Predicting Recovery after a Stroke

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Wouldn’t it be great if...

• we could predict if a stroke survivor was going to regain functional use of their hand.
• we could predict if a stroke survivor was going to walk independently again.
• we could predict if a stroke survivor was going to be able to communicate effectively with words.
• tell them and their family what to expect as far as recovery.
How might this information affect how we practice?

- Length of hospital stay
- Types of services ordered and covered
- Discharge location
- Length/intensity of services offered
- Realistic goals
- More personalized treatment
- Patient and family empowerment
Outline

• Predicting Recovery of Arm/Hand Function
• Predicting Recovery of Locomotion
• Prediction Aphasia Recovery
Predicting Recovery of Arm/Hand Function

- Multiple studies have demonstrated that UE strength early after a stroke can predict scores on Functional Outcome Measures at 3 or 6 months post stroke.
  - Patients with active shoulder abduction (MRC grade 1) and some active finger extension after mass finger grasp within 72 hours of stroke onset have a 98% probability of improving by at least 10 points or more on the Action Research Arm Test at 6-month follow-up. (Nijland et al 2010)
    - Those without either only have a 24% chance
    - Those with only one have between a 73% and 84% chance
Predicting Recovery of Arm/Hand Function

– A combined MRC score of 8 or better in testing shoulder abduction and finger extension 72 hours after stroke predicts a score of 54 or better on Action Research Arm Test at 12 weeks after stroke. (Stinear et al 2010)

– The presence of active finger extension at 7 days after stroke predicts higher Barthel Index scores and better hand ability at 6 months as measured by 9-hole peg test, Fugl Meyer, and motricity index (Samnia et al 2007, 2009)
Predicting Recovery of Arm/Hand Function

– Proportional Recovery Rule

• In individuals with mild to moderate upper extremity paresis, initial Fugl Meyer Score (within a few days after stroke) can predict Fugl Meyer Score at 3 months.

• (Total Possible Score – Initial Score) x .7 = the predicted change in score

• This best holds true for individuals who have some level of preserved corticospinal tract function, as measured by TMS

Predicting Recovery of Arm/Hand Function

– Imaging
  • MRI imaging of the corticospinal tract in the internal capsule and transcranial magnetic stimulation (TMS) have been used to assess the intactness of the corticospinal tract.
  • If weighted corticospinal tract lesion load (wCST-LL) in the internal capsule was $\geq 7.0$cc as measured by diffusion weighted imaging, then upper extremity Fugl Meyer score will be $\leq 25$ at 3 months, i.e. poor outcome

Feng et al 2015
Predicting Recovery of Arm/Hand Function

<table>
<thead>
<tr>
<th>Patients</th>
<th>FM-UE</th>
<th>NIHSS</th>
<th>Lesion Size (cc)</th>
<th>Weighted Lesion Load (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acute</td>
<td>3 mo.</td>
<td>Acute</td>
<td>3 mo.</td>
</tr>
<tr>
<td>A</td>
<td>8</td>
<td>8</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td>11</td>
<td>65</td>
<td>13</td>
<td>1</td>
</tr>
</tbody>
</table>

Feng et al 2015
Predicting Recovery of Arm/Hand Function

• Imaging has now been combined with the functional data to create predictive algorithms

• One algorithm for predicting UE function that uses both strength and imaging data is the PREP2 algorithm
PREP2 Algorithm

http://presto.auckland.ac.nz/

Stinear et al 2017
PreP2 Algorithm

• Transcranial Magnetic Stimulation (TMS)
PREP2 Algorithm

• NIH Stroke Scale (NIHSS)
  – 15 item scale
  – Each item max score ranges from 2-4
  – Max score is 42
  – Lower score is better

PREP2 Algorithm

- NIH Stroke Scale (NIHSS)

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Minor stroke</td>
</tr>
<tr>
<td>5-15</td>
<td>Moderate stroke</td>
</tr>
<tr>
<td>15-20</td>
<td>Moderate/severe stroke</td>
</tr>
<tr>
<td>21-42</td>
<td>Severe stroke</td>
</tr>
</tbody>
</table>
PREP2 Algorithm

