Motor and Cognitive Neurorehabilitation: Diagnosis and Prognosis in Treatment Planning

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Disclosures
Douglas Katz, MD has no financial interest to disclose.

Brigid Dwyer, MD has no financial interest to disclose.

This presentation may include information on off-label use of medications.

Outline
• Models of rehabilitation: traditional & neurological
• Recovery: predictors, recovery curves, pathophysiology, neuroplasticity
• TBI as example:
  – natural history diffuse and focal injury
  – Predictors outcome: domain general vs. domain specific
  – Neural organization of function and recovery
• Neurological model as guide to rehabilitation (case examples)
Outline

• Discuss how neurological diagnosis and prognosis can be used to guide rehabilitation treatment for cognitive and behavioral problems.
• Explain expectations for motor recovery in the post-acute period.
• Identify aspects of care that are especially important in facilitating optimal recovery

Traditional Model of Rehabilitation

Traditional Rehabilitation Model

• Diagnosis / functional assessment:
  – Based on WHO International Classification of Functioning framework on health and disability: health condition, body functions and structures, activities, participation in the context of environmental and personal factors
  – Emphasis on present functional manifestations
  – Amalgam of team members’ assessments
  – Periodic reassessment to track recovery / response to therapy
• Treatment planning:
  – Treatment goals for each functional problem
  – Preference for evidence-based treatment, best-practices
  – Reassess & adjust goals periodically
  – Strategies aiming for best functioning possible during this epoch of treatment (shorter term recovery horizon)
  – Develop plan and recommendations for next setting
Neurological Model of Rehabilitation

• Diagnosis:
  – clinical impairments in relation to neuropathology
  – functional dx in context of impairments & neurologic syndromes

• Prognosis:
  – project recovery based on dx, natural history and other factors (personal, social, environmental)

• Rx planning:
  – Inform rx strategies & goals in context of neuro syndromes, stage of recovery and outcome expectations.
  – Strategies to enhance and extend adaptive neuroplasticity to restore function
  – Strategies to emphasize compensation and environmental adaptations when natural history suggests futile restorative goals


Factors Influencing Recovery

Multiple interacting factors

• Pathologic consequences largely determine the clinical consequences, especially in earlier course of recovery.

• Comorbid factors may have an important effect on recovery (other injuries, illnesses, medical complications, iatrogenic)

• Other non-injury factors influence recovery, especially later in the course (e.g., personal characteristics, age, psychological, environmental, educational, vocational, financial).
RECOVERY CURVES: Recovery and TBI severity
Arciniegas DB et al., 2010

Time (days)
1 7 14
Time (months)

Baseline or Recovery
Posttraumatic Amnesia
Posttraumatic Confusional State
Posttraumatic Coma
Posttraumatic Dysexecutive Syndrome

Stage of Posttraumatic Encephalopathy

RECOVERY CURVES:
Recovery and TBI severity
Arciniegas DB et al., 2010

Time (months)
5 10

Copenhagen Stroke Study 1995

Recovery CNS Injury
e.g., Stroke Recovery Curves for best outcome of ADLs

Weeks From Stroke Onset
1 2 3 4 6 8 10 12 13 14 16 17 18 19 20 20

% of Total Recovery
100 80 60 40 20 0

More severe

Recovery of ADLs after Stroke

Initial Motor Score

Initial assessment
3 6 12

Months Poststroke

Final assessment

High (over 60)
Medium (41 - 60)
Low (up to and including 40)
Neuropsych recovery curves over 2 years related to TBI severity

Pathophysiology of recovery

Neuroplasticity

- A property of the brain that allows it to change structure and function in response to
  - sensing and perceiving, experiencing
  - moving, interacting and achieving goals
  - thinking and imagining
- Involved in learning, memory, acquiring skills
- Involved in neural repair and recovery after brain damage and disability

Nudo & Dancause, 2007

Predicting neurologic recovery

- Recovery trajectory and prognosis relate to:
  - Severity of impairment or activity limitation at index time
  - Rate of early change
  - Covariates with magnitude of neuropathology
  - Focal vs diffuse pathology may produce more 'domain specific' vs. 'domain general' impairments

