Robotic Rehabilitation in Stroke

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ABSTRACT

Stroke is a leading cause of acquired disability worldwide, with significant motor, sensory, cognitive, and psychological deficits. Motor impairments significantly impair the mobility and participation in daily activities, reducing the quality of life and increasing the socioeconomic burden. Traditional rehabilitation methods put physical strain on therapists and have limitations in efficacy, especially for patients with severe impairments. The integration of robotics into rehabilitation has emerged as a promising solution. While early robotic devices were made for performing repetitive tasks, modern robotic systems use feedback-based training to enhance neuroplasticity. Robotic rehabilitation addresses the need for intensive, repetitive training crucial for motor recovery and neuroplasticity. Rehabilitation robots are categorized by body part (upper and lower limb), function (therapeutic and assistive), and design (exoskeletons, end-effector systems, and wearable robotics). Robotic therapy is beneficial for both acute and chronic stroke patients, offering faster progress in functional gains. Future trends in robotic rehabilitation include integrating technologies such as virtual reality, brain–computer interface, and artificial intelligence to enhance adaptability and effectiveness. These advancements hold the potential to further revolutionize stroke rehabilitation, providing more personalized and efficient recovery pathways.

KEYWORDS- Robotic Rehab, Neuroplasticity, Exoskeleton, Upper limb Robotics, Lower limb robotics

EDITORIAL

Stroke is a prevalent, severe, and disabling healthcare problem on a global scale. With an increasing elderly population and increasing incidence of stroke in young, it has emerged as a major challenge. The array of deficits include motor, sensory, speech, and swallow, cognitive and psychological components. Motor deficits profoundly impacts functioning of the arms and legs which can lead to impaired motor control and negatively affects patients' quality of life and increases the socioeconomic burden of stroke. Studies show that at least one-third of stroke survivors fail to achieve a good functional outcome after the stroke[1]. Achieving a functional walking has long been a major goal of rehabilitation following a stroke. Earlier, patients who had severe weakness and needed significant support did not practice walking until their motor status improved sufficiently which led to functional dependence and disability. While treadmills have been utilized as an aerobic exercise device in healthy populations, they were used infrequently in therapy for people with neurological disabilities as good walking stability is a prerequisite for their use. Animal studies showed treadmill training can produce coordinated stepping movements in spinalized cats that lead ultimately to the discovery that this was also possible in humans with complete spinal cord injuries[2]. To facilitate step training, body weight support systems for treadmills were developed which drastically reduced the amount

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of physical assistance needed to safely participate in ambulation training.

It was then tried in patients with stroke with multiple studies focusing on machine-assisted step training in these populations[3]. The Cochrane Review of robotic rehabilitation in 1990's in the stroke population recommended that further investigation was required to understand the clinical benefits of the same[4]. The most effective frequency and duration of technology assisted training has been the focus of many recent studies.

Majority of post-stroke treatment to improve patient's independence relies on rehabilitation treatments. The integration of robotics into rehabilitation began in the late 20th century. Early robotic rehabilitation devices were simple and primarily used for repetitive tasks, designed to assist therapists by automating movements. Newer approaches involve feedback based training to enhance neuroplasticity. Neuroplasticity is the ability of the nervous system to reorganize following an injury which can be affected by external factors like intensive training, pharmacotherapy and non-invasive brain stimulation and this forms the basis of neurorehabilitation[5]. Challenges such as the labour intensive nature of rehabilitation treatment and need for repetitive training for long duration have driven the development of robotic technologies that are capable of hastening the rehabilitation process. As role of rehabilitation in preventing and managing disability is becoming more apparent, robotics is seen as a game changer in its ability to improve efficiency of rehabilitation programs. Rehabilitation robots are interactive motorized devices allowing the mobilization of a limb for sensorimotor rehabilitation. They are designed with different working modes: simple passive mobilization, robot-assisted mobilization that interacts with the patient and resistance training. Most robots also enable the interaction with a virtual environment to improve feedback and participation. Classification of robotics makes it easy for us to understand the technology used and intended function. Robotics are generally divided into upper limb and lower limb robotics based on body part that is target of the treatment. Within this framework, they are further classified on the basis of function into therapeutic and assistive robots. Based on design they are generally divided into exoskeleton type systems, end-effector systems and wearable robotics.

