Stroke Rehab Medical Management

- Introduction
- AHA/ASA Practice Guidelines
- Depression
- Emotional Lability
- Impaired Cognition
- Aphasia
- Neglect
- Hemiplegic Shoulder Pain
- Spasticity
  - Splinting
  - Medications
  - Injections: Botox, Phenol
  - Surgery
- Dysphagia
- Malnutrition
- Impaired Gait
- Bladder & Bowel Dysfxn
- Post-Stroke Seizures
- Sleep Dysfunction
- CRPS
- Central Pain
- DVT Prophylaxis & Tx
- Return to home, work, & play
- Many, many more topics….
Neuro-Robotics Outline

• Understand the evolution of rehab technology aids
  – Stroke (TBI), spinal cord injury, amputation
• Cursory description of devices (high → low tech)
• Compare conventional rehab to robotic therapy
• General findings of rehab technology studies
  – Body weight support treadmill
  – FES/NMES
  – Transcranial magnetic stimulation
  – Constraint Induced Therapy
  – Biofeedback
  – Wii, Virtual Reality

• Barriers to wide spread use of rehab technology

• No Disclosures
Stroke Disability

- Leading cause of **severe** long-term disability
  - Arthritis is the leading cause of overall disability, but generally less severe disability
- AHA 2005
  - 40% moderate functional impairment
  - 15-30% severe disability
- Framingham study (2003):
  - Ischemic stroke survivors ≥ 65 yrs @ 6 months
    - 68% functionally independent (32% not independent)
    - 50% had some hemiparesis
    - 30% unable to walk w/out some help
    - 26% dependent in ADLs
    - 19% had aphasia
    - 35% had depressive Sx
    - 26% were in SNFs
• Strongly recommend that rehabilitation therapy start as early as possible, once medical stability is reached.

• Supports early mobilization of acute stroke pts to prevent complication like DVTs, skin breakdown, contractures, constipation, PNA, etc.

• Recommend that the patient receive as much therapy as “needed” to adapt, recover, and/or reestablish the pre-morbid or optimal level of functional independence.
  – No specific guidelines on intensity, duration, or location of therapies
Better outcomes when pt receive coordinated, multidisciplinary evaluation and intervention (both inpatient & outpatient rehab)

More likely to live at home, more ADL independence, less mortality, higher QOL at 5 yrs

- Cifu et al, Archives PM&R 1999.
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Depression

- Estimated: 25-75%, likely ~40%
- Framingham Study (2003): 35% at 6 months in Medicare pts
- Difficult to Dx: similar to CVA sequelae, grief rxn
- Persistent depression
  - Slower recovery, poorer outcome
- AHA/ASA 2005 guidelines:
  - SSRI (less SE) > TCAs ± methyphenidate
  - Insufficient evidence for/against psychotherapy
  - Assistance from psychologist/psychiatrist if persistent distress or worsening disability
Involuntary Emotional Expression Disorder

- Uncontrollable crying or laughing
  - Unrelated to underlying mood
  - Out of proportion to circumstances
  - Episodic, brief (seconds – minutes)
  - Can be episodic bouts of anger

- Seen in up to 20% post-CVA pts
  - More common in right frontal, brainstem, limbic system, cerebellar CVAs
Involuntary Emotional Expression Disorder

• Tends to improve with time w/out meds, but may be chronic
• Also in ALS, MS, TBI, Alzheimer’s, brain tumors, Parkinson’s
• Educate patient/family

• AHA/ASA Guidelines:
  – Consider meds when “lability interferes with the patient rehabilitation or complicates the patient’s relationship with family members.”
  – SSRIs (fluoxetine, citalopram, sertraline): medication of choice
Involuntary Emotional Expression Disorder

Treatment with SSRIs:

- Clinical effect much quicker than for depression
- Fluoxetine 20mg qday
  - 13/13 decrease episodes w/in 3-14 days
  - Selinger et al, Brain Injury 1992
- Citalopram 20mg qhs (10mg >66yo)
  - 15/15 pts: absent or ↓ episodes
  - Immediate response (1day): 8 pts
  - By 3 days: 3 pts
  - After 3 days: 4 pts
    - Older, earlier CVA pts
    - All relapsed after citalopram stopped (7w follow-up)
    - Andersen et al, Lancet 1993
- Newer more expensive meds
Cognitive Dysfunction

- DDx: stroke sequelae, infection, Sz, hydrocephalus, electrolytes, hypothyroid, medications, premorbid dementia
- Higher cortical function abnormalities in 63.5% post-CVA
  - Aphasia, apraxia, amnesia, executive function
  - Hoffman, Neurorehab NeuroRepair 2001
- Stroke: 2-10x ↑ risk of dementia
- Fatigue: 30-68% post-CVA (de Groot et al, Arch PM&R 2003)
  - Meds: methylphenidate, pemoline, dextroamphetamine, modafinil, amantidine, stimulating antidepressants (ie: bupropion, fluoxetine)
  - Consider use, although no RCT studies in post-CVA
Cognition