- Action Research Arm Test (ARAT)
  - The ARAT's is a 19 item measure divided into 4 sub-tests (grasp, grip, pinch, and gross arm movement).
  - Performance on each item is rated on a 4-point ordinal scale ranging from:
    3) Performs test normally
    2) Completes test, but takes abnormally long or has great difficulty
    1) Performs test partially
    0) Can perform no part of test
  - Max Score is 57

https://www.sralab.org/rehabilitation-measures/action-research-arm-test
Table 2. ARAT scores for functional outcome categories 3 months poststroke.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Mean</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>56</td>
<td>57</td>
<td>50</td>
<td>57</td>
<td>113</td>
</tr>
<tr>
<td>Good</td>
<td>43</td>
<td>42</td>
<td>34</td>
<td>48</td>
<td>55</td>
</tr>
<tr>
<td>Limited</td>
<td>22</td>
<td>22</td>
<td>13</td>
<td>31</td>
<td>16</td>
</tr>
<tr>
<td>Poor</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>23</td>
</tr>
</tbody>
</table>

PREP2: Overall accuracy 75%
- Excellent N = 113: PPV (95% CI) = 79% (73–84%), NPV (95% CI) = 83% (75–89%), Accuracy for SAFE ≥ 5 = 78%, Accuracy for SAFE < 5 = 70%
- Good N = 55: PPV (95% CI) = 58% (46–68%), NPV (95% CI) = 84% (79–88%), Accuracy for SAFE ≥ 5 = 78%, Accuracy for SAFE < 5 = 70%
- Limited N = 16: PPV (95% CI) = 86% (44–98%), NPV (95% CI) = 95% (93–97%), Accuracy for SAFE ≥ 5 = 78%, Accuracy for SAFE < 5 = 70%
- Poor N = 23: PPV (95% CI) = 91% (73–98%), NPV (95% CI) = 99% (96–100%), Accuracy for SAFE ≥ 5 = 78%, Accuracy for SAFE < 5 = 70%

Stinear et al 2017
Predicting Recovery of Arm/Hand Function

• Bottom Lines
  – Active control of shoulder abduction and finger extension early after stroke predict better functional recovery
  – Preservation of the CST in the internal capsule is important for recovery
  – In many stroke survivors 70% of available recovery will be seen in the first 3 months
Rehab After Stroke, Recommendations

• UE
  – http://www.viatherapy.org/
Predicting Recovery of Locomotion

- Two predictive models have emerged that use trunk control/sitting balance, and lower extremity strength to predict independent walking (Veerbeek et al 2011, Smith et al 2017)
Predicting Recovery of Locomotion

Table 3. Probabilities of Achieving Independent Gait Six Months Post Stroke (N = 154)

<table>
<thead>
<tr>
<th>Determinants</th>
<th>TCT-s</th>
<th>MI leg</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutoff Model &lt;72 hours</td>
<td>25</td>
<td>≥25</td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>.98</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>−</td>
<td>.85</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>+</td>
<td>.75</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>−</td>
<td>.27</td>
</tr>
<tr>
<td>Model day 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>.96</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>−</td>
<td>.83</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>+</td>
<td>.59</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>−</td>
<td>.23</td>
</tr>
<tr>
<td>Model day 9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>.96</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>−</td>
<td>.80</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>+</td>
<td>.40</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>−</td>
<td>.10</td>
</tr>
</tbody>
</table>

Abbreviations: FAC, Functional Ambulation Categories; TCT-s, Trunk Control Test sitting balance; MI leg, Motricity Index, lower extremity.

