenodesis?)
## Class of Orthotic

<table>
<thead>
<tr>
<th>Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Therapeutic</td>
<td>- Therapeutic</td>
</tr>
<tr>
<td>- Functional</td>
<td>- Functional</td>
</tr>
<tr>
<td>- General positioning</td>
<td>- More aggressive positioning</td>
</tr>
<tr>
<td>- Joint protection/ preservation</td>
<td>- Contracture management</td>
</tr>
<tr>
<td>- Muscle length maintenance</td>
<td>- Add strength to particular function</td>
</tr>
</tbody>
</table>

## Static/Therapeutic: Resting Hand Splint

For maintenance of length/tension relationships and joint integrity

*NorthCoast Medical*
Static/ Functional:
Dorsal Wrist Splint (WHO)

To prevent wrist drop, put hand in a more functional position, and/or serve as a point to attach utensils

Static Progressive

The use of inelastic components to apply torque to a joint to statically position it as close to end range as possible. It maximizes total end-range time, thus increasing passive range of motion.
Dynamic/ Therapeutic: Elbow Extension (EWHO)

For contracture management/prevention

UltraFlex EWHO with rotation

DynaSplint Neurological Elbow Extension

Dynamic/ Functional: Tenodesis Splint (WHO)

Wrist driven hand orthoses to increase power of tenodesis
Custom Splints: Therapeutic

Dynamic Finger Extension

Dorsal View

Volar View

Dynamic MCP Flexion

Dorsal View

Volar View

Custom Splints: Functional

Dynamic Finger Extension

Dorsal View

Volar View

Dynamic MCP Flexion

Dorsal View

Volar View

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continued™
Balanced Forearm Orthosis (BFO)/Mobile Arm Support (MAS)

Provides proximal support with/without elevation assist to complete functional reaching patterns
International Classification of Surgery of the Hand in Tetraplegia

- Developed in 1979 (Moberg)
- Describes the number of transferable muscles
- Does not include triceps, which are recorded separately
- Also records sensibility (2pt discrimination of thumb and index pulpa; >10mm=O, <10mm=OCu)

<table>
<thead>
<tr>
<th>Group</th>
<th>Grade 4+ Muscles</th>
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<tbody>
<tr>
<td>IC 0</td>
<td>No muscle below the elbow</td>
</tr>
<tr>
<td>IC 1</td>
<td>m. brachioradialis</td>
</tr>
<tr>
<td>IC 2</td>
<td>m. extensor carpi radialis longus</td>
</tr>
<tr>
<td>IC 3</td>
<td>m. extensor carpi radialis brevis</td>
</tr>
<tr>
<td>IC 4</td>
<td>m. pronator teres</td>
</tr>
<tr>
<td>IC 5</td>
<td>m. flexor carpi radialis</td>
</tr>
<tr>
<td>IC 6</td>
<td>finger extendors</td>
</tr>
<tr>
<td>IC 7</td>
<td>thumb extensor</td>
</tr>
<tr>
<td>IC 8</td>
<td>partial digital flexors</td>
</tr>
<tr>
<td>IC 9</td>
<td>lack only intrinsic</td>
</tr>
<tr>
<td>IC X</td>
<td>exceptions</td>
</tr>
</tbody>
</table>

Surgical Hierarchy

- Wrist extension
- Lateral pinch
- Grasp
- Release
Things to Consider

- Strength and potential excursion of donor
- Maintaining biomechanics of the hand
- Maintenance of action balance
- Long term sequelae
- Patient's ability to comply with rehabilitation

Tendon Transfers

- Unipolar redirection of a strong, redundant muscle to restore a desired action or balance across a joint
- Examples:
  - Biceps to triceps to restore elbow extension
  - Brachioradialis to FPL with fusion of thumb IP to restore thumb CMC flexion (lateral pinch)
  - Brachioradialis to FDP for grip
  - Transposition of ECRB align wrist extension and allow for tenodesis
Tendon Transfer: Rehabilitation Protocol

- Immobilization: 1-3 weeks post-op, generally casted in desired end range, putting the muscle on slack.

