Telerehabilitation for Stroke Survivors
A Systematic Review and Meta-analysis

Type of paper: Original article

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Title character count: 78
Number of references: 30
Number of tables: 0
Number of figures: 4
Word count abstract: 194
Word count paper: 2256
Supplemental data: PRISMA checklist (supplementary file 1), Risk of bias summary (supplementary file 2)

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ABSTRACT

Background: Telemedicine is increasingly evaluated for rehabilitation of stroke survivors. However, little is known about the utility of telerehabilitation in stroke survivors.

Objectives: To summarize the evidence on the utility of telerehabilitation in stroke survivors.

Methods: Eligible randomized controlled trials (RCTs) were selected from Medline, Cochrane CENTRAL and Web of Science databases. Continuous data on the outcomes were analyzed using the RevMan software as standardized mean difference (SMD) and 95% confidence interval (95% CI) in a fixed effect meta-analysis model.

Results: Fifteen studies, providing data on 1,339 stroke survivors were eligible for inclusion. The combined effect estimate showed that telerehabilitation is as good as usual care as Barthel index (SMD = -0.05, 95% CI [-0.18, 0.08]), Berg Balance Scale (SMD = -0.04, 95% CI [-0.34, 0.26]), Fugl-Meyer Upper Extremity (SMD = 0.50, 95% CI [-0.09, 1.09]) and Stroke Impact Scale [mobility] (SMD = 0.18, 95% CI [-0.13, 0.48]) scores were statistically similar in both groups. Further, quality of life (of the stroke survivor), caregiver strain index and patients' satisfaction with care scores were also similar for both the groups. One study showed that the cost of telerehabilitation was lower than usual care by $654.

Conclusion: Telerehabilitation can be a suitable alternative to usual rehabilitation care in post-stroke patients, especially in remote or underserved areas.

Keywords: Rehabilitation, Stroke, Telemedicine, Meta-analysis
INTRODUCTION

Background

Telemedicine is the exchange of medical information from one location to another using electronic communication to achieve clinical healthcare from a distance [1]. These technologies allow communication between medical staff, as well as the transmission of imaging, medical and health information data from one place to another [2]. It can be used to accelerate medical emergency services in conditions with a narrow therapeutic window, such as stroke [3] and myocardial infarction [4] and to facilitate access to medical services that would not often be available in rural communities [2].

The aim of stroke rehabilitation therapy is to improve the patients' motor function, quality of life and psychological well-being [5]. Successful rehabilitation depends on stroke severity, rehabilitation team skills, and the cooperation of patients and their families [6]. However, many patients have reduced access to care due to limited regional and logistical resources. These patient groups could benefit from a system that allows a health professional to provide rehabilitation services from a remote location [7]. A physical medicine or rehabilitation specialist at a hospital can observe the patients as they execute movements and monitor their improvement. Quantitative data such as range of motion and physical force can be recorded and transported via the network to hospital for review [8].

Over the past decade, several randomized controlled trials (RCTs) investigated the utility of telerehabilitation in stroke survivors. These studies have showed that telerehabilitation could be either equally effective [9, 10] or even superior to usual
rehabilitation [11, 12] in improving daily activities and enhancing the psychological well-being of stroke survivors as well as caregivers.

**Objective**

In this study, we aimed at summarizing the evidence on the utility of telerehabilitation in stroke survivors using a meta-analysis framework.

**METHODS**

This study was performed and reported following the PRISMA Checklist for Systematic Review of interventions (Supplementary file 1).

**Literature search and study selection**

In January 2018, we performed a comprehensive search of the following databases: Medline (via PubMed), Cochrane Central and Web of Science. The following keywords were used with different combinations: "Telemedicine", "Telestroke", "Telerehabilitation", "Stroke" and "Brain infarction" with no filters applied. We also searched the clinical trial register "Clinicaltrials.gov" for any unpublished or ongoing studies. Further, a manual screening of the bibliography of included studies was performed to identify further studies.