Probability of I walking at 6 months

Modified from Veerbeek et al 2011
Predicting Recovery of Locomotion

• Functional Ambulation Category (FAC)

0) Patient cannot walk, or needs help from 2 or more persons
1) Patient needs firm continuous support from 1 person who helps carrying weight and with balance
2) Patient needs continuous or intermittent support of one person to help with balance and coordination
3) Patient requires verbal supervision or stand-by help from one person without physical contact
4) Patient can walk independently on level ground, but requires help on stairs, slopes or uneven surfaces
5) Patient can walk independently anywhere
Predicting Recovery of Locomotion

- **TCT-s (Trunk Control-Sitting)**
  - Can the patient sit unsupported for 30 seconds?
    - If yes then get 25, if no then 0

- **MI Leg (Motricity Index Leg)**
  - Patient in sitting position (hip 90-knee 90)
  - Score each of the following movements
    - Dorsiflexion of the ankle
    - Extension of the knee
    - Flexion of the hip
  - Looking for a total score of 25

Veerbeek et al 2011
Motricity Index Leg

The lower extremity scores for muscle strength using the Motricity index.

<table>
<thead>
<tr>
<th>Quality of muscle contraction</th>
<th>Motricity scores</th>
<th>MRC Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Movement</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Palpable contraction in muscle, but No Movement</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Visible Movement, but not full range against Gravity</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Full range of Movement against Gravity, but not against resistance</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Full Movement against gravity, but weaker than the other side</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Normal Power</td>
<td>33</td>
<td>5</td>
</tr>
</tbody>
</table>

Demeurisse (1990)
Predicting Recovery of Locomotion

• Bottom Line for Veerbeek’s model
  – If a patient can sit unsupported for 30 seconds and has visible contractions in the tibialis anterior, quadriceps, and iliopsoas/rectus femoris by day 9 after their stroke, they have a 96% probability of walking independently at 6 months.
  – If they don’t have any of this, then the probability is only 10%.

Veerbeek et al 2011
Predicting Recovery of Locomotion

TWIST Algorithm

TCT > 40 → Hip extension ≥ 3

1 week

Hip extension ≥ 3 → 6 WEEKS

Hip extension < 3 → DEPENDENT

1 week

At 12 weeks

http://presto.auckland.ac.nz/

Smith et al 2017
Predicting Recovery of Locomotion

- TWIST
  - Trunk Control Test

<table>
<thead>
<tr>
<th>4 Items</th>
<th>Score for Each Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Rolling to weak side</td>
<td>0 = unable to perform movement without assistance.</td>
</tr>
<tr>
<td>2) Rolling to strong side</td>
<td>12 = able to perform movement, but in an abnormal style, for example, pulls on bed</td>
</tr>
<tr>
<td></td>
<td>clothes, rope or monkey pole, or uses arms to steady self when sitting.</td>
</tr>
<tr>
<td>3) Balance in sitting position</td>
<td>25 = able to complete movement normally.</td>
</tr>
<tr>
<td>(unsupported for 30s)</td>
<td></td>
</tr>
<tr>
<td>4) Sit up from lying down</td>
<td>Score range: 0-100</td>
</tr>
</tbody>
</table>
Predicting Recovery of Locomotion

• Bottom Line for TWIST
  – If a patient has a modest amount of trunk control and can flex their hip against gravity within 7 days after stroke they have a 95% probability of walking independently at 12 weeks.

Veerbeek et al 2011
Predicting Recovery of Locomotion

• The breadth of deficits also predict recovery of locomotion
  – 90% of those with only motor deficits are independent walkers at 14 weeks after stroke
  – 35% with motor and sensory deficits walk at 22 weeks
  – 3% of those with motor, sensory, and visual deficits are walking on their own even at 30 weeks after stroke.