- Mobilization: 3-6 weeks post-op, immobilize at night, protective splinting during the day, increase allowed movement 10-15°/week, no resistive or passive movement, begin edema and scar management, watch for lag in desired action

- Strengthening and Functional Retraining: 6-12 weeks post-op, no passive movement before 3 months, continue protective splinting

Nerve Transfer/Grafts

- Transfer of a functional (rostral to lesion) nerve to a distal irreparable (caudal to lesion) nerve within the “golden period”

- Involves severing of the original nerve, eliminating the chance for “natural” recovery

- Has the potential to innervate more than one muscle, does not change the biomechanics of the joint

- Little to no rehab. Recovery 1cm/month
Free Muscle Transfer

- Bipolar transfer of a muscle
  - Ex: Gracilis transfer to restore elbow flexion
- Need to have nerve and blood supply available in deficit location
- Used with significant atrophy and suspected degradation of the neuromuscular junction (12-18 months post injury)

Bipolar Transfers with microvascular and nerve anastomosis

- Transfer of a muscle to another limb location with its blood and nerve supply intact.
  - Ex: Rotation of Latisimus Dorsi to restore elbow extension
- Don’t need to have anything existing (nerve/blood) in deficit location.
- Generally, a bulky muscle is transferred to allow for loss of motor units, but maintain adequate strength.
### Reconstructive Options (0-4)

<table>
<thead>
<tr>
<th>O/CU</th>
<th>NL</th>
<th>Has</th>
<th>Needs</th>
<th>Procedure</th>
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<tbody>
<tr>
<td>0</td>
<td>C5</td>
<td>Sh Abduct Bi/Brachialis</td>
<td>Elbow Ext</td>
<td>Bi to Tri TT</td>
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<tr>
<td>1</td>
<td>C5</td>
<td>+ Brachiorad</td>
<td>Elbow Ext</td>
<td>Bi to Tri</td>
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<tr>
<td></td>
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<td>Wrist Ext</td>
<td>Brd to ECRB</td>
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<td>Thumb Pinch</td>
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<td>2</td>
<td>C6</td>
<td>+ECRL</td>
<td>Elbow Ext</td>
<td>Bi to Tri</td>
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<td></td>
<td>Thumb Pinch</td>
<td>Brd to FPL</td>
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<tr>
<td>3</td>
<td>C6</td>
<td>+ECRB</td>
<td>Elbow Ext</td>
<td>Bi/PD to Tri</td>
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<td>Thumb Pinch</td>
<td>Brd to FPL</td>
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<td></td>
<td>Finger Flex</td>
<td>ECRL to FDP</td>
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<td></td>
<td></td>
<td></td>
<td>Finger Ext</td>
<td>EDC Tenod</td>
</tr>
<tr>
<td>4</td>
<td>C7</td>
<td>+ Triceps PQ, PT</td>
<td>Thumb Pinch</td>
<td>Brd to FPL</td>
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<td></td>
<td>Finger Flex</td>
<td>ECRL to FDP</td>
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<td></td>
<td></td>
<td>Finger Ext</td>
<td>PT to EDC</td>
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</table>

### Reconstructive Options (5-9)

<table>
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<tbody>
<tr>
<td>5</td>
<td>C7</td>
<td>+FCR</td>
<td>Thumb Pinch</td>
<td>Brd to FPL</td>
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<td>Finger Flex</td>
<td>ECRL to FDP</td>
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<td>Finger Ext</td>
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<td>6</td>
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<td>+EDC</td>
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<td>Thumb Abduct</td>
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<td>7</td>
<td>C7</td>
<td>+EDC</td>
<td>Thumb Pinch</td>
<td>Brd to FPL</td>
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<td>Finger Flex</td>
<td>ECRL to FDP</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Thumb Abduct</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>C7/C8</td>
<td>Only missing</td>
<td>MP Flex wit IP</td>
<td>Zancolli Lasso</td>
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<td>Ext</td>
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</table>
Restoration of Elbow Extension

Deltoid to Triceps
- Most frequently used (although losing ground). Higher innervation, more pts will have available.
- Complications:
  - Elongation of the tendon s/t early mobilization
  - Attenuation
  - Graft failure
  - Elbow flexion contracture
  - Long immobilization phase with demanding rehab

Biceps to Triceps
- May be a better option, especially if pec absent. Need to have intact brachialis and supinator.
- Complications:
  - Lateral rounding = radial nerve injuries
  - Better candidates for early mob—better tendon without external graft
  - Graft failure, although less
  - Long immobilization with demanding rehab

