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The impact of telerehabilitation therapies and information and communication technology on stroke recovery

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Abstract
A novel approach to offering stroke survivors rehabilitation services is telerehabilitation. Providing mainstream therapies for mobility, cognitive, speech and language, and other problems is a promising strategy. Information and communication technologies and stroke therapies are the two main pillars of telerehabilitation. Information and communication technology offer a platform for the delivery of therapies, which in turn leads to stroke recovery. We discussed stroke therapies that can be provided using telerehabilitation platforms in this mini-review, along with aspects of information and communication technologies that support telerehabilitation. Next, we looked at how telerehabilitation affected different types of stroke. According to the majority of research, telerehabilitation is a practical and efficient way to provide patients with interventions. With the same dosage and level of intensity, it is not less effective than standard care and in-clinic therapy. For certain illnesses, telerehabilitation may be more effective than standard care thanks to new technologies. However, telerehabilitation has a number of drawbacks that may make it less effective than traditional rehabilitation. At the conclusion, we talked about the main issues with telerehabilitation, potential fixes, and future paths for the field's growth.

Keywords: stroke; telehealth; telerehabilitation; rehabilitation

introduction

One of the main causes of death and disability in the world is stroke. [1] As the population ages, the number of strokes is rising quickly in absolute terms. [2] There are 143 million stroke survivors globally in 2019 who have a range of symptoms, including depression, hemiplegia, and aphasia, which significantly reduce their independence and place a heavy cost on patients, their families, and society at large. [3] Numerous studies have shown that appropriate rehabilitation programs can enhance quality of life, lessen long-term disability, and ease the symptoms of stroke. [4] In order to avoid long-term brain damage, patients should begin therapy as soon as possible [5] and keep going even if their recovery is slower than it was previously. [6] Rehabilitation services are typically delivered in clinic settings by medical experts. Patients in remote locations, particularly those in low- and middle-income nations, find this challenging. They are either unable to receive rehabilitative treatments or must expend additional time and energy traveling a considerable distance. Telerehabilitation may provide an alternate method of treatment delivery in this case. [7]

Telerehabilitation reduces the distance barrier between patients and rehabilitation providers by utilizing information and communication technologies. [8] Information and communication technologies are used to make sure that patients receive traditional in-clinic rehabilitation services as efficiently as feasible from a distance. The use of telerehabilitation for stroke patients has several benefits. It is not a new subspecialty [7]; rather, it encompasses all facets of rehabilitation, including "evaluation, assessment, monitoring, prevention, intervention, supervision, education, consultation, and coaching. [9]" Telerehabilitation offers additional training opportunities for therapies requiring greater doses, facilitates access to healthcare specialists, and can save time and money. Additionally, it reduced the risks of infection for several disorders and might help patients feel better about staying at home. [10]

The two main facets of telerehabilitation—information and communication technology and stroke interventions—as well as the results of telerehabilitation for different stroke situations will be the main topics of this mini-review. Platforms for delivering interventions are information and communication technologies. Both of them are essential to telerehabilitation's viability, efficacy, and safety as well as to patients' contentment and compliance. Prior evaluations of stroke and telerehabilitation have mostly concentrated on a single topic, including virtual reality applications or upper limb rehabilitation. [11] Therefore, we believe it is essential to present a broad overview in order to highlight important aspects of this subject. Finally, we also talked about current problems and possible advancements in the future.

Technologies for information and communication in telerehabilitation

Telerehabilitation is based on information and communication technology, which enable stroke patients to use home-based therapy to attain the best possible recovery outcomes. [12] Text, audio, video, mobile, computer, online, sensors, and wireless devices are among the various information and communication technologies that are available. [13] Providing a platform for patients to obtain rehabilitation treatments as though in clinical settings is the main goal of information and communication technologies. For all users with a high mistake tolerance, the platform should be safe, easy to use, and practical for applying stroke therapies. [14] The platform should be easily adaptable to provide individualized service whenever feasible. Numerous factors, including the efficiency of the intervention, customer support, cost, accessibility, usability, and acceptability, are taken into account while developing a telerehabilitation platform. [15] For instance, low-cost platforms might not be very effective, but most people can afford them; high-cost platforms, on the other hand, are typically more complex and have a greater learning curve, which makes them less useful.

