Arthroplasty Today 27 (2024) 101415

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Impact of a Remote Patient Monitoring Platform on Outcomes Following a Total Hip or Knee Arthroplasty

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ARTICLE INFO

Article history:
Received 31 October 2023
Accepted 28 April 2024

Keywords:
Perioperative education
Length of stay
Emergency department
Hospital readmission
Total Knee Arthoplasty (TKA)
Total Hip Arthroplasty (THA)

ABSTRACT

Background: The coronavirus pandemic highlighted the need for remote patient monitoring to deliver and provide access to patient care and education. A mobile-based app providing interactive tools for patient education and monitoring was piloted at Thunder Bay Regional Health Sciences Centre (TBRHSC) in November 2020. We aimed to examine the platform's impact on postoperative length of stay, hospital readmissions, and emergency department (ED) visits 60 days postsurgery in total hip and knee arthroplasty patients in Northwestern Ontario.

Methods: Data were assessed from patients undergoing primary total hip or knee arthroplasties at TBRHSC from March 1, 2020, to February 28, 2022. Patients were divided into 2 cohorts based on enrollment with the mobile-based app (SeamlessMD). Statistical differences in outcomes were determined using Mann-Whitney or χ^2 tests. An odds ratio was calculated for ED visits.

Results: Patients enrolled in the mobile-based app had statistically lower length of stay ($U = 7779.0$, $P < .001$) and fewer ED visits ($\chi^2_{(1,212)} = 5.570$, $P = .018$) than patients not enrolled in the program. Patients not enrolled had 2.31 times greater odds of visiting the ED postsurgery (odds ratio = 0.432, 95% confidence interval = 0.213-0.877, $P = .022$). There were no statistical differences found in readmission rates.

Conclusions: The implementation of the mobile-based app at TBRHSC showed its potential value as a tool to reduce costs in the healthcare system and improve patient outcomes. Consequentially, more formal studies are required to elucidate the magnitude of this effect.

Introduction

Length of stay (LOS) for surgical procedures has reduced dramatically over the last decade [1]. This has been propelled by a progressive decrease in in-patient bed availability across all surgical specialties in Canada [2]. In orthopaedic surgery, there has been a widely supported move toward outpatient care for total hip arthroplasty (THA) and total knee arthroplasty (TKA). This has decreased the cost per joint replacement but has presented significant challenges in managing patient education, expectations, safety, and satisfaction [3–5]. Historically, the majority of patient education was conducted in an in-person setting prior to surgery and during the hospital stay, with patients assuming a passive role in their surgery preparation and recovery [6]. As LOS has shortened with procedures being conducted in the outpatient setting, the specialty has seen a significant increase in the number of patients presenting to the emergency room for postoperative issues [7,8].

With the coronavirus (COVID-19) pandemic, the need to deliver and provide access to patient education remotely was recognized. As such, there has been an increased integration of remote healthcare tools for healthcare providers to use in their everyday practice. Healthcare systems across the world that utilized digital

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https://doi.org/10.1016/j.artd.2024.101415

healthcare technologies during the pandemic are recognizing the potential benefits of utilizing these tools in postpandemic healthcare [7]. Various forms of digital healthcare have emerged as patient engagement platforms such as patient portals, mobile health applications, chatbots, and wearable devices with the aim of improving the delivery of healthcare remotely [9]. In the surgical context, these platforms are used perioperatively for remote patient monitoring, patient education, and provide a direct line of communication between the patient and the healthcare provider [7]. In Northwestern Ontario, a significant portion of healthcare has historically been delivered virtually due to the remote/rural setting requiring many patients to travel to access tertiary care; remote patient monitoring perioperatively is expected to be a significant value-add to current care trends.

SeamlessMD is a patient engagement platform that functions as a mobile health application. This mobile-based app enables hospitals and health systems to engage, monitor, and stay connected with patients throughout their perioperative experience. Since the introduction of the platform in the procedural healthcare setting, SeamlessMD has been shown to reduce readmissions by approximately 72%, reduce LOS by approximately 2 days, and reduce emergency department (ED) visits by approximately 47% [10]. Thunder Bay Regional Health Sciences Centre (TBRHSC) began using the mobile-based platform in November 2020. Preliminary findings from case studies at TBRHSC have demonstrated a reduction in LOS, 30-day readmission, and 30-day ED visits postoperatively after the introduction of the platform [11,12]. Due to the large proportion of patients using the program when undergoing total hip and knee arthroplasties, an analysis of the impact of the mobile-based app at TBRHSC is warranted. Therefore, the purpose of this study is to examine the impact of the virtual platform on outcome measures such as postoperative LOS, readmission, and ED visits following total hip and knee arthroplasty. We hypothesize that due to the effectiveness of the program in other locations and the propensity for virtual care in Northwestern Ontario, participants enrolled in the SeamlessMD program at the time of their total hip or knee arthroplasties will have lower LOS and lower 30-day ED visits and readmission rates.