Restoration of Elbow Extension

Deltoid Outcomes
- Elbow extension was restored
  - MMT >3 in 1 out of 8
- No loss of elbow flexion or supination
- Elbow flexion torque loss of -32% at 2 yrs post…not clinically significant
- Improved performance of ADLs and on self-selected goals (COPM)

Biceps Outcomes
- Elbow extension was restored
  - MMT >3 in 7 out of 8
- No loss of elbow flexion or supination
- Elbow flexion torque loss of -47% at 2 yrs post…not clinically significant
- Improved performance of ADLs and on self-selected goals (COPM)
Restoration of Elbow Extension: So What?

- Biceps-to-triceps transfers yield better clinical outcomes as compared to deltoid transfers
  - Early mobilization
  - Maintain integrity at the shoulder
  - Better chance of antigravity extension (overhead reaching)
- Good candidates have 4+/5 strength at the biceps, brachialis, and supinator
- Both procedures require diligent rehab

RESTORATIVE INTERVENTIONS
Activity-based Restorative Therapy
Combination Strategy

NEUROPROTECTION
BRIDGING
GROWTH FACTORS
TRANSPLANTATION
REHABILITATION

Science Is Great, but Therapy Is Better

Activity Based Restorative Therapy framework

- Higher intensity and frequency
- Stimulation below the level of the injury
- Optimizing the nervous system for recovery
- Enhancing the physical integrity of the body
Activity Promotes Remyelination

Why Is Myelin So Important?

Saltatory Conduction

Demyelination is a big problem, but an easier fix.
Activity Promotes Sprouting Of Collaterals

collaterals of stalled axons

ABRT?
Complete Transection

Implantable Chip

Ground Wire

FES Electrode

Peroneal Nerve

SCI Suction Ablation T8-T10

FES implant

Perfusion Cell Birth Group

Perfusion Cell Survival Group

FES Activation Interval

BrdU Pulse labeling

Stimulation: 3 x 1 hr per day, R / L alternate, 1 sec on /off
FES Induces New Cell Birth


Spinal Learning

Image: Scientific American, 1999
Rats whose flexor stimulation was contingent on their leg positions increased the time their legs were flexed. Neither the yoked rats nor (as expected) the unstimulated rats exhibited any learning.
What is Activity-Based Restorative Therapy?

- Repeated near-normal activity, specifically below the level of the lesion, intended to:
  - Optimize the neurological system
  - Offset the rapid aging, physical deterioration and secondary complications associated with SCI
- Characterized by:
  - High intensity practice
  - Task-specific and patterned activity above and below the level of lesion
- Goal:
  - Restore CNS function
  - Promote neural recovery and regeneration
Compensate vs. Restore

**Traditional Therapy**
- Activate nervous system above the level of the lesion
- Low intensity practice (1 hour per day)
- Non-patterned movements
- Compensates for loss function
- Uses compensatory devices

**ABRT**
- Activate nervous system above and below the level of the lesion
- High intensity practice (2-5 hours per day)
- Non-patterned and patterned movements
- Restores lost function
- Minimizes or eliminates compensatory devices

Why Activity?
- “Regular Physical Activity throughout life is important for maintaining a healthy body. Nevertheless, 60% of the global population fails to achieve the minimum physical activity recommendations.”

- “Persons with chronic physical condition are at greater risk due to inactivity than able-bodied persons because they are often restricted in performing normal everyday activity such as walking, housekeeping, gardening, shopping, and participating in sports.”

Key Components of ABRT

1. Functional Electrical Stimulation (FES)
2. Locomotor Training (LT)
3. Weight Bearing
4. Massed Practice
5. Task-Specific Practice

FUNCTIONAL ELECTRICAL STIMULATION (FES)
# UE FES Cycling

![Image of UE FES Cycling](image)

## Therapeutic Electrical Stimulation

<table>
<thead>
<tr>
<th>TES</th>
<th>NMES</th>
<th>FES</th>
<th>TENS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Therapeutic Electrical Stimulation</td>
<td>Neuromuscular Electrical Stimulation</td>
<td>Functional Electrical Stimulation</td>
<td>Transcutaneous Electrical Nerve Stimulation</td>
</tr>
<tr>
<td>Use of electricity to drive a desired nerve response for therapy.</td>
<td>Electricity applied across the surface of the skin over intact peripheral nerve evokes an action potential in the nerve fiber which causes an exchange of ions to drive the muscle to contract.</td>
<td>Application of electrical stimulus to a paralyzed nerve or muscle to restore or achieve function. Also refers to orthotic substitution (Bioness L300).</td>
<td>Pain modulation by exciting peripheral nerves.  Common Types:  • Sensory  • Motor  • Noxious</td>
</tr>
</tbody>
</table>
Therapeutic Applications