- Multiple potential modifiers can shift recovery curve, and improve prediction somewhat, e.g.:
  - Age
  - Lesion characteristics/localization
  - Secondary neuropathology
  - Late complications
  - Premorbid capacity
  - Comorbidities
  - Complications
  - Psychosocial factors

Example: TBI

- Diffuse, focal and secondary pathology
- Clinical consequences, typical syndromes relate to their combined effects
- Overall severity of contributing components largely determine natural history with particular clinical characteristics (domain specific) that may relate to focal pathology

Neuropathological Consequences of TBI

<table>
<thead>
<tr>
<th>Primary</th>
<th>Diffuse axonal injury</th>
<th>Focal cortical contusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>small white matter hemor.</td>
<td>deep cerebral hemorrhage (extracerebral hemorrhage)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary</th>
<th>Hypoxic-ischemic injury</th>
<th>Hypoxic-ischemic injury (stroke)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Microvascular injury</td>
<td>Hermiation damage</td>
</tr>
<tr>
<td></td>
<td>Swelling</td>
<td>Swelling</td>
</tr>
<tr>
<td></td>
<td>Excitotoxicity</td>
<td>Excitotoxicity &amp; neuronal injury</td>
</tr>
<tr>
<td></td>
<td>Delayed neuronal injury</td>
<td>Late hemorrhages</td>
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</tbody>
</table>
Diffuse Axonal Injury - LM

Natural History of Recovery From Diffuse TBI
3 Main Phases of Recovery (domain general effects)

Pattern of recovery from diffuse TBI

<table>
<thead>
<tr>
<th>Duration</th>
<th>Mild Duration</th>
<th>Moderate to Severe Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconsciousness</td>
<td>None - min.</td>
<td>Hrs - wks.</td>
</tr>
<tr>
<td>Post-traumatic amnesia (PTA)/confusion</td>
<td>Min. - hrs.</td>
<td>Days - mos.</td>
</tr>
<tr>
<td>Post-confusion / recovery of function</td>
<td>Wks - mos.</td>
<td>Mos - yrs.</td>
</tr>
</tbody>
</table>
Relationship of duration unconsciousness (LOC) to PTA (n=228 patients with DAI)  

Katz et al., (abs.) JINS, 1999

1 year outcome related to duration of unconsciousness (n= 225 rehab. admissions w/ diffuse TBI)

Katz et al. JINS, 1999

1 year outcome related to duration of PTA (n=220 rehab. admissions with diffuse TBI)

Katz et al. JINS, 1999
Problems disrupting the natural course of recovery (e.g. hydrocephalus, chronic subdurals, seizures)

Level of Recovery

Time

Focal neuropathology
(domain specific effects)

Focal Cortical Contusions
Predisposed Locations: Anterior-inferior Frontal and Temporal Lobes
Regional Cortical Vulnerability to TBI Predicts Neurobehavioral Syndromes
(domain specific effects)

Dorsolateral prefrontal cortex
(executive function, including sustained and complex attention, memory, response inhibition, judgment, insight, problem solving)

Orbitofrontal cortex
(emotional and social responding)

Anterior temporal cortex
(memory, language, emotional responding, face recognition, temporal lobe)

Amygdala
(emotional learning and conditioning, including fear/anxiety)

Hippocampus
(only partially visible in this view - declarative memory)

Ventral brainstem
(arousal, ascending activation of diencephalic, subcortical, and cortical structures)

Neural organization of functions and recovery
• Propose 3 levels based on extent of redundancy, lateralization and discreet mapping of function.
• More discreet, more lateralized, less redundant = shorter sensitive period for neuroplastic reorganization.
• Probably more distinct early thresholds of milestone to predict favorable vs unfavorable recovery.
• Structural imaging informs prognosis better

Neural organization of functions and recovery
• Network pathways with discrete mapping and low redundancy
  - e.g., control of the hand, primary visual projections, some aspects of speech production, encoding memory
• Some capacity for reorganization, particularly in preserved perilesional areas
• Recovery evolves over weeks to about 3 months, but limited later reorganization possible.
21 yo RHM in MVA
Severe DAI and large left deep (lenticulostriate) hemorrhage
Basal ganglia area syndrome, nonfunctioning arm, mild anomia

