

Telerehabilitation for veterans with a lower-limb amputation or ulcer: Technical acceptability of data

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Abstract—A study was undertaken to determine the technical acceptability of information available via a customized telerehabilitation system regarding patients with lower-limb ulcers or recent lower-limb amputations receiving care at a Veterans Affairs Medical Center. Among the 54 participants, 57 wounds (39 ulcers, 19 amputation incisions) were evaluated by means of still photographs and skin temperature data sent via ordinary telephone lines. Three experienced clinicians served as raters. Intrarater agreements and McNemar χ^2 tests were assessed between decisions made after telerehabilitation sessions and decisions made by the same rater after in-person sessions. Interrater agreements and κ coefficients were assessed between two raters for both telerehabilitation and in-person sessions. The intrarater agreement on 57 wounds for the primary rater was 93%, and the McNemar test indicated no significant difference in the ratings ($p < 0.63$). Interrater agreement on 18 wounds was 78% ($\kappa = 0.55$, $p < 0.02$) for the telerehabilitation sessions and 89% ($\kappa = 0.77$, $p < 0.001$) for the in-person sessions. Most qualitative comments by three clinicians on picture quality (54/63 = 86%) and temperature data (39/44 = 88%) were favorable (good to excellent). The information yielded from this study provides evidence that the telerehabilitation system has the potential to present sufficient information to experienced clinicians so they can make informed decisions regarding wound management. The next phase of the study will include in-home trials and improvements in the technology.

Key words: amputation, telehealth, telemedicine, telerehabilitation, ulcer, wounds.

INTRODUCTION

Telerehabilitation, or telemedicine used in the field of rehabilitation, has been applied to seating system consultation, home modification evaluation, computer access evaluation, and augmentative communication training [1]. As the technology improves and the cost of the cutting-edge technology decreases, many of the barriers to effective telerehabilitation are removed. The removal of these barriers, combined with the potential benefits, suggests that telerehabilitation principles can help to optimize the treatment of rehabilitation patients who either are at risk for amputation or who have had a recent lower-limb amputation due to the presence of diabetes, peripheral vascular disease (PVD), or nondiabetic peripheral neuropathy.

Abbreviations: PACT = Prevention/Amputation Care and Treatment, PVD = peripheral vascular disease, VA = Department of Veterans Affairs, VAMC = VA Medical Center, VHA = Veterans Health Administration.

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Foot and leg ulcers are serious complications of these conditions because they often precede lower-limb amputations [2,3]. Adler et al. found that in a group of 776 veterans, those with lower-limb ulcers were 2.5 times more likely to have a lower-limb amputation within the follow-up period (median = 3.3 years, range 0–5.8 years) [4]. Healing these ulcers is often a long and difficult process. Margolis et al. performed a meta-analysis on the control groups for 10 clinical trials of treatments for diabetic foot ulcers [5]. Six of the studies had a 20-week endpoint, at which time only 31 percent of the ulcers had healed. In four other groups, 12 weeks was the endpoint and 24 percent of the ulcers had healed. Percentages were similar across trials. It has been shown that patient compliance/adherence to wound care regimens can make a substantial difference in the rate of ulcer healing [6]. Frequent follow-up via home healthcare has been shown to increase compliance and reduce the risk of complications in patients with PVD [7]. These findings suggest that a telerehabilitation program for veterans with lower-limb ulcers is likely to result in improved outcomes.

Older individuals who have an amputation due to diabetes, PVD, and neuropathy often do not fare well afterwards. McWhinnie et al. found that 10 percent of transtibial amputations performed on patients with arterial disease did not heal and required revision to a higher level [8]. Mortality rates following amputations indicated by nontraumatic causes are very high. For example, McWhinnie et al. reported that 24 percent of the sample had died within 1 year after amputation and 67 percent had died within 5 years [8]. Pohjolainen reported that, in a mostly elderly sample, 38 percent died within 1 year and 73 percent within 5 years [9]. Czerniecki reported that the mean 3-year survival rate for diabetic patients is 25 percent to 50 percent [10]. Mobility status is often reduced after amputation. McWhinnie et al. documented that at 1 year postamputation, 36 percent of persons with a transtibial amputation walked outdoors, another 11 percent walked indoors, 28 percent did not walk at all, and the remainder had died [8]. At 5 years postamputation, the situation was even worse, with only 9 percent walking outdoors, 8 percent indoors only, 15 percent not walking, and 67 percent deceased [8].

