Motor Recovery

Strategies to optimize functional recovery after Stroke

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• None
Quote of the Day

• We are what we repeatedly do; Excellence, then, is not an act but a habit.
  • *Aristotle, 350 B.C.E.*

Objectives

• Understand basic tenets of the neurophysiology of stroke recovery.
• Explore commonly known motor recovery patterns.
• Describe pitfalls to optimal motor recovery.
• Explore tried & true methods to optimize motor recovery.
• Examine novel approaches to improve motor recovery.
• Participate in “stump the presenter”.
• Pledge allegiance to University of Kentucky athletics.
Introduction

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Basics of Motor Recovery

• Literature dictates three principal determinates of motor recovery:

  1) Timing, intensity and training approach.
  2) Poststroke neuroplasticity milieu.
  3) Extent of cortical reorganization.
Basics of Motor Recovery

• Neuroplasticity

Neuroplasticity defined

• “The ability of the brain to form and reorganize synaptic connections, especially in response to learning or experience or following injury.”
  – Oxford English Dictionary

• Terminology originated in the early 1950's.

• It is impossible to understand the complexities of motor recovery without first becoming familiar with the engine that drives it.
Neuroplasticity continued

- Hyperacute to acute transitional phase:
  1) Resolution of edema and tissue death.
  2) Reperfusion of the ischemic penumbra.

- Acute phase:
  1) Localized reorganization via neuronal mechanisms such as vicariation, recruitment, disinhibition, resolution of diaschisis and neurogenesis.
Neuroplasticity continued

- Subacute to chronic transitional phase
  1) Long-term potentiation (Hebbian synaptic learning)
     - develops from repetitive associated inputs.
  2) It is the product of the feed-forward and sensorimotor feedback loop of the CNS.

Motor Learning

Stage 3: Autonomous Stage
- Almost automatic/habitual
- Subconscious control
- Multitasking
- Minimal performance variability
- Very few errors

Stage 2: Associative Stage
- Associate environmental cues with actions
- Achieving consistency
- Refinement
- Fewer/smaller errors
- Can detect and correct errors

Stage 1: Verbal-Cognitive Stage
- Identifying task goal
- Self-talk/questioning
- Rapid performance
- Error-ridden
- Clumsy/inefficient
How do we bring basic science to the Bedside?

• Decades of neuroscience and movement science literature has led to a more holistic approach to neurorehabilitation.

• Basic guiding principles have led to demonstrable, research validated, neuronal adaptation measured by functional MRI (fMRI), magnetic source imaging (MSI), electroencephalography and neurophysiological mapping after craniotomy.

Applications to clinical practice

• Positive thinking and imagery, complete with clear goals and objectives, targeting optimal health and recovery.

• Devising creative learning activities that are progressively difficult, but goal directed combined with positive feedback.

• Integrating training objectives with meaningful functional activities, incorporating multiple sensory modalities.

• Avoiding training activities which propagate abnormal movements.
Applications to clinical practice

- Maintain self-esteem, yet avoiding an egocentric focus.
- Cultivating an enriching environment where the patient can be progressively challenged, but maintain an air of discovery, possibility and fun.

Positive Neuroplasticity

Examples for promoting positive neuroplasticity include:
- Mental stimulation
- Intellectual pursuits
- Social interaction
- Good emotional health
- Physical exercise
- Proper nutrition
- Proper sleep
- Cognitive remediation therapy

Negative Neuroplasticity

Examples for promoting negative neuroplasticity include:
- Nonstimulating activities
- Social isolation
- Poor emotional health
- Sedentary lifestyle
- Inadequate nutrition
- Inadequate sleep
- Substance abuse
Literature validated outcomes

• Expansion of healthy nerve cell populations and neuronal connections.
• Increased volume of brain centers and delayed atrophy of the brain.
• Faster and more reliable neuronal interconnections leading to improved sharpness and attention.
• Improved ability to recognize and maintain trunk and joint position.

Motor Learning driving Neuroplasticity

EXPERIENCE-DEPENDENT PLASTICITY

Motor skill learning acquisition

Neuronal-level changes

Greater amounts of cortex dedicated to that skill

Synaptogenesis

Dendritic spine growth

Axon arborization

# DAYS TRAINING

1 2 3 4 5 6 7 8 9 10

Significant increase in skill

Significant increase in synapses per neuron

Significant expansion of wrist and digit movement representations on motor cortex map

Appalachian Regional Healthcare
Clear as mud?

Based on all the head tilts, maybe I’d better explain this again...