CT 4 wks

Hemorrhage in 1° motor pathways
Limited progress
Poor BORP function

33yoM assaulted
delayed LOC; craniotomy to evacuate EDH

Acute
EDH; herniation

3 months
PCA infarct

Neural Organization of Functions and Recovery

- Distributed network pathways with regionally consolidated nodal areas with relatively low anatomical redundancy
  - e.g., language, visuospatial functions and visual recognition
- Some capacity to reorganize.
- Recovery largely evolves over several months, but later improvement possible.
31yoF fell 200 feet skiing
GCS 14; aphasic

53yoF struck by car while jogging
GCS 4 after lucid interval

**Neural organization of functions and recovery**

- Network pathways with distributed mapping and higher redundancy
  - e.g., visual attention, discourse, executive functioning
- may allow considerable reorganization within the system to compensate.
- recovery may evolve over many months
18yoM fell to ground intoxicated
No LOC; GCS 12; PTA 1/2 week

MRI 2 days
L. frontal contusion

39yoM fell 4 feet off loading dock
brief LOC, then lethargic; PTA 4 wks

Bilat. Frontal contusions

33yo GSW bifrontal
Neuro model: informing rehab treatment based on natural history and prognosis
e.g., Cognitive functions
18yo woman 3 months post MVA; unconscious 21 days:

Problems

- Severe amnesia at 3 months post-injury

Neuro asses.

- Severe DAI
- Continuing PTA
- No major focal injury or secondary injury

Plan/goals

- Use procedural learning strategies
- Allow more time for PTA to clear
- May delay elaborate compensatory systems (e.g., memory book)

18yoF TBI in MVA, unrestrained, struck tree
GCS 4; prolonged unconsciousness

Callosal and other deep hemorrhages (gradient echo)

CM
38yoM 3 mos. post MVA; GCS 13, LOC 8 days after lucid interval, Aortic tear / hypotensive

### Neurorehab. Model: Prognosis and selection of rx strategies

#### Problems
- Severe amnesia at 3 months post-injury

#### Neuro asses.
- Mild DAI
- No major focal injury but MRI c/w hippocampal injury
- Severe secondary hypoxic-ischemic injury

#### Plan/goals
- Poor prognosis for independence; requires long-term plan for supervision
- Attempt to proceduralize use of memory book; environmental cues

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38yo M with hypoxic/ischemic brain injury associated with aortic rupture after TBI

MRI 5 days post injury

Bilateral hippocampal injury
Neurorehab. Model: *Prognosis* and selection of rx strategies

38yoF 3 mos. post MVA; GCS 9, LOC ½ to 1 day, CT – small IVH:

**Problems**
- Severe amnesia at 3 months post-injury

**Neuro asses.**
- Moderate DAI
- No major focal injury or ischemic injury
- Comorbidity: MS

**Plan/goals**
- PTA should have cleared, more diagnostic w/u?
- ?
- Compensatory systems; long-term supervision

38yoF TBI in roll-over MVA; prolonged PTA

SS

MRT 2 weeks post-injury

Neurorehab. Model: *Prognosis* and selection of rx strategies

38yoF 3 mos. post MVA; GCS 9, LOC ½ to 1 day, CT – small IVH:

**Problems**
- Severe amnesia at 3 months post-injury

**Neuro asses.**
- Moderate DAI
- No major focal or ischemic injury
- Comorbidity: MS

**Plan/goals**
- Prolonged memory impairment, greater disability & deterioration expected
- Compensatory systems; long-term supervision
Neurorehab. Model: *Prognosis and selection of rx strategies*

**41yoM 3 mos. post fall at work; GCS 14, LOC 1 to 2 minutes, CT neg.:**

**Problems**
- Severe amnesia at 3 months post-injury

**Neuro asses.**
- Mild DAI
- No major focal or ischemic injury
- No comorbidities

**Plan/goals**
- Evaluate for other factors including conversion dis., malingering
- Psych eval., case mgt., hold on formal rehab.

