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Current Topics in Upper Limb Loss and Difference Virtual Conference

Guest Editor: Debra Latour, OTD, MEd, OTR/L

Current Topics in Upper Limb Loss and Difference: OT for Targeted Muscle Reinnervation and Pattern Recognition Control

Kristi Turner, DHSc, OTR/L
Center for Bionic Medicine
Shirley Ryan Ability Lab
Acknowledgements

- The information presented is from the work completed in the Center of Bionic Medicine at Shirley Ryan AbilityLab

Learning Outcomes

After this course, participants will be able to:

- Describe targeted muscle reinnervation surgery and the training process.
- Describe pattern recognition control and identify the difference between direct control and pattern recognition.
- Describe the benefits of pattern recognition and TMR for individuals with upper limb differences.
Nerves still there

- Even though arm is amputated, nerves going to the arm remain
- Signals are still there
- Nerves carried all of the information to arm before - so can record signals from nerves to operate
Biological solution

Muscle makes myoelectric signal 1000x bigger than nerve signals
Don’t break down
Have their own power supply

Targeted Muscle Reinnervation

TECHNIQUE
- Muscle acts as a ‘biological amplifier’ of the motor command

ADVANTAGES
- Additional control signals for simultaneous control of more DOFs
- Control signals are physiologically appropriate
- No implanted hardware required
- Can use existing myoelectric prosthetic technology

DISADVANTAGE
- Requires additional surgery (unless it is done at time of amputation)

Dr. Todd Kuiken, MD, PhD
First TMR participant

Musculocutaneous N.
Pectoralis Major (Clavicular Head)
Median N.
Pectoralis Major (Sternal Head)
Ulnar N.
Pectoralis Minor
Radial N.

Goal: Create more control sites

Pre-Op
1 available control signal

Post Op
4 available control signals
Motion During Contraction After TMR

Benefit from TMR

Original Prosthesis (Used more than 20 months)  Post-TMR Prosthesis (Used about 2 months)
First TMR Patient

"Doc, now I don’t have to think about what I’m doing so much—I just do it."

Jesse Sullivan, 2003

Conventional transhumeral fitting

Elbow Up/Hand Close

Elbow Down/Hand Open

Electrodes

Biceps Musculocutaneous nerve

Triceps Radial nerve
Differences with TMR vs. standard myoelectric

- Large amount of motor control info transferred to target muscles
- Each large transferred motor nerve contains motor control content for a variety of arm & hand functions
  - Reinnervated in a relatively small area of muscle
- Understanding of peripheral function
- Based on surgery, which nerves anticipated to reinnervate muscle regions
### Native Nerve Actions

<table>
<thead>
<tr>
<th>Musculocutaneous Nerve</th>
<th>Radial Nerve</th>
<th>Median Nerve</th>
<th>Ulnar Nerve</th>
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<tbody>
<tr>
<td>• Elbow Flex</td>
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<td>• Ulnar Deviation</td>
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<td></td>
<td>• Supination</td>
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<td>• Thumb Ext</td>
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### TMR OT Progression

- **Pre-surgery**
  - Evaluation of shoulder, posture, functional ability with prosthesis and without
  - Education

- **Immediately After Surgery**
  - Ensure optimal control of interim prosthesis
  - Strengthen signals & rebuild muscle bulk

- **3-4 Weeks after surgery**
  - Begin Motor Imagery

TMR OT Progression

- 6-15 weeks after surgery
  - When muscle twitching, begin motor imagery strengthening
  - Gross movement patterns

- 10-20 weeks after surgery
  - Discrete movement strengthening
  - As become stronger, begin graded contraction exercises

- 24+ weeks** after surgery
  - When 3 or more potential myosites, begin prosthesis control training
  - Trouble shoot: socket fit, electrode sites, best transferred nerve actions


Examples of Gross Motor Patterns

- Flexion: Median and Ulnar nerves (top)

- Extension: Radial and Ulnar nerves (bottom)

Examples of Discreet Motions

- Radial Nerve Actions
  - Hand Open
  - Wrist Extension
  - Supination
  - Relax
  - Pronation

- Median Nerve Actions
  - Wrist Flexion
  - Hand Closed

https://www.youtube.com/watch?v=EPeXM_Wgu5o

Document Changes in Ability

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<th>Qualitative Outcome Measures</th>
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<td>• Orthotics &amp; Prosthetics User-Survey-Upper Extremity Functional Status (OPUS-UEFS)</td>
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<td>• Box &amp; Block Test</td>
<td>• Disabilities of the Arm Shoulder &amp; Hand Outcome Measure (DASH)</td>
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<tr>
<td>• Jebsen Taylor Hand Function Test</td>
<td>• Patient Specific Functional Scale (PSFS)</td>
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</table>

TMR Functional Outcomes

- More than 1000 TMR patients worldwide and growing...
  - Walter Reed Army Medical Center
  - Brooke Army Medical Center
  - Vienna, Austria
  - Edmonton, Canada
  - University of Washington
  - Quito, Ecuador
  - Many more...

