A Novel, Automated Text-Messaging System Is Effective in Patients Undergoing Total Joint Arthroplasty

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Background: Digital patient engagement platforms are designed to improve the efficacy of the perioperative surgical home, but the currently available solutions have shown low patient and provider adoption. The purpose of this study was to evaluate the effectiveness of a text-messaging (Short Message Service [SMS]) bot with respect to patient engagement following joint replacement procedures in a randomized clinical trial.

Methods: One hundred and fifty-nine patients (83 patients in the control group and 76 patients in the intervention group) were enrolled in a randomized controlled trial comparing the effectiveness of an SMS bot (intervention group) with the traditional perioperative education process (control group) in patients undergoing primary total knee or hip arthroplasty. There were no significant differences in the demographic characteristics between the 2 groups. The primary outcome of time participating in home-based exercises and the secondary outcomes of knee range of motion, the use of narcotics, visual analog scale (VAS) mood score, telephone calls to the office, patient satisfaction, and visits to the emergency department were measured and were compared between the 2 groups. Continuous outcomes were analyzed using linear regression, and categorical outcomes were analyzed using the Pearson chi-square test.

Results: Patients in the intervention group exercised for 8.6 minutes more per day: a mean time (and standard deviation) of 46.4 ± 17.4 minutes compared with 37.7 ± 16.3 minutes for the control group ($p < 0.001$). The intervention group had an improved mood (mean VAS, 7.5 ± 1.8 points compared with 6.5 ± 1.7 points for the control group; $p < 0.001$), stopped their narcotic medications 10 days sooner (mean time, 22.5 ± 13.4 days compared with 32.4 ± 11.8 days for the control group; $p < 0.001$), placed fewer telephone calls to the surgeon's office (mean calls, 0.6 ± 0.8 compared with 2.6 ± 3.4 for the control group; $p < 0.001$), and had greater knee range of motion 3 weeks after the surgical procedure (mean flexion, 101.2° ± 11.2° compared with 93.8° ± 14.5° for the control group; $p = 0.008$), but had an equal range of motion at 6 weeks. There was a trend toward fewer visits to the emergency department in the intervention group, but this comparison lacked statistical power.

Conclusions: An SMS bot can improve clinical outcomes and increase patient engagement in the early postoperative period in patients undergoing hip or knee arthroplasty.

Level of Evidence: Therapeutic Level I. See Instructions for Authors for a complete description of levels of evidence.

In an era of value-based reimbursement and high-volume surgical procedures, the patient experience is becoming increasingly important. Despite publicized efforts to place a greater emphasis on patient-centered care, patients often report poor access to their physician, lack of effective perioperative education, and frustration as their care is commoditized[1-3].

A text-messaging (Short Message Service [SMS]) bot has the potential to help to fill some of these voids. Bots are computer programs that are inherently automated to simulate human-like tasks. Although physicians may wish that they could contact each of their patients daily, it would be an impossible undertaking for most. An SMS bot could make daily contact

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possible by automating it, potentially improving patient education and engagement before and after the surgical procedure. Standard SMS has been previously reported to be an effective means for delivering timely information, increasing patient compliance and outcomes (medication adherence, decrease in surgical infections with antiseptic showers), and reaching a socioeconomically diverse patient population[4]. Further benefits may be seen with an SMS bot due to its automated capabilities.

The purpose of this study was to evaluate the effectiveness of an automated and unidirectional SMS bot in patients undergoing primary total hip or knee arthroplasty. We hypothesized that patients randomized to a physician-specific SMS bot would spend more time completing their home-based therapy exercises, use less narcotic pain medication, have higher visual analog scale (VAS) mood scores, make fewer calls to the office, and have higher postoperative satisfaction scores compared with patients who received the traditional perioperative education.

