Chapter

Current Trends in Stroke Rehabilitation

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Abstract

Stroke remains a leading cause of adult disability. The social, physical and psychological consequences of stroke are devastating. With better understanding of causation and breakthrough advances in management, we are witnessing a greater population of stroke survivors with varying neurological and functional deficits. Poststroke rehabilitation is a multi-disciplinary and multi-modal endeavor and not a 'one size fits all' intervention. A combination of interventions may be better suited to treat motor and sensory impairments, cognitive problems and psychological issues. There is great interest in exploring novel rehabilitation technologies to augment conventional therapies to reduce neurological disability and improve function. Yoga and spirituality, though ancient practices, are finding a bigger role in field of rehabilitation. In spite of good potentials for recovery, these rehabilitative measures are underutilized and major barriers are limited availability, geographical distance, high cost and lack of awareness about its benefits. While conventional measures are well engraved, this article review the recent concepts in stroke rehabilitation.

Keywords: gait rehabilitation, repetitive task training, mirror therapy, cognitive rehabilitation, robotic therapy, telerehabilitation, virtual reality, yoga, meditation, spirituality

1. Introduction

Stroke is a major public health concern and remains a leading cause of adult disability [1, 2]. The social, physical and psychological consequences of stroke are devastating. In spite of best treatment available, 30–50% stroke survivors are left with significant physical and/or psychological disabilities and consequent decline in quality of life (QOL) [3]. Such patients require long-term rehabilitation to the restore and improve motor functions for the paralyzed limbs. There is marked inconsistencies in quality of care and rehabilitation services across the globe.

The rehabilitation of the stroke is a multidisciplinary process involving doctors, nurses, physiotherapist, occupational therapists, neuropsychologists, linguistic and speech specialists, audiologists, and nutritionists [4]. With better understanding of causation and breakthrough advances in management, we are now witnessing a greater population of stroke survivors with varying neurological and functional deficits [5, 6]. There is great interest in exploring novel technologies to augment conventional therapies to reduce neurological disability and improve function.

2. Prognosis in stroke recovery

Approximately one third to half of the patients is left with significant physical and/or psychological disabilities [4, 5]. This leads to a marked decline in QOL which increases with passage of time. Neurorehabilitation with conventional physiotherapy, occupational therapy and speech therapy offers them a good opportunity to regain QOL and activities of daily livings (ADLs). A large number of prognostic factors have been identified [2, 7]. Extent and severity of initial injury to brain is perhaps the most important factor for stroke recovery. Many techniques are available to assess which include bedside evaluation, functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS) etc. [5, 7]. It has also been observed that presence of comorbid conditions such as past stroke or transient ischemic attacks, diabetes, hypertension, dyslipidemia, cardio-respiratory status, advancing age, and degree of periventricular white matter hyperintensities on MRI adversely affect outcomes [5].

3. Physical therapy

While motor deficit and spasticity management is well organized, there is a requirement to develop a holistic module considering other deficits such as difficulty in swallowing, nutrition, fear of falls, sensory impairment, dysarthria, aphasia, cognitive impairment and depression also.

3.1 Muscle strengthening and early Mobilization

Strength training is defined as an intervention where participant exercised a muscle or group of muscles against an external resistance. Both active and passive exercises are safe to perform for hemiplegic stroke patients and can induce functional improvement [8]. Passive exercises, by the therapist or with motorized ergometer, are defined as movement of the body without the effort of the patient. Progressive resistance exercises are functional patterns of movements against progressively increased resistance or weight. Passive and active muscle movements and progressive resistance training is most commonly employed and perhaps most effective therapy to improve motor power and functions including walking, gait and balance [9]. They are also effective in reduction of fatigue and improvement in QOL in individuals with stroke. Most of stroke patients have a high prevalence of cardiovascular risk factors that are potentially modifiable with exercise. However, to document such quality of improvement, high-quality methodological designed studies are required.

It has been observed that passive exercises over limbs and early mobilization even during acute stage of stroke leads to better recovery [5, 10, 11]. Apart from psychological benefit, early mobilization also enhances neuroplasticity. Thus acute rehabilitation can be recommended on a continuous basis once cardio-respiratory status is stabilized.

3.2 Repetitive task training (RTT)

It is based on the principle that our brain is tuned for complexity and pattern of task rather than just on a single movement. Repeated practice of task-specific motor activities (e.g. lifting a cup) on regular basis is more effective than simple movements at joints. In RTT, an active motor sequence of a desired movement is performed repetitively within a single training session, aimed toward a clear functional goal. There is low to moderate quality evidence for RTT in improving upper and lower limb functions, walking and functional ambulation up to six months post treatment [12].