Material and methods

The TBRHSC Research Ethics Board reviewed the study proposal and provided waiver of review due to the quality improvement approach of the study. Data were retrospectively assessed from all patients undergoing a primary THA or TKA at TBRHSC from March 1, 2020, to February 28, 2022. Surgeries were conducted by one of 5 orthopaedic surgeons. Patients were divided into 2 cohorts: cohort 1 were patients enrolled in the program, and cohort 2 were patients not enrolled in the program. Inclusion/exclusion criteria (Table 1) for participants were determined after a review of mean age and body mass index (BMI) of patients undergoing primary THA/TKA procedures from 2018-2021. This ensured similar populations were compared between cohorts and limited the confounding impact of age and BMI. Populations were also statistically compared on all demographic variables measured using both χ^2 (categorical data) and Mann-Whitney tests (quantitative data). As the mobile-based app was not implemented at TBRHSC until November 2020, cohort 1 participants were only included from January 1, 2021, to February 28, 2022.

Table 1
Inclusion/exclusion criteria.

Inclusion criteria:
• Patient has undergone a primary THA or primary TKA at TBRHSC between March 1, 2020, and February 28, 2022 (inclusive)
• Age between 56 and 75 at the time of surgery (inclusive)
• BMI between 29.84 and 37.84 (inclusive)
Exclusion criteria:
• Underwent a partial THA or TKA
• Underwent a bilateral THA or TKA
• Underwent a revision THA or TKA

The data were collected using patient medical records and included demographic information (age, sex, and BMI), type of procedure (THA or TKA), LOS postsurgery, hospital readmissions within 60 days postsurgery, and ED visits within 60 days postsurgery.

Statistical differences in LOS were measured using Mann-Whitney tests due to non-normal distribution of data. Differences in hospital readmissions and ED visits were determined by χ^2 tests as the data were categorical in nature. Calculations of odds ratios were conducted for ED visits. Statistical tests were conducted using JASP software (University of Amsterdam, Amsterdam, Netherlands).

Demographics

A patient list from hospital records was developed, of which 212 patients were determined to be eligible for inclusion. The mean age of patients was 66.13, with a mean BMI of 34.64. The majority of patients were women (57%). Demographic characteristics can be found in Table 2. There were no statistical differences between cohorts in any demographic factor measured. Age and BMI were compared using Mann-Whitney tests, while all other factors were compared using χ^2 tests. Unknown scores were excluded when conducting statistical comparisons for American Society of Anaesthesiologists scores.

Results

Patients enrolled in the mobile-based app program had a lower mean LOS (1.85 ± 1.01) compared to patients not enrolled in the program (2.43 ± 1.12) (Table 3). Prior to the comparison of LOS, parametric assumptions were tested using the Brown-Forsythe homogeneity of variance test and the Shapiro-Wilk normality test. Data were shown to be non-normal but had homogeneity of variance. A Mann-Whitney test showed that LOS was statistically significantly lower in patients enrolled in the mobile-based app than patients not enrolled in the program ($U = 7779.0$, $P < .001$).

Patients enrolled in the mobile-based app had a lower readmission rate postsurgery (3.48%) compared to patients not enrolled in the mobile-based app (8.25%) (Table 3). All mobile-based app enrolled patients who were readmitted were readmitted a single time. Of the nonenrolled patients who were readmitted, 5 (62.5%) were admitted once and 3 (37.5%) were admitted twice (Table 4). As the data were categorical and met all assumptions, as per McHugh, χ^2 testing was conducted to compare readmissions [13]. This showed that there were no statistical differences in readmissions between the 2 cohorts ($\chi^2_{(1,212)} = 2.241$, $P = .134$).

Approximately 13.04% of patients enrolled in the mobile-based app had ED visits after their surgery, compared to 25.77% of patients not enrolled in the mobile-based app (Table 3). Of the patients enrolled who visited the ED, 12 (80%) visited once and 3 (20%) visited twice. Of the nonenrolled patients who visited the ED, 18 (72%) visited once, 3 (12%) visited twice, 2 (8%) visited 3 times, 1 (4%) visited 5 times, and 1 (4%) visited 7 times (Table 5). As the data were categorical and met all assumptions as per McHugh, χ^2 testing was conducted to compare readmissions [13]. This showed that there were significantly fewer ED visits in the mobile-based app-enrolled patients compared to those who were not enrolled in the program ($\chi^2_{(1,212)} = 5.570$, $P = .018$). Patients not enrolled had 2.31

Table 2
Demographic characteristics of patients undergoing THA or TKA.