Materials and Methods

Patient Selection, Enrollment, and Randomization

After institutional review board approval, clinical trial registration with ClinicalTrials.gov (NCT03388502), and an a priori power analysis, patients provided consent to participate in the study. Inclusion criteria consisted of patients who were ≥18 years of age, were scheduled for primary total hip arthroplasty or total knee arthroplasty, had smartphone capability, and had proficiency in English. The control group consisted of patients who received the traditional perioperative education, which included a preoperative clinic appointment and a supply of perioperative instructions. The patients randomized to the intervention group received the same patient education as the control group, but were additionally enrolled into their surgeon's SMS bot (StreaMD), which was hosted on a Health Insurance Portability and Accountability Act (HIPAA)-compliant server, and received scheduled text and video messages. The content of the text and video messages reinforced the perioperative instructions and were delivered to patients at the appropriate time based on their recovery progress.

Patients were randomized into 1 of the 2 groups in a 1:1 ratio using a block randomization scheme to ensure equal distribution into the 2 groups. Specifically, a random number generator was used to select from block sizes of 4, 6, or 8. If a block size of 4 was selected, for example, the next 4 patients would be randomized such that 2 of them were placed in the text group and 2 of them were placed in the no-text group. Once that block of 4 was completed, another block size was randomly selected, and patients from that block were again equally and randomly split between groups. This scheme continued until the target sample size had been reached[5].

Intervention

The automated text messages included recovery instructions paired with encouraging and empathetic statements, personalized video messages from their surgeon, and short instructional therapy videos (Fig. 1). The bot did not encourage or accept inbound text responses from the enrolled patients. However, patients did have the opportunity to respond to preconfigured keywords (for example, pain or shower) and receive additional automated, informational responses. Inbound patient responses were not monitored by the surgeon's clinical staff.

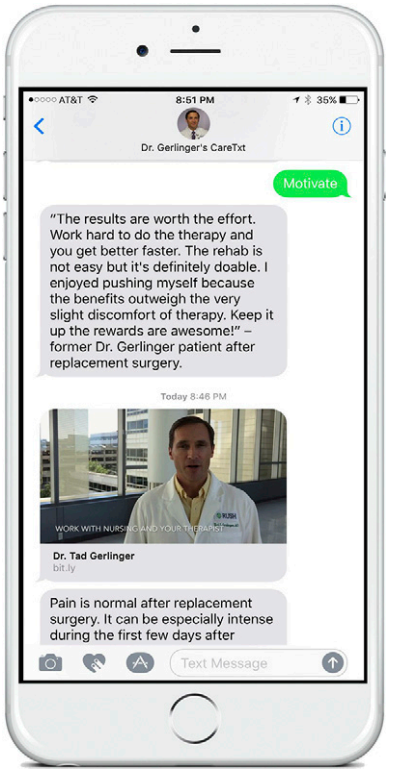

Fig. 1

Example of the senior author's SMS messages and videos delivered to a patient's phone.

Data Collection

Demographic information collected on all subjects included age, sex, body mass index (BMI), Charlson Comorbidity Index, smoking status, and diagnosis of diabetes mellitus.

On the first day after the surgical procedure (postoperative day 1), patients were provided a calendar diary to record the amount of time that they spent on their home-based exercises (outside of formal physical therapy sessions), their VAS mood score, and whether they were using narcotics. Stretching, strengthening, and other rehabilitation-specific exercises counted toward their exercises, and walking was excluded. VAS mood scores were collected from patients on the standard 10-point validated scale. If a patient circled 2 adjacent numbers, an average of the 2 numbers was assigned for that day. Medications designated as narcotics included hydrocodone, oxycodone, codeine, morphine, or tramadol. Patients were instructed to record their responses during the same 2-hour window each day. A member from the research team called each patient in both groups 3 days after the surgical procedure (postoperative day 3), 2 weeks after the surgical procedure (postoperative day 14), and between 4 and 5 weeks

after the surgical procedure (postoperative days 29 to 35) to remind them to complete their diaries.