- Prevent/Reverse disuse atrophy
- Orthotic Substitution
- Strengthening
  - Improve and maintain muscle mass during or following periods of inactivity
  - Maintain/Increase ROM
  - Re-educate/facilitate voluntary contraction
  - Reduce effects of spasticity

Benefits of FES

- Maintain muscle health (size, composition, profusion)
- Maintain bone health
- Improve cardiovascular status (endurance, VO2, HR)
- Normalize tone
- Optimize nervous system for recovery
- Improve motor function? Speed recovery?
Clinical Application of FES

- Combine with functional activities using portable e-stim unit (EMPI, Intellect)
- Orthotic substitution (Bioness L300 & H200, Walk Aide)
- FES cycling (upper and lower extremities- RT 300, MotoMed)
- Biofeedback (Neuromove, Myotrack Infiniti, Otto bock STI WEL med4)

WEIGHT BEARING

![Image of weight-bearing exercise](image-url)
Weight Bearing

• Loading across a joint
• Promotes joint alignment, bone stress, and muscle co-contraction
• Normalized afferent input

Weight Bearing

• UE weight bearing can be achieved through:
  – Seated prop
  – Quadruped
  – Prone positioning

• LE weight bearing can be achieved through:
  – Quadruped or tall kneel
  – Standing:
    • With or without assistance
    • With or without bracing- No or minimal bracing preferred
  – Supported standing in standing frame
    • Static stander
    • Dynamic stander
    • Stander with glider component
Benefits of Weight Bearing

- Improved bowel and bladder function
- Decreased number of bed sores
- Improved range of motion
- Improved autonomic regulation
- Decreased spasticity
- Improved bone mineral density
- Improved cardiovascular function
- Improved motor function
- Improved quality of life

Stander Examples

[Images of people using stander devices]

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Locomotor Training

- An activity-based rehabilitative strategy designed to improve sensory, motor and autonomic function, health and quality of life

- Provides sensory cues to re-train neural patterns that will result in effective locomotion

- Emphasizes recovery of motor function using the intrinsic mechanisms of the nervous system, rather than compensatory strategies
Benefits of Locomotor Training

- Increased walking speed
- Increased walking independence
- Increased walking endurance
- Improved balance
- Motor recovery
- Decreased asymmetry of gait
- Improve gross motor skills
- Improved well being, life satisfaction, and perceived health

Locomotor Training Basics

4 Principles of LT:
1. Maximize weight bearing on the legs
2. Optimize sensory cues
3. Optimize kinematics for each motor task
4. Maximize recovery; minimize compensation

3 Components to LT:
1. Treadmill training
2. Overground training
3. Community training
Locomotor Training Activity-Based Basics

- 4 Principles of LT ABR:
  - Maximize weight bearing
  - Optimize sensory cues
  - Optimize kinematics for each motor task
  - Maximize recovery; minimize compensation

- 3 Components to LT ABR:
  - Treadmill training (High volume repetition)
  - Overground training (Skilled practice)
  - Community training (Independent program)

MASSED PRACTICE
Massed Practice

- Repetitive task specific and non-task specific activities
- Promote cortical reorganization
  - In CIMT, benefits result from frequency of use of involved side, not constraint of uninvolved side
- Repeated multiple times for multiple hours/days
- Improve strength and ROM
- Perfect practice makes perfect
- Incorporate other components
  - Principles of LT
  - FES

Repetitions in traditional rehab

- 312 therapy sessions in post-stroke rehab
- Average duration (min) 36 (±14)
- UE (functional movement) 32
- LE (functional movement) 6
- Gait (steps) 357
- Transfers 11
NOT ENOUGH!

• “Amount of practice...is small compared with animal models...Current doses...during rehabilitation are not adequate to drive neural reorganization needed to promote function poststroke optimally.”