With the current practice of assessing progress via outpatient clinic visits every few weeks, a delay occurs in identifying patients who are not progressing favorably or who are experiencing complications. Being able to interact with patients and monitor their progress from home

via telerehabilitation would allow healthcare providers to identify problems more quickly, encourage adherence to self-care regimens, recognize and rectify misunderstandings of recommended self-care practices, provide ongoing education as needed, and identify a patient's readiness for prosthetic fitting sooner. A telerehabilitation system could also be used for the early identification of contralateral limb problems and the encouragement of preventive health practices, both of which can have important long-term benefits in reducing future limb loss and increasing the quantity and quality of life.

Before telerehabilitation can be used to monitor patients with wounds in their homes, it is necessary to establish confidence in the data obtained when the system is used. The provider who communicates with the patient via telerehabilitation must be able to obtain information of sufficient quality to allow appropriate decisions regarding care to be made. Several studies have compared ratings of diagnoses and treatment plans made by telemedicine with those made in person [11–15]. Debray et al. found reasonable agreement between two physicians (one using images and one onsite) with regard to wound size ($r = 0.90$), pressure ulcer classification ($\kappa = 0.49$ – 0.61), and wound bed color ($\kappa = 0.39$ – 0.64) [11]. However, assessment of undermining of the wound was difficult remotely, even with the use of probes that were photographed, and this was judged to be a major limitation. Problems also arose with the assessment of wound edges, infection status, and presence of exudate. Nitzkin et al. reported 87 percent agreement ($\kappa = 0.66$), on average, for 736 pairs of observations of 20 ophthalmology, physical therapy, cardiac, or pulmonary patients with regard to a variety of variables such as conjunctival inflammation for ophthalmology patients, extension and flexion for physical therapy patients, diastolic murmur for cardiac patients, and pleural effusion for pulmonary patients [12]. Pacht et al. reported κ statistics ranging from 0.59 for dyspnea and 0.60 for cough to 1.0 for rales on auscultation, diagnostic impression of chronic obstructive pulmonary disease, and diagnostic impression of sarcoidosis [13]. The data were sent on 40 pulmonary patients by T-1 (broadband) line with real-time video. Phillips et al. compared telemedicine and conventional ratings of 51 patients at a skin cancer screening site using a T-1 line [14]. There was 59 percent agreement ($\kappa = 0.32$) on diagnosis. Better agreement was found on whether a biopsy should be done (86%, $\kappa = 0.47$) and on whether a lesion was malignant (69%, $\kappa = 0.56$). Remote raters were more likely to recommend a biopsy. Wirthlin et al. examined

24 patients with 38 wounds [15]. Onsite and remote surgeons agreed on 60 percent to 83 percent ($\kappa = 0.12\text{--}0.60$) of wound descriptors and 60 percent to 87 percent ($\kappa = 0.30\text{--}0.43$) of management decisions. Many investigators appear to have labeled as “acceptable” agreements as low as 50 percent to 70 percent. Nitzkin et al. suggested a guideline of 80 percent agreement or better as being acceptable [12]. Perfect agreement cannot be expected, since even comparisons among raters who are all onsite yield agreements in the 70 percent to 85 percent range. Agreement depends on many factors, including not only the quality of the transmitted data but also the types of data being evaluated. To summarize, on the whole, the comparability of ratings between onsite and remote raters has been less than ideal.

A study was undertaken at the Houston Department of Veterans Affairs (VA) Medical Center (VAMC) to determine the technical acceptability of the information available via a customized telerehabilitation system regarding patients with lower-limb ulcers or recent lower-limb amputations. Ratings by clinicians based on data derived from telerehabilitation sessions were hypothesized to differ only insignificantly from ratings derived from in-person examinations.

