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RESEARCH PAPER

Expanding stroke telerehabilitation services to rural veterans: a qualitative study on patient experiences using the robotic stroke therapy delivery and monitoring system program

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Abstract

Purpose: The present study reports on a robotic stroke therapy delivery and monitoring system intervention. The aims of this pilot implementation project were to determine participants' general impressions about the benefits and barriers of using robotic therapy devices for in-home rehabilitation. *Methods*: We used a qualitative study design employing ethnographic-based anthropological methods including direct observation of the in-home environment and in-depth semi-structured interviews with 10 users of the hand or foot robotic devices. Thematic analysis was conducted using an inductive approach. *Results*: Participants reported positive experiences with the robotic stroke therapy delivery and monitoring system. Benefits included convenience, self-reported increased mobility, improved mood and an outlet for physical and mental tension and anxiety. Barriers to use were few and included difficulties with placing the device on the body, bulkiness of the monitor and modem connection problems. *Conclusions*: Telerehabilitation robotic devices can be used as a tool to extend effective, evidence-based and specialized rehabilitation services for upper and lower limb rehabilitation to rural Veterans with poor access to care.

➤ Implications for Rehabilitation

- Participants whose formal therapy services had ended either because they had exhausted their benefits or because traveling to outpatient therapy was too cumbersome due to distance were able to perform therapeutic activities in the home daily (or at least multiple times per week).
- Participants who were still receiving formal therapy services either in-home or in the clinic were able to perform therapeutic activities in the home on the days they were not attending/receiving formal therapy.
- Based on the feedback from these veterans and their caregivers, the manufacturing company is working on modifying the devices to be less cumbersome and more user-friendly (lighter-weight, more mobile, changing software, etc.), as well as more adaptable to participants' homes. Removing these specific barriers will potentially allow participants to utilize the device more easily and more frequently.
- Since participants expressed that they wished they could have the device in their homes longer than the 3-month usage period required for this pilot project, the project team is working on a proposal to extend this project to a wider area and the new paradigm would extend the usage period until the patient reaches a plateau in progress or no longer wants to use the device.

Keywords

Physical therapy, quality of life, qualitative, rehabilitation, robotics, rural, stroke, tele-robotics

History

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Introduction

Stroke is the leading cause of adult disability in the USA with a prevalence of 6.8 million and 795 000 new or recurrent cases each year [1]. Stroke prevalence is predicted to increase with the aging US population [2]. In fact, rural regions of the USA are expected

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to see an increase of their older adults surviving a stroke. Approximately one-fifth of ischemic stroke patients are diagnosed and treated in rural areas [3]. Indeed, the Veterans Health Administration (VHA) has a rapidly growing rural older adult population. Eight percent of enrolled rural Veterans are 85 or older and nearly half are over the age of 65 [4]. The VHA estimates 15 000 veterans per year are hospitalized for stroke, and 40% of these stroke survivors experience moderate functional impairments and up to 30% experience a severe disability [4]. Moderate or mild functional impairments may limit mobility, increase risk for falls and have a detrimental impact on overall quality of life (QOL) [2].

Rural[1] veterans make up a growing percentage of total veterans using the VA system. Approximately 3.2 million rural veterans are receiving care from VHA representing 36% of the total veteran enrolled population [5]. Rural veterans have greater healthcare needs, lower QOL scores and experience higher rates of physical illness in comparison to their urban counterparts [5]. However, despite their greater needs, rural veterans are less likely to access health services, often due to travel barriers including lack of public transportation and greater distance to care [3]. Approximately 30% of VHA stroke patients live greater than 60 min of travel time to the nearest VA Medical Center [6]. Rural areas have also been found to have the following factors that serve as barriers for timely and high-quality care for stroke: limited availability of specialists, limited technology and diagnostic testing at rural hospitals [3].

One of the major problems in the US healthcare system for stroke survivors is the inability to provide quality post-stroke rehabilitation [7]. One way to manage the physical limitations resulting from stroke is long-term care and physical therapy. Many US veterans are older and live in rural areas with limited transportation and long drive distances, which are access barriers to receipt of VA care. Rural residents experience more functional limitations caused by chronic conditions such as stroke than do urban residents with similar conditions [8].