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**49 yo man 8 weeks post 6ft fall; large bilateral frontal contusions**

**Problems**
- Failure to perform ADLs despite adequate motor function

**Neuro asses.**
- "Frontal" deficits: impaired executive functioning, compulsive use of objects, utilization behaviors, disinhibited, distractible

**Plan/goals**
- Modify environment: reduce distractions, present objects serially
- Train task-specific routines
- External compensatory systems: e.g. lists, schedules, planners
39yoM fell 4 feet off loading dock
brief LOC, then lethargic; PTA 4 wks

Bilat. Frontal contusions

Neurorehab. Model:
Diagnosis informs rx plan (ADLs & cognitive disorders)

49 yo man 8 weeks post 6ft fall; large bilateral frontal contusions

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<th>Problems</th>
<th>Neuro assess.</th>
<th>Plan/goals</th>
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| • Failure to perform ADLs despite adequate motor function | • "Frontal" deficits: impaired executive functioning
• Compulsive use of objects, utilization behaviors
• Disinhibited, distractible | • Modify environment: reduce distractions, present objects serially
• Train task-specific routines
• External compensatory systems: e.g. lists, schedules, planners |

Pt JAL 19 yo – GSW to top of R head;
CT 3mos post injury
**Neurorehab. Model:**
*Diagnosis* informs rx plan (ADLs & cognitive disorders)

19 yo woman 3 mos post gun shot wound; Rt superior parietal lesion

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<th>Problems</th>
<th>Neuro asses.</th>
<th>Plan/goals</th>
</tr>
</thead>
</table>
| • Failure to perform ADLs despite adequate motor function               | • Left neglect                                                             | Modify environment:  
|                                                                         |   impaired spatial                                                          |   e.g. call bells,  
|                                                                         |   and body orientation                                                      |   telephone, TV on right                                      |
|                                                                         |   "dressing apraxia"                                                       | Strategies to increase  
|                                                                         |   topographic disorientation                                                 |   directed attention to  
|                                                                         |                                                                             |   left                                                     |
|                                                                         |                                                                             | Cues to orient clothing  
|                                                                         |                                                                             |   to body                                                   |
|                                                                         |                                                                             | Visual cues to find way around environment                       |

**Neurorecovery after Stroke:**
*Foundations*

- Dr. Dwyer
Neurorecovery after Stroke: Foundations

- Cellular events – restorative, regenerative
  - Growth-associated protein expression
  - Axonal sprouting adjacent to lesion
  - Endothelial cell proliferation
- Angiogenesis
  - Mostly in areas surrounding infarct
  - Mainly supports regenerative (axonal sprouting and stem cell) response, not reperfusion

Rehabilitation Period: Cells to Networks

- Growth of dendrites and synaptogenesis
  - Facilitated by enriched environments and skill learning in adult animals
- Long-term potentiation and long-term depression

Rehabilitation Period: Underpinnings of Neurorecovery

- Motor system is a complex network of cortical and subcortical areas in which neuronal populations interact with each other by both excitatory and inhibitory mechanisms.
  - Stroke may critically disturb the complex balance of excitatory and inhibitory influences within the motor network.
  - Motor skill learning in animal models is accompanied by changes in the strength of connections within primary motor cortex.
- Also at play: sensory perception, attention and motor behavior

(Breakspear et al., 2003)
How are spatially distributed areas bound together?

- M1 might be driven by enabling or inhibitory influences from:
  - Premotor areas
  - Prefrontal relays
  - Posterior-parietal centers
  - Sensory areas

Rehabilitation Period: Underpinnings of Neurorecovery

- The more damage M1 (primary motor strip) cortex, the lower the likelihood of successful recovery
- Stronger the recruitment of higher motor areas such as the supplementary motor area or premotor cortex to compensate for M1 deficiency is seen
- However...