Studies fulfilling the following 3 criteria were selected for analysis; (1) assessed the efficacy of telerehabilitation in stroke survivors, (2) employed a RCT design and (3) was reported in the English language. Two authors evaluated the search results using a 2-step screening protocol, title and abstract screening followed by full-text screening of potentially relevant articles. A third author was consulted to resolve any discrepancies arising thereof.
Data extraction and outcomes

Two authors used a preformatted Excel sheet to extract data for the pre-specified outcomes, including: (1) activities of daily living: Barthel Index [BI] and Berg Balance Scale [BBS], (2) motor function: Action Research Arm Test [ARAT], Fugl Meyer Upper Extremity [FM-UE], and Stroke Impact Scale [SIS- Mobility sub-scale], (3) Quality of life [QoL] outcomes and satisfaction with care and (4) Cost-effectiveness. Data were extracted as the mean ± standard deviation of change before and after intervention. When unavailable, these values were calculated as per the guidelines of the Cochrane Handbook for Systematic reviews of intervention [13]. When numerical data was not available for these outcomes or could not be reliably extracted, a qualitative approach was undertaken.

Risk of bias was in the included RCTs was assessed the Cochrane Risk of Bias tool [13], which deals with the following sources of bias: (A) selection bias [random sequence generation and allocation concealment], (B) performance bias [blinding of participants and outcome assessors], (C) attrition bias [incomplete outcome data], (D) reporting bias [selective reporting] and (E) other sources of bias.

Statistical analysis and interpretation of outcomes

We used the RevMan Software (Version 5.3; the Cochrane Collaboration) to perform all statistical analyses. Based on the nature of extracted data (continuous), they were pooled as standardized mean difference (SMD) with 95% confidence interval (95% CI), using the Inverse Variance Meta-analysis method. A two-tailed p value of < 0.05 was considered statistically significant for the effect estimate. A random effects model was used for heterogenous datasets. Heterogeneity was assessed using the Chi-square
test (p value < 0.1 was considered significant for between-study heterogeneity) and its extent was measured using the I-square test.

RESULTS

Study selection

Our literature search retrieved 245 unique records, which were reduced to 52 records after title and abstract screening. After a meticulous full-text screening, 15 studies (1,339 patients) were identified as eligible for our systematic review [9-12, 14-24], 12 (1,246 patients) of which were eligible for meta-analysis [9-11, 16-24]. Figure 1 shows the details of our screening process.

Figure 1: PRISMA flow diagram of study selection process.

Characteristics of included studies
The included RCTs had enrolled between 9 to 536 patients. They compared different models of telerehabilitation to standard rehabilitation care or a home-based exercise program. The follow-up period in these studies ranged between 4 and 24 weeks. Supplemental file 2 shows a summary of the design of included studies and the baseline characteristics of the subjects.

Risk of bias assessment

All the included studies adequately reported methods of random sequence generation, blinding of outcome assessors and measures to reduce the risk of attrition bias, except for three trials in each domain. Due to the nature of the intervention, blinding the participants was not possible in any of the trials. Only nine studies reported adequately on their methods of allocation concealment [9-12, 14, 17, 19-21]. Figure 2 shows a summary of the risk of bias assessment results with the judgements underlying these results illustrated in supplementary file 3.
Figure 2: Risk of bias assessment summary according to the Cochrane risk of bias tool.
Results of outcome assessment

1) Activities of daily living and balance function

1.1. Barthel index: Pooling data from six trials [9-11, 17, 20, 23] showed no significant difference between telerehabilitation and control groups in terms of BI score (SMD = -0.05, 95% CI [-0.18, 0.08], P = 0.47, 909 patients). Pooled studies were homogenous (P = 0.51, I² = 0%); Figure 3A.

