4. Motor Rehabilitation

4b. Rehab of Hemiplegic Upper Extremity Post Stroke

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4.5 Recovery for Upper Extremity

4.5.1 Brunnstrom Stages of Motor Recovery

The Seven Brunnstrom Stages of Motor Recovery (see table below for more details)

1. Flaccid paralysis. No reflexes.
3. Spasticity is marked. Synergistic movements may be elicited voluntarily.
5. Spasticity wanes. Can move out of synergies although synergies still present.
6. Coordination and movement patterns near normal. Trouble with more rapid complex movements.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>1</td>
<td><strong>Flaccid paralysis is present.</strong> Phasic stretch reflexes are absent or hypoactive. Active movement cannot be elicited reflexively with a facilitatory stimulus or volitionally.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Spasticity is present</strong> and is felt as a resistance to passive movement. <strong>No voluntary movement</strong> is present but a <strong>facilitatory stimulus will elicit the limb synergies reflexively.</strong> These limb synergies consist of stereotypical flexor and extensor movements.</td>
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<tr>
<td>3</td>
<td><strong>Spasticity is marked.</strong> The synergistic movements can be elicited voluntarily but are not obligatory.</td>
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<tr>
<td>4</td>
<td><strong>Spasticity decreases.</strong> Synergy patterns can be reversed if movement takes place in the weaker synergy first. Movement combining antagonistic synergies can be performed when the prime movers are the strong components of the synergy.</td>
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<td>5</td>
<td><strong>Spasticity wanes,</strong> but is evident with rapid movement and at the extremes of range. Synergy patterns can be revised even if the movement takes place in the strongest synergy first. Movements that utilize the weak components of both synergies acting as prime movers can be performed.</td>
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<tr>
<td>6</td>
<td><strong>Coordination and patterns of movement can be near normal.</strong> <strong>Spasticity</strong> as demonstrated by resistance to passive movement is <strong>no longer present.</strong> Abnormal patterns of movement with faulty timing emerge when rapid or complex actions are requested.</td>
</tr>
<tr>
<td>7</td>
<td><strong>Normal.</strong> A “normal” variety of rapid, age appropriate complex movement patterns are possible with normal timing, coordination, strength and endurance. There is no evidence of functional impairment compared with the normal side. There is a “normal” sensory-perceptual motor system.</td>
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4.5.2 Typical Recovery and Predictors

- Nakayama et al. (1994) reported that for stroke patients with severe arm paresis with little or no active movement at the time of hospital admission:
  - 14% complete motor recovery.
  - 30% partial recovery.
- Kwakkel et al. (2003) reported that at 6 months, 11.6% of patients had achieved complete functional recovery, while 38% had some dexterity function.
- Potential predictors of upper extremity recovery include active finger extension and shoulder abduction:
  - Active finger extension was found to be a strong predictor of short, medium and long term post-stroke recovery (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).
  - The EPOS study demonstrated that patients with some finger extension and shoulder abduction on Day 2 after stroke onset had a 98% probability of achieving some degree of dexterity at 6 months; this was in contrast to only 25% in those who did not show similar voluntary motor control.
  - In addition, 60% of patients with finger extension within 72 hours had regained full recovery of upper limb function according to ARAT score at 6 months. (Nijland et al. 2010).

4.5.3 Recovery of Upper Extremity: Fixed Proportion

- Within 6 months post stroke upper limb impairment recovers by fixed proportion.
- Fixed proportion notes that 70% of each patient’s maximal possible motor improvement occurs regardless of the initial impairment (i.e. Fugl-Meyer score) but only for those with an intact corticospinal (motor) tract function (Prabhakaran et al. 2008).
- Irreversible structural damage to the corticospinal tract severely limits recovery of the upper limb (Stinear et al. 2007; 2012).
- This fixed proportion of motor recovery of impairment appears to be unaffected by rehabilitation therapies.
- 3D kinematics in subacute and chronic stroke survivors have shown motor recovery associated with rehabilitation is driven more by adaptive or compensatory learning strategies.
- Most clinical tests designed to evaluate upper extremity motor recovery (i.e Action Research Arm Test (see below)) only assess function or a patient’s ability to accomplish a task.
4.6 Evaluation of Upper Extremity

4.6.1 Action Research Arm Test (ARAT)

Action Research Arm Test (ARAT)

