View Point

Teleneurorehabilitation for Parkinson's Disease: A Panacea for the Times to Come?

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Abstract

Telemedicine is witnessing a rebirth due to the COVID-19 pandemic and the continuing need for limited-contact or contactless care in medicine. Telerehabilitation, an offshoot of telemedicine, is a valuable yet underexplored tool in the therapeutic armamentarium of patients with neurological conditions, particularly Parkinson's disease (PD). Although there is evidence in literature reporting the use of telerehabilitation and virtual reality-based services in providing rehabilitation to improve speech, swallowing, gait, and postural instability among persons with PD, the evidence is limited due to small patient numbers. Teleneurorehabilitation (TNR) is an underutilized strategy that may be as effective and perhaps more feasible and affordable among Indian PD patients and also allows sustained rehabilitation. In this article, we encapsulate the evidence on the utility and efficacy of TNR among persons with PD and call upon the neurology community to recognize and utilize the valuable asset that TNR may be for PD patients.

Keywords: Cognition, neurorehabilitation, Parkinson's disease, telemedicine, teleneurology, virtual care

Introduction

The practice of medicine is witnessing several upheavals in response to the COVID-19 pandemic. An erstwhile underutilized field, telemedicine has had a rebirth. Telemedicine is the use of technology for the application of medicine and includes remote videoconferencing, e-mail, telephone, fax, and other technological services. "Teleneurology" is the practice of neurology via telemedicine.[1] Telerehabilitation is one of the offshoots of telemedicine. Although telemedicine has been in existence from the late 1950s, its growth and evolution has been unhurried till now.[2] However, the demand for virtual care and telemedicine is witnessing an upsurge to avoid transmission of infection via physical contact between physicians and patients and when patients are unable to visit their neurologists due to movement restrictions in place. Telerehabilitation is the natural next step, once the provision of medical opinion and prescription via telemedicine becomes seamless. Telerehabilitation may be defined as a set of interventions and protocols designed to deliver rehabilitation at a distance virtually using digital technologies.[3]

Persons with Parkinson's disease (PD) form an optimal target population for telerehabilitation due to an unfortunate combination of motor disability and difficulty with travel combined with myriad benefits from rehabilitation.[4] Long-term rehabilitation is known to improve motor and cognitive outcomes in PD.[5] However, long-term rehabilitation requires intensive inputs from rehabilitation specialists, keen patient commitment, and dedicated rehabilitation space and causes financial burden.[6] In this viewpoint, we rest the case for teleneurorehabilitation (TNR) as an ideal answer to the call of the times for continued rehabilitation, particularly in pandemic settings. However, scientific evidence of TNR for various facets of PD is fairly limited [Table 1].

The COVID-19 Crisis and The Need for Teleneurorehabilitation

The reliance on teleneurology has rapidly increased with the ongoing COVID-19 crisis. Patients are either unable to access in-person hospital services due to lockdowns or are unwilling due to fear of contracting the COVID-19 infection in hospital. This technology-based service enables access to healthcare from remote sites. Due to lack of routine services, regular rehabilitative efforts on the part of the patient are disrupted and may contribute to detriment in physical and emotional well-being. This is particularly true for persons with PD, who need to exercise and continue rehabilitation on a maintenance basis.

Teleneurorehabilitation: The Journey So Far

The field of telerehabilitation is fairly new, with the first scientific publication dating to 1998.[22]

In a review of telerehabilitation assessment including clinical outcomes, costs, practice, and utilization including broad

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Submitted: 07-Jun-2020 **Revised:** 28-Jul-2020 **Accepted:** 04-Aug-2020
Published: 26-Oct-2020

DOI: 10.4103/aian.AIAN_566_20

Table 1: List of PubMed-indexed studies on teleneurorehabilitation in Parkinson's Disease