3.3 Constraint-induced movement therapy (CIMT)

CIMT involves constraining of the non-paretic arm while doing task-oriented training with paretic limb. It was developed mainly to upper limb functions and perhaps is the most investigated intervention in stroke rehabilitation [13]. Original CIMT include constraining of non-paretic upper limb with a sling or glove for 90% of the waking hours 2 weeks, while affected limb undergoes intensive training of the 5–6 hours per day. In modified version of CIMT (mCIMT), the therapy sessions are less intense (1/2 hour to 2 hour per day for 3 days a week) and have better tolerance and acceptability [14]. Both CIMT and mCIMT have demonstrated benefits in motor function, arm-hand activities, and ADLs on immediate as well as on long-term follow-up [13, 14].

3.4 Mirror therapy

In mirror therapy, a mirror is placed in the person's midsagittal plane reflecting movements of the non-paretic side as if it were the affected side [15]. It is provided for 15–60 minutes three to seven times a week for four to eight weeks. A sustained mild to moderate improvement in motor function, motor impairment and ADLs has been observed mainly with upper limb after mirror therapy which maintained for 6 months or more [12, 15, 16]. However, there was a small to insignificant improvement in pain and visuospatial neglect. One of the additional advantages with mirror therapy is that it can be performed even in presence of severe or complete paralysis of a limb [16]. Thus it can be safely employed as an adjunct for training post-stroke impairments (motor, sensory, perceptual deficits) in acute, sub-acute, and chronic phases.

3.5 Botulinum toxin

Poststroke spasticity is seen in approximately a quarter of patients which interfere with ADLs, personal hygiene, social participation, and QOL [17]. Effective spasticity management is often challenging for the clinician as commonly prescribed drugs to treat spasticity such as lioresal, tizanidine, benzodiazepines, and dantrolene sodium have limited role [18]. Botulinum toxin A (BoNT-A), one of the most potent biological toxins, is extensively used now a day to treat focal spasticity [18]. Injection BoNT-A combined with conventional rehabilitation training is a major advance in improving motor functions [17]. It safely and effectively reduces the muscle tone and increases the range of motion. The major disadvantage with this form of therapy is that its effect vanishes in 2–6 months and it requires skill person to administer it. Though experience is limited, it is perceived that functional outcome of many patients would be improved if BoNT-A is introduced aggressively.

3.6 Gait rehabilitation

Improvement in walking capacity is one of the main concerns with stroke victims and their family. Marked limping with unsteady gait and poor obstacle clearing increases the risk of falling [19]. Thus strengthening of trunk and hip muscles (particularly hip extensor) and gait training are major goals in rehabilitation [20]. Six-min walking test is a simple assessment of gait in community setting.

Common available techniques for gait training are walking stick, stationary cycle, stepping machine and treadmill training with or without support [21]. Gait training with robotic-assisted therapy and augmented or virtual reality (VR) is now being evaluated and preliminary results are encouraging [20]. In VR, treadmill training is supplemented with visual cues through projectors that display shapes on the walking surface. The training schedule includes specific exercises for gait symmetry, coordination enhancement and gait agility. A daily session of 30-min duration for 4 weeks has provided a significant improvement in gait speed and in balance [20].

4. Rehabilitation technologies

Though conventional motor rehabilitation are effective, the major limitation with them is an inadequate dose of rehabilitation therapy, in terms of repetition and intensity [22]. Rehabilitation technologies are defined as 'those whose primary purpose is to maintain or improve an individual's functioning and independence, to facilitate participation and to enhance overall well-being'. Such devices are quite helpful in engaging patient's interest and motivation. A wide range of such applications are available e.g. robotic and virtual reality technologies, assistive devices, neuroprostheses and smartphone applications.

4.1 Robotic devices & virtual reality (VR)

While robotic devices are characterized by machines capable of carrying out a series of complex actions automatically, virtual reality (VR) is characterized by a machine produced interactive simulations to allow users to engage in environments that closely resemble the real-world [22]. During such simulation, visual and multisensory feedback constitutes an important attribute. Many robotic devices and VR technologies are available which facilitate joint movements, walking, improve muscle strength, motor function and ADLs in upper limb and possibly in lower limb [22]. Electromechanical-assisted gait training combined with conventional physiotherapy is more effective than training without these devices. Combining robotic and VR technologies increase the intensity and amount of rehabilitation training. However, such devices are complex and costly for routine use and there is a requirement to develop a low cost simple module.

