CHAPTER II

LITERATURE REVIEWS

1. Definition of stroke

Stroke or brain attack is the sudden onset loss of neurological function caused by discontinue of the blood flow to the brain (28). The term cerebrovascular accident (CVA) is used exchangeably with stroke to refer to the vascular conditions of the brain. Clinically, variety of deficits are possible, that is, changes in the level of consciousness and impairments of motor, sensory, perceptual, cognitive, and language functions. Paralysis (hemiplegia) or weakness (hemiparesis) is a common motor deficits in stroke survivors. Usually, impairment of the stroke patients occurs characteristically on the side of the body opposite to the side of the lesion (3). Stroke is divided into two major categories (28).

1) Ischemic strokes are the most common type, resulting from a clot blocks or lack of cerebral blood flow to lead the oxygen and nutrients to the brain. It was found about 80 percents of individuals with stroke (3). Ischemic strokes are divided by pathophysiologic mechanism into thrombosis, embolism and decreased systemic perfusion (28).

1.1) Thrombosis refers to an obstruction of blood flow due to a localized occlusive process within one or more blood vessels. The blood vessels are narrowed or occluded by an alteration in the vessel wall or by surperimposed clot formation.

1.2) Embolism refers to material elsewhere within the vascular system lodges in a vessel and blocks the blood flow. The most common of the material arises from the major arteries of the heart.

1.3) Decreased systemic perfusion or diminished flow to brain tissue is caused by low systemic perfusion pressure. The most common causes are cardiac pump failure and systemic hypotension.

2) Hemorrhagic stroke refers to the blood released into the brain and into extravascular spaces of the cranium. The brain are damaged by cutting off connecting pathways and by causing localized or generalized pressure injury to brain tissue. Hemorrhage can be subdivided into two subtypes: intracerebral and subarachnoid hemorrhage (28, 29).

2.1) Intracerebral hemorrhage is caused by rupture of a cerebral vessel with subsequent bleeding directly into the brain substance. The cause is usually hypertension, with leakage of blood from small intracerebral arterioles damaged by the elevated blood pressure.

2.2) Subarachnoid hemorrhage is caused by blood leaks out of the vascular based on to the brain's surface and is disseminated quickly via the spinal fluid pathways into the spaces around the brain. Bleeding often originates from aneurysms or arteriovenous malformations. A ruptured aneurysm releases blood rapidly at systemic blood pressure, suddenly increasing intracranial pressure. Bleeding trauma can also cause subarachnoid hemorrhage (28).

2. Upper extremity impairments of stroke survivors

2.1 Weakness

Weakness is an inability to generate normal levels of muscular force and is defined as a decrease in the maximum voluntary torque or force after stroke. It is reported that 80 to 90 percents of all patients after stroke have major problems of functional disabilities (29). Most rapid recovery of the upper extremity function occurs within the first month after stroke (4, 30, 31). Nevertheless, even 3 to 6 months after stroke only 20% of the stroke patients have normal UE function (30, 31). The one third of all patients who involved in a chronic stroke will have some residual impairment of the UE (4). Hemiplegic patient may be possible to use the affected arm in mid-range, but difficult when the affected arm is in the last 0–20° of elbow extension (32). A study of isometric peak torque of elbow flexor and extensor muscle in hemiplegic patients showed that muscle weakness is a problem of reduced peak torque in the affected side. This might have significant implications for stroke patients whose force needs to be generated quickly (33).

Muscle weakness is also associated with a number of changes in both muscle composition and motor unit. There is a selective loss of type II fast twitch fibers which results in difficulty in initiation and production of rapid, high-force movements (34). The number of functioning motor units and discharge firing rates also decrease, in one study by as much as 50 percents at 6 months after stroke (34).