METHOD

Sample

Participants were recruited at the Houston VAMC from among veterans who were (1) outpatients being seen for a lower-limb ulcer either by the coordinator for the Veterans Health Administration (VHA) Prevention/Amputation Care and Treatment (PACT) Program or the Wound Care Clinic, or (2) patients with recent lower-limb amputations receiving inpatient rehabilitation. Fifty-four individuals (57 wounds) with a wide range of ages (mean = 63.4 years, standard deviation [SD] = 11.4, range = 29–86) participated in the technical acceptability study. All but one participant were male; 68 percent were Caucasian, 26 percent were African-American, and 6 percent were Hispanic. Sample size was based a priori on several assumptions: (1) false negative rate = 10 percent (i.e., patient is judged to need to come to the clinic within 24 hours when examined in person but not judged to need to come in when examined via telerehabilitation), (2) 50 percent of wounds will be judged to require that the patient come to the clinic within 24 hours when evaluated in person, and (3) at least one false negative

would occur with a probability of 95 percent, given the assumed false negative rate. Given these assumptions, a total of 56 wounds needed to be evaluated [16]. The distributions of age, gender, race/ethnicity, education, and marital status of the study sample are generally representative of patients receiving care for lower-limb ulcers and/or amputations at the Houston VAMC [17].

Equipment

A telerehabilitation system was developed to test the technical acceptability of the information obtained via computers over a standard telephone line. The system consisted of a host unit and a client unit. The host unit was housed in the office of a physician/investigator on the rehabilitation service. The client unit was housed in the telerehabilitation laboratory in another area of the same building. The host and client units were linked by the client using a modem to dial in on a standard telephone system to a toll-free number at the Houston VAMC. Once the phone answered at the VA, the call was routed through the VA network to the IP address of the host unit.

Host Unit Hardware

The hardware for the host unit consisted of a Dell Intel Pentium III[®] computer (Windows 98[®]) and monitor, a second monitor, a dual-monitor video card, an Internet video camera (Videum Conference Pro[®]), a video-capture card, and a network interface card.

Host Unit Software

Software included Microsoft NetMeeting[®] (teleconferencing software that allows data compression, sharing programs, and transferring files), Microsoft Office[®] (allows storage of temperature data in Excel[®] files), and a program developed specifically for the project to store and display still photographs and temperature measurement data. The host unit was connected to the VAMC local area network and had a designated VA IP address.

Client Unit Hardware

The hardware for the client unit included a Dell Intel Pentium III[®] computer (Windows 98[®]) and monitor; an internal US Robotics[®] 56K Voice PCI modem; two Internet cameras (Videum Conference Pro[®], Logitech Quick-Cam Pro 300[®]; **Figure 1**), one of which used a USB port; and a video capture card. The Videum[®] camera, which uses very compressed data to reduce the quality and size of the display, was used for the teleconference. The Logitech[®]

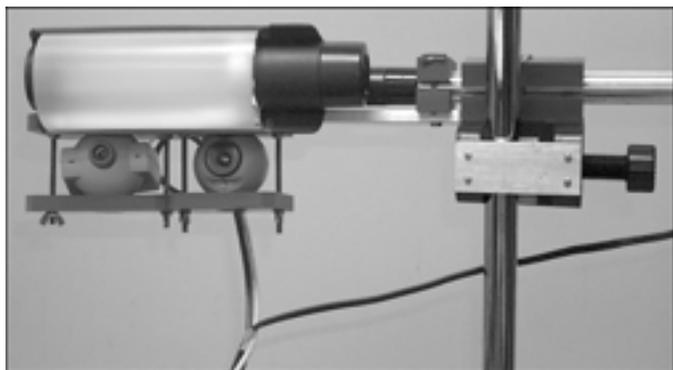


Figure 1.
Cameras, light, and IV pole.

camera, which produces high-resolution images and separates processing, capture, and transfer functions, was used for the pictures of the wounds. Before patients were evaluated in the study, the camera's sensitivity to color variations was checked by five raters who evaluated a series of color samples. Seven color panels, each with a different number of color swatches of different hues of the same color were prepared. The colors included white, pink, red, and earth tones. The number of hues varied from 16 to 22 for each panel. The panels were placed in front of the camera, one at a time, and the rater was asked to count the number of different swatches on the panel as seen on the monitor and record the result. Of the five raters, only one rater missed one swatch on one panel, thus it was concluded that the camera provided sufficient hue differentiation to assess the color of the wounds that would be evaluated with the system.

