The Role of Virtual Rehabilitation in Total and Unicompartmental Knee Arthroplasty

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Abstract

This study evaluated the use of telerehabilitation during the postoperative period for patients who underwent total knee arthroplasty (TKA) or unicompartmental knee arthroplasty (UKA). Specifically, this study evaluated the following: (1) patient compliance and adherence to the program, (2) time spent performing physical therapy exercises, (3) the usability of the virtual rehabilitation platform, and (4) clinical outcome scores in a selected primary knee arthroplasty cohort. A total of 157 consecutive patients underwent TKA ($n = 18$) or UKA ($n = 139$). These patients used a telerehabilitation system with an instructional avatar, three-dimensional motion measurement and analysis software, and real-time televisit capability designed for arthroplasty patients. Compliance was determined by how many times the patients followed prescribed repetitions of exercises. The total time spent performing exercises for each patient was collected. The usability of the virtual rehabilitation platform (on the patient's end) was evaluated using the system usability scale (SUS) questionnaire. The number of in-person and televisits was recorded for each patient. Patient-reported outcomes were collected through the patient and clinician interfaces and included the Knee Society Score (KSS) for pain and functions, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, and Boston University Activity Measure for Post-Acute Care (AM-PAC) score. Patients spent an average of 29.5 days partaking in the therapy. TKA and UKA patients had a mean of 3.5 and 3.2 outpatient follow-up visits, each, for in-office therapy with a physical therapist, respectively. This figure exceeded the mean number of real-time virtual patient–clinician visits by 0.8 visits per patient in the TKA cohort and by 1 visit per patient in the UKA cohort. Patients spent on average 26.5 minutes per day conducting an average of 13.5 exercises. By the end of rehabilitation, patients had spent an average of 10.8 hours performing exercises, and of all the exercises performed, approximately 21 exercises were uniquely designed. Mean SUS score in the cohort was 93 points, which was interpreted as being

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above the 50th percentile point of the scale. Following therapy, KSS pain and function scores improved markedly and the improvements were measured at 368% for TKA and 350% for UKA (pain) and 27% for UKA and 33% for TKA (function). In addition, WOMAC scores improved by 57% and 66% for UKA and TKA patients while the improvement in AM-PAC scores was at 22% and 24%. This telerehabilitation platform encouraged clinician–patient interaction beyond the hospital setting and offers the advantage of cost savings, convenience, at-home monitoring, and coordination of care, all of which are geared to improve adherence and overall patient satisfaction. Additionally, the biometric data can be used to develop custom physical therapy regimens to assure proper rehabilitation, which is lacking in other telerehabilitation applications that use noninteractive videos that can be watched on mobile devices and tablets.

Virtual medicine, specifically telerehabilitation, has been rapidly expanding as an alternative or a compliment to conventional face-to-face physical therapy (PT) since its development at the turn of the 21st century. Owing to the evolution of wireless communication, motion capture technologies, and advanced animation capabilities, Internet-based solutions have been developed to provide rehabilitation services to patients before, during, and after hospitalization.[1–3] To meet the needs of an aging population, particularly in industrialized countries, there is call for scalable, sustainable, and cost-effective rehabilitation programs to improve adherence, patient-satisfaction, and objective clinical outcomes.

In order for virtual rehabilitation systems to achieve full approval, they must demonstrate feasibility, user-friendliness, high patient and clinician satisfaction, clinical efficacy, and an acceptable overall cost of care; to date, many of these goals have not been supported.[4] Current literature has turned focus toward studying the use of virtual rehabilitation services in patients with various musculoskeletal disorders, specifically on its ability to improve overall care.[5,6] There has been evidence suggesting that virtual rehabilitation offers similar results in terms of functional improvement and pain relief compared with conventional PT in patients with musculoskeletal conditions. Additionally, with increased pressure to mitigate health care costs, there is escalating interest in the potential of these virtual systems to lower costs for both patients and health care providers.[7]

This study proposed that a telerehabilitation platform should be used for rehabilitation purposes during the postoperative period for patients who underwent total knee arthroplasty (TKA) or unicompartmental knee arthroplasty (UKA). Specifically, this study evaluated the following: (1) patient compliance and adherence to the program, (2) time spent performing PT exercises, (3) the usability of the virtual rehabilitation platform, and (4) clinical outcome scores in a selected primary knee arthroplasty cohort.