2.2 Spasticity

Spasticity is a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex. Spaticity is one of the upper motor neuron syndrome components (35). The larger and quicker the stretch, the stronger the resistance of the spastic muscle which is one of clinical characteristic features of upper motorneuron syndromes such as stroke. Spasticity is a potential obstacle to improvement in motor control and functional ability of the upper limb (3, 36). It emerges in about 90 percents of cases and occurs on the side of the body opposite to the lesion (3). The duration of spasticity is highly variable, lasting days or weeks. It is typically presented after flaccidity which immediately found after stroke (29). Usually, spasticity in UE is appeared in the flexor pattern more than extensor pattern and occurs throughout the hemiplegic side (37, 38).

Lin and Sabbahi (39) studied the correlation of spasticity and upper limb dysfunction in wrist-hand movement of the hemiparesis. The electromyography showed that the degree of wrist spasticity was associated with impaired hand function in hemiplegic patients. In addition, the hyperactive electromyographic response of the stretch reflex, recorded from active muscles, was a valid indicator of spasticity. It was shown that deficits in agonist-antagonist muscle activation of the single-joint of elbow in spastic hemiparesis are directly related to the control of muscle activation. Musampa and coworkers (40) studied double-joint flexor muscle (elbow-shoulder joint) in chronic stroke patients. They found that stretch reflex threshold (STRs) in single- and double-joint flexor muscles correlated with the positions at which muscles were activated during voluntary movements for all shoulder angles. This effect was greater in elbow flexor muscles (brachioradialis, biceps brachii). STRs of the flexor muscles correlated with clinical spasticity in elbow flexors only while elbow muscles were at 90° or mid-length. They suggested that STRs correlated in the presence of spastic zones might be a major cause of motor impairments after brain damage. However, the research on spasticity did not support focusing treatment on suppressing stretch reflexes and preventing secondary structural muscle changes in patients with spasticity (41). Recently, several studies (19, 22, 42-44) showed that spasticity in UE hemiplegia decrease when using botulinum toxin, and task-related training or electrical stimulation. Reciprocal inhibition and large sensory fiber activation have all been suggested as possible mechanisms for the spastic reduction. Spastic reduction is a primary target of treatment in patients with spasticity for improvements in other parameters such as active range of motion (19).

2.3 Disability

Disability is any restriction or lack of an ability to perform an activity in the manner, a disturbance in the performance of daily tasks such as ADL, quality of life, and social and family relationships (28, 45, 46). Aprile and coworkers (45) evaluated the effects of rehabilitation on disability and quality of life (QoL) in 66 patients with chronic strokes. Subjects were participated a rehabilitation program (strengthening, stretching, mobilization and muscle retraining/facilitation exercises, transfers, walking, self-care and feeding), 50 minutes per day and 6 days per week for 2 months. The data showed significant improvement in clinical disability, QoL, physical function and social function immediately after rehabilitation. They suggested that repeated cycles of rehabilitation program were needed to maintain the level of improvement reached. In addition, the patients who lived urban and rural regions of Northeastern Thailand showed significantly improved functional outcomes, psychological condition and QoL scores when received full rehabilitation program from the team (47).

3. Recovery after stroke

Neural recovery mechanisms and restoration functional rehabilitation occurs during the first weeks and 2 to 3 months after stroke onset (4, 27). Functional gain may result from two recovery process. Natural process or spontaneous recovery may contribute a major part of functional improvement (28). The process of recovery from stroke usually follows a stereotyped series of stages leading to a final stage of recovery that varies with the individual patients (48). Seven-stage of motor recovery following stroke was described by Brunnstrom (49).

Overall patterns of motor recovery occur through individual recovery are highly variable. The degree of recovery depends on a number of factors, such as, lesion, locations, severity, and capacity for adaptation through training (29). Furthermore, the process of motor or sensory recovery can continue to occur 6 months to year later (46). Brain recovery can occur as a result of changes in neural organization. The brain plasticity was considered, that is, the ability to adapt to changes and to meet the dangers of life. It is the capacity of the central nervous system to reorganize following injure and to restore adequate function. Post-stroke brain plasticity includes synaptogenesis, change of function in pre-existing synapses, cortical reorganization and probably neurogenesis. These changes are stimulated by both of passive and active activities. A number of studies (50, 51) provided evidences to support that intensive task-oriented arm training could induce brain reorganization in subacute (51) or in chronic stroke patients (50).