Brunnstrom

1) Described stages of motor recovery.

1 - Complete flaccidity, no voluntary movement.

2 - Basic synergy patterns emerge, minimal spasticity.

3 - Escalating spasticity, early volitional movements.

4 - Alternative movement combinations develop out of synergy, diminished spasticity.

5 - Volitional movements become easier, spasticity continues to wane.

6 - Complex coordinated movements reappear, spasticity nearly completely resolved.

7 – Return of normal function.
Motor Recovery Patterns cont.

- Twitchell
  1) Described typical anatomical patterns of recovery.
  2) Regarding dominant MCA distribution infarcts, patient’s exhibit several common themes.
  3) Upper extremity typically more affected than the lower extremity.
  4) Lower extremity recovers more rapidly.
  5) Patients more likely to have long-term functional sequelae of the upper extremity.

Pitfalls to Optimal Motor Recovery

- Neuroplasticity can be negatively impacted by numerous factors.
Complications Impacting Neuroplasticity

• **Infection** – Pneumonia and UTI most common. Early diagnosis and treatment is paramount.

• **Medications** – 1st generation antipsychotics, Benzodiazepines and Anticholinergics are generally avoided.

• **Depression** – occurs in upwards of 50% of patients. Treatment is necessary to ameliorate the impact on neuroplasticity.

Complications Impacting Neuroplasticity

• **Recurrent infarct/Hemorrhagic conversion**
  - risk of recurrent CVA is 30% over 5 years, 13% within the 1st year.
  
  - incidence of hemorrhagic conversion after massive cerebral infarction if ~9%.

  - both phenomena require lengthy evaluation and treatment, delaying rehabilitation and potentially expanding neurological impairments.
Complications Impacting Neuroplasticity

- **Fall with injury**
  - stroke patients fall at a rate 1.77 times more frequently than their matched counterparts.
  
  - this occurs due to the fact that stroke patients typically have significantly lower balance, mobility and balance confidence.
  
  - leads to fractures with activity restriction, fear of falling and depression.

Optimizing Motor Recovery: Past & Present

1) **Initiate acute level inpatient rehabilitation in a timely manner**
   - transfer to stroke specialized acute level inpatient rehabilitation unit within 48-72 hours is preferred.
   
   - earlier transfer can overload the glutamate/NMDA receptors and hinder recovery.
Past & Present

• 2) Exercise (Aerobic, Strength training, Flexibility, Neuromuscular)
  - Intensity/frequency/duration parameters:

  A) Aerobic – 3-7 days per week; 40-70% peak O2 uptake and heart rate reserve, 50-80% peak heart rate; Borg RPE 11-14.

• B) Strength training (Free weights, Circuit, Weight machines, Isometric exercises)
  - 2-3 days per week; 1-3 sets, 10-15 reps, 8-10 exercises utilizing major muscle groups.
  - Preceding or following aerobic or strength training 10-30 secs per stretch.
Past & Present

- D) Neuromuscular (Balance/Coordination exercises)
  - 2-3 days per week

Past & Present

- Primary goals of exercise after stroke
  1) Increase ADL independence, as well as safety/stability during performance of ADLs.
  2) Increase walking speed/efficiency/balance.
  3) Bolster tolerance for physical activity.
  4) Improve joint extensibility and proprioception.
Past & Present

• Secondary goals of exercise after stroke
  1) Reduce risk of further cardiovascular/cerebrovascular disease.
  2) Reduce the risk of stroke-related complications.

Past & Present

• Task-specific training
  – Repetitive task specific training has long been known to facilitate motor recovery.
  - Unlike simple generalized motor exercises, neuroimaging has revealed a greater degree and persistence of cortical reorganization.
Past & Present

• Action Observation/Mirror Therapy/Motor Imagery
  - all work via the same mechanism.
  - mirror neurons are activated in the bilateral ventral premotor cortex, bilateral superior temporal gyrus, the supplementary motor area and the contralateral supramarginal gyrus.
  - best used in combination with functional tasks to “prime” neurons.

Past & Present

• Mirror Therapy
  - best represented in the literature.
  - found to have a significant effect on motor function, ADLs, pain.
  - limited effect on improving hemispatial neglect.
Past & Present

• Bilateral Arm Training
  - Meta-analysis performed in 2010 by Cauraugh et al revealed a significant training effect with symmetric bilateral arm training.
  - Specifically, two protocols were associated with more robust treatment effects.
  - BATRAC and coupled bilateral arm training with concurrent electrical stimulation.