One of the first telerehabilitation techniques was the telephone, which is still widely used today. Subacute patients' physical activity levels can be increased upon hospital discharge with nurse-initiated phone call interventions. [16] Making phone calls to talk about a patient's condition may also improve their satisfaction and adherence to treatment. [17] Stroke knowledge education and goal-setting programs for self-management of daily activities also employ it. [18] These findings imply that inexpensive options, including texting and calling, are still practical in many circumstances.

An alternative to phone service is videoconferencing, which allows patients and medical staff to communicate both visually and audibly. Both computer-based and mobile videoconferencing are available to facilitate in-person information sharing. Li and associates. [19] Examined the viability, validity, and reliability of employing videoconferencing to evaluate stroke patients' functional abilities following hospital release; home visits and phone service served as controls. At the conclusion of two weeks and three months, the patients' functional state was assessed. The authors discovered that the functional status scores of patients who had home visits and videoconferencing were comparable. According to the study's metrics, videoconferencing is more valid and reliable than phone calls. High levels of confidence and happiness were also displayed by the patients in the videoconferencing group. The findings imply that videoconferencing is a superior option to phone calls.

Information and communication technologies that are based on mobile devices, computers, and the internet are typically incorporated into interventions through games, virtual reality, and other trainings. They can provide healthcare experts with user training data for assessment [13]. For greater results, they can also be used in conjunction with videoconferencing. Data such as falls, heart rate, blood pressure, breathing rate, and blood oxygen levels are gathered by wearable sensors to track patients' health. [20] A review was conducted via videoconference after 61 patients completed rehabilitation training using a tablet-based telerehabilitation system in a study by Asano et al. [21] For safety reasons, sensors were employed to gather physiological signals in order to identify any negative consequences from telerehabilitation. For telerehabilitation, Nasrabadi et al. [22] created an activity recognition system based on inertial measurement units. During movement-based therapies, the system can be used to track body motion to identify incorrect acts and evaluate the efficacy of training. Electromyograph, gyroscope, and accelerometer sensors are also commonly employed to monitor muscle activity and body movements. Additionally, the application of artificial intelligence in stroke recovery has grown. For instance, machine learning techniques were embraced as a potentially useful aid for physicians to forecast stroke patients' functional recovery. [23]

Telerehabilitation interventions and associated technology

A highly regarded review article classified stroke recovery therapies into four categories. These strategies include neuromodulation, pharmacological, technological, and training approaches. [24] Among these, telerehabilitation is not directly linked to pharmacological therapies. Only the other three categories of interventions will be discussed below.

Exercise and physical activity are associated with both technology and training treatments. While the latter includes robots, virtual reality, and serious gaming, the former takes the shape of strength or task-oriented training. There is no conflict between these interventions. To receive the best results for stroke rehabilitation, they can be mixed instead. For instance, Lee et al. [25] investigated how a smart glove can aid in the recovery of upper limb function. Task-oriented behaviors were required of participants in a virtual reality setting. The control group engages in leisure activities in addition to their regular routine. Consequently, the intervention group showed improved results on every metric. 260 stroke patients were included in Hao et al.'s [11] study of the effects of virtual reality-based telerehabilitation systems. Regarding upper limb and balance functions, the virtual reality-telerehabilitation group's

results were comparable to those of the in-person rehabilitation group. In a telerehabilitation context, Rozevink et al. [26] investigated the effects of serious game therapy aided by an upper limb robot. Patients' motor function was greatly enhanced by their method, and they were highly satisfied and adhered to.

Electrical and magnetic stimulation are examples of neuromodulation techniques that aim to improve neuronal pathways in many human body systems. [20] Transcranial direct current stimulation for the central nervous system and functional electrical stimulation for the peripheral nerve system are two subcategories of electrical stimulation, a well-known and widely used stroke therapy intervention. [27] Numerous studies have examined the efficacy of electrical stimulation for stroke recovery, with encouraging findings. [28] However, to correctly utilize electrical stimulation devices, these interventions demand a sufficient level of education and experience. Furthermore, there are safety issues. Because of this, there aren't many trials that combine telerehabilitation and electrical stimulation for stroke recovery. Ko et al. [29] documented the utility of home-based transcranial direct current stimulation for cognitive training, whereas Hermann et al. [30] investigated the effectiveness of functional electrical stimulation treatment for post-stroke arm dysfunction. Their findings point to the potential of electrical stimulation in telerehabilitation. Transcranial magnetic stimulation, on the other hand, has been utilized extensively to treat a variety of stroke symptoms. [31] However, our literature search revealed no usage of transcranial magnetic stimulation in telerehabilitation, perhaps due to the device's high cost and complexity. More research is required to assess the results of neuromodulation therapies, which are only now beginning to be used in telerehabilitation.