4. Functional electrical stimulation in neurorehabilitation

Several treatment techniques are being used in clinical rehabilitation for patients with hemiplegia (10, 23, 52). Neurodevelopmental treatment (NDT) aims to inhibit abnormal muscle patterns and to facilitate autonomic reactions. Functional movement patterns with sensory stimulations or the proprioceptive neuromuscular facilitation (PNF) technique is also used in neurorehabilitation (52). The aims of these techniques are restoring of motor control after stroke. Recently, constraint-induced movement therapy (CIMT) and task-specific training were developed specifically for restoration of hand function (23, 52). Task-specific training provides some evidences of the effectiveness of this approach in comparison with a control group or traditional therapy (23). Another rehabilitation approach is based on using functional electrical stimulation (FES) (17, 20, 24, 42, 52-60).

FES is the application of the electrical current to excitable tissues. The effects of electrical stimulation in neurological rehabilitation can be divided into improvement in motor function (17, 20), reduction in spasticity (19), increase in muscle strength (53), increase in range of movement of wrist (18), and reduction of shoulder subluxation (53, 61) in stroke patients. Hara et al. (62) studied hybrid power-assisted of FES with EMG and nerve block therapy. Sixteen stroke patients who had upper-extremity impairments more than 1 year were recruited. Targets muscles were the extensor carpi radialis longus (ECRL) and brevis, extensor digitorum communis (EDC), and extensor indicis proprius muscles on the hemiparetic side. Subjects were trained with 40-min FES session once or twice a week for 4 months after motor point blocks at the spastic finger flexor muscles. The results were the improvement of root mean square of EMG, active range of motion, modified Ashworth scale, and clinical tests in target muscles in all patients as compare with the control subjects. They concluded that the hybrid therapy which consisted of a decreasing negative factor (antagonist muscle spasticity) and an increasing positive factor (agonist muscle strength) was effective for patients with chronic spastic hemiparesis. Proprioceptive sensory feedback may have an important role in power-assisted functional electrical stimulation therapy (17). The FES was also used with task-specific training in UE of acute ischemic strokes (10.9±5.4 days) (17). Subjects were asked to perform 1 hour per session, 4 times a day and continued for 12 weeks. The results found that FES could improve both clinical and statistical hand functions of patients with moderate paresis more than task-oriented training without FES.

Ring and Rosenthal (63) used neuroprosthetic functional electrical stimulation in subacute 3 to 6 months after stroke. Subjects who had moderate to severe upper limb dysfunction defined as less than full active range of motion in the involved upper limb; cognition adequate to follow multi-step commands. Subjects were divided to the control and two sub-group intervention subjects. The intervention groups were divided to type I: the patients with no active voluntary motion at the fingers and wrist, and type II: the patients with partial active voluntary range of motion. Standard treatments were functional treatment to improve ADL and neuromuscular re-education using the Bobath technique. FES and neuroprosthesis started for 10 minutes twice a day, progressed up to 50 minutes, 3 times per day over the first 2 weeks, and remained at this level of use until the end of the 6-week study. They found that the intervention of type I demonstrated significantly greater improvements in spasticity reduction, and tended towards greater active range of motion of the proximal limb. In type II intervention, significant gains were noted in tests of hand function, as well as significant improvement in spasticity reduction and increased active range of motion or voluntary motion. In addition, in a few patients with pain or edema in the involved limb, all of those treated with the experimental group improved, while less improved in the control group. There was no adverse effect related to the neuroprosthesis functional electrical stimulation treatment. Recently, several researchers reported that task-specific combined with FES resulted in significantly recovery of UE function in both chronic and subacute stroke survivors

(19, 20, 55). In acute stroke, Alon et al (17) also reported that FES enhanced improvement of UE function better than task-specific exercise alone. These findings are important in clinical implication of active motor learning. FES may reverse maladaptive brain reorganization in the chronic and acute phase of stroke (64). The report mentioned above suggests that task-specific training can be more effective if combined with FES.