Author/year	Study design and strategy used for TNR	Outcome
Theodoros *et al*., 2019[7]	Scoping review on the use of technology in communication and swallowing dysfunction in PD—17 studies included	Review concluded that evidence was limited and of low quality
Lei *et al*., 2019[8]	Systematic review of virtual reality (VR)-based rehabilitation for PD on improvement of gait and balance. 16 articles and 555 PD patients included. VR rehabilitation training performed better than traditional rehabilitation in: Step and stride length, balance and mobility	VR rehabilitation training can not only achieve the same effect as conventional rehabilitation training but also had better performance on gait and balance in patients with PD
Chan *et al*., 2019[9]	Pilot study in Malaysia: Intensive voice therapy administered to 11 PD patients using smartphone videoconferencing via WhatsApp Messenger in 12 sessions over 4 weeks	Intervention improved sound pressure level in sustained vowels and monologue. High level of patient satisfaction also noted
Quinn *et al*., 2019[10]	Pilot study among 8 PD patients to determine feasibility of group speech maintenance program (eLoud and Proud) using telerehabilitation	Feasible in improving vocal loudness
Cikajlo *et al*., 2018[11]	Developed a telerehabilitation self-adapting exergaming system using the Kinect sensor and tested 28 patients with PD. Clinical outcome measures included Box and Blocks Test, UPDRS III, daily activity Jebsen's test, writing a letter and moving light objects, Nine-Hole Peg Test	The study found that exergaming was feasible but may need technical support. However, clinically meaningful results could not be achieved
Albiol-Pèrez *et al*., 2017[12]	Virtual Motor Rehabilitation conducted on 10 PD patients using the active balance rehabilitation system (ABAR) and postural control assessed over 15 sessions	Trend toward improvement of postural control but not significant
Seidler *et al*., 2017[13]	Pilot study: 26 people with mild-to-moderate PD assigned to either the telerehabilitation or in-person rehabilitation, twice-weekly over 12 weeks.	Balance and motor sign improved significantly ($P < 0.001$) in both groups, with no difference between groups. No effect on gait
Gandolfi *et al*., 2017[14]	Randomized multicentric trial which enrolled 76 PD patients (modified Hoehn and Yahr stages 2.5-3) to receive either in-home VR telerehabilitation via Nintendo Wii Fit system or in-person sensory integration balance training (SIBT) 3 days/week for 7 weeks	Significant improvement on the Berg Balance Scale for the VR group ($P = 0.04$) and significant improvement in Dynamic Gait Index ($P = 0.04$) for the in-clinic group
Theodoros *et al*., 2016[15]	Randomized trial of 31 participants with dysarthria with PD randomly assigned to either face-to-face or online Lee Silverman Voice Treatment (LSVT LOUD)	Noninferiority of online treatment for clinical and quality of life outcomes compared to face-to-face interaction
Russell *et al*., 2013[16]	Pilot study: eHAB telerehabilitation service versus face-to-face rehabilitation in 12 patients to evaluate physical assessment via timed stance test, Timed "Up and Go" test, step test, steps in 360-degree turn, Berg Balance Scale, lateral and functional reach tests	Tele-based rehabilitation assessment can be performed via internet-based services
Constantinescu *et al*., 2011[17]	Evaluated online delivery of the Lee Silverman Voice Treatment (LSVT®) for speech and voice disorder in 34 PD patients using personal computer-based videoconferencing systems	Mean change in sound pressure level on a monologue task was noninferior in the online versus face-to-face mode of delivery
Constantinescu *et al*., 2010[18]	Randomized trial that assessed validity and reliability of telerehabilitation (online) compared to face-to-face interaction for assessing speech and voice disorder among 61 PD patients	Comparable levels of agreement were achieved between the two environments. Online assessment of disordered speech and voice in Parkinson's disease appears to be valid and reliable
Tindall *et al*., 2009[19]	11 caregivers of PD patients were interviewed using a structured interview to assess caregiver burden after 16 weeks of speech therapy given via videophones	On average, this speech therapy protocol delivered by videophones saved 48 h of time, more than 92 h of work time, and $1024 for each caregiver
Hoffman *et al*., 2008[20]	Randomized trial to compare activities of daily living (ADL) and hand function via using the motor component of the functional independence measure (FIM) and selected items from the Unified Parkinson's Disease Rating Scale (UPDRS). The Nine Hole Peg Test, Jamar dynamometer and Preston pinch gauge were also used to assess hand function. Telerehab versus face-to-face rehabilitation.	Telerehabilitation system was found to be a valid measure of ADL status and hand function in people with Parkinson's disease and to have a high level of intra- and inter-rater reliability
Giansanti *et al*., 2008[21]	This study tested a wearable device with a force-sensing resistor (Gastrocnemius Expansion Monitoring Unit) for step-counting to enable telemonitoring on 5 patients with PD	Good performance in PD patients

fields of cardiology, neurology, trauma, community, and speech and language disorders, Kairy *et al*. highlight that telerehabilitation was highly acceptable by both patients and rehabilitation therapists.[23] The clinical outcomes were

generally good, although measurements against an alternative mode of rehabilitation delivery were scarce. Patients had high rates of compliance. Consultation times were also longer with telerehabilitation. Home-based rehabilitation, including rehabilitation utilizing technology-based service, already has a distinct and effective role in stroke rehabilitation.[24]