Other hardware included a clamp-on light with a natural daylight bulb and an opaque filter added to reduce glare (Ott-Lite Clamp-on Lamp[®], **Figure 1**); a wheeled IV pole, to which the light and the cameras were attached (**Figure 1**); a temperature sensor (modified Exegen Skin Surface Temperature Scanner[®], **Figure 2**); and a custom six-channel analog-to-digital converter module for use with the temperature sensor. The modification to the temperature sensor was necessary to allow the data to be read by the computer and be used by individuals who have limited computer skills. The sensor was mounted in a housing that incorporated a touch-sensitive activation switch that assured the sensor was at a preset distance from the skin when the readings were made. The sensor was adapted to collect analog values that represent temperature, digitize those values, and deliver the values to the computer so that



Figure 2.
Temperature monitor.

they can be displayed on the screen. The sensor also sequenced the operation to be able to keep track of the data and to turn off the power to the sensor when the user finished using it. These modifications did not affect the reliability and accuracy of the readings. Each system was calibrated at the factory and was tested before and after being modified. The clinical accuracy of the Exegen Skin Surface Temperature Scanner[®] is $\pm 0.1^{\circ}\text{C}$, with a response time of 0.1 s.

Client Unit Software

Software on the client unit included Microsoft Net-Meeting[®], Microsoft Office[®], and four programs designed for the study that accomplish the following: (1) store and display photographs and temperature data, (2) enable host system to operate the still camera and temperature sensor, (3) monitor the still camera and accept commands from the host system, and (4) record temperature data and link still photograph files with temperature data files. The client unit was connected to a standard telephone line and used a toll-free number to dial in to the VAMC.

Procedure

Potential participants came to the telerehabilitation laboratory. The study was explained to the patients and, if they chose to participate, they signed a consent form approved by the local institutional review board for research with human subjects. They also responded to a questionnaire that included demographic information and descriptive data about the wound (i.e., location, duration, bleeding, draining, odor). The psychometric properties of the questionnaire were not assessed. However, the questions were derived from existing wound assessment instruments, as well as being based on recommendations from the clinicians on the research team. Ulcers were

measured for maximum diameter and the diameter perpendicular to the maximum diameter.

Client Procedure

A research staff member stayed with the participant in the laboratory. If necessary, the staff member assisted the participant with removal of wound dressings so the wound could be photographed. The staff member also assisted the client in initiating the telephone connection with the VAMC and the connection to the host computer with the use of the mouse to click on specified icons and buttons on the client computer screen. The Videum[®] camera was used for teleconferencing. The staff member and the client positioned the Logitech[®] camera, which produced higher resolution images than the conferencing camera. The camera was positioned so that the image of the wound was centered in the window on the client's computer screen. The camera was positioned as close to the wound as feasible to produce as large an image as possible while staying within the camera's focal range. The orientation of the camera was then adjusted to produce an image with as little reflection from the moist surfaces of the wound as possible. The focus of the camera was then set and the system was ready to use.

Host Procedure

The questionnaire was given to the clinician rater for that session who went to the host unit in the physician's office. The rater was not permitted to view the wound in person prior to evaluating it via telerehabilitation. The study was designed to always have the telerehabilitation session first and the in-person session second, rather than counter-balance them, because the in-person session is to be considered the "gold standard" against which the telerehabilitation session is judged. In-person sessions would be likely to affect the telerehabilitation rating more than vice versa.