<table>
<thead>
<tr>
<th>Questions</th>
<th>Answer</th>
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<tbody>
<tr>
<td>What does it measure?</td>
<td>Upper extremity function and dexterity (Hsueh et al. 2002).</td>
</tr>
<tr>
<td>What is the scale?</td>
<td>The ARAT consists of 19 items designed to assess four areas of function; grasp, rip, pinch, and gross movement. Each question is scored on an ordinal scale ranging from 0 (no movement) to 3 (normal performance of the task).</td>
</tr>
<tr>
<td>What are the key scores?</td>
<td>Scores range from 0 – 57, with lower scores indicating greater levels of impairment.</td>
</tr>
<tr>
<td>What are its strengths?</td>
<td>Relatively short and simple measure of upper limb function. No formal training is required. Testing can be completed quickly on higher functioning patients.</td>
</tr>
<tr>
<td>What are its limitations?</td>
<td>Good concurrent validity, although other forms of validity have not been evaluated within the stroke population. Significant floor and ceiling effects have been identified (Van der Lee et al. 2002). Unidimensional measure; hence, subset analyses should not be used independently but rather summated to provide a single overall score representing upper extremity function (Koh et al. 2006).</td>
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4.6.2 Box and Block Test

Box and Block Test

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<thead>
<tr>
<th>Questions</th>
<th>Answer</th>
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<tbody>
<tr>
<td>What does it measure?</td>
<td>Performance based measure of gross manual dexterity.</td>
</tr>
<tr>
<td>What is the scale?</td>
<td>150 small wooden blocks are placed in one of two equal compartments of a partitioned rectangular box. Respondents are seated and instructed to move as many blocks as possible, one at a time, from one compartment to the other in 60 seconds.</td>
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<tr>
<td>What are the key scores?</td>
<td>The BBT is scored by counting the number of blocks that are carried over the partition from one compartment to the other during the one-minute trial period.</td>
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<tr>
<td>What are its strengths?</td>
<td>Quick and easy to administer. The simplicity of the performance task and the seated administration position may make the test more accessible to a wider range of individuals. Established age and gender-stratified norms increase the interpretability to the results. Results may have utility as a prognostic indicator of physical health.</td>
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<tr>
<td>What are its limitations?</td>
<td>Noisy to administer and could be distracting to other patients.</td>
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4.6.3 Chedoke-McMaster Stroke Assessment Scale

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<tr>
<th>Questions</th>
<th>Answer</th>
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<tbody>
<tr>
<td>What does it measure?</td>
<td>The Chedoke-McMaster Stroke Assessment Scale (CMSA) is a 2-part assessment consisting of a physical impairment inventory and a disability inventory. The impairment inventory is intended to classify patients according to stage of motor recovery while the disability inventory assesses change in physical function.</td>
</tr>
<tr>
<td>What is the scale?</td>
<td>The scale’s impairment inventory has 6 dimensions; shoulder pain, postural control, arm movements, hand movements, leg movements, and foot movements. Each dimension (with the exception of ‘shoulder pain’) is rated on a 7-point scale corresponding to Brunnstrom’s 7 stages of motor recovery. The disability inventory consists of a gross motor index (10 items) and a walking index (5 items). With the exception of a 2-minute walking test (which is scored as either 0 or 2), items are scored according to the same 7-point scale where 1 represents total assistance and 7 represents total independence.</td>
</tr>
<tr>
<td>What are the key scores?</td>
<td>The impairment inventory yields a total score out of 42 while the disability inventory yields a total score out of 100 (with 70 points from the gross motor index and 30 points from the walking index).</td>
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<tr>
<td>What are its strengths?</td>
<td>The use of Brunnstrom staging and FIM scoring increases the interpretability of the CMSA and may facilitate comparisons across groups of stroke patients. The CMSA is relatively comprehensive and has been well studied for reliability and validity.</td>
</tr>
<tr>
<td>What are its limitations?</td>
<td>Taking approximately 1 hour to complete, the length and complexity of the CMSA may make the scale less useful in clinical practice. As primarily a measure of motor impairment, the CMSA should really be accompanied by a measure of functional disability such as the BI or the FIM.</td>
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</table>

- CMSA is based on the Brunnstrom stages of motor recovery (see above).

4.7 Rehabilitation Management of Upper Extremity

4.7.1 Enhanced or More Intensive Therapy in Upper Extremity

Role of Intensity of Therapy
- Post-stroke rehab increases motor reorganization while lack of rehab reduces it; more intensive motor training in animal’s further increases reorganization.
- Clinically greater therapy intensity improves outcomes; reported for PT, OT, aphasia therapy, treadmill training and U/E function in selected patients (i.e. CIMT).
- One exception is VECTORS trial (Dromerick et al. 2009); showed high intensity upper extremity CIMT (6 hrs/day) starting day 10 showed less improvement at 3 months than less intense treatment; Rationale uncertain and it was not a large trial (n=52).