At the preoperative, 3-week, and 6-week postoperative clinic appointments, range of motion was assessed by the treating clinician and was recorded for all patients who underwent a total knee arthroplasty. The examiner was blinded as to treatment. Patient calls to the office were also recorded by the medical staff. A medical chart audit was completed to record visits to an emergency department or urgent care clinic. After their 6-week postoperative visit, patients completed a final survey assessing the clarity of the postoperative instructions, their perception of the motivation they received from their treatment team, and their overall satisfaction with their care.

Sample Size Calculation

An a priori sample size calculation was completed as a part of our institutional review board submission. Time spent on home-based physical therapy was selected as the primary outcome. A sample of 18 patients who underwent knee or hip arthroplasty was polled in the clinic in the early postoperative period, and they were asked how many minutes they spent doing their home therapy exercises per day. The mean response (and standard deviation) was 27.4 ± 13.9 minutes. Through clinical impression, we determined that an increase in 8 minutes per day of home-based therapy would be clinically important. Using these data and a significance criterion of $p < 0.05$, 128 patients (64 per group) would be required to have a 90% chance of detecting a difference, if one truly existed. To account for patient crossover and loss to follow-up, an additional 20% (26 patients) was added; hence, the final sample size required was 154 (77 per group).

Patient Population

Two hundred and thirty-six patients were assessed for eligibility. Seventy-seven patients were excluded. Forty-nine of the excluded patients enrolled into their surgeon's bot but were not included as part of the study cohort. Therefore, 159 patients consented to participate and were eligible for randomization during the enrollment period, which extended from November 2016 to July