Methods

Patient Selection

A total of 157 consecutive patients who underwent primary TKA or UKA for advanced knee osteoarthritis, by a single surgeon, and used a telerehabilitation platform from June 2014 to August 2016 were identified. Of those, 83 were women and 74 were men. A total of 18 patients underwent TKA and 139 patients underwent UKA. Patients belonging to the TKA cohort had a mean age of 59 years (range: 47–74 years), and patients belonging to the UKA cohort had a mean age of 63 years (range: 37–85 years).

Virtual Exercise Rehabilitation Assistant

The Virtual Exercise Rehabilitation Assistant, VERA (Reflexion Health, San Diego, CA), was used in this study. For patients who undergo TKA or UKA, this telerehabilitation system provides clinician-prescribed PT protocols to patients at home through an animated image on a display, which demonstrates and coaches patients by using three-dimensional motion tracking cameras to detect real-time movements. Additionally, this system can provide real-time feedback to educate and help patients improve their performance. Visual cameras record videos of the patients performing the PT exercises, which thereby allow clinicians to monitor patient progress. Moreover, patients can report exercise outcomes and concerns, for example, if they have experienced pain during any of the exercises or movements. This is achieved through the clinician portal where clinicians can review patient-reported outcomes, administer functional assessments, and modify exercise plans.

On the clinician's end of the system, a dynamic interface enables clinicians to build and prescribe patient-specific therapy protocols as well as to virtually communicate with patients in real time. The interface allows clinicians to review and monitor patient-reported outcome measures such as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores. In addition, clinicians can assess specific functional tests such as sit-to-stand and timed-up-and-down tests, as well as range-of-motion.

Study End Points

Compliance with the program was determined by how many times the patients followed prescribed repetitions of exercises and adhered to the instructed regimen.

The total time spent performing exercises for each patient was collected and reported by the platform software.

The usability of the virtual rehabilitation platform (on the patient's end) was evaluated using the system usability scale (SUS) questionnaire, which is a standardized 10-item questionnaire that allows for evaluation of a wide variety of products and services. The questionnaires were filled in by the patients, and subsequently the SUS score was calculated. A score of 68 represents the 50th percentile of the SUS scale.

Patient-reported outcomes were collected through the patient and clinician interfaces, where patients filled out the outcome scores, which were uploaded for the clinician to review. The following outcome scores were reported: the Knee Society Score (KSS) for pain and functions, the WOMAC score, and Boston University Activity Measure for Post-Acute Care (AM-PAC) score.

Data Analysis

The data were collected in an Excel spreadsheet (Microsoft Corporation, Redmond, WA). Outcomes were stratified by type of procedure, and data were analyzed using SPSS version 24 (IBM Corporation, Armonk, NY). Descriptive statistics were used to report all of the study variables as means and ranges.

Results

On average, 78% of postoperative TKA and UKA patients adhered to the prescribed rehabilitation regimen. UKA patients had a mean adherence rate of 78% (range: 22–100%) throughout the study, whereas TKA cohort had a 76% adherence rate (range: 46–100%).

Patients spent an average of 29.5 days partaking in the therapy postoperatively. During therapy time, no face-to-face home health visits were conducted; however, TKA and UKA patients had a mean of 3.5 and 3.2 outpatient follow-up visits, each, for in-office therapy with a physical therapist, respectively. This figure exceeded the mean number of real-time virtual patient–clinician visits by 0.8 visits per patient in the TKA cohort and by 1 visit per patient in the UKA cohort. Patients spent on average 26.5 minutes per day (range: 6–63 minutes) conducting an average of 13.5 exercises (range: 6–19 exercises). By the end of rehabilitation, patients had spent an average of 10.8 hours performing exercises (range: 1.5–30.5 exercises), and of all exercises performed, approximately 21 exercises were uniquely designed (range: 10–39 exercises).