1.2. Berg Balance Scale: The pooled analysis of data from four studies [10, 11, 17, 19] showed no significant difference between telerehabilitation and control groups in terms of BBS (SMD = -0.04, 95% CI [-0.34, 0.26], P = 0.78, 171 patients). Pooled studies were homogenous (P = 0.77, I² = 0%); Figure 3B.

Figure 3: The pooled standardized mean difference between telerehabilitation and control groups in terms of (A) Barthel index and (B) Berg Balance Scale scores.
2) Motor function: Different scales were used to assess this outcome

2.1. *Fugl-Meyer Upper Extremity*: Two homogenous studies \( P = 0.43, I^2 = 0\% \) reported data on the mean FM-UE score in both groups \([21, 22]\). The pooled effect estimate showed no significant difference \( \text{SMD} = 0.50, 95\% \text{ CI } [-0.09, 1.09], P = 0.1, 46 \text{ patients} \) between telerehabilitation and control groups with regard to FM-UE; Figure 4A.

2.2. *Action Research Arm Test*: Two homogenous studies \( P = 0.93, I^2 = 0\% \) provided data on the mean ARAT score in both groups \([16, 24]\). There was no significant difference between both groups in terms of the ARAT score between telerehabilitation and control groups \( \text{SMD} = -0.06, 95\% \text{ CI } [-0.46, 0.33], P = 0.75, 98 \text{ patients} \); Figure 4B.

2.3. *Stroke Impact scale – Mobility subscale*: The pooled effect estimate of two studies showed no significant difference \( \text{SMD} = 0.18, 95\% \text{ CI } [-0.13, 0.48], P = 0.26, 162 \text{ patients} \) between the telerehabilitation and control groups in terms of SIS – Mobility subscale score. Pooled studies were homogenous \( P = 0.87, I^2 = 0\% \); Figure 4C.
Figure 4: The pooled standardized mean difference between telerehabilitation and control groups in terms of (A) Fugl-Meyer Upper Extremity, (B) Action Research Arm Test and (C) Stroke Impact Scale [Mobility] scores.

3) Patients’ quality of life

Six studies reported on the QOL of stroke survivors. Boter and colleagues reported that telerehabilitation patients achieved better scores on the Short-Form (SF-36) emotional role limitation (mean difference = 7.9, 95% CI [0.1, 15.7]) than the control group [9]. However, Forducey et al. and Mayo et al. showed no significant differences ($P > 0.05$) between both groups with regard to the SF-12 and the physical component score (PCS) of the SF-36, respectively [15, 20].

Two studies used two different version of the Functional Independence Measure (FIM): self-administered and telephone versions. Both studies recorded no differences
between the telerehabilitation and control groups [14, 15]. Interestingly, Smith et al.
compared the effects of both treatments on the outcomes of mastery, self-esteem and
social support, and reported no significant effects of either treatment on these
outcomes [12].

Four of the six studies assessed the treatment effects on depression. Two studies by
Linder et al. and Smith et al. recorded no differences between both rehabilitation
methods (tele- and usual) on the Center for Epidemiological Studies - Depression
(CES-D) scale in post-stroke patients [12, 18]. Similarly, Boter et al. and Mayo et al.
reported no significant difference between both groups on the Hospital Depression
scale and the Geriatric Depression Scale [9, 20]. Only one study by Redzuan et al.
reported comparable rates of post-stroke complications in these groups, but did not
specify the nature of these complications [23].

4) Caregivers' quality of life

Five included studies reported on the QoL of the caregivers of post-stroke patients.
Four of these studies showed no significant difference \((P < 0.05)\) between the two
rehabilitation modalities (tele and usual) in terms of the Caregiver Strain Index (CSI)
[9-11, 23]. On the other hand, Smith and colleagues reported that the caregivers in the
telerehabilitation group had lower depression scores than those in the usual care group
[12].