Applications of Telehealth, which integrates information and communication technologies, have been proposed as a cost effective solution to increase access to care in rural areas [9]. Telehealth techniques have been posited as an innovative solution for chronic conditions like stroke impairment in rural populations since it integrates multiple technologies to provide medical services without in-person physician-to-patient encounters [10]. Randomized controlled trials in telehealth have demonstrated its effectiveness for patients and results indicate that telerobotic therapy provides consistent and reproducible treatment [11,12]. Few if any studies to our knowledge have assessed rural veterans' general impressions on effectiveness, benefits and barriers of using robotic therapy devices for in-home rehabilitation.

Other research has found that patient satisfaction is often high for telehealth [13–20], as well as for home-based telehealth interventions in particular [21–23]. Yet, reviews of research on patient satisfaction with telehealth initiatives often have noted a lack of quality in study designs [24–26]. Some critiques of studies to gauge patient satisfaction include: small sample sizes; use of research instruments that are not assessed for validity or reliability and failure to define what is meant by ''satisfaction''. Others have argued that surveys, the most commonly used research instrument to measure patient satisfaction, do not adequately capture patients' experiences and perceptions of telehealth because they do not detail the functioning and challenging aspects of a program [27]. Patients may also be more reluctant to voice negative feedback in either a survey or interview, whereas barriers may be uncovered through observation by the researcher.

The present study reports on a pilot implementation project of a robotic stroke therapy delivery and monitoring system. The purpose of this system is to provide veteran stroke survivors with accessible, effective and affordable stroke rehabilitation care in rural underserved locations through the use of telerehabilitation using therapy robotic devices in their homes or in their local VA Community Based Outpatient Clinics (CBOCs). The aim of this pilot implementation study is to improve access and quality of care for rural veterans by developing evidence-based and innovative practices to support the unique needs of veterans who reside in geographically remote areas. This is a novel application of technology to improve quality of care and access to care. This study takes a qualitative approach to assessing veterans' impressions on effectiveness, benefits and barriers of using robotic therapy devices for rehabilitation delivery. The results from this novel study will be used to make recommendations on how to improve the telerobotic stroke therapy delivery and monitoring system program.

Methods

This study used a qualitative design employing ethnographic-based anthropological methods including direct observation of the in-home environment and in-depth semi-structured interviews with users of the telerobotic devices. In total, there were 13 veterans enrolled in the program; 10 of these 13 individuals participated in interviews.

Recruitment

The robotic stroke therapy delivery and monitoring system program was conducted in the VISN 7 Rural Districts of Blairsville, Georgia and Carrollton, Georgia and surrounding areas. Participants formed a convenience sample and were introduced to the project by their clinician, who was their primary care doctor, nurse practitioner or physical therapist at the VA Hospital or CBOC where they accessed care. If the patient expressed interest in using one of the telerobotic devices, their clinician contacted the telerehabilitation team who then discussed participation with the patient. The prospective participants were given a description of the project and asked if they would be willing to have a home visit and participate in an interview on their experiences using the device after they completed their therapy. Study participants were veterans aged 45–90 who had experienced a unilateral ischemic or hemorrhagic stroke. Inclusion and exclusion criteria are outlined in Table 1.

Participants

The demographics of the participants are outlined in Table 2. All participants were male between the ages of 52 and 88. Six of the nine were married and all were currently retired or on disability leave from their jobs. Only one of the participants lived alone.

Intervention

Once participants' eligibility was verified and they became enrolled in the program, they were granted use of an in-home robotic rehabilitation device (Kinetic Muscles, Inc., Tempe, AZ). Individuals with residual upper limb impairments were given a Hand Mentor™ device, while individuals with residual lower limb impairments were given the Foot Mentor™. The device is comprised a hand or foot peripheral component wired into a processing unit containing the pneumatic pump and a touchscreen

[1]Rural is defined by the US Census as ''Territory, population, and housing units not classified as urban. This is in contrast to the definition of urban'' which is defined as ''comprising all territory, population, and housing units in urbanized areas and in places of 2500 or more persons outside of urban areas''

Table 1. Inclusion and exclusion criteria for participation in the robotic stroke therapy delivery and monitoring system program.