Mean SUS score in the cohort was 93 points, which was interpreted as being above the 50th percentile point of the scale, which is 68 points.[8]

Following therapy, KSS pain scores increased markedly, and the increases were measured at 368% for TKA and 350% for UKA patients. KSS function scores showed 27% improvement in UKA patients and 33% in TKA patients. In addition, WOMAC scores improved by 57 and 66% for UKA and TKA patients, respectively, whereas the improvement in AM-PAC scores was at 22 and 24%, respectively (►**Table 1**).

Table 1 Stratified data for TKA and UKA cohorts

	TKA	UKA
Age (mean)	59	63
Days spent in therapy (mean)	32.1	29.2
% Adherence (mean)	76%	78%
Difference in outpatient vs. virtual visits (visits per patient)	0.8	1
% ΔWOMAC	66%	57%
% Δ KSS: A	368%	350%
% Δ KSS: B	33%	27%
% Δ AM-PAC	24%	22%
SUS (mean)	90	94

Abbreviations: AM-PAC, Boston University Activity Measure for Post-Acute Care score; KSS: A, Knee Society Score for pain, KSS: B; Knee Society Score for function; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty; SUS, system usability scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index score.

Discussion

In the field of orthopaedic surgery where there continues to be a growing demand for more cost-effective, quality patient care, there is a great deal of interest surrounding the potential benefits of implementing telerehabilitation technology for postoperative management plans. These benefits may include improved adherence to prescribed rehabilitation regimens, earlier and more successful recoveries, better overall patient satisfaction, greater care coordination, decreased costs to the patient, and enhanced efficacy for providers. Arguably one of the most important benefits for telerehabilitation therapy is the ability to provide more frequent and detailed monitoring of a patient's at-home recovery, allowing clinicians and rehabilitation specialists to intervene earlier and supplement regimens if needed.[9–13] This study was able to confirm some of these benefits in the context of postoperative knee arthroplasty rehabilitation, further supporting the claim for its use.

This study is not without limitations. The small sample size and the retrospective review may render the study underpowered and introduce selection bias. However, compared with previous study, our study remains one of the largest, and all the patients were enrolled consecutively. Additionally, the follow-up time may be relatively short, which may not accurately represent the true final outcomes in the cohort. However, we mainly aimed to demonstrate the feasibility of use and patient compliance with the virtual rehabilitation system. Furthermore, the observed consistency in outcomes in the short term among patients who had two unique arthroplasty procedures may represent a degree of internal validity to the results.

Efforts to evaluate methods for reducing health care overexpenditures and improving standards of care, particularly in respect to aftercare management, such as PT, have been made.[14] The annual expenditure of PT for postoperative TKA rehabilitation has been reported to be US$468 million, and expenditures of up to US$180 million have been reported for postoperative total hip arthroplasty (THA) rehabilitation.[10] These figures are expected to rise with the rates of hip and knee arthroplasty, which are projected to double over the next decade.[15] Following arthroplasty and upon hospital discharge,

patients may have the option to receive home PT sessions, where a physical therapist visits the home to conduct rehabilitation exercises with the patient a certain number of times per week. This option of therapy, albeit also convenient for the patient in terms of travel, is responsible for up to 73% of all PT costs following joint arthroplasty.[10] Tousignant et al[16] reported on 197 TKA patients who were assigned to biweekly PT for 8 weeks through either telerehabilitation or in-home physical therapist, and found that costs for telerehabilitation were significantly less than the costs of home visits by a physical therapist (mean difference: –US$263; 95% confidence interval: –$382 to –$143, ~35% lower). A clear outcome of telerehabilitation is fewer in-home and outpatient rehabilitation health care provider visits, which equates to decreased costs. Virtual monitoring, as is the case when using VERA technology, can replace these costly visits without sacrificing valuable interactions between patients and health care professionals. In addition, cost savings may assist in maximizing the success of bundled care payments.[17] Furthermore, at the present time, two randomized controlled trials are being performed to assess telerehabilitation outcomes in patients who received THA.[18–20]