• AHA/ASA 2005 Guidelines
  – Against use of:
    (as much as practical)
    • Neuroleptics, benzos, barbiturates, phenytoin during stroke recovery
    • $\alpha_2$-agonists (clonidine),
      $\alpha_1$-antagonists (prazosin, tamsulosin)
    • CNS depressants a/w poorer outcomes
• AHA/ASA 2005 Guidelines
  – Insufficient evidence, but “Consider stimulants/NT-releasing agents in selected pts to improve participation in stroke rehab or to enhance motor recovery.”
    • Dextroamphetamine has been the most tested stimulant at 10mg per day, but insufficient evidence is available with regards to optimal dosing and safety to support routine use of CNS stimulants during rehab.”
  – “Consider bromocriptine or dextroamphetamine in selected aphasic pts.”
  – Also cited small RCT: fluoxetine may improve motor recovery in 48 non-depressed stroke pts (Dam et al, Stroke 1996)
SSRIs for Stroke Recovery

• Low threshold to offer SSRIs: depression, lability, fatigue, and possibly increased neuroplasticity

• Nov 2012 Cochrane Review (plain language summary):

  “Selective serotonin reuptake inhibitors (SSRIs) are a class of drugs that have been in use for many years, mainly for the treatment of mood disorders such as depression. Animal studies have shown that SSRIs may have other direct effects on the brain, such as encouraging the development of new brain cells. If this also occurs in humans, recovery from stroke may be improved. This review brought together the results of 52 trials (4060 participants) of SSRIs in people who had had a stroke in the previous year, to find out whether SSRIs might reduce dependency and disability. The review found promising evidence that SSRIs might improve recovery after stroke, even in patients who were not depressed. Large trials are now needed to confirm or refute these findings, and to determine whether SSRIs increase the risk of side effects such as seizures. If effective, SSRIs would be a low-cost, simple and widely applicable treatment for patients with stroke.”
2011 FLAME Study

Fluoxetine for motor recovery after acute ischaemic stroke (FLAME): a randomised placebo-controlled trial

François Chollet, Jean Tardy, Jean-François Albucher, Claire Thalamas, Emilie Berard, Catherine Lamy, Yannick Bejot, Sandrine Deltour, Assia Jaillard, Philippe Niclot, Benoît Guillon, Thierry Moulin, Philippe Marque, Jérémie Pariente, Catherine Arnaud, Isabelle Loubinoux

- 118 ischemic stroke patients with hemiparesis (France)
- Fugl-Meyer motor scale score (FMMS) of ≤55, 18-85 y.o.
- 59 pts: fluoxetine 20mg/day for 3m 5-10 days post-CVA
  - 59 patients placebo. Both groups had standard rehab care
- FMMS improvement at 90 days
  - SSRI group ~36 pts (17 to 53) vs placebo ~24 pts (13 to 35)
- Adverse events:
  - Hyponatremia: 2 pts [4%] vs 2 pts [4%]
  - GI Sx (nausea, diarrhea, abd pain): 14 [25%] vs 6 [11%]
  - Hepatic enzyme disorder: 5 [9%] vs 10 [18%]
  - Psychiatric disorder: 3 [5%] vs 4 [7%]
  - Insomnia: 19 [33%] vs 20 [36%]
  - Partial Seizures: 1 [<1%] vs 0 [0%]
- Some limitations to this study → debates
Fugl-Meyer Motor Assessment

Developed in 1975: ~30 minute quantitative evaluation of Brunnstrom’s stages of motor recovery in the hemiplegic stroke patient

- 0 dense hemiplegia, 100 normal motor performance

<table>
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<th>Upper Extremity (66 points)</th>
<th>Lower Extremity (34 points)</th>
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<td>Shoulder retraction</td>
<td>Hip flexion</td>
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<tr>
<td>Shoulder elevation</td>
<td>Hip extension (supine)</td>
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<tr>
<td>Shoulder abduction</td>
<td>Hip adduction (supine)</td>
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<tr>
<td>Shoulder abduction to 90 degrees</td>
<td>Knee flexion (supine)</td>
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<tr>
<td>Shoulder adduction/external rotation</td>
<td>Knee flexion (sitting)</td>
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<tr>
<td>Shoulder external rotation</td>
<td>Knee flexion (standing)</td>
</tr>
<tr>
<td>Shoulder flexion 0–90 degrees</td>
<td>Knee extension (supine)</td>
</tr>
<tr>
<td>Shoulder flexion 90–180 degrees</td>
<td>Ankle dorsiflexion (supine)</td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>Ankle dorsiflexion (sitting)</td>
</tr>
<tr>
<td>Elbow extension</td>
<td>Ankle dorsiflexion (standing)</td>
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<tr>
<td>Forearm supination</td>
<td>Ankle plantar flexion (supine)</td>
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<td>Forearm pronation</td>
<td>Heel-shin speed</td>
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<td>Forearm supination/pronation (elbow at 0 degrees)</td>
<td>Heel-shin tremor</td>
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<tr>
<td>Forearm supination/pronation (elbow at 90 degrees, shoulder at 0 degrees)</td>
<td>Heel-shin dysmetria</td>
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<tr>
<td>Hand to lumbar spine</td>
<td>Knee reflex</td>
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<td>Wrist flexion/extension (elbow at 0 degrees)</td>
<td>Hamstring reflex</td>
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<tr>
<td>Wrist flexion/extension (elbow at 90 degrees)</td>
<td>Ankle reflex</td>
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<tr>
<td>Wrist extension against resistance (elbow at 0 degrees)</td>
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<tr>
<td>Wrist extension against resistance (elbow at 90 degrees)</td>
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<tr>
<td>Wrist circumduction</td>
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<td>Finger flexion</td>
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<td>Finger extension</td>
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<td>Extension of MCP joints, flexion of PIPs/DIPs</td>
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<tr>
<td>Thumb adduction</td>
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<td>Thumb opposition</td>
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<td>Grasp cylinder</td>
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<td>Grasp tennis ball</td>
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<tr>
<td>Finger-nose speed</td>
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<tr>
<td>Finger-nose tremor</td>
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<tr>
<td>Finger-nose dysmetria</td>
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<tr>
<td>Finger flexion reflex</td>
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<tr>
<td>Biceps reflex</td>
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<tr>
<td>Triceps reflex</td>
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</tbody>
</table>