Number of Repetitions in the Upper Extremity
- No study has systematically determined a critical threshold of rehab intensity needed to obtain a benefit (MacLellan et al 2011).
- Animal research involves hundreds of repetitions (250-300 per session).
- The EXCITE trial involved 196 hours of therapy per patient.
- If threshold is not reached, there is less recovery of the affected arm; patient develop compensatory movements (Schweighofer et al 2009).
• Lang et al. (2007) found practice of task-specific, functional upper extremity movements occurred in only 51% of rehab sessions meant to address upper limb rehab. Average number of repetitions per session was only 32.
• Technology (video gaming, robotics) may be necessary to achieve the maximum number of reps (Saposnik et al. 2010).

**Studies looking at Enhanced Therapy**
• A wide variety of treatments, many non-specific, and a large number of outcome measures make coming to a general conclusion more difficult.
• There is conflicting evidence enhanced therapies improve short-term upper extremity function; results may not be long lasting.

**HIGHLIGHTED STUDY**

**Methods:** 123 patients who had stroke causing upper extremity impairment within the previous 10 days were randomized to either enhanced upper extremity care within 10 days of stroke for 30 min/d x 5d/week x 6 weeks, compared to the control group who received regular stroke unit care.

**Results:** No significant differences between the two groups.
HIGHLIGHTED STUDY

Methods: 103 patients admitted for inpatient rehab participated in a 4 week program of upper extremity therapy. Patients randomized to either the graded repetitive upper limb supplementary program (GRASP group, n=53) or the control group (education protocol, n=50). Primary outcome measure was the Chedoke Arm and Hand Activity (CAHAI). Assessment conducted before and after treatment and at 5 months post stroke. Secondary measures were used to evaluate grip strength and paretic upper extremity use of outside of therapy time.

Results: Subjects in the GRASP group showed greater improvement in upper limb function (CAHAI) compared to the control group (mean change score: 14.1 vs 7.9, p<0.001). The GRASP group maintained this significant gain at 5 months post stroke. Significant differences were also found in favor of the GRASP protocol for grip strength and paretic upper extremity use.

4.7.2 Task-Specific Training

- Task-specific practice is required for motor learning to occur. The best way to relearn a given task is to retrain for that task.
- Task-specific training vs. traditional stroke rehab yields long-lasting cortical reorganization of specific area involved.
- Repetition, in the absence of skilled motor learning, is often not enough for cortical relearning to occur. Page et al. (2003) have noted intensity alone does not account for differences between traditional stroke and task-specific rehab. Task-specific sessions for as short as 15 minutes are also effective in inducing lasting cortical representation changes.
- Task-specific, low-intensity regimens designed to improve use and function of affected limb have reported significant improvements (Smith et al. 1999; Whitall et al. 2000; Winstein and Rose 2001).

Repetitive Task-Specific Techniques for Upper Extremity

- There were 18 RCTs as of 2015.
- Many of the treatments reviewed were nonspecific in nature, not well described, and evaluated at different stages of recovery; sample sizes were small (mean n<40 subjects) and there are quality issues (mean PEDro 5.9; concealed allocation in 28% and blinded assessor in 11%).
- Often multiple outcomes were assessed, some of which demonstrated a benefit, while others did not.
- There is strong evidence that repetitive task practice may be superior to conventional training at improving upper extremity motor function following a stroke.
HIGHLIGHTED STUDY

Methods: 103 patients with a Brunnstrom stage of 2 for arm recovery, avg. 12 weeks post stroke randomized to a 4 week course of either task-specific training or standard training using Bobath NDT. Patients in both groups received 1 hour of therapy 5X/wk. Outcomes were assessed before and after treatment and at 8 weeks follow-up and included Fugl-Meyer assessment (FMA), Action Reaction Arm Test (ARAT), Graded Wolf Motor Function Test (GWMFT), and Motor Activity Log (MAL).

Results: 95 participants completed the 8 week follow-up. Patients in task-specific group achieved significantly greater gains compared to patients in the control group, at both the end of treatment and at follow-up on FMA, ARAT, GWMFT and MAL.

Specific Therapy Interventions for Rehabilitation Management of the Upper Extremity Post-Stroke

4.7.3 Sensorimotor Training in Hemiparetic Upper Extremity

• Sensorimotor stimulation treatment included thermal stimulation, intermittent pneumatic compression, splinting, cortical stimulation, and sensory training programs.
• Interventions were tested in acute, subacute, and chronic stages of stroke.
• There is conflicting evidence that sensorimotor training improves U/E function, compared to traditional techniques.