Rehabilitation Period: Underpinnings of Neurorecovery

- **Ipsilesional** premotor and supplementary motor recruitment is associated with a higher level prognosis
- **Contralesional** activation is associated with a worsened prognosis

Newton et al., 2006; Ward et al., 2006; Stinear et al., 2007
Rehabilitation Period: Underpinnings of Neurorecovery

- More affected patients appear to recruit more of the primary and secondary motor systems in both affected and unaffected hemispheres, whereas patients with the best outcome had a “normal” activation pattern when compared with controls.
- Negative linear correlation was seen between magnitude of task-related activation and outcome in cortical motor areas such as:
  - Ventral ipsilesional M1
  - Contralesional M1
  - Bilateral dorsolateral premotor cortex (PMd), supplementary motor area, cingulate motor areas, and parietal cortices
- Is the contralateral hemisphere is exerting an abnormally high degree of interhemispheric inhibitory drive toward ipsilesional M1 during attempted voluntary movement of the affected limb?
- This has led some to suggest that suppressing activity in contralesional motor areas might be beneficial, as suggested by (among others) Ward in 2005.

Rehabilitation Period: Underpinnings of Neurorecovery

- Contralesional M1 inhibits an inhibitory influence on ipsilesional M1 not seen in healthy subjects
- The strength of this pathological inhibition from contralesional M1 correlated with the motor impairment of the paretic hand.

Grefkes et al., 2008
• Neural activity during movement of the left or right hand in healthy subjects and in stroke patients with left-sided subcortical lesions.
• In stroke patients, movements of the impaired hand were associated with significant activations in ipsilateral (= contralesional) motor areas, which were absent in the healthy controls.

Motor Recovery: What can we say? (Prognosis)

• What information can we offer patients when they present with motor deficits?

Motor Recovery: Weaker is Bleaker

• Jorgensen et al. (1995): 1,197 consecutive stroke survivors and noted a positive correlation between decreased functional abilities at admission to rehabilitation and:
  - Decreased abilities at rehabilitation discharge
  - Decreased rate of discharge to home
• Nakayama et al. (1994) showed in a homogeneous patient sample with severe arm paresis (little or no active movement) on admission that 14% of the patients experienced complete motor recovery and 30% partial recovery.
Motor Recovery: Weaker is Bleaker

- Kwakkel et al. (2003) reported that at 6 months, 11.6% of patients had achieved complete functional recovery, while 38% had some dexterity function.
- In cases of lower extremity paralysis, complete motor recovery occurred in less than 15% of the patients, both for the upper and lower extremities. (Hendricks et al., 2002)

Motor Recovery: Weaker is Bleaker

- Hendricks et al. (2002): A patient with initial paresis was 4.58 times as likely to show motor recovery as a patient with initial paralysis. (CI 2.21-7.26)
- Jorgenson, 1995: The initial grade of lower extremity paresis was the most important predictor for overall motor recovery. Bonita and Beaglehole, 1998: odds of motor recovery in stroke survivors with mild paresis is 8.7 compared to those with severe paresis (CI, 4.43-17.06)

Motor Recovery: Weaker is Bleaker

- Granger et al.: 461 consecutive stroke survivors. Decreased abilities in bowel control, self feeding, self grooming and bladder control (in decreasing order of importance) at rehabilitation admission associated with decreased overall functional skills at rehabilitation discharge.
Individual movements

- **Active finger extension** was found to be a strong predictor of post-stroke recovery by Smania et al. 2007.
- **Minimal shoulder abduction and upper motor control** of the paretic limb upon admission to rehabilitation had a reasonably good chance of regaining some hand capacity whereas patients without proximal arm control had a poor prognosis for regaining hand capacity (Houwink et al. 2013).
- Kwakkel et al. 2003: Lack of voluntary motor control of the leg within the first week and no emergence of arm synergies at 4 weeks is associated with poor outcome at 6 months.

Individual movements

- Patients with **finger extension and shoulder abduction** on Day 2 after stroke onset had a 98% probability of achieving some degree of dexterity at 6 months
  - 25% in non-abductors/extenders at day 2
- 60% of patients with **finger extension within 72 hours** had regained full recovery of upper limb function according to the Action Research Arm Test (ARAT) score at 6 months (Nijland et al. 2010).

