Technological advancements in stroke rehabilitation

Arshad Nawaz Malik,[1] Hina Tariq,[2] Ayesha Afridi,[3] Farooq Azam Rathore[4]

Abstract

Early, coordinated, and multidisciplinary rehabilitation plays a major part in motor recovery after stroke. The conventional stroke rehabilitation primarily includes physical therapy, occupational therapy, and speech therapy. However, with these conventional methods, many stroke survivors still have a residual functional disability which impairs their ability to perform activities of daily living. This could be attributed to the insufficient therapy dose, low engagement and motivation of the patient, and lack of objective feedback to achieve significant improvements in function.

Various technology-based stroke rehabilitation interventions have been developed in the last few decades which have shown promising results in improving stroke patients' functional mobility and independence. The use of technology promotes repetitive, task-specific training, active engagement of patients, integrating constructive and concurrent feedback, and accurately measuring functional improvement.

This review summarizes the important technological advances in stroke rehabilitation, including exergames, telerehabilitation, robotic-assisted systems, virtual and augmented reality, wearable sensors, and smartphone applications

Keywords: Rehabilitation, Robotics, Stroke, Virtual Reality.

Introduction

Stroke is the most common cause of mortality and adult neurological disability worldwide. The estimated global prevalence in 2019 was 101 million[1] while in Pakistan an incidence of 250 per 100,000 has been reported.[2]

Along with the neurological impairment, stroke also has long-term adverse effects on the physical, emotional, and social well-being of the stroke survivor. It reduces patients' overall activity level, participation, and active

....

[1,3]Faculty of Rehabilitation and Allied Health Sciences, Riphah International University, Islamabad, Pakistan, [2]Bournemouth University, UK, [4]Armed Forces Institute of Rehabilitation Medicine (AFIRM), Rawalpindi, Pakistan.
Correspondence: Farooq Azam Rathore. E-mail; farooqrathore@gmail.com

involvement in the community. After being discharged from the rehabilitation centers, 65% of the individuals still do not make full motor recovery and cannot actively engage the affected limbs in the activities of daily living, indicating a need for further intensive intervention.[3]

Stroke rehabilitation services vary significantly across the globe. Although developed and high-income countries are gradually shifting towards advanced technology-based stroke rehabilitation, conventional rehabilitation (i.e., physical and occupational therapy) remains the standard practice worldwide.[4] Although conventional rehabilitative approaches help restore motor function and body movement, most stroke survivors are still left with a long-term residual functional disability.[5] The growing body of evidence on stroke rehabilitation suggests that neuroplasticity and optimum motor recovery depends on several elements such as repetitions and intensity of training, task-specificity, objective feedback, and motivation during therapy.[5]

Repetitions and Intensity of Training

The literature suggests that the stroke patients should be engaged in task-specific training. However, the outcomes of the task-oriented training will depend upon dosage and intensity of the exercise for optimum neuromotor recovery. Conventional rehabilitation practices often cannot fulfill the intensity and dosage requirement for stroke rehabilitation. The higher the dose of exercise the better are the results for stroke recovery.[6]

Task-specificity

Recent evidence has shown that technologies in stroke rehabilitation such as augmented reality and robot-assisted systems have the potential to provide a safe environment for intensive task-specific training. Task-specific training elicits cortical reorganization, which is difficult to achieve with conventional rehabilitation approaches.[7,8]

Objective Feedback and Motivation

Feedback and subsequent motivation play an essential role in motor learning. Post-stroke sensory and motor impairments make it difficult for the individual to detect and correct movement errors. Objective feedback is vital to learning references of correctness which allows the individuals to detect errors from sensory information.