Patients value personal satisfaction above all else. Often, they relate satisfaction to the quality of care they perceive to have received. During the in-patient postoperative period, especially, patients receive a marked amount of medical attention, and an emphasis is placed on maintaining patient comfort and wellness progression. Studies have been published that examine patient satisfaction following TKA and THA during hospitalization; however, few studies have reported on patient satisfaction profiles after discharge, when interaction with health care professionals is minimal, and patients must care for themselves.[17,21–23] The Centers for Medicare and Medicaid Services (CMS) has begun incorporating patient satisfaction surveys as an assessment tool for hospital performance, and results from this survey could potentially affect hospital reimbursements.[24,25] Telerehabilitation has been shown to improve patient satisfaction, and this can be attributed to its offering of remote access and feature of convenient patient rehabilitation monitoring. Benefits of using a virtual rehabilitation model for postarthroplasty PT has been reported by Pastora-Bernal et al,[7] and in the study, strong evidence supported the use of virtual systems, video conferencing, and phone calls to enhance patient satisfaction.

Patient satisfaction can be correlated to the telerehabilitation system's usability. The SUS used in this study has proven to be an effective tool for assessing a product's user-friendliness. The scale is a 10-item questionnaire that offers responses ranging from 1 to 5, with 1 being "Strongly Disagree" and 5 being "Strongly Agree." This scale is converted to a 0 to 100 score, and a score of 68 has been determined to signify average usability. To support the effectiveness of this scale, a 2009 study reviewed nearly 1,000 SUS surveys, adding to it a 7-point adjective Likert scale, which consisted of a single question requesting the user to summarize a product's overall user-friendliness; adjective responses included Worst imaginable, Awful, Poor, OK, Good, Excellent, and Best Imaginable. The study found the Likert scale to correlate well with SUS scores ($r = 0.822$).[26] Although no study has used the SUS to assess the telerehabilitation system, one study that evaluated a different telerehabilitation system found comparable usability outcomes when using other scoring systems, including the IBM After-Scenario Questionnaire, Post-Study System Usability Questionnaire, and the Telehealth Usability Questionnaire.[27]

To obtain maximal recovery, adherence to a postoperative rehabilitation regimen is of utmost importance. This study discovered a relatively high adherence to telerehabilitation compared with reports from other studies examining adherence rates with other methods of rehabilitation delivery. This finding has also been supported by two other recent studies.[28,29] Groth and Wulf,[30] in a study analyzing compliance with outpatient in-office rehabilitation for hand therapy, reported poor overall adherence, with only 50% of patients completing their exercise programs. On the other hand, compliance with home exercise programs has had conflicting reports in the literature, ranging from 35 to 70%.[31–33] A qualitative study published in 2016 analyzed the main factors for nonadherence to PT regimens, claiming that treatment costs, poor patient-provider relations, lack of time, and a desire to return to normal functioning with false anticipation of a brief recovery all contributed to poor compliance. By design, telerehabilitation addresses many of these issues, particularly cost and timing concerns, but also increases patient satisfaction, which may also improve compliance.