Feasibility in In-patient Rehab

• 15 pts. with UE paralysis s/p CVA in IRF

• 4 days/week of individually tailored UE training
  - Ex: lifting cans to a shelf
  - Reaching, grasping, manipulating, releasing
  - >/=300 reps in 60 min

• 2 days/week of ADL training
Massed Practice Does Not Inhibit Skill Acquisition

- 289 repetitions/session; 47min engaged
- Fatigue was a complaint, pain was not
- Sessions were not often missed
- Improvements in ARAT, grip/pinch strength, UE-FIM
  - Pts with various UE capacities could participate
  - Higher doses were associated with better outcomes
  - ADL retraining was not sacrificed.

Waddell et al., 2014

 Might Take Longer for the UE

- 127 pts with mod-to-severe UE impairment, >6mos post CVA
  - Intensive robotic assisted therapy (RA)
  - Intensive therapist assisted therapy (TA)
  - Usual care (UC)
- Outcomes: Fugl-Meyer Assessment, Wolf Motor Function Test, Stroke Impact Scale
- At 12 wks, RA was better than UC, but worse than TA. Not significant differences
- At 36 wks, RA and TA were significantly better than the UC

Lo et al., 2010
Strategies to Incorporate

- Breakdown functional skills
  - Repeat half roll
- Facilitation techniques
  - PNF to encourage mass flexion
- Combine with other components
  - FES to abs
- Technology where appropriate
  - Balance benefit
  - Don’t want to build reliance on

Technology to unweight arm
Don’t Let Bad Habits Persist

• Use it or lose it: Abhorrent patterns and compensatory strategies have to be overcome by rehabilitation

• Patients will figure out how to get things done (ex: tenodesis)

• Cortical reorganization responds to non-use as much as therapy

• The body learns what we teach it
Train the Affected Limb

“[In rats,] behavioral experience with the less-affected forelimb early after unilateral [brain] lesions has the potential to increase disuse and dysfunction of the impaired forelimb, consistent with a training-induced exacerbation of learned non-use. These findings are suggestive of competitive processes in experience-dependent neural restructuring after brain damage.”

Allred, et al. 2005

Task Specific Practice

- Practice of context specific motor tasks
- Training functional task rather than impairment
- Paired with feedback
- Goal directed
- Repetition
- Incorporate other components
  - Stand at sink to brush teeth
  - FES to ankle dorsiflexion during gait
  - High repetitions of elbow flexion followed by self-feeding
Example: Transfers

- Overground component of LT/ Weight bearing
  - Transfers with feet on the ground
  - Work on hip hinge
- Don’t stim a muscle in isolation
  - FES to triceps/scap depressors during transfers
- Massed practice of part of a task
  - Once on the mat, scoot around the side
- All other components come back to task

Home Rehabilitation Program

- SCI requires a lifetime of care
- Incorporates ABRT principles
- Prioritize the patient’s impairments and functional limitations
- Consider building challenges into the environment

- Common recommendations for equipment for home:
  - Electrical stimulation unit
  - FES Cycle (UE and/or LE)
  - Standing frame (mobile or glider)
Late Recovery Following SCI  
(McDonald, et.al. 2002)

- Prospective single case study
- Hypothesis: “patterned neural activity might stimulate the central nervous system to become more functional”

- C2 ASIA A white male (age 42) with tetraplegia:
  - Sustained a traumatic displaced C2 fracture (odontoid) 5 years prior to initiating ABRT program.
  - Motor complete with some sensation below the level of injury
  - Ventilator dependent

ABRT initiated 5 years after injury

- FES leg cycle ergometry: 1 hour, 3 times week
  - Gluteals, quadriceps, hamstrings
- Aquatic therapy 1 hour, 1 time per week
- NMES: 3 days per week alternating muscles:
  - Paraspinals, abdominals, upper extremities
- ROM exercises: daily
- Breathing exercises: daily

- Duration of program: 3 years
Major outcomes

- ASIA grade conversion: from AIS A to C
- Motor scores: From 0/100 to 20/100, Return of voluntary control of right hemi diaphragm
- Sensory scores
  - Light touch: From 5/112 to 58/112
  - Pin prick: From 7/112 to 77/112
- Reversal of osteoporosis (DEXA)
  - From T-score of -4.1 to -0.5
- Reduced medical complications
  - Including a 90% reduction in amount of days on antibiotics
- Reduction of spasticity (Ashworth)
  - From 3/5 to 1-2/5
- Increase in muscle mass (girth)