Robot assisted therapy in the rehabilitation of upper limb focuses on improving motor control, muscle strength and participation in self-care activities. They use force, visual, and audio feedback to guide precise movement execution and improve patient engagement. In comparison with conventional therapy, addition of robot assisted training is useful in improving motor functional recovery especially in patients with chronic stroke. Robot assisted therapy in the rehabilitation of lower limb provide force assistance and feedback for gait training. They improve motor control by facilitating movements at trunk, hips, knees and ankle. Cochrane review of effect of robotic assisted gait training (RAGT) in stroke found that among non-ambulatory patients, addition of robotic training could improve functional improvements in 1 out of 7 patients[6]. The purpose of therapeutic robotics is to provide continuous passive or active assisted movements to the affected limb in order to increase training. They use technologies to improve patient participation like sensory and game-based feedbacks. They can be used for repetitive gait training and improve functional walking ability or repetitive Arm control and functional training. Newer trainers also provide EMG activation of muscles to facilitate the activation of paralysed muscles. Assistive robots are used of compensation of a lost function allowing users to be functionally independent for daily activities when functional recovery has not occurred. Assistive upper limb robots are used for tasks like feeding or dressing, while assistive lower limb robots improve knee control or ankle control. Based on design, robotic systems are classified into exoskeleton, end-effector and wearable robotics. Exoskeleton robots where robot axes are aligned with the anatomical axes of the body to provide direct control of individual joint movements while end-effector devices interact with the patient's limb at the distal end (hand or foot) without direct control of various joints. Wearable robotics are compact devices that can be used at every environment especially home and provide functional and psychological efficiency for the patients and helps them to reach independence.

Our understanding of motor learning, neuroplasticity, and functional recovery after stroke has greatly expanded in recent years. Robotic rehabilitation provides the repetitive training that is essential for neuroplasticity and functional recovery, something that is difficult to achieve through conventional therapy alone. They can help break synergy movements, improve gait patterns, and enhance balance. These adjunctive benefits contribute to a more comprehensive recovery, addressing multiple aspects of post-stroke deficits[7]. The use of robotic devices in rehabilitation also leads to higher patient satisfaction and participation. The technology can make therapy sessions more engaging and motivating, which is crucial for maintaining patient adherence to long-term rehabilitation programs. They also provide a controlled and safe environment for rehabilitation exercises, reducing the risk of falls and injuries. This can boost patient confidence, encouraging them to push their limits[8].

Early intervention is generally recommended to maximize recovery potential. Robotic rehabilitation can be started as soon as the patient is medically stable and able to participate in therapy, typically within the first few weeks post-stroke. It is useful in preventing secondary complications like muscle atrophy and joint stiffness as well. Patients with moderate to severe motor deficits are good candidates for robotic rehabilitation. In particular non-ambulatory patients benefit from robot assisted therapy in early rehabilitation. Advantages of robotic rehabilitation are faster progress in rehabilitation, easy tracking of patient progress and reduction of physical strain on therapists. A single therapist can operate the machine providing an option for consistent gait training safely. Gait pattern and guidance force are adjustable to the patient needs to optimise functional training. Robotic rehabilitation may not be suitable for patients with certain medical conditions, such as severe cardiovascular issues, uncontrolled epilepsy, and severe osteoporosis where the physical demands of robotic therapy could pose a risk. Additionally, patients with severe spasticity or contractures that limit their range of motion may not benefit from certain types of robotic devices. Robots can be programmed to adapt to the patient's abilities, gradually increasing the challenge as the patient improves. Initially, the goal is to facilitate muscle activation and avoidance of muscle contractures. Here robotics can provide positional control for passive mobilisation or weight support for self-initiated proximal movements. In less severe weakness where the goal is functional training, robotics can provide proximal gravity support for reach and grasp activities. The number and duration of robotic rehabilitation sessions can vary depending on the patient's needs and progress. Typically, sessions are conducted regularly lasting between 20 to 60 minutes each. The overall duration of the rehabilitation program can range from 2 weeks to 2 months, depending on the severity of the stroke and the goals of therapy[9]. Integrating other technologies like virtual reality to create engaging environment with robotic rehabilitation can enhance its effectiveness. Brain-computer interfaces can provide real-time feedback and adjust the therapy based on the patient's brain activity, further personalizing the rehabilitation process. Future trends in robotic rehabilitation are focused on increasing the adaptability and intelligence of these devices using artificial intelligence[10].

Robotic rehabilitation represents a significant advancement in stroke recovery, offering a promising approach to improving outcomes for stroke patients. By providing consistent, repetitive, and intensive task specific training, these devices can enhance neuroplasticity, promote functional recovery, and improve patient satisfaction. As technology continues to evolve, the integration of robotics with other innovative technologies will further revolutionize stroke rehabilitation, making it more effective. The future of stroke rehabilitation lies in harnessing the power of robotics to help patients regain their independence and improve their quality of life. With ongoing advancements and positive clinical outcomes, robotic rehabilitation is not just a temporary innovation but is here to stay and evolve further.

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