5. Mechanisms of functional electrical stimulation with stroke patients

FES interventions for stroke patients are the application of electrical current to excitable tissue to supplement in abnormal motor functions (18). It can be applied in both of upper and lower extremities after stroke. The mechanisms underlying the effects of FES at the paretic side after stroke are uncertain in detail. FES has been believed to involve in peripheral and central mechanisms (19, 20, 65).

5.1 Peripheral mechanism

FES may facilitate cutaneous receptors, muscle and joint proprioceptive afferents. FES could improve muscle strength via motor unit recruitment during stimulated practice (18). FES might also improve or maintain range of motion of the affected limb (18, 19), and reduce the amount of spasticity in the muscle (19, 42). Finally, FES could be promoting recovery of hand function (19, 20).

5.2 Central mechanism

The central mechanism effect of FES is believed to occur through the stimulation of sensory and motor inputs of an affected limb. FES has been proved to increase cortical excitability, induce brain reorganization, and enhance descending voluntary commands (17, 25). Wu and coworkers studied a short session of 2 hours of electrical somatosensory stimulation combined with voluntary hand function on an affected hand in chronic strokes. Improvement in functional hand motor skills was tested by Jebsen-Taylor Hand function tests (JTHFT) (66). The JTHFT engages a distributed network of interconnected cortical regions including primary motor and somatosensory cortices of brain lesion (67). FES effect also demonstrated by functional magnetic resonance imaging (fMRI) (65). In conclusion, electrical stimulation combined with voluntary hand function could induce brain reorganization (17).

6. Effects of electrical stimulation on neurorehabilitation

Several effects of electrical stimulation have been reported. These can be classified as follows.

6.1 Improved muscle strength (18, 61)

Kobayashi and coworkers studied in hemiparesis patients with chronic shoulder subluxation. The supraspinatus and middle deltoid muscles were stimulated using electrical stimulation (61). Patients were stimulated 15 minutes twice a day, 5 days a week for 6 weeks. The muscles were tested by EMG. The results showed that the supraspinatus and middle deltoid muscles were significantly increased in maximal voluntary contraction force and reduced in shoulder subluxation.

6.2 Increased range of motion (17, 20)

FES is not only induced reciprocal inhibition of antagonistic muscle, but FES with simultaneous voluntary muscle contraction could also decrease muscle tone of antagonist (17). Thus, patients can easily manipulate objects during functional activities. In addition, the stimulation was provided regular stretching or similar to passive stretching of the limited joint. It can be applied over a more extended period with no adverse effect (18). Sullivan and Hedman (25) found that stimulation 2 hours per day, for 18 weeks can increase ROM of wrist joint on UE hemiplegia.

6.3 Relaxation of spastic muscle (25)

When a muscle contracts, activity in the muscle spindle is relayed via inhibitory interneurones to the α motor neurons of the antagonistic muscle and reducing its activity (5). This is known as reciprocal inhibition and its effect can be exploited by stimulation the antagonist muscle to the spastic muscle (5, 25). The Ia afferents, the nerves that pass from the muscle spindles to the spinal cord and inhibitory interneurones, are of large diameter, they require only a low level of stimulation to excite them. Thus the Ia afferents will always be excited even if the stimulation produces only a small contraction. Consequently, stimulation will have a direct effect as well as via mechanical changed of tension in the muscle itself. Generally, after stimulation the antagonists to the spastic muscle there is a period of reduce spasticity which can be strengthened via long term potentiation (31).