Inclusion
• Persistent hemiparesis as indicated by a score of 1–3 on the motor arm or leg item of the National Institutes of Health Stroke Scale (NIHSS)
• Either hand function or foot function significantly limits activities of daily living
• Functional Independence Measure (FIM) score of between 17 and 88
• The presence of some upper or lower extremity voluntary activity as indicated by the ability to move proximal and/or distal joints against gravity
• No receptive aphasia, as indicated by a score of 0 on Best Language item of the NIHSS
• Ability to read and follow simple directions
• Access to telephone, either cell or landline
• No injury or conditions that limit use of the more affected side before the stroke
• Resides in a rural or highly rural location based upon zip code in database of VISN 7[a]
Exclusion
• Clinically significant fluctuations in mental status within 3 days of enrollment
• Not independent before stroke
• Extinction and inattention (formerly Neglect) score greater than 0 on item #11 of the NIHSS
• Sensory loss = 2 on the sensory item #8 of the NIHSS
• No Botox injections within 6 months of enrollment
• Not expected to survive one year due to other illnesses (i.e. cardiac disease, malignancy, etc.)

[a]Veterans Integrated Service Networks (VISN). The VISN 7 serves veterans in the tri-state area that includes Alabama, Georgia and South Carolina.

interface. The device also has a cellular modem so that data from the therapy could be sent to a secure server to be monitored by a therapist. The device is powered through a wall-outlet. For examples of the devices including proper seating, fitting and training program games query YouTube (www.youtube.com) using the keywords ''Hand Mentor'' or ''Foot Mentor''.

Participants were assigned 2 h of daily Robotic Assisted Therapy (RAT) over a maximum duration of 3 months and were asked to use the device even if formal therapy had already begun or was ongoing. Daily RAT used training programs (similar to computer-games) for motor control and spasticity reduction. The goal of these programs was to increase the active range of motion of wrist and finger or ankle and toe flexion and extension, and to improve the accuracy of these actions. Participants began RAT at an easy level requiring only a small degree of wrist or ankle motion, and then progressively moved through levels of higher difficulty as their motion and accuracy improved. Conversely, if participants experienced difficulty at a level, the device would automatically decrease the difficulty level. The devices and their use in the intervention are described in more detail elsewhere [9].

Data collection methods

Direct observation

Direct observation was conducted during in-home site visits by two interviewers trained in ethnographic research methods. During site visits, the interviewers took notes on the key areas outlined in Table 3. Their observations focused on proximity to a CBOC and/or VA Hospital, participants' accessibility to public transportation, the home environment, availability of a caretaker and other means of social support. The notes taken during the site visit were typed and stored in electronic files and reviewed during data analysis. The interviewers also discussed their observations immediately following each visit to ensure consistency of their findings.

Semi-structured Interviews

Interviews were conducted with the participants during the site visit following the protocol outlined in Table 3. One researcher took the lead in asking questions, while the second researcher took notes. The interviews were digitally recorded with permission from the participants, and excerpts of the interviews were transcribed verbatim. The presence of both interviewers during all 10 interviews ensured consistency. The average duration of the interviews was 32 min.

Data analysis

The interview transcripts were input into *NVivo* qualitative data analysis software (QRS International Doncaster, Victoria, Australia). Observational and interview data were inductively analyzed by creating codes organized around key themes and subthemes. As the coding progressed, subthemes were identified and grouped within overarching themes as patterns emerged about how the codes related to one another. The interviewers discussed overarching themes after each of the interviews were conducted, allowing them to identify emerging themes and areas that required further exploration. For example, as the interviews progressed it was agreed by both interviewers that thematic saturation had occurred regarding the positives and benefits of the device, but there were less data on the barriers and negatives of the device. Therefore, prompts focusing on negatives and barriers were emphasized during the last few interviews.