Motor Recovery: Stroke Severity Prolongs Recovery

- The recovery period in patients with severe stroke was twice as long as in patients with mild stroke
- Jorgensen et al., 1995: Mean recovery time of 15 weeks with severe paresis vs. 6.5 weeks with mild paresis
- Bonita and Beaglehole and Duncan et al: most of the overall improvement in motor functions occurred within the first month after stroke, although some degree of motor recovery continued in some patients for 6 months, especially in the initially severe subgroups.
Motor recovery: Location-based factors

- Brainstem and hemispheric infarctions fare equally; Tunney et al (N=188)
  - 87% of the hospitalized patients with hemispheric infarctions showed motor deficits at onset versus 78% of patients with brainstem infarctions
  - At 1 year follow-up, the proportions of patients with residual motor deficits had declined to 57% and 39%, respectively. An OR of .93 (CI, 0.62–1.37) indicated no significant difference between groups.
- Hospitalized patients with small lacunar strokes showed relatively good motor recovery. (Samuelson et al., 1996; Hendricks et al., 2002)

Motor recovery: Location-based factors

- Better functional recovery is associated with preserved activity in primary cortices.
- Puig et al. in 2013 (n=70) measured fractional anisotropy asymmetry of corticospinal tracts at the level of the pons 30 days after stroke.
  - Greater asymmetry predicted worse motor outcome at 2 years after stroke.
- Greater stroke lesion damage to the corticospinal tract results in poorer recovery from impairment that is not proportional to the initial impairment.
  - Greater fractional anisotropy asymmetry along the corticospinal tracts can identify patients who will not have proportional recovery from upper-limb motor impairment.

Motor Recovery: Reliability of Initial Assessments

- Duncan et al. (1992): On Day 1, the initial Fugl-Meyer Motor Assessment motor score accounted for only half of the variance in motor functions at 6 months.
- 5-day motor and sensory scores explained 74% of the variance.
- 30-day motor score explained 86% of the variance.
- Stinear 2007: Several studies and a systematic review have confirmed that motor impairment assessed within a week after stroke can predict functional outcomes.
Motor Recovery: Rehabilitation and Prognosis

- Ottenbacher and Jannell (1993): Level I meta-analysis including 36 investigations with 3,717 stroke survivors:
  - Positive correlation between early initiation of rehabilitation interventions and improved functional outcome.
  - Onset of rehabilitation interventions within 3 to 30 days poststroke is strongly associated with improved functional outcome.
- Mouse model of stroke: 7 day delay in poststroke practice of a skilled reach-to-grasp resulted in incomplete recovery of task performance. (Zeiler, 2016)

Treatment Planning: Role of Rehabilitation

- Cochrane reviews have reported that physical therapy improves recovery of motor function after stroke. (Stinear, 2007)
- Kramer and colleagues (1997) noted decreased mortality and improved function in stroke survivors randomly assigned to inpatient rehabilitation units.

Effectiveness of Multidisciplinary Rehabilitation Services in Postacute Care: State of the Science. A Review
Bettger and Stineman, 2007
Rehabilitation and Outcome: Interdisciplinary vs. Multidisciplinary

- Multidisciplinary settings also usually include diverse professionals, but regular communication and common goal orientation less consistent.
  - More typically seen at an acute care hospital
- Interdisciplinary setting
  - Rehabilitation services are provided by diverse professionals
  - Team that communicates regularly
  - Common goals
  - Rehabilitation units

Rehabilitation and Outcome: Interdisciplinary vs. Multidisciplinary

- Cifu and Stewart, 1999: When compared with multidisciplinary rehabilitation, interdisciplinary rehabilitation was associated with:
  - Improved functional outcome
  - Improved quality of life
  - Shorter length of stay
  - Decreased costs
- Three meta-analyses of this literature confirmed these findings and, additionally, noted that inpatient interdisciplinary rehabilitation decreased mortality

AHA/ASA Guideline

Guidelines for Adult Stroke Rehabilitation and Recovery

A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association

Endorsed by the American Academy of Physical Medicine and Rehabilitation and the American Academy of Neurorehabilitation

The American Academy of Neurology affirms the value of this guideline as an educational tool for neurologists and the American Congress of Rehabilitation Medicine also affirms the educational value of these guidelines for its members