Subjective Responses

- Minimize risk of infection and hospitalization
- Greater engagement in work and life tasks
Key Therapeutic Components: SUMMARY

- Repeated near-normal activity, above and specifically below the level of the lesion, intended to:
  - Optimize the neurological system
  - Offset the rapid aging, physical deterioration and secondary complications associated with SCI

- Characterized by:
  - High intensity practice
  - Task-specific and patterned activity above and below the level of lesion

- 5 Key Components
  1. Weight Bearing
  2. Functional Electrical Stimulation (FES)
  3. Locomotor Training (LT)
  4. Massed Practice
  5. Task-Specific Practice
### ICSCI Patient Demographics

#### Patient Distribution

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total population n=3999</th>
<th>Adult n=474 (79.1%)</th>
<th>Pediatric n=125 (20.9%)</th>
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</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>28.0 (17.4)</td>
<td>32.9 (16.0)</td>
<td>9.2 (5.9)</td>
</tr>
<tr>
<td>Sex, Male, n (%)</td>
<td>391 (33.8)</td>
<td>313 (66.0)</td>
<td>68 (54.4)</td>
</tr>
<tr>
<td>Pathology</td>
<td></td>
<td></td>
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<tr>
<td>Traumatic</td>
<td>375 (96.2)</td>
<td>307 (64.9)</td>
<td>56 (53.2)</td>
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<tr>
<td>Non-traumatic</td>
<td>264 (37.5)</td>
<td>166 (25.0)</td>
<td>58 (46.4)</td>
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<tr>
<td>Time from injury to start of rehab, years</td>
<td>6.5 (6.7)</td>
<td>7.6 (10.5)</td>
<td>2.2 (3.3)</td>
</tr>
<tr>
<td>Treatment units, n (Q2)(I 1 unit=15 min)</td>
<td>320.3 (94-379)</td>
<td>336.5 (66-413)</td>
<td>259.2 (82-235)</td>
</tr>
<tr>
<td>Type of Injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incomplete</td>
<td>416 (46.5)</td>
<td>339 (71.5)</td>
<td>27 (68.6)</td>
</tr>
<tr>
<td>Complete</td>
<td>133 (36.5)</td>
<td>135 (28.5)</td>
<td>46 (36.4)</td>
</tr>
<tr>
<td>AIS Classification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>187 (31.2)</td>
<td>139 (29.1)</td>
<td>49 (99.2)</td>
</tr>
<tr>
<td>B</td>
<td>265 (53.5)</td>
<td>168 (34.4)</td>
<td>57 (57.0)</td>
</tr>
<tr>
<td>C</td>
<td>331 (35.5)</td>
<td>127 (26.6)</td>
<td>24 (50.9)</td>
</tr>
<tr>
<td>D</td>
<td>166 (37.7)</td>
<td>141 (29.5)</td>
<td>25 (70.0)</td>
</tr>
<tr>
<td>Total Motor score, mean(SD)</td>
<td>53.2 (28.6)</td>
<td>34 (28.6)</td>
<td>49 (22.5)</td>
</tr>
<tr>
<td>Total pin prick score, mean (SD)</td>
<td>58.0 (33.0)</td>
<td>59.3 (32.2)</td>
<td>66.8 (36.1)</td>
</tr>
<tr>
<td>Total light touch score, mean (SD)</td>
<td>87.7 (31.5)</td>
<td>68.1 (30.2)</td>
<td>62.5 (35.5)</td>
</tr>
<tr>
<td>LEMS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤10</td>
<td>342 (66.0)</td>
<td>256 (64.0)</td>
<td>96 (68.2)</td>
</tr>
<tr>
<td>&gt;10</td>
<td>250 (43.5)</td>
<td>218 (46.0)</td>
<td>80 (32.0)</td>
</tr>
</tbody>
</table>

---

![Bar chart showing patient distribution across different spinal segments (C1-C3, C4, C5-T1, T2-T6, T7-T11, T12-S5)].
## Transition Probability: Adult