*See Fugl-Meyer and others for details and scoring instructions.*
2011 FLAME Study

- **Exclusion Criteria**
  - Severe post-stroke disability: NIHSS > 20
  - Substantial premorbid disability
  - Residual motor deficit from previous stroke
  - Comprehension deficits severe enough to impact motor testing
  - Severe aphasia masking detection of depression
  - Clinically diagnosed with depression pre-stroke
  - Premorbidly taking AD meds, MAO-I, neuroleptics, or benzos
  - Due to undergo CEA
  - Pregnancy or other major illnesses
118 patients randomly assigned

59 allocated to fluoxetine
- 1 died from respiratory distress after inhalation of food
- 1 withdrew (severe hypoxia)
- 57 analysed for primary endpoint in full-analysis set at day 90

59 allocated to placebo
- 1 died from septic shock
- 2 withdrew (1 kidney tumour, 1 pulmonary embolism)
- 56 analysed for primary endpoint in full-analysis set at day 90
## 2011 FLAME Study

### Table 3: Fugl-Meyer motor scale (FMMS) scores

<table>
<thead>
<tr>
<th></th>
<th>Fluoxetine (n=57)</th>
<th>Placebo (n=56)</th>
<th>Difference between groups (95% CI)</th>
<th>p value</th>
</tr>
</thead>
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<tr>
<td><strong>Day 90</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total score</td>
<td>53.7 (27.8)</td>
<td>35.1 (22)</td>
<td>18.6 (9.2 to 27.9)</td>
<td>--</td>
</tr>
<tr>
<td>Mean (SD)</td>
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<tr>
<td>Median (IQR)</td>
<td>59 (28 to 77)</td>
<td>29 (22 to 47.5)</td>
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<td>0.0006*</td>
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<tr>
<td>Upper limb</td>
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<tr>
<td>Mean (SD)</td>
<td>29.7 (22.2)</td>
<td>16.2 (16.6)</td>
<td>13.5 (6.2 to 20.8)</td>
<td>--</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>32 (6 to 50)</td>
<td>10 (4 to 24)</td>
<td>5.1 (2.1 to 8.1)</td>
<td>0.001*</td>
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<tr>
<td>Lower limb</td>
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<tr>
<td>Mean (SD)</td>
<td>24 (7.9)</td>
<td>18.9 (8.2)</td>
<td>5.1 (2.1 to 8.1)</td>
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<tr>
<td>Median (IQR)</td>
<td>27 (19 to 31)</td>
<td>19 (13 to 25)</td>
<td>0.001*</td>
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<td><strong>Change from day 0 to day 90</strong></td>
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<tr>
<td>Total score</td>
<td>36.4 (21.3)</td>
<td>21.9 (16.7)</td>
<td>14.5 (7.3 to 21.6)</td>
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</tr>
<tr>
<td>Mean (SD)</td>
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<tr>
<td><strong>Adjusted mean (95% CI)</strong></td>
<td>34.0 (29.7 to 38.4)</td>
<td>24.3 (19.9 to 28.7)</td>
<td>9.8 (3.4 to 16.1)</td>
<td>0.003†</td>
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<tr>
<td>Upper limb</td>
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</tr>
<tr>
<td>Mean (SD)</td>
<td>24.2 (19.8)</td>
<td>11.8 (14.8)</td>
<td>12.4 (5.9 to 18.9)</td>
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<tr>
<td>Adjusted mean (95% CI)</td>
<td>22.9 (18.6 to 27.1)</td>
<td>13.1 (8.9 to 17.4)</td>
<td>9.7 (3.6 to 15.9)</td>
<td>0.002†</td>
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<tr>
<td>Lower limb</td>
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<tr>
<td>Mean (SD)</td>
<td>12.2 (6.8)</td>
<td>10.1 (6.8)</td>
<td>2.1 (-0.4 to 4.6)</td>
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</tr>
<tr>
<td>Adjusted mean (95% CI)</td>
<td>12.8 (11.1 to 14.5)</td>
<td>9.5 (7.8 to 11.2)</td>
<td>3.3 (0.8 to 5.7)</td>
<td>0.010†</td>
</tr>
</tbody>
</table>