Telerehabilitation's impact on functional deficits following a stroke

Disorders of movement

Movement abnormalities affect the majority of stroke survivors [32], and rehabilitation techniques are essential for helping patients restore their lost capacities. [24] 124 patients with arm motor impairments were split equally between two groups in a random randomized trial: one group received in-clinic therapy, and the other group received telerehabilitation. The identical therapies, which included daily functional games, exercise videos, and stroke education, were given to all patients in 36 sessions lasting 72 minutes each. Based on Fugl-Meyer scores with high satisfaction, the results showed that both groups had significantly improved arm functionality, and there was no discernible difference between them. However, adherence was higher in the in-clinic therapy group than in the telerehabilitation group. [33] Early telerehabilitation following a stroke is appropriate for rigorous arm motor training with great feasibility, safety, and efficacy, according to a related study's authors. [34] A computer game-assisted telerehabilitation platform was created by Stzurm et al. [35] to increase program accessibility and compliance for participants. They discovered that the telerehabilitation service significantly improved the hand-arm functions of the patients, as measured by a specialized computer-based system and the Wolf Motor Function Test. Furthermore, patients' upper limb function was significantly enhanced with great satisfaction with robotic rehabilitation for motor recovery via telerehabilitation services. [36]

Held et al. [37] created an autonomous telerehabilitation system for balance and gait recovery for problems linked to the lower limbs. Patients spend 40 minutes each session playing fitness games in a virtual reality setting over the course of 12 weeks. Their findings imply that the telerehabilitation system is practical, safe, and capable of offering intensive therapy for lower limb training at home. 24 chronic stroke patients were enlisted by Lin et al. [38] and requested to complete a 50-minute balancing training exercise three times a week. According to the Berg Balance Scale, the authors discovered that telerehabilitation improved patients' balancing skills. They also observed no difference in training effectiveness or patient satisfaction between the telerehabilitation and conventional therapy groups. A serious game-based telerehabilitation system for ankle motions was shown to be highly acceptable and satisfactory by patients in another study. [39]

A vital sign of a person's functional condition, the recovery of activities of daily living following a stroke is another area in which telerehabilitation is crucial. The authors of a comprehensive study come to the conclusion that there is no discernible difference between the usual care group and the telerehabilitation intervention group and the in-person physical therapy group [8]. According to these research, telerehabilitation is a practical and efficient means of helping stroke patients with their motor functions, and its results are on par with those of conventional therapy. However, when compared to standard treatment, augmented telerehabilitation training might not be as successful in enhancing physical function. [40]

Cognitive impairments

In addition to causing poor treatment adherence, post-stroke cognitive impairments can significantly impair independence on activities of daily living and quality of life. [41] 36 chronic stroke patients were enrolled in a study by Faria et al. [42] and split into two groups: one for adaptive virtual reality-based telerehabilitation and the other for paper-and-pencil-based control using a task generator. Over the course of a month, both groups completed 12 sessions of comparable cognitive training. According to the findings, the telerehabilitation group's cognitive abilities significantly improved when compared to the control group. Another study found that stroke patients who received virtual reality-based cognitive telerehabilitation outperformed those who received traditional rehabilitation in terms of their global cognitive level, attentiveness, memory, and language abilities. [43] Lawson et al. also showed that telerehabilitation is feasible for cognitive trainings and that it is not inferior to their earlier in-person rehabilitation trainings. [44] For general cognitive problems, Bernini et al. also demonstrated that telerehabilitation is not less effective than in-person rehabilitation with a satisfactory user experience. [45] All things considered, telerehabilitation

systems are viable for cognitive training and perform on par with or better than conventional cognitive training techniques.