Once the connection was made by the client, the rater took remote control of the client computer for the remainder of the session. Communication with the rater was via speakerphones at each end. The rater asked the participant additional questions about how the wound and the skin around the wound looked—dry, wet, scaly, color, oozing, swelling. Once the camera was properly positioned by the client or staff member in the laboratory, the rater used the remote control software to take a still photograph of the wound and send it over the telephone line to the host computer, where it was displayed full

screen on the second monitor (**Figure 3**). If other views were needed, the rater would instruct the participant and staff member as to what was needed and the camera was repositioned appropriately in the laboratory.

Temperature Readings

Once the rater was satisfied that sufficient photographs had been taken to be able to evaluate the wound, the camera unit was moved out of the way by laboratory staff. The temperature software was initiated remotely by the rater. The laboratory staff member or participant then obtained temperature readings by placing the temperature sensor on the skin at various points around the outer edge of the wound. Participants were able to use the sensor by themselves if they were able to see and reach the wound area. Participants whose wounds were inaccessible, such as on the bottom of a foot, needed someone else to manipulate the temperature sensor. For a moderate-sized ulcer, four readings (at 3, 6, 9, and 12 o'clock) were usually taken, in addition to a reference reading taken in an area near the wound but not directly affected by the wound (i.e., a "healthy" area). More readings were taken for larger ulcers. For an amputation wound, six readings were usually taken, three above the incision (right end, center, left end) and three below the wound in addition to the reference temperature.

The reference and wound area temperatures were displayed numerically, and the readings around the wound were also displayed graphically (**Figure 4**). The small



Figure 3.
Wound.

colored circles represent the order of the readings, beginning at 3 o'clock and continuing counterclockwise. The color map provides a quick way for the clinician to assess the skin temperature. Red means that the skin temperature near the wound is more than 5° higher than the reference temperature, yellow indicates greater than 3 and up to 5° higher than the reference, green indicates 1° below to 3° above the reference, and blue indicates more than 1° below the reference. The data were stored in an Excel file for analysis after the session. This concluded the telerehabilitation session.

Telerating

Based on the information obtained during the telerehabilitation session, the rater completed a rating form indicating whether, if the person had been at home during the telerehabilitation session, the rater would have recommended that the patient (1) come to the clinic within 24 hours or (2) continue current treatment and be seen via telerehabilitation within 1 week. This distinction was

considered to be the “bottom-line” question that would need to be answered in an actual home-based telerehabilitation session.

In-Person Rating

The rater then came to the laboratory to evaluate the wound in person. Based on the information obtained during the in-person session, the rater completed a second rating form indicating whether the rater would have recommended that the patient (1) come to the clinic within 24 hours or (2) continue current treatment and be seen via telerehabilitation within one week.

Participant Responses

Finally, the participant was asked whether he/she would have room to accommodate the telerehabilitation system if one were to be placed in the home, whether there was anyone who could help him/her during a telerehabilitation session at home, and whether the participant thought that having a telerehabilitation system at home would be helpful. This ended the session. A voucher for \$20 was provided for participating in the study.