Accepted by the American Speech-Language-Hearing Association

Carolee J. Winstein, PhD, PT, Chair, Joel Stein, MD, Vice Chair;
Ross Auema, PhD, PT, FASHA; Barbara Bates, MD, MBA; Laura R. Chorney, PhD;
Steven C. Cimino, MD; Frank Denoyer, PhD; Janice J. Eng, PhD; BSc; Beth Fisher, PhD, PT;
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Kenneth J. O’Toole, MD, PhD; Sue Pugh, MSS, RN, CNS-BC; CHPN; CNRN, FASNA;
Matthew J. Bates, PhD, DYV, FASHA; Lorrie G. Richards, PhD, OT/R; William Siem, PhD, ARPP (R);
Richard D. Zwislocki, MD, on behalf of the American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, and Council on Quality of Care and Outcomes Research.
Treatment Planning: Approaches

- Remediation: Same strategy, more effort / time to perform skill

<table>
<thead>
<tr>
<th>Recommendations: Organization of Poststroke Rehabilitation Care (Levels of Care)</th>
<th>Class</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended that stroke patients who are candidates for postacute rehabilitation receive organized, coordinated, interprofessional care.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>It is recommended that stroke survivors who qualify for and have access to IRF care receive treatment in an IRF in preference to a SNF.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Organized community-based and coordinated interprofessional rehabilitation care is recommended in the outpatient or home-based settings.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>ESD services may be reasonable for people with mild to moderate disability.</td>
<td>IIb</td>
<td>B</td>
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</tbody>
</table>
Treatment Planning: Approaches

- Adaptation
  - Adjust intentions or select new goals
  - Adjust expectations of others or modify the environment

Richards et al. (1993): 27 acute stroke survivors randomized to one of three treatment groups:
- Intensive, early-onset, task-specific physical therapy
- Intensive, early-onset, generalized physical therapy
- Standard physical therapy.

Intensive, early-onset, task-specific physical therapy demonstrated the greatest degree of gait recovery at 3 months.

Stern and colleagues (1971): 62 consecutive acute stroke survivors demonstrated similar functional improvement with general versus specialized (use of "facilitatory techniques") therapy.

Treatment Planning: Example CIMT

- Traditional CIMT:
  - Participants’ less affected upper limbs are restricted during 90% of waking hours of a 2-week period.
  - Participants engage in 5-hour activity sessions using their more-affected limbs in the 15% admixture of the same 2-week period.
- Modified CIMT (mCIMT):
  - Structured, 30-minute, functional practice sessions with restriction of the less-affected upper limb 5 days a week for 10 weeks. Both during a 10-week period.
  - Moreover, by using randomized controlled
- Other less stringent variants
CIMT Theoretical Support

- Increase in somatosensory input from the paretic hand, e.g., by using somatosensory stimulation, may improve motor function.
  - Cutaneous anesthesia leads to performance improvements in the nonanesthetized hand in healthy volunteers.
  - In patients with chronic stroke and in healthy controls, cutaneous anesthesia of the intact hand results in behavioral gains in the paretic hand that outlast briefly the duration of the anesthesia.
  - Immobilization of the intact hand (which reduces somatosensory input from the immobilized limb) in patients with chronic stroke undergoing constraint induced movement therapy.

Treatment Planning Example: CIMT

- Hodges et al., 2006: fMRI after CIMT
  - During activation of the affected hand, there was a treatment-associated increase in activation within the ipsilesional primary motor cortex dorsal premotor cortex and supplementary motor areas.
  - Intensive finger tracking training resulted in relatively greater involvement in or contribution from components of the motor network in the ipsilesional hemisphere.
  - Studies using virtual reality or fluoxetine also emphasized a treatment-related shift toward increased ipsilesional activation.
  - These treatment-related ipsilesional increases are concordant with findings in PET and most, but not all, TMS studies.