An individual with an above-elbow amputation from Walter Reed Army Medical Center demonstrating the use of his TMR prosthesis

Things that Help Outcome

**Communication**
- Copies of the surgical report
- Know where to start looking!

**Working as a team**
- Prosthetic fitting should take place in conjunction with occupational therapy
Requirements for Successful TMR

Independent Signal

- Each target muscle needs to be fully denervated
- Transferred nerves to reinnervate one muscle segment

Signals large enough to record

- Strengthen nerves

Neuroma Pain Study

Traction Neurectomy with Burying

Targeted Muscle Reinnervation (TMR)

TMR for Transradial

- Distal median nerve transfer to *flexor digitorum superficialis* (FDS) or *brachioradialis* muscle
- Distal Ulnar nerve transfer to *flexor carpi ulnaris* (FCU) muscle

- Improved control for multiarticulating hands?
Direct Control vs. Pattern Recognition

Muscle contractions produce electrical activity that we can sense using electrodes on the skin surface.
Myoelectric Prosthesis Control

- **CONVENTIONAL**
  - Depends on isolated myosites
  - Uses signal amplitudes
  - Requires mode switching (such as co-contraction)

- **PATTERN RECOGNITION**
  - Uses information from multiple myosites
  - Uses signal content (features)
  - Provides intuitive control of multiple DOF

Calibration Guided by Prosthesis

*Courtesy of RIC*
Pattern Recognition Considerations

- TR, TH, or SD prosthesis
- Motivated user with good cognitive function
- Any combination of powered components
- Earlier fittings for TMR
- Funding

Pattern Recognition Education

- Review pattern recognition concepts
- Differences between direct control (if applicable)
- One DOF at a time
- Educate on fatigue (Physical/Mental)

- Establish unique and *repeatable* movements
  - Start with native movements and modify as needed
Pattern Recognition Education

- Understanding pattern recognition concept
  - EMG “picture”
  - Repeatability

Phantom Limb Considerations

- Can they identify phantom limb position?
- Are they able to move phantom limb?

- Try to move, even if feels immobile
- Use photos to assist – can use as HEP as well
Home Exercise Program Example

Elbow Down
Elbow Up

Palm Down
Palm Up

Lead with thumb

Hand Close
Hand Open

Calibration of the Prosthesis

- Review calibration sequence
- Focus on timing of contractions/relaxation
- Mirror with sound limb (if able)
- Therapist verbalize motions/timing
Observations

- Watch for postural changes and/or facial expressions
- May indicate too forceful contractions
- RELAX
- Watch for fatigue

Multiple Calibration

- Useful when control is not optimal in other positions
- May increase functional envelope
Same Therapy

- Pre-positioning Education
- Various sizes, weights, materials
- Different positions
- Bimanual Tasks
- Functional Tasks
- Watch for postural adaptations

Home Use

- Patient should monitor their performance with the prosthesis and learn to recalibrate as necessary
- Understand when it is beneficial to use multiple calibration data
- May achieve good control with more refined movements and less effort
Pattern Recognition: Pros/Cons

**PROS**
- No Switching
- Easy access to all motors
- More “natural” movements
- Prosthetist time
- Begin OT sooner
- Interruptions of OT
- Can recalibrate when control is not as desired

**CONS**
- Easy access to all motors
- Possibility of unintended movements
- Recalibration is needed
- Need to educate patient of when to recalibrate

Troubleshooting

**Unintended Movement**
- Move during “No Movement” collection

**Confusion with movements**
- Watch posture – are they trying harder?
- Mirror movement – did they change their movement?
- Modify movements to be more unique

**Hand opens too easy, fearful of dropping**
- Calibrate/train that movement with stronger contraction
Take Home Points

- IMPORTANT TO RELAX

- Review phantom limb awareness/movements as practice continues with PR

- NOT SCARY

Please Note!!!

- You **DO NOT** need to have TMR to benefit from Pattern Recognition
- You **DO NOT** need Pattern recognition if you have TMR

**HOWEVER**

- TMR & Pattern Recognition work well together!
- Especially for complex prosthesis
References


Questions?

- kturner@sralab.org
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