Results

Analyses of interviews with participants revealed benefits and barriers to using the devices. The results are grouped according to benefits of and barriers to using the devices as articulated by participants. The results include direct quotations from the participants and caregivers as well as observational data from the notes taken by the two interviewers.

Benefits of use

The following overarching themes were identified as positive benefits of using the devices: increased mobility, a sense of control over therapy and scheduling, an outlet for physical and mental tension and anxiety and increased independence.

Mobility

Participants articulated an overall increase in mobility from the use of the devices. In some cases, the participants themselves did not notice the difference, but their caregivers or therapists did. One participant stated, ''I didn't notice much of a difference but my sister did notice that I was moving my arm better''. Another said, ''I noticed a difference almost immediately''. Another participant said, ''It loosened up my leg a lot ... you see I can move my leg now''. Another stated, ''In order to be able to walk they say you have to be able to tap your toes. I can do that now''. In some cases their mobility improved so much that they were able to walk considerable distances. One user said, ''I couldn't

Table 2. Participant demographics.

Participant identifier	ORH-1	ORH-4	ORH-5	ORH-6	ORH-7	ORH-8	ORH-9	ORH-10	ORH-12	ORH-13
Gender	Male	Male	Male	Male	Male	Male	Male	Male	Male	Male
Age (years)	68	68	59	67	57	57	52	49	57	88
Side of stroke	Left	Left	Left	Left	Right	Left	Left	Right	Right	Left
Time since stroke	1y, 3w, 3d	1y, 4m, 1w	3m	5m, 2w, 5d	9m, 2d	1y, 3w, 2d	10m, 1w, 1d	2m, 5d	1y, 2w	4y, 1m, 3w, 2d
Therapies	∅	∅	PT	PT & OT	PT, OT	∅	PT	OT	PT, OT	PT
Marital status	M	M	M	M	S	S	M	D	S	M
Employment	R, D	R, D	D	R, D	D	D	D	D	D	R
Education Level	11	11	12	12	12	16	14	12	12	9
Living situation	Lives with wife, child, grand-child	Lives with wife, child, grand-child	Lives with wife	Lives with wife	Lives with other adult	Lives alone	Lives with wife	Lives with mother and son	Lives with other adult	Lives with wife

PT refers to physical therapy. OT refers to occupational therapy. ∅ refers to no therapy. Marriage status is listed as S for single, M for married, D for divorced. Employment status is listed as R for retired or D for disabled. Education is reported as years of formal schooling.

Table 3. Questions and prompts used to collect data during observations and interviews with participants.

Direct observation protocol
1. Accessibility and distance from VAMC or CBOC?
2. Home environment – caregiver support for assistance with the device?
3. Space to set up the device?
4. Electrical outlet for the device?
5. Table and chair to use the device?

Interview questions and prompts
1. Tell me about your experience using the robotic [arm or leg] device Prompts:
   - Where do you usually use it?
   - What time of day?
   - For how long each session/day?
   - How do you feel during or after using the robotic device?
   - What else can you tell us about using the robotic device?
2. What are some of the things that you like about using the device?
3. What are some of the things that you do not like about using the device?
4. In what ways is using the robotic device different than going to physical therapy sessions at the VA or CBOC?
5. If you could change something about the device, what would it be?

move nothin' but now I can do all of this and do all of this. I can go up and down the ramp out there now four times by myself down and up ... I couldn't do nothin' before''.

In many cases, the participants noticed an improved mind-body connection from using the device. One stated, ''It was hard at first because my mind is broken and the leg don't work unless the mind is working''. He later stated, ''... the game made me realize that my leg was there''. The games reportedly improved the memory of their arm or leg without users being explicitly conscious of the process. One user stated, ''The game got me thinking better ... and it did it without me knowing about it''.

Sense of control over therapy

Due to the convenience of being able to use the device in their homes, participants gained a sense of control over the scheduling of their therapy. One user expressed it like this, ''I can stop it and go back to it. Like if I want to eat I can stop it and go back to it and be in the same place''. Another user stated, ''Let's say I had something to do this afternoon, I could miss the afternoon session and come back tomorrow and do them both''. This ability to split up sessions was important for many participants, especially at the beginning when they would more easily tire from using the device.