Although there are sundry laws to protect data pertaining to healthcare in different countries such as US and Canada, India lacks such provisions. Although the Ministry of Health and Family Welfare created Digital Information Security in Healthcare Act (DISHA) in 2015, this did not become legislation.[25] Telemedicine has been largely considered disapprovingly by Indian legislature and governing systems. However, in view of the COVID-19 pandemic, the Medical Council of India (MCI) in concert with the NITI Aayog formulated guidelines encompassing the practice of telemedicine in India, which was released in March 2020.[26] These are the regulations that guide all telemedicine-based communication in India till date.

Prior to this, development in the field of telemedicine and telerehabilitation was naturally snail-paced. Telemedicine invokes the learning and relearning of a new paradigm of care delivery, and hence, efforts to initiate it formally may lack organizational vigor and thrust, especially when the traditional model of care seems to run in a relatively well-oiled fashion.

There is very little data from India on TNR. One study from the National Institute of Mental Health and Neurosciences (NIMHANS), a retrospective chart review, assessed 37 TNR consultations performed over 3.5 years.[27] The study concluded that TNR services are feasible, effective, and less resource-intensive in delivering quality telemedicine care in India. In another study that assessed geriatric rehabilitation through teleservices, 22 people were recruited from the four Community Centers in Delhi/NCR, age range 65–90 years.[28] Modified conventional balance protocol with individualized and preventive education on falls was given through Skype. Improvement was shown in Berg Balance Score. 100% clients agreed that telerehabilitation could be used to continue follow-up rehabilitation and for saving costs.

Why is TNR An Ideal Solution for Indian Parkinson's Disease Patients?

In our resource-constrained settings, duration of hospitalization tends to be minimized, shifting the rehabilitative phase of care as a predominantly outpatient activity. The benefits obtained from hospital rehabilitation tend to attenuate over time, leading to functional waning. PD as such is usually managed as an outpatient condition. Rehabilitation services for PD patients are also primarily outpatient based. Many PD patients continue to be stable on medications and come to the hospital for a prescription refill after a gap of several weeks to months. Rehabilitation services are likely accessed to an even lesser extent. This leads to a disruption in the care continuum for these patients. TNR, which may be administered via various potential modalities [Table 2], may be a solution providing home-based care. Multiple application software under the gamut of digital health are in existence that are dedicated to the diagnosis, management, and assessment of PD patients. However, scientific evidence validating the same is limited and low quality by and large, serving to highlight the lacunae in literature. In addition, India seems to offer a perfect milieu for such an endeavor. It is estimated that around 50 crore Indians are using smartphones in the year 2020. Above 77% of Indians are accessing broadband services via smartphones.[29]

Potential benefits and pitfalls

In general, telehealth increases access to health care, facilitates greater continuity of care, and shrinks expenses while simultaneously preserving or improving patient outcomes. TNR has obvious apparent benefits [Table 3]. Patients with PD need not travel to the hospital for rehabilitation. Travelling has been restricted in view of lockdowns in these difficult times. Travel is also known to be a deterrent to continued rehabilitation. The economic ramifications are also favorable, with cutting down the cost of travel of the patient and the caretaker to hospital. Waiting room physical distancing and delays are circumvented. Rehabilitation delivered at home avoids person-to-person contact and is also comfortable. In addition, the intensity and duration of rehabilitation may be increased.[22] Telerehabilitation also encourages patient engagement and motivation for sustained rehabilitation effort. It is also likely to make adherence less cumbersome by removing issues pertaining to cost and travel, as well as ancillary inconveniences.

Technology-based symptom assessment in PD has been demonstrated with use of the SENSE-PARK system.[30] This consists of three sensors worn during the day and one at night integrated with a smartphone App, balance board, and a computer software. In a controlled 12-week study, this system had good acceptability by PD patients.