Mean was adjusted for age, history of stroke, and FMMS score at inclusion. *Mann-Whitney U test. †Linear regression including treatment and centre as fixed effects, and confounding factors (age, history of stroke, and FMMS score at inclusion).
2011 FLAME Study

- Slightly better motor NIHSS at 90 days
- modified Rankin scale (mRS) with more independent pts (scores 0-2)

<table>
<thead>
<tr>
<th></th>
<th>Fluoxetine</th>
<th>Placebo</th>
<th>p value</th>
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<td>NIHSS scores on day 90</td>
<td>n=57</td>
<td>n=55</td>
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</tr>
<tr>
<td>Total score, mean (SD)</td>
<td>5.8 (3.7)</td>
<td>6.9 (4.4)</td>
<td>0.151*</td>
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<tr>
<td>Patients with score 0-5, adjusted mean (95% CI)</td>
<td>55% (45 to 64)</td>
<td>43% (34 to 52)</td>
<td>0.193†</td>
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<td>Motor scores, mean (SD)</td>
<td>4.7 (3.2)</td>
<td>6.3 (3.2)</td>
<td>0.012†</td>
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<tr>
<td>mRS scores on day 90</td>
<td>n=57</td>
<td>n=55</td>
<td></td>
</tr>
<tr>
<td>Patients with mRS score 0-2§</td>
<td>15 (26%)</td>
<td>5 (9%)</td>
<td>0.015†</td>
</tr>
<tr>
<td>Patients with mRS score 0-2§, adjusted mean (95% CI)</td>
<td>34% (25 to 43)</td>
<td>11% (6 to 15)</td>
<td>0.021¶</td>
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<td>MADRS scores</td>
<td>n=56</td>
<td>n=54</td>
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<tr>
<td>Day 90, mean (SD)</td>
<td>5.4 (4.9)</td>
<td>8.4 (7.9)</td>
<td></td>
</tr>
<tr>
<td>Day 90, median (IQR)</td>
<td>4.5 (1.5 to 8)</td>
<td>7.5 (0 to 14)</td>
<td>0.101</td>
</tr>
<tr>
<td>Change from day 0 to day 90, mean (SD)</td>
<td>0 (6.1)</td>
<td>3.1 (9.1)</td>
<td></td>
</tr>
<tr>
<td>Change from day 0 to day 90, adjusted mean (95% CI)</td>
<td>-0.1 (-2.1 to 1.9)</td>
<td>3.2 (1.1 to 5.3)</td>
<td>0.032**</td>
</tr>
</tbody>
</table>

Data are number (%), unless otherwise indicated. Mean was adjusted for age, history of stroke, and Fugl-Meyer motor scale score at inclusion. NIHSS=National Institutes of Health stroke scale. mRS=modified Rankin scale. MADRS=Montgomery Åsberg depression rating scale. *Student’s t test. †Binomial regression including treatment and centre as fixed effects, and confounding factors (age, history of stroke, and NIHSS score at inclusion). ¶χ² test. §None of the patients had an mRS score of 0. ¶Binomial regression including treatment and centre as fixed effects, and confounding factors (age, history of stroke, and NIHSS score at inclusion). ||Mann-Whitney U test. **Linear regression including treatment and centre as fixed effects, and confounding factors (age, history of stroke, and Fugl-Meyer motor scale score at inclusion).
Aphasia

- Medication management considered experimental
- Piracetam
  - European studies
  - Unregulated by FDA
  - Cyclic derivative of GABA
- Bromocriptine: ? Improved cerebral blood flow
- Dextroamphetamine: 30 minutes b/f SLP session
- Cholinesterase Inhibitors (donepezil: Alzheimer’s dz)
  - ? augment neuroplasticity
Aphasia

- Melodic intonation therapy
  - ↑ speech melody to ↑ right hemisphere role in inter-hemispheric control of language?

- Constraint Induced Language Therapy
  - Avoid use of compensatory strategies such as gesturing, drawing, writing, etc.

- Transcranial magnetic therapy
  - After stroke, contralesional hemisphere has ↑ excitability
  - ? ipsilesional magnetic stimulation to ↑ ipsilesional excitability, ↓ excitability of contralesional hemisphere
  - Research in Boston
  - ? Motor and language improvements
Neglect & Right Brain Dysfxn

- **Neglect (hemi-inattention):** Failure to report, respond, or orient to stimuli in contralesional space after brain injury
  - Primarily seen in right hemispheric lesions
  - Left >>> right neglect (usually bilat involvement needed)

- **Asomatognosia:** inability to recognize own body part

- **Anosodiaphoria:** indifferent to existence of their illness

- **Effects on hygiene, medical compliance, trauma**

- **Poorest prognosis for independent living of all behavioral problems from focal brain damage**
  - Worse than those with global aphasia, right hemiparesis
Treatment for Neglect