6.4 Re-education of movement (5, 20)

When a muscle contraction is produced by electrical stimulation, a whole range of sensory inputs is produced. This includes the direct sensation from the stimulation and mechanoreceptors (66). The patient is suggested to try and assist the action of the stimulator with voluntary movement to enhance this effect. However, this voluntary effort must not be so great that it causes a rise in spasticity and inhibits the desired movement (16).

6.5 Improve sensory awareness (20, 68) and reduce pain (61)

Sensory input will encourage new synaptic connection in the sensory cortex and increase sensory awareness. Many studies have been reported improvement of sensory ability after using electrical stimulation such as two-point discrimination (20, 68). Pain can be reduced or eliminated because of the effects of stimulation in reducing spasticity and improving the resting position of joints (20, 61).

6.6 Enhancing the effect of botulinum toxin (14, 69)

This enhancement can be done in two ways. Firstly, it has been shown that botulinum toxin is more easily taken up by the receptors if the muscle is active. This can be achieved by direct stimulation or exercise of the antagonist muscle leading to reduction of stretch reflexes in the target muscle. Botulinum take up occurs over the first two days after injection. Secondly, an electrical stimulation was used to enhance relearning of selective movements for the three months before spastic tone returns.

7. Recent functional electrical stimulation modalities for stroke

7.1 Electrical stimulator combined with a wrist-hand orthosis (24, 25, 42)

NESS Handmaster® is the only device available in this category. The Handmaster neuroprosthesis combines a wrist-hand orthosis with muscle stimulation via integrated surface electrodes (19, 23). The Handmaster's design permits accurate electrode positioning and reproducible by patients. It is permitted wrist stabilization and maintains the wrist in a functional position of 10 to 20 degrees of extension. It allows the user to select from among 3 exercise modes and 3 functional modes. The modes stimulated to the target finger and the electrodes are fitted into the orthosis remains in position for all subsequent applications of grasp, hold, and release hand function (5).

7.2 The electromyography (EMG)–monitored electrical stimulator (24)

The Neuromove 900® is one of the available devices in this category. It is approved by United States Food and Drug Administration for use by stroke patients (24). This stimulator is consisted of 3 reusable and self-adhering round surface electrodes which 2-active surface electrodes placed at the motor point of the targeted muscle and 1 ground electrode over a bony protrusion. The electrode detects EMG signals in the affected muscles and stimulates the target muscles. A computer is evaluated the amount of activity present in the muscle and determines whether the patient's muscle contracting meets or exceeds a preset threshold. While the subject reaches the threshold, the Neuromove 900® activates the muscle with its own biphasic waveform with pulse width ranging from 100 to 400 ms (5).

The power-assisted FES is another device which measures EMG before stimulated the target muscles (22, 62). This FES system was used with different treatment approach, that is, home-based program (5, 62) or combined with other intervention, such as, phenol (62, 69).

Home-based program with power-assisted FES resulted in improve recovery for patients with partial hand control. The new power assisted FES system is a portable and two channels neuromuscular stimulator (62). It promotes wrist or finger extension or shoulder flexion movement during coordinate movement but will not work when target muscles cannot contract. It induces voluntary muscle contraction by integrated EMG signal picked up (24, 62). The patients with hemiplegia who used the FES have significantly improvements in active range of motion, the modified

Ashworth scale, EMG root mean square, and motor performance and were able to smoothly perform ADL using their affected UE (5).

Hybrid power-assisted FES consisting of a motor point block decreasing antagonistic muscle spasticity (negative factor) and the power-assisted FES increasing agonistic muscle strength (positive factor) (24). Nerve or motor point block with phenol combined with FES is useful for improving hemiparetic hand function (69). It is used to improve motor control and the balance of activity at a joint or increase tolerance to splinting and passive stretching (5, 62). Surface electrodes picked up the EMG signals and stimulated target muscles in proportion to the integrated EMG signal obtained by the FES device.