Past & Present

• Bilateral arm training with rhythmic auditory cueing
  - performed in 20-60 minutes sessions, 3-4 sessions per week for 4-6 weeks.
  - symmetric or alternating movements paired with metronome auditory cues.
Past & Present

- Coupled bilateral training with electrical stimulation
  1) Symmetric or asymmetric training paired with FES.
  2) Symmetric or asymmetric training paired with EMG-triggered neuromuscular electrical stimulation.

Past & Present

- Constraint Induced Movement Therapy (CIMT)
  - Therapy was born from the propensity of stroke survivors to utilize their nonparetic limb over their paretic limb.
  - This, in turn, creates a negative feedback loop and invariably learned non-use.
Past & Present

• CIMT
  - Original protocols called for the patient's paretic arm to be constrained for 90% of waking hours, participating in targeted functional tasks for 6 hours over the course of 2 weeks.
  - Modified versions have proven successful only requiring 30 minutes – 3 hours per day for 2-10 weeks.

• mCIMT
  - fMRI studies have demonstrated substantial and equivalent cortical reorganization between CIMT and mCIMT.
  - Results have shown that patients exhibit long term impairment reversal rather than adaptation alone.
Past & Present

- Body Weight Supported Treadmill Training (BWSTT)
  - enables safe repetitions of complex gait patterns.
  - initial studies demonstrated superiority to over-ground training in improving walking speed, swing symmetry and stride length.
  - 1 hour, 4 days per week for 6 weeks.

Past and Present

-More recent studies, including STEPs and LEAPS, demonstrated that BWSTT is not superior to traditional over-ground gait training.
**Past & Present**

- **Music Therapy**
  - Music-supported therapy (MST) or Neurologic music therapy (NMT).
  - Passive or active protocols.
  - Passive protocols synchronizes functional tasks with music.
  - Active protocols utilize musical instruments directly to train fine and gross motor tasks.

**Past & Present**

- RCTs and systematic reviews have demonstrated significant evidence for both active and passive training when compared to standard rehab protocols.
  - Evidence is most robust for upper extremity impairment regardless of chronicity.
  - However, there are currently no standardized treatment parameters.
**Past & Present**

- Transcutaneous Neuromuscular Electrical Stimulation
  - incorporates placement of electrodes on the skin overlying key muscles.
  - 2 types: functional and therapeutic.
  - the difference between the two is that FES pairs stimulation with a desired functional task.

- FES
  - performed 3 hours per day, 5 days per week for 4 weeks.
  - can be applied to a home-based program.
  - facilitates neuroplasticity by significantly increasing afferent inputs.
Optimizing Motor Recovery: Beyond

• Robotics assisted training has numerous potential advantages to enhance current approaches to stroke rehabilitation.
  - precise, quantifiable, intensive and specific
  - current technologies are proving successful in complementing tried & true methods.
Optimizing Motor Recovery: Beyond

- Noninvasive Brain Stimulation
  1) Repetitive Transcranial Magnetic Stimulation (rTMS)
  2) Transcranial Direct Current Stimulation
Optimizing Motor Recovery: Beyond

• Repetitive Transcranial Magnetic Stimulation (rTMS)
  - High frequency stimulation is applied to the ipsilesional motor cortex.
  - Increases cortical excitability, thereby sparking neuroplasticity and allows for more efficient and expeditious motor learning.

Optimizing Motor Recovery: Beyond

• rTMS
  - Conversely, low frequency stimulation is applied to the contralesional motor cortex.
  - Reduces interhemispheric inhibition thereby reducing the probability of maladaptive plastic changes.
Optimizing Motor Recovery: Beyond

- Brain-Computer Interface

Types

- Invasive BCI

Optimizing Motor Recovery: Beyond

- Goal-oriented task
- Spinal lesion (plasticity)
- Multimodal feedback
- Action
- Effector device
- CPU
Optimizing Motor Recovery: Beyond

• BCI
  - potentially very useful in patients with severe stroke deficits.
  - Animal studies have shown that synaptic transmissions can be recorded, decoded and translated into visual, tactile, auditory and kinesthetic feedback and used to voluntarily control external devices.

Optimizing Motor Recovery: Beyond

• Virtual/Augmented Reality
Optimizing Motor Recovery: Beyond

• VR/AR
  - provide an avenue for multisensory immersion into a simulated environment.
  - Currently, there is limited data. But, early evidence suggests improved upper extremity function as well as improved ADL outcomes.

Stump the Presentor

• Questions?
Thank You