- Many pts improve with time
- Dopaminergic agonists: case reports, no RCT trials
  - Bromocriptine
- Functional adaptation: 6 small RCT
  - Visual, auditory scanning
  - Visual, auditory, verbal cues
    - Red tape, flashing lights, bells
  - Environmental adaptation
  - Pt/family education
  - Limb activation, constraint therapy
  - ? right eye patching
  - Bilat gloves for edema.
- Prism glasses: image distortion to the right (Rosetti et al, Nature 1998)
  - ? Influence on ADLs, transient
- Left ear cold caloric stimulation, neck/hand vibration
  - Transient effect at best
Hemiplegic Shoulder Pain

- Hemiplegic stroke pts: 34-84%
  - Peaks at 4m at 60%, 35% at 6m, 20% at 4y
    - Wanklyn et al, Disabil Rehab 1996

- ↓ outcomes, QOL, mood
- Difficult management, unclear Tx efficacy
Shoulder Pain

• Prevention
  – Avoid pulling of arm with transfers
  – Pillow b/w arm and trunk in bed
  – Avoid sleeping on paretic shoulder
  – Avoid use of overhead pulleys
  – Taping: may delay onset, ↓ pain
  – Insufficient evidence for slings & MWC arm troughs/trays
    • ? GivMohr slings vs neoprene sleeves better

• Meds
  – Acetaminophen, NSAIDS efficacious
  – Steroid injections (intra-articular, subacromial, etc)
  – Botox injections to shoulder IR/Add
    • esp subscapularis (Yelnik 2007)

• Therapies
  – FES to posterior delts, supraspinatus (TC, implanted)
  – Scapular stabilization
  – PROM (esp ER, FF, Abd) to avoid immobilization, adhesive capsulitis
    • Augmented by TENS
Shoulder Pain

• AHA/ASA Guidelines
  – Recommendation for prevention
    • E-stim to improve shoulder lateral rotation
    • Shoulder strapping (sling)
    • Staff education (transfers, lifting, side lying, etc)
    • Avoiding use of overhead pulleys
  – Recommendations for treatment
    • Intra-articular steroid injections
    • Shoulder strapping
    • ROM exercise program, esp ER/abduction
    • Modalities: ice, heat, soft tissue massage
    • FES
    • Strengthening
Spasticity & Contracture Prevention

- Proper bed positioning
- ICU: early PROM with PT/OT, RNs
- Ward: early mobilization
- Daily stretching
- Frequent monitoring of joint ROM
- Resting hand splints
- Posterior foot splints
- Adequate pain control to promote mobility
Serial Casting

- Indications: when PROM, positioning, splinting have failed to correct a contracture
- Goals: increase PROM or prevent PROM loss, reduce hypertonicity, improve long-term function
- Only evidence: improved PROM (Mortenson et al, Phys Ther 2003)
Dynamic and Static Progressive Orthoses

- **Static progressive orthoses**
  - Joint angle held constant for a prescribed time
  - Incremental like serial casting
  - Patient can change joint angle
  - Typically worn 30 minutes BID-TID, can be up to 6-12hrs daily
  - Easier removal than serial casts
  - Can be removed for therapies

- **Dynamic orthoses**
  - Torque generated by a coil, gas, or flat spring
  - Coil spring, gas spring, clockwork or flat spring
  - Occasional adjustment w/ ∆ROM
Oral Medications

- Baclofen: pre-synaptic GABA “B” agonist
- Tizanidine: $\alpha_2$-adrenergic agonist
- Dantrium: blocks Ca++ release from SR
- Diazepam: enhances post-synaptic GABA effect
- Gabapentin, Pregaglin
- THC (other cannabis)
Botulinum Toxin

- Botulinum toxin A (or B) for spasticity
  - Neurotoxins from Clostridium botulinum
  - Potent pre-synaptic blockade of acetylcholine at NMJ
  - Intramuscular injection
    ± EMG guidance
    or muscle stimulation
Spasticity

- AHA/ASA Guidelines
  - Tx spasticity/contractures: antispastic positioning, ROM exercises, stretching, splinting, serial casting, or surgical correction
  - Against use of benzos during stroke recovery
  - For disabling spasticity, poor skin hygiene, or decrease function, consider use of
    - Tizanidine, dantrolene, baclofen
    - Botulinum toxin, phenol/alcohol
    - Intrathecal baclofen
    - Neurosurgical procedures, such as selective dorsal rhizotomy or dorsal root entry zone lesion
Other Complication Rates

• Pulmonary Embolism: 13-16% of acute stroke deaths
  – ~3% PE incidence after stroke
  – 50% of pts with PEs after stroke die
  – Leading cause of death in 2-4th week post-CVA
• Malnutrition upon rehab admission
  – 49% malnourished: all stroke pts
  – 65% malnourished: stroke pts with dysphagia
• Bladder Incontinence: 50-70% in 1st month, 15% after 6 months (~general population)
Other Complication Rates

- Immediate post-CVA central pain onset 20%
  - 50% in 1st month
  - 30% 1-36 months
- CRPS type I: 12-25% of stroke pts
  - After CVA, nerve traction w/ subluxation, nerve impingement
- Post-stroke Seizures: 5-20% post-CVA
  - 1/3 tonic-clonic, 2/3 partial Sz
- 20-40% w/ post-CVA sleep-wake disorders
  - Insomnia, excessive daytime sleepiness, fatigue, hypersomnia, apnea
Other Complication Rates