4.2 Electrical stimulation (ES)

Electrical stimulation (ES) is one of the most widely used therapy and its reported benefits include spasticity reductions, improvements in range of motion, improved sensation and reduced pain. In spite of promising benefits, there are insufficient evidences in case control studies [3]. However, its benefit in stroke rehabilitation has not been adequately demonstrated. There are many types of ES and commonly applied in stroke are neuromuscular electrical stimulation (NMES), functional electrical stimulation (FES) transcutaneous electrical neuromuscular stimulation (TENS) and iontophoresis (to administer medicines). Combining ES with physical exercises is critical for achieving maximum results.

NMES is delivered by surface electrodes over involved muscles and giving pulse stimulation. In 15–30 minute sessions for 4–8 weeks. FES is a technique that uses low-energy electrical pulses to induce movements in a muscle or group of weak muscles in paralytic limb. They are useful in retraining voluntary motor functions such as grasping, reaching and walking [23]. TENS is a non-invasive inexpensive and self-administered technique to relieve pain associated with stiffness and contractures in hemiplegic limbs [24]. During TENS, pulsed low intensity electrical currents are delivered through surface electrodes.

5. Regenerative therapy

Till recent, it was believed neural tissues do not regenerate. Now we have learnt that it is possible to reconstruct neural circuits with transplanted endogenous neural stem cells [25]. In many studies, stem or progenitor cells like neural stem cells, neural precursor cells, embryonic stem cells, mesenchymal stem cells, and induced pluripotent stem cells showed a beneficial effect in restoration of lost neuronal and vascular elements. Cell therapy considers not only replenishment of deficit cells but also to create a regenerative environment. Preliminary evidences suggest that regenerative cell-based therapies can lead to functional recovery in stroke patients [26].

5.1 Growth factors and neuromodulators

There are studies that higher levels of many growth factors has positive impact on stroke recovery, neuroplasticity, neurogenesis, neuronal and and dendritic changes, synaptogenesis and cortical reorganization after stroke [27]. Such factors include vascular endothelial growth factor (VEGF), hepatocyte growth factor (HGF), Brain-derived neurotrophic factor (BDNF), nerve growth factor (NGF), glial-derived thrombospondin 1 and 2, erythropoietin (EPO),and growth-inducing proteins (neuromodulin, CAP23, mArCKS). While exogenous growth factor therapy has emerged as a potential treatment for ischemic brain injury in recent years, more studies are needed to quantify timing, dosing, route of administration, optimize combination therapy and their place in clinical setting [28].

5.2 Drugs to enhance motor recovery

Recovery after stroke depends on the neuroplasticity which is defined as ability of brain to reestablish the structural and functional organization of neurovascular networks [29]. While most of studies have focused on neuroprotection in the acute phase, drugs to enhance recovery during chronic phase of stroke has not been adequately researched. Currently, there are some drugs that can facilitate brain repair and improve clinical effect even years after stroke onset. Drugs that have been evaluated for recovery after stroke in animals and poststroke patients are D-amphetamine, levodopa and other dopaminergic agents, fluoxetine, niacin, inosine, and cticoline. However, no significant clinical benefit has been observed with any of the drugs.

5.3 Cognitive rehabilitation

Cognitive impairment is perhaps second common deficit after motor impairment following stroke [6]. Though 30% of them recover spontaneously, a large number of such patients remain cognitively impaired. Cognitive rehabilitation therapy (CRT) is defined as a wide range of interventions to improve cognitive functioning by (i) reestablishing or strengthening previously learned patterns of behavior or (ii) establishing new patterns of cognitive activity or compensatory mechanisms for impaired neurological functioning [30]. There are many types of cognitive deficit in postsroke patients and they include forgetfulness, confusion, disorientation, problems with attention, executive functioning, and information processing etc. [31]. However, being subjective, it is difficult to quantify cognitive deficits and we must develop suitable biomarkers including MRI, and magnetoencephalography (MEG) to assess them. Cognitive rehabilitation is still far from satisfaction.

Cognitive deficit interact with motor deficits in exponential way to result in disablement after stroke. Thus combining motor and cognitive rehabilitation is a practical way of enhancing recovery after stroke particularly in moderate-to-severe cases. CRT is an individualized program of specific skills training and practices involving memory, attention, self-awareness, problem-solving skills, executive functions, social skills, self monitoring, activities planning and task sequencing [32]. To have complete benefit, CRT should be administered as a part of the multidisciplinary and not as a "stand alone" approach. Right hemispheric infarct patients need additional spatial retraining to promote rapid recovery [33].

