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Robotic Training for Upper Limb Rehabilitation

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Abstract

This paper discusses the benefits of Robotic therapy for upper limb rehabilitation in patients post stroke. Rehabilitation robotics is a field of research dedicated to understanding and augmenting rehabilitation through the application of robotic devices. Robots can be used to generate objective measures of patient's impairment and therapy outcome, assist in diagnosis, customize therapies based on patient's motor abilities, and assure compliance with treatment regimens and maintain patient's records. It is shown in many studies that there is a significant improvement in upper limb motor function after stroke using robotics for upper limb rehabilitation.

Keywords: Cerebro-vascular accident; Upper limb rehabilitation; Robotic therapy.

Introduction

Limb impairment can be a serious impediment to a person being able to independently perform the activities of daily living. This can have a negative effect on their quality of life. One of the primary causes of limb impairment is stroke.[1]

Stroke or cerebral vascular accident, is the sudden death of brain cell due to inadequate blood flow. The WHO clinically defines stroke as the rapid development of clinical signs and symptoms of focal neurological disturbance lasting for more than 24 hours, or leading to death with no apparent cause other than of vascular origin (WHO 2005). Stroke increases with age, individual Indian studies have estimated that the prevalence rates increases from 21/100,000 for the 20-40 age group to 625/100,000 in the 60+ year age group (Ghamija *et al* 2000).[2]

Although prospective epidemiological studies are lacking, findings of several longitudinal studies indicate that in 30% to 66% of hemiplegic stroke patients, the paretic arm remains without function when measured 6 months after stroke, whereas only 5% to 20% demonstrate complete functional recovery.[3]

It was also found in many studies that, 30% to 60% of patients treated with traditional rehabilitation, a residual functional impairment of the paretic arm and consequently of ADLs is common. There is strong evidence that intensity as well as task specificity are the main drivers in an effective treatment program after stroke. In addition, this training should be repetitive, functional, meaningful, and challenging for a patient.[4,5]

Although occupational and physical therapies are widely accepted treatments for upper extremity dysfunction in stroke patients, they are labor intensive and therefore expensive.6 Applying robot-assisted therapy enables patients to practice intensively with their upper paretic limb.[5,7]

Robots can be used to generate objective measures of patient's impairment and therapy outcome, assist in diagnosis, customize therapies based on patient's motor abilities,

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and assure compliance with treatment regimens and maintain patient's records.[6]

Systematic review confirms the potential for robotic assisted devices to elicit improvements in upper limb function.[5,8]

Moreover virtual reality provided a unique medium where therapy can be provided within a functional, purposeful and motivating context and can be readily graded and documented.[9]

For the upper extremity, the most employed and deployed therapeutic robot is the MIT-Manus.[10,11,12] Many other devices have been designed to deliver arm therapy in individuals with stroke, like the ARM Guide (Assisted Rehabilitation and Measurement guide)[13], the MIME (Mirror-Image Motion Enabler)[14,15], the InMotion Shoulder-Elbow Robot[3,16], and the Bi- Manu-Track[17] were tested in at least 1 RCT.

The MITMANUS is a robot that allows subjects to execute reaching movements in the horizontal plane. This 2 degrees of freedom (DoF) robot enables unrestricted movements of the shoulder and elbow joints.[10] The ARM Guide is a trombone-like device and has 4 controlled DoF.[13] The MIME robot consists of a 6-DoF robot arm. The robot enables the bilateral practice of a 3-DoF shoulder-elbow movement, whereby the nonparetic arm guides the paretic arm.[18] The InMotion Shoulder-Elbow Robot, which is the commercial version of MIT-MANUS, has 2 DoF and provides shoulder elbow training in the horizontal plane with a supported forearm.[16] The Bi-Manu-Track is designed to specifically train distal arm movements by practicing bilateral elbow pronation and supination as well as wrist flexion and extension in a mirror or parallel fashion.[17] NeReBot allows to train in the acute and post–acute stroke phase of the patient on 3-dimensional movements of the arm (flexion and extension, pronation and supination, adduction and abduction, circumduction), not only while sitting but also in the supine position.

Robots can be used in a local or domestic setting, for this it has a number of features that are not required for robots intended primarily for use in a specialist rehabilitation centre setting. These include low cost, portability, robustness and a strong emphasis on safety and also allowing to monitor patient progress. These variables can be adjusted by a therapist throughout the course of rehabilitation therapy to optimize patient recovery post stroke.1 Robot-based assessment measures are highly repeatable, have the potential to detect smaller changes than standard manual assessment measures and could potentially reduce the time it takes to administer an assessment.[19,20]

Types

There are two types of rehabilitation robot from the mechanical design point of view:

1) End-effector based robots
2) exoskeleton-type robots.

MIT-MANUS is an example to the end-effector based robots, which interacted with subjects at the end of robot arm.[12] The design of end-effector could adapt to subjects with different body size. While exoskeleton-type robots can resemble human anatomy and apply torque to specific joints, moreover, the working-space of the rehabilitation training provided by such kinds of exoskeletons could approximate the working-space performed by human subjects.[21,22]

Control strategy is another important factor to affect the training effect of robot-aided rehabilitation. MIT-MANUS applied impedance control in the robot-assisted upper limb rehabilitation, and it could keep a compliant trajectory under perturbation and promote interaction between subject and robotic system.[12]

The important feature of MIME was that patients could use the unaffected sides to control the affected sides to practice mirror-image movement by a bimanual position feedback strategy. The admittance control could facilitate the movement with providing target position, velocity, and acceleration based on interactive torque.[23]