- Dysphagia present in 20-90% of hospitalized stroke patients
  - Likely approx 30-45%, AHA/ASA 45%
  - Brainstem > bilateral CVAs > left CVAs ~ right CVAs
- Pneumonia accounts for up to 34% of all stroke deaths
  - Leading cause of death in 2nd and 3rd months post-CVA
    - 3rd leading cause in 1st month
    - 1st week: stroke itself
    - 2-4th week: PE
Neuro-Robotics Outline

• Understand the evolution of rehab technology aids
  – Stroke (TBI), spinal cord injury, amputation
• Cursory description of devices (high → low tech)
• Compare conventional rehab to robotic therapy
• General findings of rehab technology studies
• Barriers to wide spread use of rehab technology
The Future: Bionics & Robotics

I, Robot (left arm)

RoboCop (whole body exoskeleton)

Terminator (pure robot)

The Six Million Dollar Man (right arm, both legs, left eye)
What path?

How Do We Get There?

Evidence-Based Medicine

Clinical Judgment  Outcomes Research

(c) 2004, Richard Slivka, Smurr, MD

SWEDISH MEDICAL GROUP
Cutting Edge Technology

Exoskeleton Devices

Brain Computer Interfaces

EEG

Intracortical

Prosthetics

Dean Kamen, Todd Kuiken

EMG/FES

NASA

+/- mirrors
- Pennsylvania local news
  https://www.youtube.com/watch?v=8xH7HSs2dik

- NHK World (Japan’s public broadcasting network)
  https://www.youtube.com/watch?v=2Ysb-Oko3Bg&ebc=ANyPxKpw1JnXV44_5ILShrAUOFkCvttg6ji7qbZrd8nB06c695691jpEWtRrjWkAi7pLPG4-Nok

- Both can be used as active and passive devices
- Most exoskeleton devices are passive devices like orthotics
Voluntary driven exoskeleton as a new tool for rehabilitation in chronic spinal cord injury: a pilot study

Mirko Aach, MD\textsuperscript{a,\ast}, Oliver Cruciger, MD\textsuperscript{a}, Matthias Sczesny-Kaiser, MD\textsuperscript{b}, Oliver Höffken, MD\textsuperscript{b}, Renate Ch. Meindl, MD\textsuperscript{a}, Martin Tegenthoff, MD\textsuperscript{b}, Peter Schwenkreis, MD\textsuperscript{b}, Yoshiyuki Sankai, PhD\textsuperscript{c}, Thomas A. Schildhauer, MD\textsuperscript{d}

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Received 17 December 2013; revised 20 March 2014; accepted 28 March 2014

- 8 chronic motor incomplete SCI patients (ASIA A/B w/ ZPP & C/D)
  - 1-19 years post-injury (mean ± SD: 97.2 ± 88.44 months)
- Must have trace motor function at KE, KF, HF, ± HE to trigger the exoskeleton EMG surface electrodes
- Completed acute & subacute rehab at German L&I center
  - Months of inpatient rehab similar to the U.S. in past decades
- Exoskeleton training with BWSTT: 5 days/week x12 weeks for 90 minute sessions (device donning/doffing & therapy)
2013-2014 HAL Exoskeleton Study

- Functional outcome measures: treadmill walking distance/speed/time, 10-meter walk test, time-up and go, 6-minute walk test, walking index for SCI II (WISCI ii)
- Physiologic measures: modified Ashworth scale, lower extremity motor score, lower extremity circumference also measured and improved
- Mean WISCI II score improvement not statistically significant
  - 1 pt improved from 6 (FWW, brace, w/ assist) to 9 (FWW, brace, w/out assist)
  - 1 pt improved from 9 to 12 (2 crutches, brace, w/out assist)

<table>
<thead>
<tr>
<th>Comparison of pre- and postinterventions</th>
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<tbody>
<tr>
<td>Outcome measurements</td>
</tr>
<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td>10MWT speed (m/s)</td>
</tr>
<tr>
<td>Number of steps</td>
</tr>
<tr>
<td>6MWT distance (m)</td>
</tr>
<tr>
<td>TUG test (s)</td>
</tr>
<tr>
<td>Distance (m)</td>
</tr>
<tr>
<td>WISCI-II</td>
</tr>
</tbody>
</table>

10MWT, 10-m walk test; 6MWT, 6-minute walk test; TUG, timed-up and go; WISCI, walking index for spinal cord injury.