Characteristic	Cohort 1: Enrolled in the mobile-based app (n = 115)	Cohort 2: Not enrolled in the mobile-based app (n = 97)	Total	*P* value
Procedure type				.496
THA	41	39	80	
TKA	74	58	132	
Sex				.463
Male	52	39	91	
Female	63	58	121	
Age				.609
Mean (±SD)	66.12 (±4.94)	66.47 (±5.12)	66.13 (±5.09)	
BMI				.647
Mean (±SD)	33.50 (±2.30)	33.63 (±2.27)	34.64 (±2.24)	
Smoking status				.172
Nonsmoker	75	58	133	
Smoker	14	21	35	
Former	26	18	44	
American Society of Anaesthesiologists score				.311
1	4	0	4	
2	56	51	107	
3	49	40	89	
4	49	3	52	
Unknown	2	3	5	

times greater odds of visiting the ED postsurgery (odds ratio = 0.432, 95% confidence interval = 0.213-0.877, $P = .022$).

Discussion

TBRHSC piloted SeamlessMD, a mobile-based app program focusing on remote patient monitoring and surgical transitions of care in November 2020. The program aims to aid patients with their preoperative needs and help guide patients postoperatively based on patient-reported experience. Along with this, its embedded smart algorithms provide patients with appropriate recommendations and access to a nurse practitioner. Preliminary outcomes of implementing the mobile-based app at TBRHSC showed a decrease in LOS, readmissions, and ED visits. This study aimed to provide further evidence for the impact SeamlessMD has had at TBRHSC, specifically its impact as a perioperative tool for THA and TKA patients. TKA and THA are among the top 3 most performed inpatient surgeries in Canadian hospitals, and thus cost savings could have significant effects on the healthcare system [14].

LOS after THA or TKA is a significant portion of the total cost of the procedure [14,15] . Historically, LOS after THA and TKA was reported as high as 3 weeks [13]. In 2020-2021, acute care LOS has dropped to a mean of 2.2 days and 2.3 days in Canadian THA and TKA procedures, respectively [14]. Importantly, decreases in LOS have not been associated with any increase in adverse events postoperatively and patients show similar outcomes at the 1-year mark in comparison to those with longer hospital stays [15,16]. Similar to these studies, we saw that the introduction of a mobile-based app as a perioperative remote monitoring tool reduced THA/TKA LOS postsurgery by approximately 34% ($P < .001$). SeamlessMD allows for easily accessible preoperative education. Access to this education may be one factor contributing to the observed decrease in LOS, as preoperative education has been shown to reduce LOS by empowering patients to have a more active role in their surgery and recovery [5,17]. Due to restrictions from COVID-19, THA and TKA rates have decreased by up to 26.4% in Canada [14]. Using a mobile-based app as a tool to help decrease LOS could allow for increased bed availability, resulting in more opportunities for patients to receive these surgeries and reducing surgical backlog.

Literature on the effect of remote monitoring and reducing LOS has shown mixed effects on readmission rates. Some studies show that an increase in monitoring and management strategies like phone applications decreases the number of readmissions after several types of surgery [18,19]. However, others show that monitoring or reduction in LOS do not affect readmission rates [8,20]. This includes a study by Smithson et al. that used SeamlessMD as a patient engagement tool in ileostomy patients (who, generally, have a high readmission rate) [10]. In our study, we found no statistically significant impact of the mobile-based app on readmission rates, but the mobile-based app-enrolled patients were readmitted 60% less than those not enrolled in the program. Further study may need to be conducted on a larger population to completely rule out the effect of the mobile-based app on readmissions.

In Ontario, from 2003-2016, LOS decreased with time while ED visits within 30 days of surgery increased, though the number of

Table 3
Evaluation of the mobile-based app on LOS, 60-day readmission, and 60-day postoperative ED visits in THA and TKA patients at TBRHSC.

Parameter measured	Cohort 1: Enrolled in the mobile-based app (n = 115)	Cohort 2: Not enrolled in the mobile-based app (n = 97)	*P* value
Mean length of stay (days ± SD)	1.85 (±1.01)	2.43 (±1.12)	<.001[a]
Number of patients readmitted (% of cohort)	4 (3.48%)	8 (8.25%)	.134
Number of patients with ED visits (% of cohort)	15 (13.04%)	25 (25.77%)	.018[a]

[a] Statistically significant results.