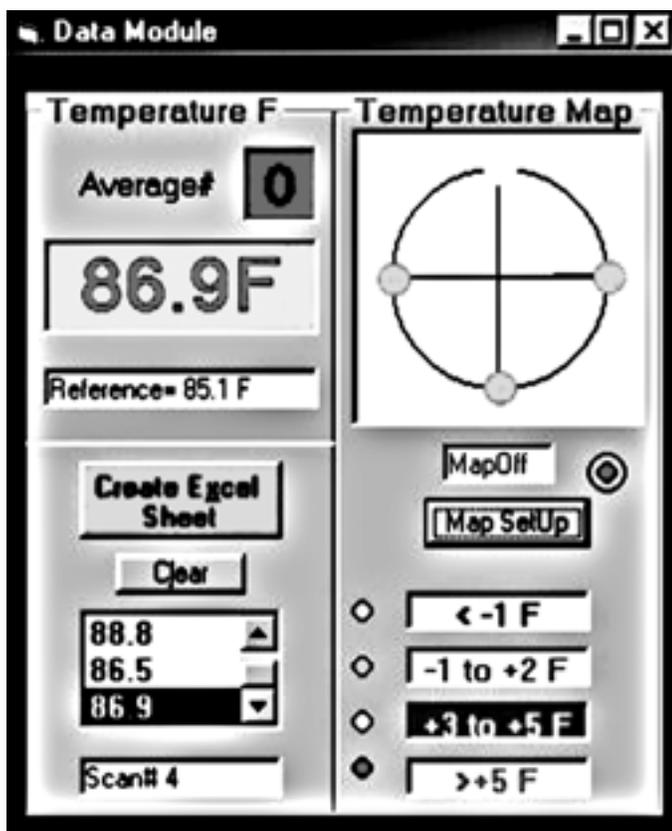


Figure 4.
Temperature data display.

Second Rater

For some sessions (18 wounds), a second rater independently evaluated the wound both during the telerehabilitation portion and the in-person portion of the session to allow assessment of interrater agreement. The two clinicians were both in the same room when the primary rater asked the participant questions, so both heard the responses. However, they did not discuss their assessments of the wound with each other. Then they both came to the laboratory to view the wound in person and, again, independently made their ratings.

Data Analysis

Descriptive statistics were calculated for each study variable (means, SDs, ranges, number, and percent). Percentage of agreement was calculated and the McNemar χ^2 test was used to test intrarater agreement between ratings by the same clinician based on the telerehabilitation session and ratings based on the in-person examination. Separate analyses were performed for the primary and secondary raters, as well as for those ratings combined. Percentage of agreement and κ (a measure that takes the agreement expected by chance into consideration) were calculated for testing interrater agreement between the primary and secondary raters for (1) ratings based on the

telerehabilitation sessions and (2) ratings based on the in-person sessions. Qualitative responses by both the primary and secondary raters regarding the quality of the pictures and the temperature data were categorized after data collection was completed and the number and percentage of responses in each category were determined. Responses by the participants to questions regarding having room at home for a telerehabilitation system, having assistance at home to help during telerehabilitation sessions, and perceived potential helpfulness of telerehabilitation were also categorized and the number and percentage of each response were calculated.

RESULTS

Characteristics of Wounds

Four participants each had two wounds evaluated, thus, there were 58 wounds among the 54 participants. Two-thirds of the wounds were ulcers and the remaining wounds were recent surgical wounds, approximately half of which were transtibial amputations. Over half of the ulcers were on the lower leg and the rest on the ankle or foot. One wound could not be assessed via telerehabilitation due to technical difficulties (the computer “froze”) and the participant could not stay long enough for the staff to correct the problem and continue the session. Thus, 57 wounds were assessed. The mean time since the ulcers began was 0.97 years ($SD = 1.46$, median = 0.50, range = 0.04–8.00). The size of the ulcers ranged from 1 to 15 cm (mean = 4.68, $SD = 3.00$, median = 4.13). The mean time since amputation was 30.01 days ($SD = 34.87$, median 14.60, range = 7–120).

Technical Acceptability of Information Obtained via Telerehabilitation

The main analysis assessing the adequacy of the information obtained via telerehabilitation involved comparing the primary rater's determination of whether a participant would be asked to (1) come for a clinic visit within 24 hours because of the condition of the wound or (2) continue treatment and be seen via telerehabilitation within 1 week based on the information obtained during the telerehabilitation session with the same rater's determination based on the in-person examination. A physiatrist was the primary rater 12 percent of the time, an occupational therapist experienced in evaluating pressure ulcers 49 percent of the time, and a certified wound care

nurse 39 percent of the time. The primary rater's determinations for the telerehabilitation and in-person sessions agreed for 93 percent of the 57 wounds. For 18 (31.6%) wounds, both ratings indicated the person should come to the clinic within 24 hours, and for 35 (61.4%) wounds, both ratings indicated the person should continue current treatment. In only one (1.8%) case was the determination via telerehabilitation to not recommend coming to clinic within 24 hours paired with an in-person determination that the person should come in within 24 hours (false negative), and in three (5.3%) cases the telerehabilitation rating indicated the person should come to the clinic but the in-person rating indicated he need not come (false positive). The McNemar test indicated that there was no significant difference ($p < 0.625$) in the two types of ratings—telerehabilitation versus in person.