8. Limitation of functional electrical stimulation

There are some technical limitations associated with the use of surface electrode stimulators. The first limitation is the lack of selectivity over the muscles or nerves recruited. Furthermore, the skin burns are the greatest risk of any continuous current technique. These problems result from very high electrical density of current in the area of contact or from setting the intensity too high for the size of the active electrode (70). The present study will use a stimulator which is powered by 9 volts battery and produced biphasic pulsed current. Therefore, the electrical shock hazard and the irritated skin under the electrode can be eliminated.

9. Differences between electrical stimulation and exercise

Activity of muscle during electrical stimulation is restricted to the stimulated muscle and the muscle is less influenced by other changes that occur in the body during exercise. Superimposed electrical stimulation bypasses the normal neuronal control mechanisms. Stimuli (pulses) need to be sufficient intensity and long enough duration to depolarize the nerve membrane, so that action potentials are generated in the motor nerves and muscle contraction occurs. There are now overwhelming evidences (71) that an important factor in determining a skeletal muscle's properties is the amount of neuronal or impulse activity relative to the activity that is usual for the muscle. Electrical stimulation manipulates the output activity pattern to the motoneurone by adding to its inherent activity. However, during voluntary exercise, the relative activity of each motor unit remains unaltered with respect to the rest of the unit relatively rigid pattern of recruitment (71).

Electrical stimulation may facilitate recruitment of the large fast motor units. The recruitment order of the motor units is thought to be reversed in electrical stimulation from the natural sequence (25, 71). Because of their large diameter axons and low activation threshold, the larger motor units are recruited first. These fast-contracting, easily fatigable motor units are often found in the superficial layers of a muscle and closer to the stimulation electrodes (71). The stimulation will also be conducted antidromically, that is, going towards the spinal cord, along the motor nerve and by the afferent sensory nerves (71, 72).

10. Task-specific training

Task-orientated model is based on the systems theory which is an integral part of the motor control and motor learning theories. Practice of motor task requires the integration of systems and environmental factors integrated into the performance of the task. In rehabilitation, task-oriented activities should be practice in a variety of contexts to enable the patient to develop and implement the strategies for performing tasks (49). Research supports (73) the use of task-orientated treatment as effective in relearning functional activities. Patients who show low function should be treated with a task-oriented model which may be appropriate to include specific traditional treatments to facilitate motor activity (49).

The analysis and practice of task-specific activities are emphasized in the Carr and Shepherd in 1987. There are four steps in the motor relearning program (74).

Step 1: Analysis of task
    Observation
    Comparison
    Analysis
Step 2: Practice of missing components
    Explanation---identification of goal
    Instruction
    Practice plus verbal and visual feedback plus manual guidance
Step 3: Practice of task
    Explanation---identification of goal
    Instruction
    Practice plus verbal and visual feedback plus manual guidance
    Re-evaluation

Encourage flexibility

Step 4: Transference of training

Opportunity to practice in context

Consistency of practice

Organization of self-monitored practice

Structured learning environment

Involvement of relatives and staff

The role of therapists in treatment is to create an environment in which patients can practice goal directed behavior that will enable them to relearn the task. Practice sessions may include breaking the task into discrete components, followed by practice of the whole task. Manual guidance is provided as needed, but emphasis is placed on using own internal feedback for learning such as somatosensory and visual systems of the patients (49). Repetitive task-specific training with or without constraining the nonparetic extremity had resulted in improvement of UE function in both chronic and subacute stroke patients (6, 73).

11. Measurement of upper limb functions in hemiplegia

A number of UE motor function assessments are available for documenting the outcome of rehabilitation program after stroke. Only the tests related to the present study will be reviewed.