The ability to use the device in the home was also very important because of the multiple barriers that participants faced due to their often remote locations. The participants expressed the convenience of using the devices in their homes rather than traveling to therapy. Direct observational data and interviews with participants and caregivers revealed the difficulties that they often faced in getting to therapy appointments. Several caregivers and participants described the long distances from their homes to the local CBOC or local VAMC through hard to traverse rural roads and heavy urban traffic. Furthermore, many of these rural areas lacked public transportation, and when public transport was available it often added hours to the already long travel time. One user stated, ''We'd have to go to Decatur [Georgia] from here and that's a good 4 hours with travel time. Normally when we have a doctor's appointment, we'd leave at around 4 in the morning so that we can get down there''. Another patient explained, ''I wouldn't have done the therapy if I had to go down there''.

A few participants expressed their preference for using the device rather than doing in-person therapy. A participant said,

''The device is better because it ain't talking back. The machine just do what it do and I can focus on the machine and trying to beat it''. Some participants also felt that using the device reduced frustrations that occurred when their caregiver, often their wife, would act the role of therapy coach. One caregiver said, ''He didn't like me running him through all of the exercises''.

Outlet for physical and mental tension and anxiety

Users felt that using the device reduced both physical and mental challenges associated with stroke recovery. Physical tension occurred for some participants in the form of stiffening or shaking in their limbs, and users noted that the device reduced this problem. One user explained, ''I get the shakes every now and again ... and what the device does is it tires it out so it doesn't have the strength to shake''. Mental tension and anxiety was expressed by some of the participants as they worried about the rate of their recovery, became frustrated by their new physical or mental limitations, or had anxiety thinking back to when the stroke occurred. Patients felt that using the device also reduced these mental issues because they found the device fun and challenging, and using it decreased boredom and gave them something to look forward to. One participant explained, ''Some days when I'd get up it'd be like, I don't feel liked doin' it today. But once you start doin' it it's like you're not thinking about your problems or the issue you got ... you kind of get away from it, you know about the way I'm feeling like I am. I liked the games because it took my mind off what I really was thinking''.

Increased independence and mood improvement

Participants expressed an increased sense of independence from their newfound mobility for which they credited their use of the device. One said, ''Now I can dress myself, cut my food, and get in and out of the bed. I can actually just stand and grab this and be on my way instead of waiting for somebody to help me''. Another user said, ''I walked out to my friend's van just with this [cane] ... I didn't use a wheelchair. It's a lot better now than what it was''.

Caregivers discussed how increased independence has improved the mood of veterans. One caregiver recalled that her husband's depression had improved through the use of the device. She states, ''After he'd been cut off from his physical therapy last November, he got depressed and he would get angry with me when I would make him do his exercises. Now he's in a much better mood and his depression has lifted''.

Barriers to use

Although feedback on the devices was overwhelmingly positive there were some barriers to use and suggestions to improvement that were identified during interviews. These included: size and placement of the device, technical difficulties, and wearing and adjusting the device.

Size and placement

One of the complaints about the devices was their size and weight, and the resulting difficulty of moving them around the home as a result. One participant said, ''It's so bulky and when you move it you throw it out of whack, so you have to stay in the same place and work around it''. Most participants reported that they did not move the device from where it was originally set up.

Direct observations of the home environment revealed other related barriers to use based on the physical nature of the devices themselves. Many of the homes were crowded spaces with limited room, few available electrical outlets or without a table or chair at proper height. As a result, setting up and using the device was sometimes difficult. Participants and caregivers often complained that they did not have a ''good chair'' or ''high enough table'' for installing the device and allowing the user to use it comfortably. One participant stated, ''It's cumbersome to find the right chair because of the height and to get the monitor at the right height and close enough''. One participant had problems with finding a chair with an arm rest that was at the right height to comfortably use the device. He said, ''Our son made an arm rest to go on the chair to make it higher than normal and wider. Before I had to hold it up and it tires the arm out fast''.