Table 4
Hospital readmissions within 60 days post-THA/TKA in patients enrolled in the mobile-based app and those not enrolled.

	Cohort 1: Enrolled in the mobile-based app (n = 115)	Cohort 2: Not enrolled in the mobile-based app (n = 97)
Number of readmissions		
1	4 (100%)	5 (62.5%)
2	0 (0%)	3 (37.5%)
Total	4 (100%)	8 (100%)

Table 5
ED visits within 60 days post-THA/TKA in patients enrolled in the mobile-based app and those not enrolled.

	Cohort 1: Enrolled in the mobile-based app (n = 115)	Cohort 2: Not enrolled in the mobile-based app (n = 97)
Number of ED visits		
1	12 (80%)	18 (72%)
2	3 (20%)	3 (12%)
3	0 (0%)	2 (8%)
5	0 (0%)	1 (4%)
7	0 (0%)	1 (4%)
Total	15 (100%)	25 (100%)

readmissions within 30 days remained consistent [8]. As ED visits are more costly than virtual visits and the majority of patients who presented to the ED were not admitted, mitigating this increasing number of ED visits could be a source of cost savings for the healthcare system [8,21]. Of the patients included in the study, 12 (5.67%) were readmitted to the hospital, and 40 (18.87%) presented to the ED; these numbers are similar to national averages of 30-day postoperative THA/TKA readmissions and ED visits [22,23]. When comparing patients enrolled in the mobile-based app and those not enrolled, the mobile-based app-enrolled patients had lower readmission and ED visit rates; however, only ED visits showed statistically significant differences ($P = .018$). Thus, through the use of the mobile-based app, ED visits may have been mitigated through engagement and monitoring from nurse practitioners.

Although we did show that the mobile-based app had a significant effect on decreasing LOS and ED visits, there were several limitations to this study. Firstly, the data accessed were those of retrospective cohorts. A formal research study with a more powerful design, such as a prospective cohort or randomized controlled trial, could further elucidate the effect of this mobile-based app on outcome variables. This would also help increase generalizability of the study, as this project was started as quality improvement initiative, and thus some information was unable to be accessed. This included potential confounders such as admission to rehabilitation hospitals, smoking status, and other concurrent comorbidities. Secondly, though the populations were matched based on the demographics and were not statistically different from one another, the vast majority of patients undergoing either procedure were enrolled in the mobile-based app upon its introduction at TBRHSC. There were only 78 eligible patients who underwent THAs/TKAs who were not enrolled from January 1, 2021, to February 28, 2022. To have a more accurate representation of patient experience and outcomes at TBRHSC for nonmobile-based app enrolled patients, patients from March 1, 2020, to December 31, 2020, were also included. As such, the populations may differ slightly due to differences in response (both from healthcare and the personal patient experience) at the start of the pandemic compared to 2021 and 2022. Finally, due to COVID-19, there were restrictions on the number of elective surgeries that could be performed. This, along with the program only being implemented for approximately 1 year at the time of the analysis, may have resulted in a nonrepresentative sample size. Larger patient populations could further elucidate differences in LOS, readmissions, and ED visits and provide further evidence for the effectiveness of the mobile-based app at TBRHSC. Interestingly, compared to national averages of approximately 9%-11%, those not enrolled in the mobile-based app had a higher ED presentation rate. This deviation from the norm could result in the apparent success of the mobile-based app. A more robust study that is able to identify the specific causes of ED visits and their relevancy could help further tease out the relationship between mobile-based app and its effect on ED visits. Due to the success of the platform in decreasing the LOS and ED visits in THA/TKA patients, future studies could look at other in-demand/common surgeries in orthopaedics as well as other services such as partial arthroplasties and colonoscopies.

Conclusions

A mobile-based app that provided patient education and monitoring tools was piloted at TBRHSC in November 2020 with the aim to examine it's impact on postoperative LOS, hospital readmissions, and ED visits 60 days postoperatively in patients undergoing THA and TKA. Using a retrospective data review, patient data were assessed from November 2020 to February 2022. Here, we showed that patients enrolled in the mobile-based app had statistically lower LOS and fewer ED visits than those patients not enrolled in the app. Although this analysis was limited in its scope, it provides important information about the impact of SeamlessMD as a remote patient monitoring tool, and its continued implementation could result in better patient outcomes and reduction of healthcare costs associated with elective surgeries.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101415.

CRediT authorship contribution statement

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