11.1 Modified Wolf Motor Function Test (mWMFT)

The mWMFT is a new time-based to evaluate UE movement ability through timed single- or multiple-joint motions, while performing functional task (75, 76). The tasks are arranged in order of complexity, progress from proximal to distal joint involvement, total extremity movement and movement speed. The test is required a few tools and minimal training for test execution (76). It includes 3 parts: the first, timing, the speed at which functional tasks can be completed; the second, functional ability, the movement quality when completing the tasks; and the third, strength, the ability to lift against gravity (77). Thus, mWMFT explores both performance time and quality of movement. It consists of 15 tasks. Tasks 1 to 6 involve timed joint-segment movement and tasks 7 to 15 consist of timed integrative functional movement. The functional ability scale (Appendix B) will be used by tester. The maximum score is 75. The reliability and validity of mWMFT have been supported by Wolf et al (76). Morris et al (78) also supported that high interrater reliability, internal consistency, test-retest reliabity, and adequate stability in adults with moderate chronic hemiplegia.

Clinical relevance of mWMFT can be determined as a minimal clinically significant. Lin and coworkers (79) suggested that the change score of within stroke group had range from 1.5 to 0.2 seconds per task and 0.2 to 0.4 scores per task in the time and functional ability of WMFT, respectively to be considered as clinical significance. They were examined in patients who had the time and functional ability of WMFT at baseline equal 7.05 seconds per task and 3.22 scores per task. In addition, change scores improvements may be considered by using Cohen's effect size. Schmitt and Fabio (80) suggested that effect size ranged form 1.06 to 1.67 for various level group patients.

11.2 The Motor Assessment Scale (MAS)

MAS is widely used both in the clinic and in research to measure improvement in motor function of paretic arm with hemiplegia (81). It provides objective measures of patients' progress over time in motor ability. The MAS is designed to measure the ability to perform functional tasks, rather than isolated patterns of movement or synergies (82). The MAS is a brief and easily administered assessment and consists of 9 items (82). There are three items of MAS measuring UE disability (i.e. upper arm function, hand movement, and advanced hand activities). The individual scores (0-6) and total scores (0-18) are used in the analysis. The reliability, validity, and responsiveness of the instruments have been well established in UE function in stroke patient receiving rehabilitation (82, 83). The present study used 2 items of UE subscales i.e. upper arm function and hand movement.

11.3 Modified Ashworth scale

The modified Ashworth scale is the most widely used for measurement of muscle spasticity in clinical practice and research (84). It is based on the assessment of resistance to passive movement at a joint. It is a 6-point scale from 0 (no increase in tone) to 4 (limb rigid in flexion or extension).

11.4 The Barthel index (BI)

The Barthel index measures basic activities of daily living and essential mobility. The initial process of assessment involves interviews the patient or the care taker to establish previously held life roles and the tasks and activities that were completed within these roles (85). It consists of 10 items: feeding, moving from wheelchair to bed and return, grooming, transferring to and from a toilet, bathing, walking on level surface, going up and down stairs, dressing, continence of bowels and bladder. The test-retest reliability of the instrument have been supported in chronic stroke pateints (86).

11.5 Thai mini mental status examination (TMMSE)

TMMSE is a standard test used in this study to identify orientation, cognition, memory, language and executive functioning, and to determine the impact of changes on the ability to resume daily function in stroke patients (87). A standard cut-off point is below 24 scores from 30 total scores (88). This test is a screening test for the detection of cognitive impairment and used primarily in connection with screening for dementia severity.

11.6 Jebsen-Taylor Hand Function Test (JTHFT)

JTHFT is consisted of the seven subtests which are administered in the standard order: handwriting, simulated page turning, picking up small common objects, simulated feeding, stacking checkers, picking up large, light objects, and picking up large, heavy objects (17). It is used to assess global hand dexterity, and testing is performed according to the standard protocol (89). All parts of this test are timed and subjects have to complete each task in the shortest time possible. Patients who are unable to perform the test or do not complete the test within 60 seconds received 60 seconds as their scores. The test is repeated 3 times with each hand, and the fastest time recorded for each hand is the final outcome measure (17).