Harvey 2015, from Reding and Potes 1988
Predicting Aphasia Recovery

- A review of the factors predicting aphasia recovery after stroke was published in 2015 (Watila and Balarabe 2015).
  - Predictors were broken down into:
    - Lesion (stroke) related factors
    - Non-lesion (patient) related factors
Predicting Aphasia Recovery

Summary: Superior temporal gyrus lesions, more severe initial aphasia, delayed return cerebral blood flow, and decreased cerebral metabolic rate area all associated with decreased aphasia recovery.
### Predicting Aphasia Recovery

**Summary:** There is some evidence that suggest that age and sex can predict aphasia recovery.

<table>
<thead>
<tr>
<th>Non-lesion related factors</th>
<th>Females recover better than males in oral expression</th>
<th>Basso et al. [3,5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Females with global aphasia had better improvement</td>
<td>Pizzamiglio et al. [80]</td>
</tr>
<tr>
<td></td>
<td>No gender difference in aphasia recovery</td>
<td>Pedersen et al. [77]; Lendrem &amp; Lincoln [61]; Inatomi et al. [44]; Seniów et al. [92]; Godefroy et al. [28]</td>
</tr>
<tr>
<td>Age</td>
<td>Older age predicts poorer aphasia recovery</td>
<td>Pickersgill &amp; Lincoln [79]; Lendrem &amp; Lincoln [61]; Laska et al. [56]</td>
</tr>
<tr>
<td></td>
<td>Non-significant tendency towards an age influence</td>
<td>Kertesz &amp; McCabe [51]; Pedersen et al. [77]</td>
</tr>
<tr>
<td></td>
<td>Age does not predict aphasia recovery</td>
<td>Lazar et al. [58]; Lendrem &amp; Lincoln [61]; Holland et al. [41]; Inatomi et al. [44]; Seniów et al. [92]; Pedersen et al. [78]</td>
</tr>
<tr>
<td>Handedness</td>
<td>No influence of handedness on aphasia recovery</td>
<td>Seniów et al. [92]; Pickersgill &amp; Lincoln [79]</td>
</tr>
<tr>
<td>Preexisting cognitive deficits</td>
<td>A correlation between cognitive decline and aphasia recovery, which was stronger in post-traumatic aphasia</td>
<td>Vukovic et al. [96]</td>
</tr>
<tr>
<td></td>
<td>The role of cognitive deficit remains unclear</td>
<td>Leff et al. [60]</td>
</tr>
<tr>
<td>Education</td>
<td>A preserved visuo-spatial working memory is associated with better improvement in comprehension and naming</td>
<td>Seniów et al. [92]; Lazar et al. [58]</td>
</tr>
<tr>
<td></td>
<td>No relationship between educational attainment and aphasia recovery</td>
<td>Connor et al. [15]; Lazar et al. [58]</td>
</tr>
</tbody>
</table>
Predicting Aphasia Recovery

- Left Superior Temporal Gyrus and/or Superior Longitudinal Fasciculus/Arcuate Fasciculus lesions are associated with poorer recovery of naming.

- Use of SSRI’s is associated with improved recovery of naming in individuals with L STG and/or SLF/AF lesions.

Hillis et al 2018
Predicting Aphasia Recovery

• Proportional Recovery Rule
  – Change in score on the Western Aphasia Battery at 3 months for stroke survivors with mild to moderate aphasia can be predicted by the following equation:
    • \((WAB_{\text{max}} - WAB_{\text{initial}}) \times .73\)
      – \((WAB \text{ naming}_{\text{max}} - WAB \text{ naming}_{\text{initial}}) \times .68\)
      – \((WAB \text{ repetition}_{\text{max}} - WAB \text{ repetition}_{\text{initial}}) \times .70\)
      – \((WAB \text{ comprehension}_{\text{max}} - WAB \text{ comprehension}_{\text{initial}}) \times .83\)

Lazar et al 2010
Predicting Aphasia Recovery

• Bottom Line:
  – Aphasia recovery appears most associated with lesion location (STG and SLF/AF) and initial impairment.
  – Efforts are currently underway to improve prediction: http://www.ucl.ac.uk/ploras
Summary

• Functional tests and noninvasive imaging performed during the first week post stroke can predict recovery of UE and LE function at 6 months with a fair amount of accuracy.

• Lesion location and initial impairment appear to be the best predictors of aphasia recovery.
Questions?