However, uniform well-tested telerehabilitation strategies and protocols designed for PD do not exist currently. Probably, training of the care deliverer, the rehabilitation specialist, in the delivery of services via rehabilitation will need to be

Table 2: Potential device and technology utilization for teleneurorehabilitation for PD

Type of technology service	Potential utilization
Video conferencing	No-contact examination may be performed, and exercises demonstrated with ease. Patient's technique may also be assessed for correctness and errors rectified. Multiple or group conferences may be conducted
WhatsApp	Freeware allowing the option of audio and video consultation. Widespread use in India
Email	Permits exchange of instruction leaflets and prescriptions
Telephone services	May be used to sort out simple issues or concerns. Prescription of drugs not possible

Table 3: Challenges, scope, and future directions of teleneurorehabilitation for PD[20]

Challenges in TNR
Conducting a thorough neurological examination to assess severity of tone abnormality, contractures, etc.
Infrastructure and cost requirements to set up a technology-driven system
Physician discomfort with using technology for rehabilitation services rather than the traditional doctor-patient medium
Designing a rehabilitation program amenable to be imparted via technology
Issues related to billing for services provided
Benefits of TNR
Wide outreach due to ability to cover remote areas
Saves on travel time, queueing time, waiting room time
Saves on expenses on travel and ancillary inconveniences such as arranging wheelchair, conveyance, etc.
Equal efficacy as in-person rehabilitation for most parameters in PD
High patient satisfaction with telerehabilitation
Scope and future directions
Improved Internet connectivity may lead to increased utilization of technology-driven service for neurorehabilitation even in remote regions
National and international experts may be available for consultation to patients without the need for travel for consultation
Cross-referencing services between specialties, for e.g., Neurology and Rehabilitation services, may be improved
Cognition and other motor and nonmotor symptoms need to be addressed via TNR

organized and tested to ensure standard care. Acceptability of the technology by both health care providers and patients, organizational support for technical support may pose additional hurdles. A study demonstrated that after completion of traditional in-person speech therapy among patients with PD, most patients (76%) showed willingness to participate in telerehabilitation in the future. This was independent of age, gender, disease severity, and self-reported skill with technology. However, better cognition among PD patients and higher school education increased acceptance to the idea of telerehabilitation.[31]

One of the adverse consequences may be loss of contact between the patient and the rehabilitation specialist, with sensory input playing an important role in the rehabilitation process. Moreover, without physical supervision, the patient may employ deficient compensation strategies during the exercise. If any expensive physical apparatus is needed for rehabilitation, the patient may not be able to afford these.

Specific Benefits of TNR in Parkinson's Disease: The Evidence

Speech and voice

Between 60% and 90% of persons with PD experience speech and voice-related issues.[32] Prominent difficulties, falling within the realm of hypokinetic dysarthria include reduced loudness, monotonous pitch, hoarseness, breathy quality, harshness, brief rushes, and altered perioral mechanics. Dysarthria may be debilitating to social interactions and negatively impacts the quality of life. The Lee Silverman Voice Treatment (LSVT) is a technique to improve voice issues in these patients.[33] This necessitates intensive daily therapy for 4 weeks. Fewer than 5% of patients with PD undergo and maintain speech rehabilitation. Foremost reasons for nonadherence include issues with travel, cost, lack of a companion, and motor disability.[34]

In a study with 24 PD patients, speech therapy (LSVT) delivered via videophones was compared to a previous similar study by Ramig *et al*. [33] and found significant improvements in vocal decibels. Ramig LO, Sapir S, Fox C, Countryman S. Changes in vocal loudness following intensive voice treatment (LSVT®) in individuals with Parkinson's disease: A comparison with untreated patients and normal age-matched controls. Move Disord 2001;16:79–83. In addition, videophone delivery of rehabilitation saved several expenses such as $953.00 for mileage, and $269.00 for other costs for 16 visits.[19] A small Malaysian study examined the feasibility of delivering intensive voice therapy to 11 PD patients via video-conferencing using WhatsApp.[9] 12 sessions were performed over 4 weeks. Improvement in speech loudness parameters was reported. The study also reported high patient satisfaction with this mode of delivery.