5) Satisfaction with care

Three studies reported on the patient satisfaction with care in both groups. Two of
these studies reported no significant difference between telerehabilitation and usual
care groups in terms of patient satisfaction scores [9, 17]. While Piron and colleagues
randomized 10 patients into a virtual reality (VR)-telerehabilitation group and VR hospital-based intervention. Using a modified satisfaction questionnaire, they reported that tele-VR patients achieved equal or higher scores to hospital-based VR patients in almost all points; however, a significant difference in motor performance was only noted in the tele-VR group [22].

6) Cost-effectiveness

Only one study by Llorens et al. reported data on the cost-effectiveness outcome. They calculated that the cost of telerehabilitation was $654 lesser than usual rehabilitation per subject [19].

DISCUSSION

This systematic review shows that patients on telerehabilitation achieve comparable restoration of daily of life activities and quality of life to those on usual care rehabilitation. Moreover, caregivers of stroke survivors in both groups had comparable quality of life (as assessed by the CSI) and one study reported lower rates of depression in the telerehabilitation group. Satisfaction with care remains a problem in post-stroke rehabilitation, as most included studies showed that telerehabilitation failed to improve the patients' satisfaction with care.

Compared to usual rehabilitation, telerehabilitation has several advantages, including easier access, mentoring for disabled stroke patients, and the ability of patients to self-record about their pain, mood and activity [25]. Unfortunately, there are several barriers that limit the spreading of telerehabilitation. These barriers include administrative licensing, medicolegal ambiguity, and financial sustainability [26].
Another barrier, especially in low-income countries (where telerehabilitation would be most needed), is the lack of technological infrastructure. A cross-sectional study (on 100 stroke survivors) in a Ghanaian outpatient neurology clinic demonstrated that 80 to 93% of patients had a positive attitude towards telerehabilitation interventions. However, only 35% of them had smart phones [27]. Further development of telerehabilitation networks is essential to overcome these barriers [28].

Our systematic review has some strength points. We performed a comprehensive literature search and reported our methodology according to the PRISMA checklist and the Cochrane Handbook for Systematic Reviews of Interventions. Compared to a former systematic review of 10 studies by Laver et al., we investigated the effects of telemedicine on several outcomes: activities of daily living, motor performance, quality of life, satisfaction with care and cost-effectiveness [29]. Moreover, we evaluated the benefits of telemedicine, but only on the stroke survivor, but on the caregiver's quality of life as well.

However, our meta-analysis has some limitations. First, the relatively small size of included patients restricts the generalizability of our findings. Second, some outcomes could not be analysed quantitatively due to the heterogeneity of data in included studies (different scales of measurements or data formats). Moreover, we could not assess the risk of publication bias because, according to Egger and colleagues, funnel plot-based methods are not accurate for less than 10 included studies per outcome [30].

Larger RCTs are required to confirm the current evidence and provide more data on outcomes, such as QoL and cost-effectiveness. Moreover, it would be interesting to clinicians to investigate the benefits of using telerehabilitation to supplement usual
care. Of note, these trials should not necessarily demonstrate that telerehabilitation achieves higher outcomes, but confirmation of comparable outcomes is needed.

In conclusion, telerehabilitation can be a suitable alternative to usual rehabilitation care in post-stroke patients. This may have potential implications for patients, especially in remote or underserved areas. Further larger studies are needed to evaluate the quality of life and cost-effectiveness with the ongoing advances in telerehabilitation systems.
Author Contributions: Huidi Tchero: Designed and conducted the study, and prepared the manuscript
Maturin Tabue-Teguo: Conducted article selection, data extraction and analysis
Annie Lannuzel: Conducted article selection, data extraction and analysis
Emmanuel Rusch: Supervised the study and prepared the manuscript

Acknowledgements: None to declare.

Author Disclosures:
Dr. Huidi Tchero reports no disclosures
Dr. Maturin Tabue-Teguo reports no disclosures
Dr. Annie Lannuzel reports no disclosures
Dr. Emmanuel Rusch reports no disclosures

Study funded by: Not funded.
Conflict of interest: Nothing to declare.

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