Recent studies show that mechanical help from robotic system should better not be conducted in a passive mode, and 'assist-as-needed' help is provided to promote brain reorganization.[24,25]

Recently, many researchers used EMG signals to continuously control exoskeleton-type robots. These robots were designed like human's joints and could be worn by the human operators as an assistive devices. The systems were under the voluntary control, functioning like additional muscle groups to provide additional forces.[26,27,28,29,30]

Method

Dosage in stroke rehabilitation trials usually uses the duration-based measure of therapy and provides the information regarding the amount of minutes or days per week of therapy provided.[16] Most Randomized trials have offered the treatment in sessions lasting 30 minutes to 1.5 hours, with 3 to 5 sessions per week for 3 to 8 weeks.[31,32,18,33]

According to a recent research, performing about 300 repetitions of task specific UE training per session was feasible in stroke rehabilitation.[34] Even greater duration or intensity of rehabilitation resulted in more functional improvement.[35]

Studies

Yu-wei Hsieh *et al* did a pilot randomized study on 18 patients to find the effects of Treatment Intensity in Upper Limb Robot-Assisted Therapy for Chronic Stroke patients. Patients were randomly divided into 3 groups, with each group receiving higher intensity Robotic therapy, lower intensity Robotic Therapy using Bi-Manu track and conventional therapy respectively. It was found that patients in the higher intensity Robotic Therapy group had better outcomes than those in the lower intensity RT group and the CR group on UE motor function, muscle strength, performance of daily function, and bimanual ability function, muscle strength, performance of daily function, and bimanual ability.[36]

Caitlyn Bosecker et al did a study on 111 community-dwelling volunteers who had suffered a stroke, to test the performance of linear regression models to estimate clinical scores for the upper extremity from systematic robot-based metrics. The subjects were trained for 18 hours with the InMotion robot. Twenty kinematic and kinetic metrics were derived from movement data recorded with the shoulder-and elbow InMotion robot. Kinematic metrics were aggregated into macro-metrics and micro-metrics and collected from 111 chronic stroke subjects. It was found in this study that in addition to delivering high-intensity, reproducible sensorimotor therapy, these devices are precise and reliable "measuring" tools that can be expanded with multiple sensors to record simultaneously kinematic and force data. These measurements are objective and repeatable and can be used to provide patients and therapists with immediate measures of motor performance. Reducing the time to evaluate improvement or deterioration and ultimately increasing the efficiency of patient's care.[37]

Rong Song *et al* did a study to evaluate the feasibility of robot-assisted rehabilitation using myoelectric control on upper limb motor recovery. Sixteen subjects after stroke had been recruited for evaluating the tracking performance and therapeutical effects of myoelectrically controlled robotic system. In this study, an exoskeleton-type rehabilitation robotic system was designed to provide voluntarily controlled assisted torque to the affected wrist. Voluntary intention was involved by using the residual surface electromyography from flexor carpi radialis and extensor carpi radialis on the affected limb to control the mechanical assistance provided by the robotic system during wrist flexion and extension in a 20- session training. The system also applied constant resistant torque to the affected wrist during the training. The study results indicate that robot-aided therapy with voluntary participation of patient's paretic motor system using myoelectric control might have positive effect on upper limb motor recovery.[38]

Antonio Frisoli *et al* did a study in a group of nine chronic stroke patients with right-side hemiparesis. In this study the effects of a robotic-assisted rehabilitation training with an upper limb robotic exoskeleton for the restoration of motor function in spatial reaching movements were investigated. The robotic assisted rehabilitation training was administered for a period of 6 weeks including reaching and spatial antigravity movements. To assess the carry-over of the observed improvements in movement during training into improved function, a kinesiologic assessment of the effects of the training was performed by means of motion and dynamic electromyographic analysis of reaching movements performed before and after training. The robot aided training showed a statistical significant improvements of kinesiologic (movement time, smoothness of motion) and clinical parameters, as a result of the increased active ranges of motion and improved co-contraction index for shoulder extension/flexion. These changes can be explained as a result of the motor recovery induced by the robotic training, in terms of regained ability to execute single joint movements and of improved interjoint coordination of elbow and shoulder joints.[39]

Stefano Masiero *et al* did a Randomized control Trial on 34 hemiparetic patients to find the effectiveness of a Robotic Assistive Device (NeReBot) for the Upper Extremity During Early Inpatient Stroke Rehabilitation. All participants received a total daily rehabilitation treatment for 120 minutes, 5 days per week for 5 weeks. The control group received standard therapy for the upper limb. The experimental group received standard therapy (65% of exercise time) associated with robotic training (35% of exercise time). It was concluded that, the robot therapy by NeReBot did not lead to better outcomes compared with conventional inpatient rehabilitation.[40]

Federica Bovolenta *et al* did a pilot study which aimed at verifying the improvement on the motor impairment and functionality in 19 patients with chronic hemiparesis after stroke treated with a robot-aided rehabilitation protocol using the ReoGo system (Motorika Medical Ltd, Israel). The treatment consisted of a total of 20 sessions lasting 45 minutes each, 5 days a week, for a total period of 4 weeks. Evaluations were done immediately before and after treatment and 1 month after cessation of the treatment. This pilot study led to the finding of a clinical improvement and excellent patients compliance.[41]

Gert Kwakkel *et al* did a review involving 218 patients shows a positive trend toward robot-assisted therapy for the proximal upper limb when compared with conventional treatment modalities with regard to motor recovery when measured with the FM assessment scale (FMA) or the arm and hand impairment part of the Chedoke- McMaster Stroke Assessment Scale (CMSA).[11]

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