4.7.4 Bilateral Arm Training

• In bilateral arm training patients practice the same activities with both upper limbs simultaneously
• This allows activation of the intact hemisphere to facilitate the activation of the damaged hemisphere through neural networks linked via the corpus callosum thereby promoting recovery.
• There are 29 RCTs examining the use of bilateral arm training for stroke patients; Mean number of subjects is 37; Mean PEDro = 6.0; Concealed allocation was used in 34% while only 17% had blind assessment of outcome measures.
• There is strong evidence that bilateral arm training is not superior to unilateral training or conventional therapy at improving upper extremity motor function.
• Verbeek et al. (2014) found non-significant summary effect sizes for motor functions and motor strength of the paretic arm.

4.7.5 Constraint-Induced Movement Therapy (CIMT)

• CIMT is designed to reduce functional deficits in the more affected upper extremity.
• The key features of CIMT are restraint of the unaffected hand/arm and increased practice/use of the affected hand/arm.
• CIMT is designed to overcome learned non-use by promoting cortical reorganization (Taub et al. 1999).
• Suitable candidates for CIMT are patients with at least 20 degrees active wrist extension and 10 degrees of active finger extension, with minimal sensory or cognitive deficits.
• CIMT can be described as either:
a) Traditional CIMT: 2 week training program, with 6 hours of intensive upper-extremity training with restraint of the unaffected arm for at least 90% of waking hours.
b) Modified CIMT: often refers to less intense than traditional CIMT, with variable intensity, time of constraint and duration of program.

Evidence for CIMT Post-Stroke for the Upper Extremity

- There are 60 RCTs examining the use of CIMT post stroke as of 2015.
- Mean number of subjects was 46; mean PEDRo of 5.9; only 35% had concealed allocation and 15% blinded assessment of outcomes.
- **Acute stage:** There is strong evidence of benefit of mCIMT in comparison to traditional therapies in the acute stage of stroke.
- **Chronic stage:** There is strong evidence of benefit for CIMT and mCIMT in comparison to traditional therapies in the chronic stage of stroke.
- Verbeek et al (2014) reported high intensity CIMT (mitt worn 90% of day and 3-6 hours of therapy/day) and lower intensity CIMT (mitt worn <90% of day and 0-3 hours of therapy/day) demonstrated significant summary effect sizes for paretic arm (synergies) and arm-hand activities.

HIGHLIGHTED STUDY

**Methods:** 69 chronic stroke patients allocated to either CIMT (n=33) or conservative treatment (n=36). CIMT group received 6 hrs of daily affected-U/E training and restrained unaffected U/Es x 5 days/wk x 2 wks; control group bimanual NDT training without restrained U/E.

**Results:** ARA test, pinch strength of affected U/E significantly higher for CIMT vs control group.
HIGHLIGHTED STUDY

Methods: 222 patients between 3-9 months post stroke received either CIMT (n=106) vs usual care (n=116). CIMT group wore a mitt on less-affected hand while performing repetitive task practice and behavioural shaping with hemiplegic hand x 30 sessions.

Results: CIMT group significantly improved in Wolf Motor Function Test (p<0.001), the Motor Activity Log (MAL) Amount of Use (p<0.001) and MAL Quality of Movement (p<0.001) and caregiver MAL.

HIGHLIGHTED STUDY

Methods: Further results reported from ECXITE trial immediately following randomization (3 – 9 months) (n=106) were compared to those who received delayed treatment (15 to 21 months).

Results: Earlier CIMT showed significantly greater improvement compared with delayed work on Wolf Motor Function Tool and Motor Activity Log. Stroke Impact Scale Hand and Arm Activities domains scores were also significantly higher among subjects in the early group. Early and delayed group comparison of scores on these measures 24 months after enrolment showed no statistically significant differences between groups.
HIGHLIGHTED STUDY

Methods: This was a three arm, single blinded, single center RCT. Patients were stratified for severity, age, NIHSS, pretest ARAT, days from stroke onset. The objective was to examine whether CIMT was superior to an equivalent amount of traditional occupational therapy and whether CIMT treatment effects were dose dependent. 1853 stroke patients were screened (acute stroke admissions) but only 52 patients eventually included in study. Duration of treatment was 2 weeks, 5 days/week. The control group received 1 hour ADL retraining and 1 hour U/E bilateral training activities. Equipment, positioning as needed; constraint not allowed. Cueing neither encouraged/discouraged use of affected U/E. Traditional CIMT group 2 hours shaping therapy + 6 hours of constraint as well as extensive verbal and written feedback on their progress. High intensity CIMT group received 3 hours shaping therapy + constraint 90% of waking hours as well extensive verbal and written feedback on their progress.