<table>
<thead>
<tr>
<th>Index/Baseline AIS</th>
<th>N</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>138</td>
<td>105 (76.1)</td>
<td>16 (11.6)</td>
<td>17 (12.3)</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>68</td>
<td>6 (8.8)</td>
<td>39 (57.4)</td>
<td>23 (33.8)</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>127</td>
<td>2 (1.6)</td>
<td>6 (4.7)</td>
<td>102 (80.3)</td>
<td>17 (13.4)</td>
</tr>
<tr>
<td>D</td>
<td>141</td>
<td>-</td>
<td>-</td>
<td>10 (7.1)</td>
<td>131 (92.9)</td>
</tr>
<tr>
<td>Total</td>
<td>474</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

## Transition Probability: Pediatric

<table>
<thead>
<tr>
<th>Index/Baseline AIS</th>
<th>N</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>49</td>
<td>40 (81.6)</td>
<td>7 (14.3)</td>
<td>2 (4.1)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>27</td>
<td>4 (14.8)</td>
<td>17 (63.0)</td>
<td>5 (18.5)</td>
<td>1 (3.7)</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>24</td>
<td>1 (4.7)</td>
<td>2 (8.3)</td>
<td>16 (66.7)</td>
<td>5 (20.8)</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>25</td>
<td>-</td>
<td>-</td>
<td>4 (16.0)</td>
<td>20 (80.0)</td>
<td>1 (4.0)</td>
</tr>
<tr>
<td>Total</td>
<td>125</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Improvements in Functional Skills

- SCIM Score
  - Baseline vs. Follow up
  - Statistical significance at p=0.0001 for ASIA A (Adults), p=0.065 for ASIA A (Peds), p=0.420 for ASIA B (Adults), p=0.319 for ASIA B (Peds), p=0.001 for ASIA C (Adults), p=0.277 for ASIA C (Peds), p=0.164 for ASIA D (Adults), p=0.158 for ASIA D (Peds).

Improvements in Quality of Life (Adult)

- SF-36 Score
  - Baseline vs. Follow-up
  - Statistical significance marked with asterisk (*)
FES Improves BMD

Hammond ER, Metcalf HM, McDonald JW, Sadowsky CL. (accepted in 2014) Bone mass in individuals with chronic spinal cord injury: associations with activity-based therapy, functional and neurologic status, a retrospective study. Archives of Physical Medicine and Rehabilitation (accepted for print)

CASE STUDY: SUSAN
Patient History

- 51-year-old female
- Accidentally fell backwards off of a deck on 05/28/07
- C4-C5 fracture dislocation and incomplete spinal cord injury
- S/p C4-C5 fusion and anterior cervical fusion with allograft with anterior cervical plate fixation
- S/p tracheostomy placement and successful decannulation
- Primary mobility via power wheelchair and dependent for most ADLs with a full-time caregiver
- Impairments:
  - C4 AIS C
  - Decreased shoulder ROM
  - Decreased UE strength (gravity eliminated function, except antigravity biceps)
  - Decreased LE strength (antigravity strength on Left side and gravity eliminated strength on Right side)
  - Decreased trunk strength
  - Spasticity impairing functional mobility
  - Does not tolerate effective doses of oral meds. Received Botox with good effect.

Day 1

![Image of a therapy session]

continued
Goals & Outcome Measures

- **Therapy Goals**
  - Increase standing endurance
  - Increase independence with ambulation
  - Improve rolling
  - Improve sit to stand transition
  - Increase shoulder and (R) wrist ROM
  - Improve (R) hand function
  - To be more independent at home and be at home throughout the day without a caregiver

- **Outcome Measures Used**
  - Spinal Cord Independence Measure (SCIM)
  - Standard Balance Test (sitting and standing)
  - Nine-Hole-Peg-Test
  - Box and Blocks Test
  - CUE Scores

---

Design a 1 Hour Session

**Impairments**

- Decreased:
  - Shoulder ROM
  - Right wrist ROM
  - Right hand strength
  - Bilateral LE strength, right weaker than left
  - Trunk strength
  - Increased tone — impacting mobility!