Wearing and adjusting the device

The most consistent barrier to using the devices reported by participants was difficulty putting the device on and adjusting it by themselves. One participant said, ''The hardest thing was getting my foot in it. Even with a helper it's hard to get it in there and get my foot to fit in there right''. Another participant said, ''It was hard to get the hand in the right spot''. In some cases, having enough room to fit a shoe was a problem. ''I had trouble getting my foot into machine with the shoe on it''. Another complaint involved the Velcro on the foot device. One participant said, ''The Velcro ... I don't know if they were positioned for enough support for the weak part of the foot''. Another said, ''The straps got Velcro on both sides but after a couple of weeks of playing the game they started just popping apart, and when I bend down it was kind of uncomfortable and then every time I'd use my foot it'd come apart and then it would tilt the machine a little and then the screen would pop up telling me I tilted the machine''.

Several of the participants said that they needed the help of the caregiver in order to put on the device. One said, ''The only difficulty was putting it on 'cause you needed two hands''. In one case, with an increase in mobility, the participant was able to do it himself. ''When I first started my wife had to help me strap it up, but then I could do it, I'd manage it, it'd take me a minute or two''.

Technical difficulties

One technical complaint centered on the computer or software becoming unresponsive or acting erratically. One participant said, ''The computer would freeze up with the leg device. Another participant said, ''Ya'll got a software problem with the machine ... the screen would just lock up on me and I'd have to unplug it and then reboot it up''. One user experienced problems with the machine jumping levels, ''When you get to level 3 or 4 it would jump on yah ... it would go up to the next level, just automatically''.

A second technical difficulty some users experienced was that the modem that was used to send their usage data to the VA facility did not always function properly. The modems reportedly took a long time to send the data and sometimes did not actually send the data at all. One participant said, ''Sometimes it took a lot of time to transmit the data and you have to wait too long. You're all hooked up and everything and you have to sit for ten minutes for the thing to transmit''. Another said, ''There were problems sending information. It would say that it sent it, but it didn't send the signal because of the area we're in''. In some cases the participants blamed the remote areas that they lived in for these difficulties since many of the rural areas lacked consistent Internet access.

Although participants reported some technical difficulties, everyone reported that the devices were ''easy to use'' even though many had limited previous knowledge of and experience with computers or gaming devices. For example, one participant said, ''It's been so easy ... even a dummy like me can understand it. It's very simplified. Like I said, we don't even have a computer''.

Discussion

The aim of this pilot implementation study was to determine what participants in a home-based telerehabilitation program viewed as benefits and barriers of using robotic devices for rehabilitation delivery. In contrast to most other studies in this type of population, we employed a qualitative study design that employed ethnographic-based anthropological methods including direct observation of the in-home environment and in-depth semi-structured interviews. This study was part of a larger intervention with the purpose of providing veteran stroke survivors with accessible, effective and affordable stroke rehabilitation care in rural underserved locations. Participants using these robotic telerehabilitation devices have been previously found to show increased motor and cognitive functions and decreased depressive symptoms [9]. Participants in previous projects using the same device and protocol also seemed generally satisfied with the devices based on their responses to a survey that asked how much they agreed with a series of 14 statements about the devices [9]. However, due to the nature of the methodological design, it is difficult to know *why* patients responded as they did to this satisfaction survey. Thus, a major contribution of our study was how we uncovered a greater depth of information for patient satisfaction than was captured previously for participants in a similar intervention.

The themes identified in interviews and observations in this qualitative study showed that patients responded both to the direct physical impact of the intervention, as well as the indirect benefits such as an improvement in mood that were made possible by physical improvements from rehabilitation. Examples of these benefits include feeling more mobile, having an outlet for mental tension and anxiety, experiencing an improved mind–body connection and becoming more independent. Patients also responded positively to the way in which rehabilitation was delivered by the home-based robotic device itself, such as having control over the timing and duration of the rehabilitation therapy sessions, and avoiding the cost and time involved with travel to do physical therapy in a clinical setting.