For 18 (31.6%) of the 57 wounds, a second rater independently determined whether a clinic visit within 24 hours would be recommended both via telerehabilitation and in-person. The physiatrist was the secondary rater 28 percent of the time, the occupational therapist 50 percent of the time, and the certified wound care nurse 22 percent of the time. The recommendations from the telerehabilitation and in-person sessions agreed in 89 percent of the cases and the McNemar test again indicated no significant difference ($p < 1.0$) in the ratings. For seven (38.9%) wounds, both ratings indicated the person should come in, and for nine (50%) wounds, both ratings indicated the person need not come in. There was one (5.6%) false negative and one (5.6%) false positive pair of ratings from the second rater.

Combining the ratings from the primary and secondary raters ($N = 75$ ratings) resulted in an overall agreement rate of 92 percent and an exact significance level based on the McNemar analysis of 0.687, again indicating no significant difference in the ratings. For 25 (33.3%) wounds, both ratings indicated the person should come in and for 44 (58.7%) wounds, both ratings indicated the person need not come in. In only two (2.7%) of the 75 rating pairs did the rater decide after the telerehabilitation session that the patient need not come to the clinic within 24 hours but then decided that the person should come in within 24 hours after the in-person session (false negatives). In four (5.3%) of the cases, the disagreement was in the opposite direction—the telerehabilitation rating was to come in within 24 hours but the in-person rating was not (false positives).

Interrater Agreement

The ratings of the primary and secondary raters were compared to each other separately for the telerehabilitation condition and the in-person condition. In the telerehabilitation condition, the two raters agreed on 14 (78%) of the 18 wounds, resulting in a κ coefficient of 0.55, indicating moderate but significant ($p < 0.02$) agreement. In the in-person condition, the two raters agreed on 16 (89%) of the 18 wounds, resulting in a κ of 0.77, indicating a relatively high and significant ($p < 0.001$) agreement.

Qualitative Evaluation of Picture Quality

Both primary and secondary raters were asked to provide an open-ended evaluation of the picture quality via telerehabilitation for each session. Ratings were provided for 63 (84%) of the 75 sessions. The ratings were divided by whether they were for pictures of ulcers or amputations. Eighty percent of the ratings of pictures of ulcers fell into the excellent, very good, or good categories and all the ratings of pictures of amputation wounds were in these same three categories. Most of the nine pictures that were considered fair or worse were of small (maximum diameter 2.5 cm) ulcers. Small ulcers tended to look worse on the telerehabilitation screen than in person.

Qualitative Evaluation of Temperature Data

The raters were also asked to provide open-ended evaluations regarding the temperature data provided via telerehabilitation. Of 34 responses for ulcers, 30 (88%) were good, helpful, useful, or "OK." In four cases, the system malfunctioned; either the activation switch got stuck in the "on" position or the computer froze when trying to send the data to the host computer. The causes of the malfunctions were identified and corrected and have not been a problem since then. Similarly, for evaluations involving amputation wounds, 9 (90%) of 10 responses were in the good/helpful/OK category, with only one malfunction. Overall, 89 percent of the responses were positive.

Participant Responses Regarding Space, Assistance, and Perceived Usefulness of the System

After the session, participants were asked whether they would have room for a telerehabilitation system if given the chance to have one placed in their home. Nearly 85 percent said they would have room. They were asked whether they would have someone at home who could help them use the system if they had one and over

81 percent said they would have someone to help. Finally, they were asked whether they thought that having a telerehabilitation system at home would be helpful to them. Almost 87 percent believed that it would be helpful.