In a noninferiority randomized controlled trial, 31 patients with dysarthria related to PD from a metropolitan area randomly received face-to-face versus online LSVT LOUD and 21 participants from nonmetropolitan areas received online treatment.[15] 21 Clinical outcomes and quality of life parameters with online treatment were found to be noninferior to face-to-face treatment. In another small trial, 34 PD patients with dysarthria were randomized to receive LSVT or face-to-face speech therapy and online treatment was found to be noninferior as well as had high rates of patient satisfaction. Thus, there is evidence that TNR is feasible and noninferior to face-to-face therapy and preferred by PD patients.

Swallowing

Swallowing dysfunction in PD is reported by one-third of PD patients. However, 80% may have dysphagia by objective assessment.[35] Swallowing dysfunction in PD may be attributable to problems in the oral and pharyngeal phases. These include poor oral and lingual bolus control, delay in the initiation of the pharyngeal phase as well as laryngeal movement and esophageal coordination.[36] All of these increase the propensity for aspiration. Dysphagia management in PD incorporates indirect strategies such as bolus adjustment as well as direct strategies. A systematic review by van Hooren *et al*. determined that exercises for oral strength as well as the articulators and larynx combined with bolus adjustment as well thermal and tactile stimulation led to improvement but could not improve all aspects of dysphagia.[37] Several other interventions that have improved dysphagia include biofeedback, expiratory muscle strength training, and video-assisted training. The use of telemedicine has been studied in only the assessment of dysphagia.[7] Ward *et al*.

compared face-to-face with online assessment of swallowing in PD patients.[38] They reported acceptable levels of agreement between assessors in both arms. However, there are no studies reporting the reliability of telerehabilitation for improvement of swallowing dysfunction in PD patients.

Posture and gait

Almost three-quarter of patients with PD have postural instability which may lead to falls.[39] PD patients experience postural instability due to several reasons, predominantly due to lack of sensory inputs from visual, proprioceptive, and vestibular pathways. Rehabilitation acquires enhanced significance because dopaminergic drugs have limited benefit in postural instability. In a multicentric study of 76 patients with PD, patients were randomized to in-home virtual reality (VR)-based balance training via the Wii Fit Nintendo system compared to in-clinic sensory integration balance training (SIBT).[14] This study found that both static and dynamic posture was improved in patients who received in-home VR-based balance training comparable to SIBT. The total cost of VR-based telerehabilitation was also lower than SIBT. Of late, VR has emerged as a new tool in the neurorehabilitation armamentarium.[8] VR has been reported to improve both balance and activities of daily living among PD patients. However, a Cochrane systematic review in 2013 concluded that VR-based rehabilitation improved only stride length and speed among PD patients compared to routine training.[40] In a recent 2019 systematic review, 16 articles and 555 PD patients were included. VR-based rehabilitation outperformed conventional rehabilitation in three fields: Step and stride length, balance, and mobility.[8] Gait speed was unaffected. In addition, VR-based rehabilitation demonstrated comparatively larger improvement in the quality of life, confidence levels, and neuropsychiatric symptoms. Cognitive functions were similar in both practices.

In a small study on 10 patients with PD and 10 healthy controls, tactile cues were delivered using a smartphone which was attached to the dominant arm.[41] An android application was used to control these. Tactile cues were used to modulate heel tapping and walking activities. The use of tactile clues enabled PD patients to perform walking tasks and diminished synchronization errors. Thus, TNR has been shown to be an effective alternative to person-to-person rehabilitation for gait and postural instability in PD patients.

Scope and Directions

From the evidence above and more, a few broad points emerge. Technology-assisted and technology-based rehabilitation strategies are both feasible and well-liked by PD patients and seem to be as effective as traditional rehabilitation strategies. There are several studies that compare telerehabilitation with in-person rehabilitation for speech, communication, postural instability, and gait among PD patients. However, a variety of areas need to be explored further such as cognition as well increase evidence in other areas as well [Table 3]. The lack of Indian data is concerning but opens up an avenue to explore to better the management of PD patients using technology-based approaches in our setting.

Conclusions

We urge the neurology community, especially neurologists taking care of persons with PD to strongly consider the potential benefits and feasibility of TNR in current practice. We also call for evidence from India on the benefits and viability of TNR not only in Parkinson's disease but also in other neurological conditions. As we deal with the demands of taking care of our patients in a limited-contact and virtual manner, there is a need to strengthen our experience with the same, particularly in the field of neurorehabilitation.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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