Interviews and observations also revealed some room for improvement with related to perceptions of the robotic telerehabilitation devices. Patients and caregivers most often identified barriers stemming from the physical qualities and technological components of the device, which in turn made the device less user-friendly. Detailed care was given to the initial in home set-up of the devices. However, while designed to be portable and easy for use in a home setting, in reality some patients found the device difficult to put on and adjust to their hand or foot, and difficult to set up and move in their homes. Observation of the home environments by the researchers revealed that the lack of open space and wall outlets inhibited the device from being truly mobile in these settings. Modifying the home environment was beyond the scope of the present study. However, future implementations of this type of program could consider environmental modifications as a contingency when integrating the program in the Veteran's home. While patients overall reported that the device was accessible even to those without previous experience in computers or video games, they did also express frustration with some technological aspects of the robotic device such as the computer becoming unresponsive or jumping levels in rehabilitation exercises, or the modem taking too much time or failing to send data off-site. These findings are consistent with other qualitative studies of telehealth interventions that have found patients can become frustrated when telehealth equipment does not operate as it should [27–29]. Interestingly, we found that people can be overall satisfied with a device *despite* the presence of technical and operational issues. Nevertheless, while these barriers may seem trivial, they should not be ignored as they may discourage patient compliance in the long run.

One of the goals of conducting this qualitative study was to create recommendations on how to improve the telerobotic stroke therapy delivery and monitoring system program. Based on our findings from interviews and observation, we suggest that the following changes could be made to the program to address current barriers.

(1) *Increase effort and time devoted to installing robotic telerehabilitation devices*: Since many patients reported that they did not move the device from where it was initially installed in their home, care should be taken to ensure that the placement of the device and its adjustment to the body of the patient is ideal from the beginning. Many patients reported that the furniture that they owned was unsuited for use in coordination with the device, and in response the program could either look into providing chairs and tables to patients, or modifying existing furniture so that it is more suitable.
(2) *Make the devices easier to put on and adjust to patients' bodies*: Some patients reported that they needed help from an informal caregiver (e.g. spouse) to put on or adjust the device, which could be addressed through redesigning the device itself or in providing additional supportive structures that makes this task easier. The device could also be redesigned to allow for more foot and hand sizes and to include stronger Velcro.
(3) *Improve the device operation to reduce ''freezing'' and ''level jumping'', and improve modem function*: Some patients reported that the device would become unresponsive and require rebooting, or would jump levels, which the manufacturer of the device should be able to correct. Furthermore, if modem connectivity to transfer user data off-site is important, solutions should be sought make this more feasible. Some of this improvement may be in the design of the device itself, but the lack of consistent Internet access in the remote locations of patients' homes may require other efforts beyond the scope of this program.

Strengths and limitations

The strength of this study was that the use of multiple qualitative research methods provided richer data than was previously elicited through surveys. Visits to the homes of stroke patients allowed the researchers to observe their home environments and observe ways in which it facilitated or impeded the rehabilitation process. Interviews with patients and their caregivers provided rich data on the experiences of rural veterans and gave insight into the benefits and barriers that they perceived with this home-based robotic telerehabilitation program.

The study nevertheless had some limitations. The sample size of 10 users and their caregivers was small and this may have introduced bias into the data. Despite this less than ideal size, we were confident that we obtained saturation with the rich themes reported here. For some of the Veterans, visits to observe and interview them were conducted after the rehabilitation intervention had already finished, which may have reduced their ability to recall with the detail and precision necessary for a qualitative research design. For this reason, we tried to complete the interviews as close to the end of their therapy as possible.

Conclusion

The results from this study are promising for demonstrating that the home-based robotic devices can be used as a tool to extend effective, evidence-based and specialized services for upper and lower limb rehabilitation to rural veterans with poor access to

care. Stroke rehabilitation therapy delivered by robotic-based telemedicine devices is perceived by veterans and their caregivers as not only improving limb rehabilitation, but also increasing mobility, independence and mind–body connection while decreasing anxiety and stress. Patients and caregivers also appreciated that the devices allowed more control over the rehabilitation process. Veteran stroke patients and their caregivers also noted that the device itself had barriers related to its size, adjustability and technology, but cited many more positives than negatives with home-based robotic telerehabilitation.

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Declaration of interest

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