Of great importance, patients using telerehabilitation technology should receive comparable outcomes compared with those receiving rehabilitation in an outpatient office setting. In 2015, Moffet et al[34] conducted a study of 205 patients who underwent TKA, comparing outcomes between telerehabilitation and home PT (matched cohort), and it was determined that no significant difference existed in the WOMAC scores pertaining to pain (84.4 vs. 82.6; $p > 0.05$), stiffness (72.1 vs. 71.9; $p > 0.05$), or function (86 vs. 83.9; $p > 0.05$). Total WOMAC scores between the groups also failed to demonstrate a significant difference (84.5 vs. 82.6; $p > 0.05$). Moffet et al[34] also compared Knee Osteoarthritis Outcome Index scores between the groups, failing to find a significant difference in symptom, pain, activity of daily living, sports/recreational, quality of life, range of motion, or strength scores. Piqueras et al[35] conducted a randomized control trial on 133 TKA patients, assigning them to either telerehabilitation or conventional in-office PT for 2 weeks, and reported no significant difference between groups in terms of active knee flexion, hamstring strength, or visual analog scale scores for pain. Upon completion of the rehabilitation program, patients belonging to the telerehabilitation group, however, demonstrated a significantly greater increase in quadriceps muscle strength, which remained significant at a 3-month follow-up visit (8.48 vs. 5.89 kg; $p = 0.018$).

On the other hand, active knee extension was significantly better immediately following conventional in-office PT than following telerehabilitation, but this difference was not appreciated at 3 months (0.8 vs. 1.3; $p = 0.478$). A similarly designed, yet smaller, randomized control trial by Russel et al[36] evaluated 65 TKA patients for 6 weeks and

found significantly improved stiffness scores (3.30 vs. 1.84; $p = 0.04$) and patient-specific functional scale scores (5.05 vs. 3.97; $p = 0.04$) on the WOMAC questionnaire in favor of telerehabilitation. All other WOMAC categories failed to demonstrate a significant difference in this study. Also, in 2011, Tousignant et al[20] followed 41 patients for a total of four months, having had them undergo 8 weeks of rehabilitation therapy following TKA. In contrast to other studies, the conventional in-office PT group ($n = 20$) was determined to have significantly better WOMAC functional scores ($p = 0.047$) following completion of PT compared with those who received telerehabilitation ($n = 21$). The failure of this study to achieve similar results to other studies may be a result of it being underpowered.

Conclusion

This study adds to the growing evidence base in support of the efficacy of virtual rehabilitation. The VERA platform used in this study both enables on-demand rehabilitation sessions for the patients, while also encouraging clinician–patient interaction beyond the hospital setting, and offers the advantage of cost savings, convenience, at-home monitoring, and coordination of care, all of which are geared to improve adherence and overall patient satisfaction. Unique to this platform, biometric data can be used to develop custom PT regimens to assure proper rehabilitation, which is lacking in other telerehabilitation applications that use noninteractive videos that can be watched on mobile devices and tablets. With growing acceptance of virtual rehabilitation technologies, further study is needed to evaluate long-term outcomes.

Conflict of Interest

M.A.M: AAOS: Board or committee member; Cymedica: Paid consultant; DJ Orthopaedics: Paid consultant; Research support; Johnson & Johnson: Paid consultant; Research support; Journal of Arthroplasty: Editorial or governing board; Journal of Knee Surgery: Editorial or governing board; Microport: IP royalties; National Institutes of Health (NIAMS & NICHD): Research support; Ongoing Care Solutions: Paid consultant; Research support; Orthopedics: Editorial or governing board; Orthosensor: Paid consultant; Research support; Pacira: Paid consultant; Peerwell: Stock or stock Options; Performance Dynamics Inc.: Paid consultant; Reflexion: Paid consultant; Sage: Paid consultant; Stryker: IP royalties; Paid consultant; Research support; Surgical Techniques International: Editorial or governing board; TissueGene: Paid consultant; Research support. M.C.: DJ Orthopaedics: Paid consultant; Sage Products: Paid consultant; Stryker: Paid consultant; Astym: Paid consultant; Reflexion: Paid consultant; Cymedica: Paid consultant. A.B.: Cymedica Orthopedics: Paid consultant; DJ Orthopaedics: Paid consultant; Guardian Inc: IP royalties; Journal of Society of Indian Physiotherapists: Editorial or governing board; On Going Care: Paid consultant; Reflexion: Paid consultant. M.C.K.: Zimmer: Paid consultant; Paid presenter or speaker.

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