5.4 Non-invasive brain stimulation

There is a substantial reorganization in brain after stroke [34]. Non-invasive brain stimulation (NIBS) has been shown to enhance neural plasticity and is a promising strategy in cognitive and motor training. Current research is limited to a small number of cases with poor methodologies. The commonly studied NIBS techniques are transcranial direct current stimulation (tDCS) and repetitive transcranial magnetic stimulation (rTMS) [34]. Such interventions induce positive effects on force production by increasing cortical activity in the ipsilesional hemisphere and decreasing cortical activity in the contralesional hemisphere [5, 6, 35]. A good improvement has been seen with NIBS in hemispatial neglect, gait speed and performance in ADLs in poststroke patients [11].

6. Remote rehabilitation

6.1 Tele-rehabilitation

Newer technologies for rehabilitation have the limitation of cost, complexity and limited access to patients in remote or rural areas. Furthermore, limited resources prevent patients from receiving intensive treatment and extensive attention at rehabilitation centres. Telerehabilitation, also known as e-rehabilitation, is the delivery of rehabilitation services over telecommunication networks and the internet [36]. It provides access to rehabilitation services at a remote area using communication technology [14]. Apart from physical therapy, with telerehabilitation services we can deliver speech therapy, occupational therapy, audiology services and psychological support also. It is a fast growing application and has the potential to improve access and reduce treatment disparities for stroke patients who live in rural areas. Combining telerehabilitation with in-person services reduces the personal visit to rehabilitation centres.

6.2 Biofeedback and wearable sensors

Hospital or clinical based functional assessment and monitoring therapy is not only time consuming with personal bias, it lacks real life individualized situation in a familiar environment [8]. Wearable sensor technology addresses many of these limitations and offers home-based therapies which can be monitored remotely [37]. Last two decades have witnessed a significant advancement in technology and low cost miniature sensors have been developed which enable objective and long-term monitoring in a patient's habitual environment [38]. Most of sensors currently in vogue are either inertial measurement units (IMUs) or electromyography (EMG) based sensors.

Biofeedback training in rehabilitation aims to improve outcomes by educating and engaging patients [39]. This is close loop system where a person learns through the data provided by sensors placed over body or head. These data are then fed in a processor unit connected to an output motor device. Neurofeedback (NF) training is also a close loop system where a person learns by self-regulating his/her own brain activity through real-time feedback [40]. EEG alpha wave feedback has been studied extensively. Recently researchers have started using real-time functional magnetic resonance imaging (rt-fMRI) signals to modulate brain activity [41].

Conventionally subject attends 2–3 sessions per week for 4–6 weeks. A mild to moderate grade improvement has been observed in motor functions, gait control, attention, memory, concentration, reading, coordination, visual perception and emotional state in chronic stroke patients. Additional advantage of this system is that it can be used during acute stage of stroke when strenuous physical exercises are not possible. During chronic stage of stroke it facilitates neuroplasticity and functional reorganization.

6.3 Brain–computer interface

Brain–computer interface (BCI) or brain–machine interface (BMI) is an upcoming technology in stroke rehabilitation [4, 5]. Brain signals are recorded through a sensor (either surface EEG signal or an invasive microelectrodes) are transmitted a computer processor to decode it and formulate a signal for intended actions with robotic limb or wheelchair. It can also be utilized as electrostimulation devices or assist with motor imagery. This high cost venture is currently in experimental stage.

7. Yoga and spirituality for stroke rehabilitation

Yoga and Meditation: Yoga is an ancient Indian science and way of life [1, 42]. Practice of yoga consists of physical postures (*asanas*), controlled breathing (*pranayam*), body relaxation, and control of thoughts and mind (meditation). Meditation is an essential component of yoga and is now being practiced worldwide. These practices strengthen willpower and control of mind and body to work in perfect synergy [1]. They have been extensively studied for promotion of physical and mental health and in management of diverse clinical disorders [42]. They are known to promote cardio-respiratory health and to reduce stroke related risk factors (e.g. carotid atherosclerosis, dyslipidemia, hypertension, diabetes, and coronary artery disease) [43].

Spirituality: There is no agreed definition of the term spirituality. It is a blend of humanistic psychology with an individual relationship with a higher powers and the subjective experience about the "deepest values and meanings by which people live," [44, 45]. Higher levels of spirituality are known to be associated with a better QOL for stroke survivors and the caregivers [44]. To have its wider application, it is necessary to distinguish it with religion which is an institutionalized and community based doctrine, beliefs, practices and rituals [44]. It must be clarified that being spiritual does not necessarily mean religious whereas the reverse is true.