Motor recovery: Short-term Improvements

- Jorgenson (1995): Recovery in patients with moderate paresis was as follows by the end of rehabilitation:
  - Complete recovery 44%
  - Partial recovery 29%
  - 20% no changes
  - 7% deteriorated
Motor recovery: 6 month improvements

- In five studies published between 2015 and 2017, researchers compared upper limb motor impairment within 2 weeks of stroke to the upper-extremity Fugl-Meyer scale score at 3 or 6 months after stroke. (Stinear, 2007)
  - >500 patients from multiple countries
  - Most patients achieved 70% of the available motor improvement within 3-6 months after stroke (63% at 3 months, 78% at 6 months)
  - Irrespective of age, sex, stroke type and therapy dose measured in minutes
- Andrews and colleagues examined 135 stroke patients at 2 weeks, 8 weeks, 6 months, and 1 year from stroke and found no significant improvement in walking function after the first 6 months.

Motor recovery: Remote improvements

- Improved upper-limb use and function were reported in pilot studies in which chronic stroke patients participated in constraint-induced movement therapy (Page et al., 2004)
- Review of intensive exercise programs after remote stroke: effective in producing plastic changes and motor improvement even at a delayed timeframe
  - Mean time from stroke onset was 26 months
  - Improved motor behavior, accompanied by reorganization of cortical function, occurs even months or years after a patient has reached the plateau that defined spontaneous recovery after stroke.

Motor recovery: Where is the Plateau?

- Patient with stroke may adapt to therapeutic exercise but this may not be indicative of a diminished capacity for motor improvement
- Adaptive states may potentially be overcome by modifying regimen aspects (e.g., intensity, introducing new exercises and modalities)
Motor Recovery: Additional Tools

- fMRI
- Fractional anisotropy
- EEG: Functional coherence in the beta frequency band between the ipsilesional primary motor cortex and the rest of the cortex, had a positive linear relationship with upper-limb motor performance during the first 3 months after stroke. (Nicolo et al, 2015)

Motor Recovery: TMS

- TMS is a noninvasive tool that allows stimulation of the cerebral cortex. A magnetic field is induced by a figure-of-8 coil held over the scalp, which causes depolarization of underlying pyramidal cells.

Motor Recovery: MEPs

- Motor evoked potentials (MEPs)
- Systematic review of 14 studies (n = 480 patients) by Niccolo et al., 2015:
  - With positive 7 day MEPs had better upper-limb outcomes than those who did not have an MEP within this time period (MEP-negative patients)
  - PPVs for MEP status were 86.93%, NPVs 72.95%
  - Presence of a MEP is encouraging, but absence does not rule out a good outcome
Motor recovery: MEPs

- Lower extremity MEPs are technically difficult to elicit and more difficult to interpret
- Conflicting results regarding presence of LE MEPs and 6 month recovery with respect to ambulatory status

Motor Recovery: MEPs

Figure 1: Recovery from baseline to 6 months. For MEP-positive patients, recovery is proportional to the available improvement, the regression line (red, 95% CI) indicated by shaded lines represents the relationship between available (x) and actual (y) improvement (y=0.70x).

Motor Recovery in Treatment Planning: Cont’d

- Ensure prompt access to the highest level of rehabilitation available
  - Age, cardiopulmonary limitations, cognitive impairment and pain are not contraindications
- Avoid discouragement and learned helplessness
- Prioritize remediation, behavioral substitution and adaptation appropriately
- Maintain access to rehabilitation: new functional frontiers, new assistive devices (months, years?)
Motor Recovery: Future Directions

- Incorporation of research techniques into clinical prognostication
- Medication interventions (FLAME trial → FOCUS, AFFINITY, EFFECTS)
- Most rehabilitation is delivered within the first 30 days after stroke, yet less than 10% of motor rehabilitation trials are initiated during this time. (Winters et al., 2016)

Conclusions - Rehabilitation in the context of natural history

Rehabilitation strategies and goals should respect natural recovery and prognosis.

- Consistency with problems and capacities at different stages of recovery
- Impairment may evolve without any specific intervention or may not recover even with intervention
- Some strategies may enhance and extend neuroplasticity and restorative goals in selected patients
- Prognosis suggests restorative vs. compensatory strategies or combination
- Recognize secondary complications and deviations from expected recovery

Thank you!

Questions?
References

• Byblow WD, Stinear CM, Barber PA, Petoe MA, Ackerley SJ. Proportional recovery after stroke depends on corticomotor integrity. J Neurol Neurosurg Psychiatry 2015; 84: 848-59.
References


References