Results: Total ARAT score improved from baseline in all groups. There was no significant difference between standard CIMT and control at day 90 for ARAT, FIM UE, SIS Hand. High intensity CIMT had lower ARAT and SIS gain at 90 days than control or standard CIMT.

4.7.6 Strength Training

- Strength training involves progressive active exercises against resistance.
- There have been 6 RCTs examining strength training of the hemiparetic upper extremity; Mean number of subjects is 29; Mean PEDro is a low 5.3 with 33% of RCTs utilizing concealed allocation, 33% using blinded assessments of outcomes and 50% an intent to treat analysis.
- There is strong evidence that strength training increases grip strength following stroke.
- Verbeeek et al. (2014) found nonsignificant summary effect sizes for motor function of the paretic arm (synergy), muscle strength, range of motion and pain.
- Harris and Eng (2010) conducted a systematic review and meta-analysis of strength training on upper limb strength, function and ADL performance following stroke; there was a significant effect associated with training (SMD=0.95, 95% CI 0.05-1.85; p=0.04)

4.7.7 Mirror Therapy

- Mirror therapy is a form of visual imagery in which a mirror is used to convey visual stimuli to the brain through observation of one’s unaffected body part as it carries out a set of movements.
- Mirror is placed in patient’s mid-saggital plane, reflecting movements of the non-paretic side as if it was the affected side.
- Premotor cortex is important to neuroplasticity and is responsive to visual feedback.
- There are 22 RCTs as of 2015 examining mirror therapy post stroke; Mean number of subjects = 41; PEDro score = 6.3; 50% had concealed allocation and 27% had blinded assessment of outcomes.
- There is strong evidence that mirror therapy in combination with other therapies or delivered alone improves motor function following stroke.
• Cochrane review (2012) included 14 studies (RCTs and randomized cross-over trials) (n=567) comparing mirror therapy with any control intervention; it had a significant effect on motor function and also improve ADLs, reduce pain and improve visual spatial neglect.

Example of Mirror Therapy

4.7.8 Mental Practice

• Mental imagery was adapted from sports psychology where the technique has been shown to improve athletic performance, when used as an adjunct to standard training methods.
• Mental practice involves rehearsing a specific task or series of tasks mentally.
• The most plausible explanation for its benefit is that stored motor plans for executing movements can be accessed and reinforced during mental practice.
• Page et al. (2001a, b, c, 2005, 2007) patients in mental practice group showed improved upper extremity function.
• Cochrane review (Barclay-Goddard et al, 2011) showed that based on results of 6 RCTS (119 participants), mental practice in combination with other treatments appeared to be more effective in improving upper extremity function than did the other treatment alone (SMD=1.37, 95% CI 0.60 to 2.15, p<0.0001).
• There are 16 RCTs looking at mental practice in the treatment of the upper extremity motor deficits post stroke; studies are typically small (means n=28 subjects) and there are quality issues (mean PEDro = 6.0; 6% had concealed allocation while 38% had blinded assessment of outcomes)
• It has been recommended as a treatment adjunct to other upper limb interventions and used as a precursor to constraint-induced therapy.
• There is strong evidence that mental practice improves upper extremity motor function when compared to standard care.
• Verbeek et al. (2014) found significant summary effect sizes for arm-hand activities but not motor function of the paretic arm (synergy) or muscle strength.

4.7.9 Orthosis in Hemiparetic Upper Extremity

Upper Extremity Orthosis
• Common orthosis used in hemiplegic upper extremity is the wrist-hand-orthosis/splints.
• Can be static/passive (volar, dorsal splints) or dynamic/active (eg. Saebo-Flex®).
Aims in Applying Orthosis

- Reduction in spasticity
- Reduction in pain
- Improvement in functional outcome
- Prevention of contracture
- Prevention of edema
- There is strong evidence that static hand splinting does not improve motor function or reduce contracture formation.

HIGHLIGHTED STUDY

Methods: RCT on 39 subjects, recruited to participate in a 5 week, home-based exercise program which incorporates stretching of wrists and finger flexor stretches with reach and grasp activities in addition to conventional therapy. The experimental group wore either a volar or a dorsal splint, while the control group wore no splint.

Results: There was no significant difference in spasticity reduction and passive range of motion of the wrists between the intervention and control group.