Disorders of speech and language

Thirty percent of stroke victims admitted to hospitals experience aphasia. It was ranked as one of the worst diseases that negatively affects quality of life and frequently results in social isolation and low mood. [46] In order to assess the efficacy of telerehabilitation for communication problems, Meltzer et al. administered identical treatments to 44 patients in both the in-person and telerehabilitation groups. All patients showed notable improvements on assessed indices following a 10-week course of treatment, and the gains were comparable for the two groups. According to their research, telerehabilitation is a very successful treatment for communication difficulties. [47] In a different study, Maresca et al. performed a randomized controlled trial (random randomized trial) with 30 aphasia patients. These patients were divided into two groups: the experimental group received training using a tablet-based telerehabilitation platform, and the control group received conventional treatment. Following a 6-month course of therapy, the experimental group outperformed the control group and showed notable progress in all assessments except writing. [48] Similarly, a web-based program showed that telerehabilitation is a successful method for training people with aphasia. [49] Ora et al. also carried out a randomized controlled trial (random randomized trial) with 31 patients in each of the telerehabilitation and control groups. They both received their regular treatment, but the telerehabilitation group additionally got extra weekly 5-hour instruction. Consequently, after four weeks, there is no discernible difference in the two groups' measured indicators. [50] The same authors demonstrated that telerehabilitation was a viable and acceptable method of aphasia training in another study. [51] Telerehabilitation may be used as a supplemental intervention for improved results, as a review indicates that the key to aphasia trainings is the intensity of therapy. [52]

Other illnesses

Telerehabilitation consisting of motion and muscle exercises can effectively enhance swallowing skills with high patient satisfaction, as swallowing difficulties affect about 50% of stroke patients. [53] In remote locations, wearable electromyograph sensors can track swallowing motions and subsequently identify dysphagia. [54] Post-stroke depression can also be lessened using telerehabilitation, and telephone interventions have been shown to have comparable benefits on depression reduction to in-person or usual care interventions. [55]

Discussion

For stroke recovery, telerehabilitation has shown significant viability and efficacy. With comparable intensity, duration, and frequency, it is not less effective than standard care and in-clinic therapy. Additionally, stroke sufferers are really satisfied with it. However, due to a variety of personal factors and technical limitations, telerehabilitation is probably not appropriate for every patient. Because certain patients, particularly those with cognitive problems, find it difficult to complete the training session remotely, telerehabilitation treatments have a greater dropout rate than typical rehabilitation programs. [42] Furthermore, many patients lack the confidence and drive to carry out therapies when medical personnel are not present, which leads to low adherence and subpar clinical results. Additionally, some interventions that need for big, costly, or hazardous equipment might not be appropriate for use in homes. Concerns exist with the interpretation of telerehabilitation results as well. First, because of the small number of patients available, the inclusion and exclusion criteria for participation are not ideal. [33] Second, the absence of control groups in cohort studies can result in incorrect conclusions. [35] Third, self-reported data, including satisfaction, are objective. [34] However, the majority of doctors and patients still choose in-person care because they don't trust the quality of telerehabilitation, according to a recent survey study on telemedicine. The main causes were identified as inaccurate interventions and a lack of physical examination. [56] The findings also imply that patient self-reported satisfaction levels can be dubious.

The key to solving the aforementioned problems is technical advancement. Technical usability limitations can be overcome by intelligent devices that require less effort from patients. To boost patients' confidence and motivation, a clinic-like environment can be created using virtual reality and haptic devices. [57] Furthermore, a lot of stroke intervention devices can be modified to work with telerehabilitation platforms. functional electrical stimulation and transcranial direct current stimulation devices, for instance, have already been utilized for neuromodulation in telerehabilitation [58], although there aren't many studies on the subject, primarily due to safety concerns. Electrical stimulation devices have the potential to be utilized in telerehabilitation more frequently with the addition of remote control and comprehensive safety features. Wearable sensors can be used to gather a range of patient parameters and to track their activities and health conditions in order to overcome the lack of physical examination and accuracy in telerehabilitation. [59] As a result, medical practitioners can identify negative consequences during telerehabilitation and create more effective intervention strategies.

Conclusions

As technology advances, a fully digitalized telerehabilitation system might become feasible. Interventions based on telerehabilitation that incorporate immersive virtual reality, rehabilitation robots, serious games, and other sensors may be more effective. Sensors can be used to gather patient data, and machine learning techniques can be used for analysis. With the right tools, traditional measures for assessing intervention results, like the Berg balance scale, can be completed automatically. [60] New telerehabilitation models should be taken into consideration in addition to technological concerns. Although community health professionals and caregivers have been extensively studied [61],

their contributions to telerehabilitation have not been thoroughly examined. They can act as a conduit to help patients and healthcare providers get beyond some technical obstacles and communication problems. All things considered, telerehabilitation is still in its infancy, and more research is required to support its best application.

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