Note: Values are means±standard deviation.
* Pre-post difference, p<.05.
<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Client is unable to stand and/or participate in assisted walking.</td>
</tr>
<tr>
<td>1</td>
<td>Ambulates in parallel bars, with braces and physical assistance of two persons, less than 10 meters</td>
</tr>
<tr>
<td>2</td>
<td>Ambulates in parallel bars, with braces and physical assistance of two persons, 10 meters.</td>
</tr>
<tr>
<td>3</td>
<td>Ambulates in parallel bars, with braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>4</td>
<td>Ambulates in parallel bars, no braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>5</td>
<td>Ambulates in parallel bars, with no braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>6</td>
<td>Ambulates with walker, with braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>7</td>
<td>Ambulates with two crutches, with braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>8</td>
<td>Ambulates with walker, no braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>9</td>
<td>Ambulates with walker, with braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>10</td>
<td>Ambulates with one cane/crutch, with braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>11</td>
<td>Ambulates with two crutches, no braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>12</td>
<td>Ambulates with two crutches, with braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>13</td>
<td>Ambulates with walker, no braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>14</td>
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<tr>
<td>15</td>
<td>Ambulates with one cane/crutch, with braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>16</td>
<td>Ambulates with two crutches, no braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>17</td>
<td>Ambulates with on devices, no braces and physical assistance of one person, 10 meters.</td>
</tr>
<tr>
<td>18</td>
<td>Ambulates with on devices, with braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>19</td>
<td>Ambulates with one cane/crutch, no braces and no physical assistance, 10 meters.</td>
</tr>
<tr>
<td>20</td>
<td>Ambulates with no devices, no braces and no physical assistance, 10 meters.</td>
</tr>
</tbody>
</table>
Variable Availability

Virtual Reality

Dysphagia
Biofeedback

TMS
Widely Available Devices

Body Weight
Supported Treadmill

Wheelchairs

Orthotics

FES
Many, Many More Devices
Traditional Devices

Walkers

Crutches

Canes

Splints
Limits of Conventional NeuroRehab

• Requires hours of therapy time
  – Increasing therapy labor costs
    • UK: ~10% of national stroke budget
    • Aging population (ex: Japan) relative to trained therapists
  – Rural access to specialists

• Frequent safety risks for patients & therapists

• Lacks repetition found to optimize neuroplasticity
  – Body Weight Supported Treadmill training vs conventional
  – Up to 1000 gait cycles in 30 min vs <50 cycles

• Low Compliance: home > hospital
  – Less engaging/entertaining (VR), 1:1 hands-on supervision

• Difficult to obtain standard study objective measures
Benefits of Conventional NeuroRehab

• Teaches compensatory strategies
  – Hemi technique for walking, dressing, eating, and other ADLs
• Much more adaptable and personalized
• Whole body > segmental approach
• Compensate for abnormal movement patterns
• Accounts for emotional & clinical status quickly
  – Provide motivation for patients in real time
• Accounts for cognitive and sensory deficits
  – Complex tasks such as stairs, toileting, gait on uneven terrain, etc.
  – Performance of actual tasks instead of simulated tasks
• Use of cheaper and more available assistive devices
  – Disability produces large financial burden, limited funds
Paradigm Shift

• Conventional therapy shifting towards technology assisted rehab

• Move away from hospital care to home/clinic based care

• Technological advances
  – Smaller processors, more complex software
  – Light weight/stronger materials, better batteries
  – Telemedicine: distant supervision, multiple pts
  – Innovative human-machine interfaces
  – Accurate physiological sensors and actuators
    • Haptics, gyroscopes, EMG, FES, electrocortical
Paradigm Shift

• Economic and marketing forces
  – Widespread use leads to cheaper devices
    • Nintendo Wii & Xbox Kinect
  – Commercialization of devices
  – Patients and families drawn to new technology
  – Marketing advantage for rehab facilities
  – ? ultimate rationale: escalating labor costs
    • Debate on its inevitability

• Benefits of robotics
  • Simulated tasks when actual tasks are dangerous
  • More entertaining therapy (increase compliance)
  • Increased repetition to promote neuroplasticity
  • Replace missing or damaged body parts
  • Psychological benefits
Paradigm Shift

• Will clinical insights keep pace with technological innovation?
  – Protocols for using technology safely and effectively
    • When, Who, Where, Dosage, Insurance coverage?
  – Keeping up with patient demands, expectations
  – ? evidence based medicine, ? enough large RCT studies
Growth in peer-reviewed articles published on rehabilitation robotics. Based on Ovid search on terms (rehabilitation or stroke or spinal cord injury or cerebral palsy) and (robotics or robot) performed on November 8, 2011.
Rehab Robotics Studies

• Primarily studied in stroke population
  – Less studies in SCI and amputation
• Upper extremity > gait devices
  – Generally smaller and less expensive devices
• Most studies are small, single-center, non-randomized
• Often suboptimal control interventions
  – Difficult to account for natural recovery
  – Limited physiological ability to improve
    • Underlying disease, residual deficit, plateau effect
• Gains often comparable to conventional therapy
  – When comparing to dose-matched treatments
Rehab Robotics Studies

- Devices typically focus on very specific movements
  - Usually targeting 1-2 large joints with single purpose
  - More difficult for small joints (wrist, fingers)
  - Primary goal is on restoration of neurologic impairments
    - Less on providing compensatory strategies
  - Most devices unable to account for sensory deficits
  - Difficult to demonstrate superior functional improvements
Rehab Robotics Studies

• Cochrane Review 2012 (19 studies, n=666)
• Mehrholz: Electromechanical and robot-assisted arm training for improving generic ADL, arm function, and arm muscle strength after stroke

“Electromechanical and robot-assisted arm training did improve generic activities of daily living in people after stroke and may have improved arm function, but did not improve muscle strength of the partial paralyzed (paretic) arm. Because adverse events were rare, based on the data of 19 trials, these devices could be applied as a rehabilitation tool, but we still do not know when, and how often they should be used.”