Specific Technology Interventions for Rehabilitation Management of the Upper Extremity Post-Stroke

4.7.10 EMG/Biofeedback in Hemiparetic Upper Extremity

- EMG biofeedback uses external electrodes attached to targeted muscles to capture motor unit electrical potentials
- Provides audio or visual feedback of how much the patient is activating the targeted muscle.
- 23 RCTs were identified which examined EMG/Biofeedback in the hemiparetic upper extremity; mean number of subjects = 38; mean PEDro score was 5.7; 30% of RCTs had concealed allocation; 22% had blinded assessment of outcomes; 61% had an intent to treat analysis.
- There is strong evidence that EMG / Biofeedback therapy is not superior to other forms of treatment and may not improve upper extremity motor function or spasticity.

4.7.11 Functional Electrical Stimulation (FES) in Hemiparetic Upper Extremity

- In FES, electrostimulation of peripheral nerves and muscles with external electrodes are applied to stimulate movement during training of activities
- FES has been studied in 49 RCTs as of 2015; Mean number of subjects was 33; Only 18% had concealed allocation and 16% had blinded assessment.
- There is strong evidence that FES treatment improves upper extremity function in acute stroke (<6 months post onset) and chronic stroke (>6 months post onset) when offered in combination with conventional therapy or delivered alone.
Example of Functional Electrical Stimulation treatment

- Verbeek et al. (2014) found a more mixed effect; summary effect sizes for wrist and finger extensor stimulation with NMS but not EMG-NMS while the opposite was true for combined stimulation of wrist and finger extensors and flexors.

Example of H200 Wireless Hand Rehabilitation System

HIGHLIGHTED STUDY

Methods: 60 hemiparetic stroke patients, 2-4 weeks post stroke randomized to receive standard rehabilitation + electrical stimulation (ES) of wrist extensors for 30 min/day x 3X/week x 8 weeks (n=25) or to routine rehabilitation (n=23).

Results: Change in isometric strength of wrist extensors was significantly greater in the ES group, at 8 and 32 weeks (p=0.004 and p=0.014). Grasp and grip score on the Action Research Arm Test (ARAT) had increased significantly in the ES group at 8 weeks (p=0.013 and p=0.02).
HIGHLIGHTED STUDY

**Methods:** 32 chronic stroke subjects participated in 30-, 60- or 120-minute sessions of repetitive task-specific practice (RTP) + FES using Bioness device every weekday for 8 weeks. A 4th group participated in a 30 minute per weekday home exercise program. Outcomes were evaluated using the upper extremity section of the Fugl-Meyer Assessment of Sensorimotor Impairment (FM), the Arm Motor Ability Test (AMAT), the Action Research Arm Test (ARAT), and Box and Block (B&B) 1 week before and 1 week after intervention.

**Results:** After intervention, subjects in 120 minute group were only ones to exhibit significant score increases on the FM (P=.0007), AMAT functional ability scale (P=.002), AMAT quality of movement scale (P=.0002, and ARAT (p=.02). They also exhibited largest changes in time to perform AMAT tasks (P=.15) and B&B score (P=.10) although did not reach significance.

4.7.12 Robotics in Rehabilitation of Upper Extremity Post-Stroke

- There is strong evidence that sensorimotor training with robotic devices improves upper extremity functional outcomes, and motor outcomes of the shoulder and elbow.
- There is strong evidence that robotic devices do not improve motor outcomes of the wrist and hand.
- Verbeek et al. (2014) found significant summary effect sizes for proximal but not distal motor function.

HIGHLIGHTED STUDY

**Methods:** 127 patients with moderate-to-severe upper limb impairment > 6 months post stroke were randomly assigned to intensive robot-assisted therapy (n=49), intensive comparison therapy (n=50), or to usual care (n=28). Therapy consisted of 36x1 hour sessions over a period of 12 weeks. Primary outcome was Fugl-Meyer Assessment (FM) at 12 wks. Secondary outcomes were scores on Wolf Motor Function Test and Stroke Impact Scale. Secondary analyses assessed treatment effect at 36 weeks.

**Results:** At 12 weeks, subjects in robot-assisted group gained more FM points, compared to subjects in usual care group (1.11 vs 1.06, p=0.08). Subjects in intensive therapy group gained more FM points compared with subjects in robot-assist group but it was not significant (4.01 vs 3.87, p=0.92). No other treatment comparisons were significant at 12 weeks.
4.7.13 Virtual Reality in Stroke Rehabilitation

- Virtual reality allows individuals to experience and interact with three-dimensional environments.
- The most common forms of virtual environmental simulators are head-mounted displays (immersion) or with conventional computer models or projector screens.
- There were 30 RCTs looking at virtual reality as of 2015; Mean number of subjects was 35; Mean PEDro score was 6.2; RCTs utilized concealed allocation in 33%, a blinded assessment of outcomes in 57% and an intent to treat analysis in only 37%.
- There is strong evidence that virtual reality treatment improves general functioning but not functional independence.
- Laver et al. (2011) in a Cochrane study examining 7 studies of virtual reality therapy primarily designed to detect improvement in motor function found that the primary outcome was statistically significant for arm function. However, the authors felt the evidence was insufficient to reach conclusions about the effect of virtual reality and interactive video gaming on grip strength or speed.
- Virtual reality can be a useful as an adjunct to other interventions enabling additional opportunities for increasing repetition, intensity and provide task-oriented training.