Bastille and Gill-Body and Singh et al. demonstrated that following practice of yoga and meditation there was significant improvement in muscle power and range of movements in hemiplegic limbs and some positive effects in the Berg Balance Scale (BBS), Timed Movement Battery (TMB) and quality of life (QOL) as assessed

Step Description	Duration
1. **Place & Position** (decided on patient's condition and disablement) • Select a quite place with least distraction. • Comfortably sitting on a chair or lying in the bed.	2–3 minutes
2. **Posture** (*asanas*) and loosening movements: • Based on patient's condition movements can be active, passive or assisted. • Based on physical disablement, one can increase upto 10–15 minutes	15 minutes
3. *Pranayam* (breathing exercises) and controlled breathing: • Make breathing slow, long and rhythmic. Take a deep breath in with mouth closed and hold it comfortably for 2–4 seconds. Then exhale effortlessly with mouth closed. Repeat this initially for 5 times in 2 minutes and with practice gradually increased it to 9–11 times in 7–10 min. *Pranayam* has shown to enhance body oxygen utilization, improve concentration and clean the respiratory passages.	10 minutes
4. **Body relaxation with awareness** (*Kayotsarga*) • Instruct body to relax each part, one by one, from toe to the upper part of the head. Autosuggest for relaxation of muscles, body and mind. Maintain this relaxation for 5 minutes and with practice increase it to 10 minutes.	5 minutes
5. **Meditation** • **Concentration meditation:** With eyes closed focus your attention on a single object, idea, sensation or an aspect of divinity (e.g. counting or monitoring breathing, reciting a mantra, visualizing processes in the body, external object, etc) at the exclusion of all other thoughts. Distracting thoughts will invariably appear but try to ignore them by focusing the mind through autosuggestions. • **Open mindedness:** This is a higher stage which can be practiced after one has mastered concentration meditation. Instead of focusing attention, there is expansion of awareness and attention. All sensory inputs, be it internal (thoughts, feelings, memory, etc.) or be it external (sound, smell, etc.), are perceived as they are without any prejudice and in a nonreactive way. This it provides a stimulus to gain access to knowledge, self-realization, and for soul (consciousness) purification.	10–15 minutes
6. **Conclusion** Gently close your meditation session. Rub your hands and move your body freely	One minute

Table 1.
Yoga and spiritual practices module for stroke rehabilitation.

with Stroke Impact Scale (SIS) [46, 47]. Cognitive and psychological improvement with reduction in anxiety and depression are additional advantages with mediation which is helpful for stroke patients and caregivers [48–51].

Yoga and meditation practices allow neurorehabilitaion in less complex and highly individualized environment [47, 50]. Being a low-cost model, it improves availability of rehabilitation in low- to middle-income countries also. However, yoga and meditation program should be tailored to deliver personalized interventions according to each person's profile and rehabilitation needs (time after stroke, level of impairment, function and mobility). A suggested module as designed by the author is given in **Table 1** and should be modified as per patient's need and disablement. Though these practices are effective and less labour intensive, there is a lack of evidence-based review to support the claim [44]. To have a larger acceptance by academic community, rigorous experimental studies are needed.

Mechanism of improvement: Long practice with yoga has been associated with increase gray matter density in structures involving memory, self-awareness, and compassion. fMRI studies have shown increased gray matter in hippocampus, prefrontal cortex, cingulate cortex and brain networks including the default mode

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network (DMN) [52]. Contrasting to this, there was decrease in volume of amygdala, associated with fear, anger and stress.

Epigenetic refers a way to regulate gene activity in real time without modifying the DNA sequence. It allows body to function with changing environment. Yoga and related practices have shown to alter gene expression particularly those related to free radicals handling, mitochondrial energy production and utilization, inflammation processes and apoptosis [53].

8. Conclusions

The field of stroke rehabilitation has a bright future. In spite of good potentials for recovery, these rehabilitative measures are underutilized and major barriers are limited availability, geographical distance, high cost and lack of awareness about its benefits. Such interventions should consider variables such as time after stroke, type and level of impairment, and functional need. In recent period, we have witnessed many novel concepts and interventions such as robot-assisted training, magnetic and electrical stimulation, brain–computer interface, telehealth, stem cells, biotherapeutics, and the use of virtual environments. Yoga and spirituality, though ancient practices, are finding a bigger role in field of rehabilitation. Medical and paramedical practioners involved in stroke care should be aware of them and educate the patients and caregivers.

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