• 2008 Cochrane Mehrholz Review (11 studies, n=328)
  – Safe, well accepted and improved function, but little evidence for ADLs.
BWSTT Studies

• Cochrane Review 2005/2009 (15 studies, n= 622)
• Moseley: Treadmill training and body-weight support for walking after stroke

“Overall no statistically significant effect of treadmill training with or without body weight support was detected. Although individual studies suggested that treadmill training with body weight support may be more effective than treadmill training alone and that treadmill training plus task-oriented exercise may be more effective than sham exercises, further trials are required to confirm these findings.”
• RCT in acute CVA: equal (Nilsson et al, Clinical Rehab 2001)
  – Severe CVA pts: BWSTT better tolerated than traditional therapy treadmill (Danielsson et al, Archives PMR 2000)

• AHA/ASA 2005 Guidelines
  • Recommends BWSTT as an adjunct to conventional therapy in pts w/ mild-to-moderate dysfunction resulting in impaired gait.
  • Recommends BWSTT for pts who are not walking 3m post-CVA (Royal College of Physicians 2004)
AHA/ASA 2005 Guidelines
- Recommends FES for pts with:
  - Impaired muscle contraction (esp ankle, knee, wrist)
  - Shoulder subluxation
- Insufficient evidence to recommend for or against using multi-channel FES for severe hemiplegic pts with gait impairments
- Recommends FES for gait training in stroke
• Cochrane Review, 2006 by Pomeroy, et al. “at present, there are insufficient robust data to inform clinical use of electro-stimulation for neuromuscular retraining. Research is needed to address specific questions about the type of electro-stimulation that might be the most effective, in what dose and at what time after stroke”. 
Insurance FES Clinical Policy

• .... considers NMES experimental and investigational for improvements of muscle strength, reduction in spasticity and atrophy, and facilitation of functional movement due to any of the following conditions:
  • SCI  
  • Stroke  
  • Cerebral Palsy  
  • Bell’s Palsy  
  • Other UMN disorders

*Last review 3/24/2009
Barriers to Wide Spread Use

• US FDA policy on medical devices
  – Less rigorous clearance for sale compared to medications
  – 510(k) mechanism: promotes innovation on low-risk devices
  – Medical Device Innovation Initiative: Feb 2011
    • Brain-controlled, upper-extremity prosthesis: pilot for the program.
  – Less pressure for industry studies
    • Little data on clinical efficacy
Barriers to Wide Spread Use

• Expensive devices generally not covered by insurance
  – No compelling evidence of its superiority
    • Primarily viewed as an adjunct to conventional therapy
  – Era of healthcare cost containment
  – Primarily at large rehab centers (east > mid-west > west)
    • Generally from research or rehab facility marketing funds
    • No additional therapy billing charges
    • Marketing advantage in competitive rehab environments
  – Limited ability for out-of-pocket purchase by vast majority
Marketing Advantage

- Many, many robotic product highlighted on rehab center websites.
- Moss Rehab (Philadelphia, Dr. Esquenazi)
- University of Pittsburg (Dr. Boninger)
- Pushing Boundaries
- Swedish
  - BWSTT, vision board, video game consoles, FES UE/LE/bike, balance biofeedback, overhead ceiling lift, dysphagia biofeedback
  - Similar to other NW ARUs +/-
  - Use of robotics for research at UW/VA/Swedish → goals clinically
    - Used clinically on East Coast
  - Likely available at large rehab centers
Summary

• Discovery Channel: Dr. Michael Boninger, University of Pittsburg, PM&R Department
  https://www.youtube.com/watch?v=STUBkUvKjJQ

• Many fascinating devices
• Increasing public curiosity
• Technology outpacing useful clinical protocols
  – Similar efficacy to conventional therapy
• Limited use in clinical practice currently
  – Most rehab centers with limited high-tech devices
Robotics Summary

• Many pros/cons to conventional and robotic therapy
  – Ultimately a blending of the two approaches
  – Optimize neurological recovery while addressing compensatory strategies
• Ongoing need for clinical studies
• Financial barriers for widespread use
  – Innovation > insurance coverage
• Marketing advantage for large rehab centers
Final Remarks

• Coordinated post-stroke therapy and medical care
• Many exciting devices and studies
• Future: combining therapy principals, traditional devices, robotics, body-computer interfaces, medications (SSRIs), and regeneration techniques (TMS, gene/stem cell)
• Keep up and stay informed about innovations
Resources

- Rehabilitation of Stroke and Neurodegenerative Disorders
  - PM&R Journal, March 2009 Supplement, Study Guide
- AHA/ASA - Endorsed Practice Guidelines
  - Management of Adult Stroke Rehabilitation Care: A Clinical Practice Guideline: 2005
  - http://stroke.ahajournals.org/cgi/reprint/36/9/e100
- AHA/ASA: Get With The Guidelines
  - Various practice guidelines: acute to chronic stroke
- Royal College of Physicians 2012 National clinical guidelines

Thanks

Questions?