HIGHLIGHTED STUDY

Methods: Single-blind controlled study at 12 sites in 4 countries. 141 stroke patients with CM score >3 (mild to moderate deficits) randomized to intensive 10x60 minute sessions of Virtual Reality using Nintendo Wii gaming system (n=71) or recreational activities (n=70) over 2 weeks. Mean time of intervention and usual care similar

Results: Each group showed improvement on Wolf Motor Function Test relative to baseline but no difference between groups for primary or secondary measures.

4.7.14 Brain Stimulation

- Brain stimulation is a procedure that uses a neurostimulator to send electrical impulses to the brain. The most common types of brain stimulation in rehabilitation include repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS). rTMS may be delivered in a single pulse, in paired pulses or as repetitive trains of stimulation. It can facilitate or suppress targeted regions of the brain, depending on the stimulation parameters. tDCS involves the
application of mild electrical currents (1-2 mA) conducted through 2 saline soaked, surface electrodes applied to the scalp, overlaying the area of interest and the contralateral forehead above the orbit; it does not induce action potentials, but instead modulates the resting membrane potential of the neurons.

- There are 59 RCTs examining brain stimulation and recovery/rehabilitation of the upper extremity post stroke as of 2015; Mean number of subjects is 31; Mean PEDro score is 6.9; Concealed allocation was utilized in 31% of the RCTs while blinded assessment of outcomes occurred in 44% of RCTs.
- There is strong evidence rTMS improved impaired arm and hand motor function in addition to grasp and pinch but not range of motion of the wrist.
- There is strong evidence anodal tDCS and cathodal tDCS improve general upper extremity function but not dynamometric measures such as pinch, grasp and grip strength.
- There is strong evidence dual rTMS (cathodal and anodal) stimulation improves dexterity and grip function.

Other Treatment Interventions for Rehabilitation Management of the Upper Extremity Post-Stroke

4.7.15 Botulinum Toxin in the Hemiplegic Upper Extremity

- Botulinum toxin- has been shown to reduce spasticity in the upper extremity.
- However, botulinum toxin has not been shown to necessarily improve function likely because underlying weakness more than spasticity results in the limitation of function.
- Modest improvements in the dressing, grooming and eating on the Barthel Index score have been reported following botulinum toxin injections.

Common Indications for Use of Botulinum Toxin in the Spastic Upper Extremity

- **Adducted/internally rotated shoulder** (subscapularis/pectoralis major) to improve on adduction and internally rotated shoulder tightness/contracture and pain.
- **Flexed elbow** (brachioradialis/biceps/brachialis) to make ADLs and hygiene easier as well as improve cosmesis.
- **Pronated forearm** (pronator quadratus/pronator teres) to improve hand orientation.
- **Flexed wrist** (flexor carpi radialis/brevis/ulnaris/extrinsic finger flexors) to improve ADLs and reduce pain.
- **Clenched fist** (flexor digitorum profundus/sublimis) to improve hygiene.
- **Thumb in palm deformity** (adductor pollicis/flexor pollicis longus/thenar group) to improve thumb for key grasp.
HIGHLIGHTED STUDY

Methods: A randomized double-blinded, placebo controlled, multicenter trial investigating the efficiency and safety of one-time injections of BTx-A in 126 subjects with increased flexor tone in the wrist and fingers after a stroke.
Results: Modified Ashworth Scale scores for the wrist and fingers were significantly different between groups (p<0.001) at 4, 6 and 12 weeks follow-up.

HIGHLIGHTED STUDY

Methods: 15 stroke patients were randomized to receive a single BTx-type B injection in the elbow, wrist, finger and thumb or placebo.
Results: Improvements were not sustained.

- There is strong evidence that treatment with botulinum toxin either alone or in combination with therapy significantly decreases spasticity in the upper extremity in stroke survivors.
- However, it has not been clear that the improvements are sustained, nor is there strong evidence that they are associated with improved function and quality of life.
- Most recent meta-analysis showed moderate treatment effect for botulinum toxin A on function (Foley et al. 2012) (see below).