Some recent technological advances in stroke rehabilitation are designed to provide feedback that helps stroke patients track their progress accurately, set further goals for themselves, and ultimately improve their functional performance.[9] It has been demonstrated that patients who were provided daily objective feedback on their walking speed could walk faster than those who did not receive any objective feedback.[10] Lack of objective feedback followed by subsequent lack of motivation is one of the significant causes of failure to benefit from rehabilitation programmes. Patients receiving conventional stroke rehabilitation have reported boredom and low motivation as one of the primary reasons for lack of adherence to exercise programmes.[9] Introducing games in stroke rehabilitation through technologies such as virtual reality and tele-rehabilitation increases patient engagement, adherence to training programmes, and better clinical outcomes.[9]

Technologies in Stroke Rehabilitation
Exer-Gaming
Gamification in stroke rehabilitation significantly motivates patients to adhere to exercise programmes. The patient uses hands or body motions to play the games, providing repeated practice to paretic limbs with consistent feedback and cues.[11,12] In addition, the games provide a source of enjoyment for the patient, ultimately increasing motivation, duration, and intensity of training.[11] Commercial games are affordable and readily available, but most are not custom-designed according to patient needs (speed, movement, and measurement).[5] Various games have already been trialed with stroke survivors, including 2D, 3D, and natural user interfaces like Nintendo Wii Sport, PlayStation, Wii Balance, Xbox, Kinect, and Armeo-Senso showed positive outcomes.[12,13]

Tele-rehabilitation
In tele-rehabilitation, the service users can access the interventions remotely through video conferencing or telephone calls. It is cost-effective, reduces hospital stay, and addresses transportation issues and the non-availability of rehabilitation centers in the patients' locality. It is a useful approach to engage stroke patients in training at home remotely through constant guidance and feedback. One of the limitations of tele-rehabilitation is however the lack of physical interaction of patients with the clinicians.[11,12]

Robotic Rehabilitation
The robotic devices, also known as an exoskeleton, provide assistance to a part of the body to achieve motor control and movement after stroke.[12,13] Research on robotics in stroke rehabilitation, has demonstrated

significant improvements in functional outcomes. Some of the most used robotic exoskeleton systems include Saebo Mobile Arm Support (SaeboMAS), Haptic Master, Hand Mentor Pro (HMP), Hand Mentor, and Myomo mPower 100.[13] Powered robotic exoskeletons have recently been designed for gait rehabilitation in stroke. It is strapped onto the legs and has electrical motors that can control the joint movement to provide intensive repetitive walking practice.[14]

Virtual and Augmented Reality
Virtual reality: Virtual reality (VR) is a computer-based technology that creates a virtual, interactive, motivational, and multi-sensory environment where patients can interact and engage with computer-generated activities.[5] VR applications and games can provide repetitive, intensive, and task-specific training, essential elements of neuroplasticity.[13] They include non-immersive, semi-immersive, and immersive technologies depending on the level of isolation of the user from the surroundings during training.[13] Various non-immersive video games have been designed for home, making it a widely available, safe, and affordable option for clinicians and stroke patients.[5]

Augmented reality: Augmented reality (AR) allows users to interact with computer-generated activities with real objects.[7] Compared to VR, which provides a virtual experience, AR enhances the real environment with images, sounds, or text through devices such as head-mounted displays, smartphones, tablets, and AR glasses.[7] An added advantage of AR is that it allows users to practice occupations and skills safely in an appropriate environment, eliminating real risks associated with them.[9]

Wearable Sensors
Wearable sensors detect the human body motion, assess the movement, and provide immediate feedback to patients for correction or modification of movement. The sensors provide objective data even in the absence of a therapist, potentially reducing diagnostic errors, which helps clinicians customize therapy and make appropriate adjustments. For example, EMG sensors providing muscle activity data can be used to monitor stroke patients' motor function, allowing customization of their intervention. Kinect and Wii mote are commonly used sensors in stroke rehabilitation.[14]

Smartphone and Tablets
Handheld devices such as smartphones and tablets are beneficial for stroke survivors in home-based rehabilitation programmes. Smartphone and tablet applications are affordable, easy to use, and easily accessible at home. Several applications have been

developed specifically for stroke patients, e.g., phonology-free application to help patients with aphasia in communication and interaction.[15]

Clinical Implementation of Technology-Based Stroke Rehabilitation

The new technologies have the potential to overcome the shortcomings of conventional rehabilitation approaches by providing intensive, repetitive, motivational, goal-oriented massed practice required for cortical reorganization. However, several barriers and limitations hinder its implementation in regular clinical practice, especially in developing countries like Pakistan. These include lack of financial resources for equipment, technical expertise and training, patient education, and patient compliance. Additionally, not all technologies will be compatible for individuals with cognitive impairments and severe movement limitations. In Pakistan, it is also important to consider the language barriers, especially for illiterate individuals.

