Robot-Aided Rehabilitation after Stroke

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Disclosures

- **Funded Research**
  - Tibion (funded research study)
  - Tyromotion (loan of equipment)
  - Myomo (loan of equipment)

- **Scientific Advisory Board**
  - Myomo (uncompensated)
Recovery & Rehabilitation

- Rehabilitation = Recovery + Compensation
Approaches to Enhance Recovery

- Exercise/Task Practice
- Brain Stimulation (Electrical, TMS)
- Sensory Enhancement or Stimulation (e.g., Vibratory, electrical, thermal, acupuncture)
- Medications (amphetamines, SSRI’s)
- Growth Factors and Stem Cells
Exercise vs. Robotics: Man vs. Machine?
Why high-tech rehab?

- Often the only way to provide certain therapies and treatments
Why high-tech rehab?

* Labor saving – cost of personnel rising while the cost of technology is falling
Why high-tech rehab?

- Able to provide treatments repetitively without therapist fatigue
Why high-tech rehab?

- More interesting for the patient
Why high-tech rehab?

* Competitive marketing advantage
Goals of Robotic Therapy

• Improve motor abilities through practice (plasticity)
• Wearable functional orthoses
• Strength and/or ROM exercise therapy
• ADL assistance/social
Advantages to Robots

- Labor saving (ultimately)
- Cost saving (ultimately)
- Greater consistency of therapy
- Achieve defined (large) number of repetitions
- Incorporate games or virtual reality
- Built-in measurement capability
- Potential for optimizing patient feedback/training algorithm
Disadvantages to Robots

- Costly and space consuming
- Risk of obsolescence
- Most devices limited to portions of affected limb
- Treatment algorithms lack the same degree of feedback/adjustment as human therapists
- No proven advantage over human therapy
- Most devices do not allow true ADL task practice or mobility in varied environments
What kind of robots do we want?

Versus
Types of Robots

- Anthropomorphic (e.g. Asimo)
- Workstation - end effector (e.g. InMotion2)
- Workstation - exoskeletal (e.g. Lokomat)
- Wearable exoskeletal (e.g. Tibion Bionic Knee)
- Non-contact/social and ADL robots
Anthropomorphic Robots
End-Effector Robots
MIT-Manus/InMotion
Shoulder-Elbow Robot

- Robot provides assistance in completing reaching tasks
- Assistance provided decreases as patient’s ability increases
- Suitable even for patients with severe weakness
- Both short (Aisen 1997) and long term (Volpe 1999) benefits demonstrated for treatment early after stroke
Motor function pre- and post-Robot Therapy

Scores

Baseline

After Robot Therapy

Fugl-Meyer

MSS (Shoulder and Elbow)

MSS (Wrist/Hand)

MRC motor power
Modular Approach

Wrist Robot

Hand Robot
VA Robot Study

- VA multicenter study
- 127 chronic (>6 months) hemiparetic stroke survivors
- 49 assigned to 12-week robot therapy, 50 to intensive therapist-assisted therapy, and 28 to usual care
- Robot Rx: 3 weeks each of Shoulder-Elbow, Vertical+Grasp, Wrist, and then combined

VA Robot Study

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<tr>
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<th>Usual care</th>
<th>Robot-assisted therapy</th>
<th>Intensive comparison therapy (ICT)</th>
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<tbody>
<tr>
<td><strong>A Fugl-Meyer Assessment, Robot vs. Usual Care</strong></td>
<td><img src="image" alt="Graph" /></td>
<td>Overall mean difference, 2.88 (95% CI, 0.57 to 5.18); P=0.02</td>
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<td><strong>B Fugl-Meyer Assessment, Robot vs. ICT</strong></td>
<td><img src="image" alt="Graph" /></td>
<td>Overall mean difference, -0.58 (95% CI, -2.97 to 1.81); P=0.63</td>
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VA Robot Study: Conclusions

- Effects of robotic therapy were modest.
- Robotic therapy was similar in outcome to intensive human therapy.
- Robotic therapy was somewhat more expensive than comparable human therapy ($9,977 vs. $8269).
- Patients receiving robotic therapy in the 2nd half of the study showed greater improvement on multiple measures (?Staff experience).
Motorika Reo Go
Hand Robot - Amadeo
Amadeo games
Increased AROM after Training
Exoskeletal Work-stations

Photo courtesy of Hocoma
Armeo Power
Lokomat System

Video courtesy of Hocoma, Inc.
It’s not just the amount of Exercise: Robot vs. Human Gait training

Changes in gait speed at post- and F/U assessments at self-selected velocity (SSV; A) and fast velocity (FV; B)

Hornby, T. G. et al. Stroke 2008;39:1786-1792
Anklebot
Wearable Robots
1. Sensors in the device and inside the shoe detect user action (for example, sitting, standing, climbing stairs).

2. Microprocessors in the device analyse this information.

3. Device provides external force to supplement muscle strength.
Tibion device: Walking
ReWalk (Argo Medical)
eLEG S (Ekso)
EMG-controlled Exoskeletal Robots: Myomo
SCI - Unassisted Motion
SCI - Assisted

Assisted Motion
Motor Impairment

Upper Extremity Fugl-Meyer Scores

Subject 1
Subject 2
Subject 3
Subject 4
Subject 5
Subject 6
Virtual Reality vs. Robotics

- “Virtual Reality” often used to encompass both gaming and real-world simulations
- Virtual Reality less well-studied than robot-aided rehabilitation
- Use of virtual environment allows real-time visual or auditory feedback for motor task training
- Some systems provide haptic (force/touch) feedback (e.g. Rutger’s Ankle)
- Overlap/convergence between robotics and VR
Robot-Human Interaction

- Should the user or the robot initiate and direct the movement?
- Is a power-assist design workable? Useful?
- Should the robot guide the user through a pre-determined path? If not, how will safety be maintained?
- Should the robot assist movement, resist movement, be neutral, or apply force to perturb movement (e.g. orthogonal to path)?
- Does a compliant interface matter?
- How should robotic algorithms adapt to changes in user performance?
Combination Therapy

* Combining two or more treatments concurrently or consecutively to maximize recovery

* Types of treatments
  * Therapeutic Exercise/Task Practice
  * Limb stimulation (electrical, acupuncture)
  * Brain stimulation
  * Medications
  * Growth Factors
  * Stem Cells
  * Others?
Are effects additive, synergistic, or zero-sum?

If therapies “A” and “B” each provide 10% benefit individually, will combining them provide:

a) 20% benefit (Additive)
b) 30% benefit (Synergistic)
c) 10% benefit (Zero-sum)
d) 5% benefit (Interfering)
e) Unknown

Answer: (e) Unknown
Conclusions

- Exercise remains our primary method for enhancing motor recovery after stroke, as well as for teaching compensatory strategies.

- Robots provide a method for providing well-defined, reproducible therapeutic exercise in a potentially labor-saving fashion.

- Technology will play an expanding role in rehabilitation in the near future, including robotic and/or virtual reality-aided therapy.

- Combination therapies are likely to be useful (especially involving exercise).