HIGHLIGHTED STUDY

Methods: Four databases (MEDLINE, EMBASE, Scopus, and ISI Web of Science) were searched to find studies that met the following criteria: (1) the study design was a randomized controlled trial comparing injection of BTX-A with placebo or a nonpharmacologic treatment condition; (2) at least 60% of the sample was composed of adult subjects recovering from either first or subsequent stroke; (3) subjects presented with moderate to severe upper-extremity spasticity of the wrist, finger, or shoulder; and (4) activity was assessed as an outcome. Data pertaining to participant characteristics, treatment contrasts, and outcomes assessing activity limitations were extracted from each trial.
Results: 16 RCTs were identified, 10 of which reported sufficient data for inclusion in the pooled analysis (n=1000). Overall BTX-A was associated with a moderate treatment effect (standardized mean difference = .564+-.094, 95% confidence interval = .352-.721, P<.0001).
4.7.16 Alternative/Complementary Medicine

Complementary Medicine includes a variety of medical therapies used in the treatment of disease and illness that are not encompassed by the scope of traditional scientific medicine. Examples include acupuncture, which involves stimulation of defined anatomic locations on the skin by a variety of techniques, the most common being stimulation with metallic needles that are manipulated either manually or that serve as electrodes conducting electrical currents, and acupressure, a form of treatment whereby finger pressure is applied to meridian points on the body.

There are 17 RCTs examining complementary medicine in stroke rehab/recovery of the upper extremity; Mean PEDro scores were 6.5; Mean number of subjects was 133; 53% utilized concealed allocation in the RCT, only 29% had blinded assessment of outcome measures and 59% employed an intent to treat analysis.

There is strong evidence that traditional acupuncture and electroacupuncture may not improve upper extremity function.

<table>
<thead>
<tr>
<th>Study name</th>
<th>Outcome</th>
<th>Time point</th>
<th>Std diff in means</th>
<th>Std diff Standard error</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brashear 2002</td>
<td>DAS</td>
<td>6 weeks</td>
<td>0.788</td>
<td>0.185</td>
<td>0.426</td>
<td>1.151</td>
<td>0.000</td>
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<tr>
<td>Kanovsky 2009</td>
<td>DAS</td>
<td>2 weeks</td>
<td>0.496</td>
<td>0.167</td>
<td>0.169</td>
<td>0.823</td>
<td>0.003</td>
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<tr>
<td>McCory 2009</td>
<td>MMAS</td>
<td>8 weeks</td>
<td>0.278</td>
<td>0.207</td>
<td>-0.127</td>
<td>0.683</td>
<td>0.179</td>
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<tr>
<td>Suputtitada 2005</td>
<td>ARAT</td>
<td>8 weeks</td>
<td>1.051</td>
<td>0.390</td>
<td>0.288</td>
<td>1.814</td>
<td>0.007</td>
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<tr>
<td>Guo 2006</td>
<td>BI</td>
<td>4 weeks</td>
<td>0.485</td>
<td>0.262</td>
<td>-0.029</td>
<td>0.998</td>
<td>0.064</td>
</tr>
<tr>
<td>Jahangir 2007</td>
<td>BI</td>
<td>4 weeks</td>
<td>0.245</td>
<td>0.279</td>
<td>-0.301</td>
<td>0.791</td>
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<tr>
<td>Meythaler 2009</td>
<td>MNL</td>
<td>12 weeks</td>
<td>0.647</td>
<td>0.342</td>
<td>-0.023</td>
<td>1.317</td>
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<tr>
<td>Bhakta 2000</td>
<td>Disability Scale</td>
<td>6 weeks</td>
<td>0.797</td>
<td>0.329</td>
<td>0.153</td>
<td>1.441</td>
<td>0.015</td>
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<tr>
<td>Kohl 2010 (low)</td>
<td>DAS</td>
<td>8 weeks</td>
<td>1.350</td>
<td>0.409</td>
<td>0.549</td>
<td>2.151</td>
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<tr>
<td>Kaji 2010 (high)</td>
<td>DAS</td>
<td>8 weeks</td>
<td>0.590</td>
<td>0.254</td>
<td>0.061</td>
<td>1.058</td>
<td>0.028</td>
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<td>Shaw 2011</td>
<td>ARAT</td>
<td>6 weeks</td>
<td>0.181</td>
<td>0.149</td>
<td>-0.111</td>
<td>0.473</td>
<td>0.225</td>
</tr>
</tbody>
</table>

Figure 2. Forest Plot of Estimated Treatment Effect Sizes

-2.00 -1.00 0.00 1.00 2.00

Favours placebo Favours BT-A
References