DISCUSSION

This study is the first in a series of studies designed to develop and evaluate relatively low-cost telerehabilitation systems that can be used in patients' homes with ordinary telephone lines. The current populations of interest are persons with recent lower-limb amputation wounds and persons with leg and foot ulcers; however, use by persons with other types of health problems is feasible and should be evaluated in future studies. This first study provides evidence of the technical acceptability of information obtained via telerehabilitation regarding leg or foot ulcers or recent amputation incisions. While simulating a telerehabilitation session with the participant at home, there was an overall agreement rate of 92 percent regarding whether the patient should come to the clinic within 24 hours when comparing clinician ratings based on telerehabilitation versus in-person examination. This finding compares favorably with the 86 percent agreement reported by Phillips et al. [14] for whether a biopsy should be done and the 60 to 87 percent agreement reported by Wirthlin et al. [15] regarding management decisions. It is well above the minimum of 80 percent agreement recommended by Nitzkin et al. [12]. As might be expected, somewhat better interrater agreement between primary and secondary raters was found in the in-person condition compared to the telerehabilitation condition (89% vs. 78%). Qualitative statements by the clinicians about the pictures via telerehabilitation were generally positive with the exception of pictures of very small ulcers. The vast majority of participants indicated they believed that having a telerehabilitation system at home would be helpful and most would have room for the equipment and assistance to use it. These responses by the participants are in line with patient satisfaction data available in the literature. For example, Dick et al. reported that after participating in a single telemedicine session, 76 percent of patients were comfortable using the system [18], and Bratton and Cody reported that 78 percent of participants would use a telemedicine system again [19].

The major limitation of this study is the potential bias in the intrarater calculations based on the memory of one's telerehabilitation rating while making the in-person rating. However, having different raters in different settings would have introduced greater confounding (person characteristics and setting) than the design used in this study. Furthermore, during this phase of the study, the focus was on identifying weaknesses in the technology. Thus, if the raters were biased, it is likely that they would have tended toward disagreement between the telerehabilitation and in-person sessions.

Other limitations of the study include (1) the clinicians were rating on only one dimension (come to clinic within 24 hours or continue treatment), however this is the key question of interest; (2) the situation was simulated since the patients were already at the medical center either as outpatients (patients with an ulcer) or inpatients (patients with an amputation); (3) the accuracy of the patients' responses to questions regarding the appearance of the wound was not evaluated, and (4) the raters were seeing the wound for the first and only time, rather than longitudinally, as would be the case in an actual home follow-up program. We believe that being able to evaluate change over time (e.g., weekly telerehabilitation sessions) would provide even better information upon which the clinician could make a wound management decision.

The information yielded from this preliminary study provides evidence that the telerehabilitation system has the potential to present sufficient information to experienced clinicians so that they can make an informed decision regarding wound management. Since the agreement between telerehabilitation ratings and in-person ratings was not perfect and could possibly have been influenced by the use of the same unblinded rater in the two settings, a cautious approach is recommended. If there is any doubt about whether a person should be seen as soon as possible, it is better to err on the side of having him or her come in more often than necessary. Alternatively, more frequent follow-up (e.g., daily sessions) using the telerehabilitation system may be indicated in cases where there is some doubt. Some limitations exist on the patient's ability to use the monitoring equipment at home on their own. Depending on the location of the wound and characteristics of the patient (e.g., physical and cognitive ability), assistance of another person such as a family member may be necessary.

Telerehabilitation may have the potential to promote better/faster healing of wounds and better adherence to

self-care regimens, both of which may reduce the costs of healthcare; however, this potential needs to be evaluated in future studies. Telerehabilitation is likely to be more practical for individuals for whom trips to the clinic are difficult and tiring. Based on the information gained thus far, five new systems (Pentium 4[®] computers with Windows 2000[®]) have been built that are more "user friendly" (e.g., touch screens, flat screen monitors, cell-phones with speaker accessory, redesigned temperature monitors, and improved custom software). The temperature ranges corresponding to the colors in the map are currently being investigated so they can be set to provide the most meaningful information to clinicians.

In the next phase of this series of studies, we will place these updated telerehabilitation systems in the homes of five patients with recent lower-limb amputations or leg or foot ulcers. Each participant will have the system in his or her home for up to 3 months. The purpose will be to assess the ease of use of the system and to identify further modifications that need to be made to make the system as foolproof and reliable as possible. With the information gained from these five participants, additional systems will be designed and tested in future phases of the study.

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