**Functional Limitations**

- Assist with rolling
- Assist to stand at walker
- Increased standing endurance
- Unable to ambulate
Achievement of Functional Goals Through ABRT

Interventions

- Locomotor training
- Upper extremity and lower extremity FES cycling
- Functional mobility training through massed practice
- Functional electrical stimulation to upper and lower extremities
- Aquatic therapy
Interventions

Functional electrical stimulation to the upper extremity

Massed Practice
- Rolling
- Sit to stand
2 years later

And another 6 months
# Aquatic Gait Training

![Image of Aquatic Gait Training](https://www.kennedykrieger.org)

## Outcomes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCIM</strong></td>
<td>29/100</td>
<td>30/100</td>
</tr>
<tr>
<td><strong>Balance Testing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static Sitting</td>
<td>3 Fair</td>
<td>4 Good</td>
</tr>
<tr>
<td>Dynamic Sitting</td>
<td>3 Fair</td>
<td>4 Good</td>
</tr>
<tr>
<td>Static Standing</td>
<td>3- Fair – 2 Poor</td>
<td>3- Fair – 2 Poor</td>
</tr>
<tr>
<td>Dynamic Standing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nine-Hole-Peg-Test</strong></td>
<td>Unable to be tested on right secondary to decreased function</td>
<td>(R) UE: 1 peg (1 minute 45 secs) 2 pegs in 1 minute 53 secs</td>
</tr>
<tr>
<td></td>
<td>3 min 3 sec on (L) UE</td>
<td>(L) UE: 1 minute 20 seconds</td>
</tr>
<tr>
<td><strong>Box and Blocks Test</strong></td>
<td>(R) UE: 9 (L) UE: 14</td>
<td>(R) UE: 17 (L) UE: 31</td>
</tr>
</tbody>
</table>

*(www.kennedykrieger.org)*
CASE STUDY: JOE

Patient History

- 35-year-old male
- Sustained SCI on July 20, 1998 in a surfing accident-underwent fusion of C5-C7 vertebrae
- Presents as C5 AIS D
- Functionally ambulates with 1 loftstrand crutch with significant gait deviations and compensatory techniques
- No other significant past medical history
- Has not received formal therapy since initial inpatient and brief outpatient bouts of care.
Goals and Outcome Measures

- Therapy Goals:
  - Increasing walking endurance
  - Eliminate use of assistive device
  - Perform independent floor transfer
  - Improve bilateral UE overhead reach strength/endurance
  - Improve fine motor skills

- Outcome measures used
  - 6-minute walk test
  - Berg Balance test
  - 10 meter walk test
  - Nine-Hole Peg Test
  - Box and Blocks Test

Design a 1 Hour Session

Impairments
- Decreased fine motor skills
- Decreased shoulder strength
- Decreased endurance
- Decreased standing balance

Functional Limitations
- Decreased endurance when walking
- Reliant on assistive device for walking
- Decreased floor transfers
- Decreased overhead reach

www.kennedykrieger.org
Achievement of Functional Goals Through ABRT

- Locomotor Training
- Task specific practice
- Walking endurance
- Floor to stand transfer
- Decreased overhead reach
- Decrease reliance on device
- Weight bearing
- FES
- Massed Practice

At Evaluation
Treatment Plans

- Electrical Stimulation
  - Where?
  - Which type?
  - With what activities?
- Locomotor Training
  - What would his session look like?
  - What would overground look like?
- Home Program

Interventions

- Massed practice for functional mobility and hand dexterity
- Locomotor training
- FES cycling
- UE/LE strengthening with and without use of NMES
- Whole body vibration
Rolling

Sit to Stand
Tricep Strengthening

Grasp and Release Training
### Outcomes

<table>
<thead>
<tr>
<th>Test</th>
<th>Evaluation</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 MWT</td>
<td>770 ft with unilateral loftstrand</td>
<td>1,043 ft without assistive device</td>
</tr>
<tr>
<td>10 MWT</td>
<td>10.69 seconds with unilateral loftstrand</td>
<td>9.3 seconds without assistive device</td>
</tr>
<tr>
<td>Berg Balance</td>
<td>47/56</td>
<td>51/56</td>
</tr>
<tr>
<td>9 Hole Peg Test</td>
<td>Right Hand: 45.32 sec Left Hand: 47.98 sec</td>
<td>Right Hand: 39.58 sec Left Hand: 36.65 sec</td>
</tr>
<tr>
<td>Blocks and Box Test</td>
<td>Right Hand: 46 Left Hand: 43</td>
<td>Right Hand: 53 Left Hand: 47</td>
</tr>
</tbody>
</table>

Got it? Questions?