Conclusion

Emerging technologies in stroke rehabilitation offer several advantages over conventional rehabilitation approaches like high repetitions and intensity, task specificity, objective feedback, increased user engagement, and motivation. The clinicians should consider the barriers and limitations associated with technology before designing a stroke patient training programme. Customized games and applications should be designed to meet individual patient rehabilitation needs and goals.

References

1. Feigin, Stark, Johnson, Roth, Bisignano, Abady, et al.Global, regional, and national burden of stroke and its risk factors, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol 2021:20:795-820.
2. Khan, Khan, Ahmed and Ali, The epidemiology of stroke in a developing country (Pakistan). Pak J Neurol Sciences 2019. 13:30-44.
3. Maceira-Elvira P, Popa T, Schmid AC, Hummel FC. Wearable technology in stroke rehabilitation: towards improved diagnosis and treatment of upper-limb motor impairment. J Neuroeng Rehabil 2019: 16:1-18.
4. Owolabi, Thrift, Martins, Johnson, Pandian, Abd-Allah, et al.The state of stroke services across the globe: Report of World Stroke Organization-World Health Organization surveys. Int J Stroke 2021:16:889-901.
5. Saposnik. Virtual reality in stroke rehabilitation, in Ischemic stroke therapeutics. 2016, Springer. p. 225-233.
6. Lin SH, Dionne TP. Interventions to Improve Movement and Functional Outcomes in Adult Stroke Rehabilitation: Review and Evidence Summary. J Particip Med. 2018;10:e3. doi: 10.2196/jopm.8929.
7. Gorman C, Gustafsson L. The use of augmented reality for rehabilitation after stroke: a narrative review. Disabil Rehabil Assist Technol. 2020:1-9. doi: 10.1080/17483107.2020.1791264.
8. Kim, Lai, Mehta, Thirumalai, Padalabalanarayanan, Rimmer, et al., Exercise training guidelines for multiple sclerosis, stroke, and Parkinson's disease: Rapid review and synthesis. Am J Phys Med Rehabil 2019:98:613.
9. Langan J, Subryan H, Nwogu I, Cavuoto L. Reported use of technology in stroke rehabilitation by physical and occupational therapists. Disabil Rehabil Assist Technol. 2018;13:641-647. doi: 10.1080/17483107.2017.1362043.
10. Powers J, Wallace A, Mansfield A, Mochizuki G, Patterson KK. The effect of frequency of feedback on overground temporal gait asymmetry post stroke. Top Stroke Rehabil. 2021:1-10. doi: 10.1080/10749357.2021.1943796.
11. Malik AN, Masood T. Task-oriented training and exer-gaming for improving mobility after stroke: A randomized trial. J Pak Med Assoc. 2021;71(1(B)):186-190. doi: 10.47391/JPMA.560.
12. Aslam M, Ain QU, Fayyaz P, Malik AN. Exer-gaming reduces fall risk and improves mobility after stroke. J Pak Med Assoc. 2021;71:1673-1675. doi: 10.47391/JPMA.875.
13. Mubin O, Alnajjar F, Al Mahmud A, Jishtu N, Alsinglawi B. Exploring serious games for stroke rehabilitation: a scoping review. Disabil Rehabil Assist Technol. 2020: 1-7. doi: 10.1080/17483107.2020.1768309.
14. Louie DR, Eng JJ. Powered robotic exoskeletons in post-stroke rehabilitation of gait: a scoping review. J Neuroeng Rehabil. 2016 8;13:53. doi: 10.1186/s12984-016-0162-5.
15. Batool Z . The 13-Year-Old Who Developed An Urdu App For The Speech Impaired. [Internet] [cited 2021 6th January]; Available from: https://www.parhlo.com/meet-ahmad-jamal-the-13-year-old-who-developed-an-urdu-app-for-the-speech-impaired/. 2021.