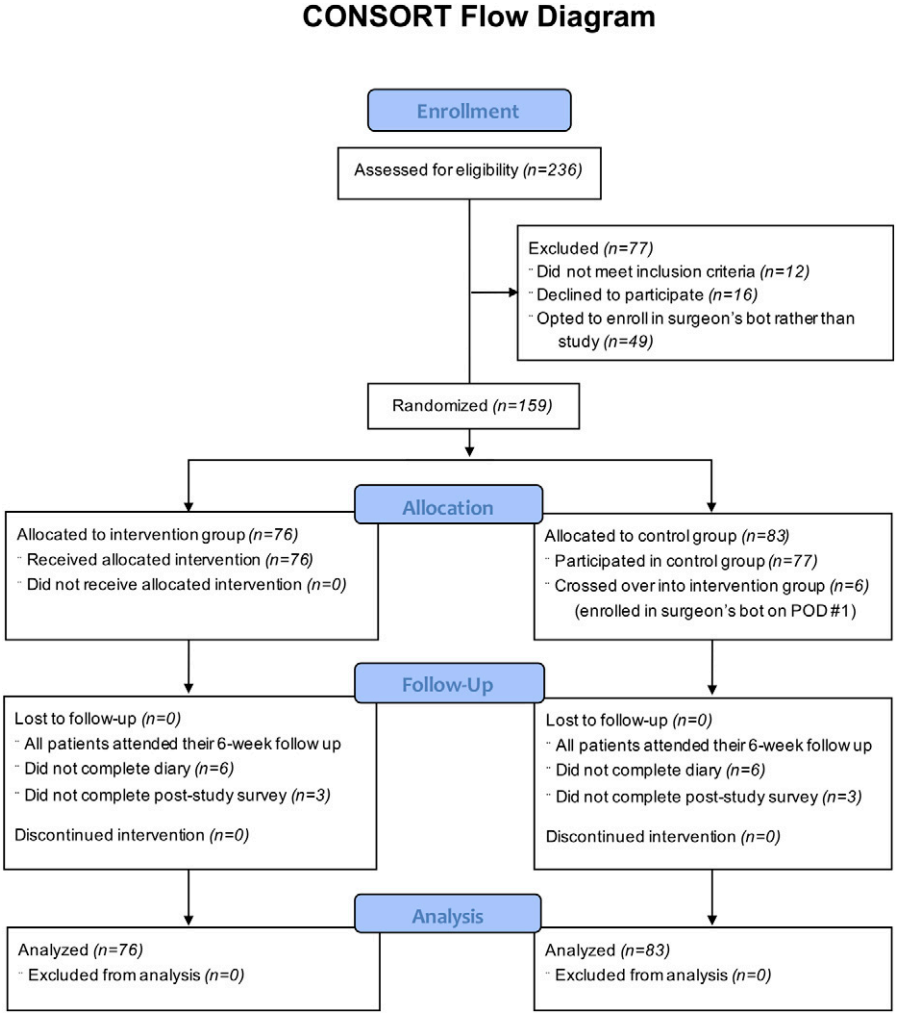

Fig. 2

Consolidated Standards of Reporting Trials (CONSORT) flow diagram demonstrating the phases of parallel randomization. POD = postoperative day.

2017. Seventy-six patients were allocated to the intervention group. Eighty-three patients were allocated to the control group. Six patients crossed over from the control group to the intervention group on the first day after the surgical procedure. Based on our intention-to-treat analysis, the data from the patients who crossed over were included in the control group analysis based on their initial treatment assignment. Of the 159 patients, completed diaries were obtained from 147 patients (93%), and 153 patients (96%) completed the post-study survey (Fig. 2). There were no significant differences ($p > 0.05$ for each) in the demographic characteristics between the 2 intention-to-treat groups (Table I).

Statistical Analysis

Statistical analyses were conducted using Stata version 13.1 (StataCorp). Patients were categorized into intervention and control groups in an intention-to-treat fashion. Continuous outcomes were analyzed using linear regression, and categorical outcomes were analyzed using the Pearson chi-square test. First, the intervention and control groups were compared in terms of baseline characteristics (age, sex, BMI, Charlson Comorbidity Index, smoking status, diabetes, and procedure type) using the Pearson chi-square test for categorical outcomes and Student t test for continuous outcomes. Second, the 2 groups were compared in terms of 6-week outcomes (time exercising per day, mood, days taking narcotics, extension motion, flexion motion, and total calls to the office) using linear regression. Finally, the 2 groups were compared in terms of survey responses (percentage stating that they "strongly agree" with each of 5 different statements) using the Pearson chi-square test. Analyses of time spent exercising per day and mood were corrected for repeated measures on the same patient (i.e., clustering). The level of significance was set at $p < 0.05$. Small proportions of data were missing for each of the outcome variables. In cases with missing data, the data points were simply excluded from each of the specific analyses. Sensitivity analyses were performed for the primary outcome question in which we assumed that all missing data on the primary outcome had a poor score (bottom 10th percentile), and, alternatively, that all missing data on the primary outcome had an excellent score (top 10th percentile).

Results

The automated and unidirectional SMS bot delivered 7,068 messages to 76 patients in the intervention group (93 messages delivered to each patient over a 6-week period). The patients in the intervention group exercised for 8.6 minutes more per day: a mean time (and standard deviation) of 46.4 ± 17.4 minutes compared with 37.7 ± 16.3 minutes for the control group ($p < 0.001$). The patients in the intervention group reported higher mean VAS mood scores throughout the 6 weeks after the surgical procedure at 7.5 ± 1.8 points compared with 6.5 ± 1.7 points for the control group ($p < 0.001$). Patients in the intervention group stopped taking narcotic medications a mean of 10 days earlier (22.5 ± 13.4 days) than patients in the control group (32.4 ± 11.8 days) ($p < 0.001$).

TABLE I Baseline Patient Demographic and Clinical Characteristics for the Control and Intervention Groups

	Control Group (N = 83)	Intervention Group (N = 76)	P Value
Age* *(yr)*	59.5 ± 8.0	61.0 ± 8.2	0.242
Sex†			0.734
Female	36 (43.4%)	35 (46.1%)	
Male	47 (56.6%)	41 (54.0%)	
BMI* *(kg/m²)*	32.4 ± 7.0	32.5 ± 6.0	0.904
Charlson Comorbidity Index†			0.886
0 to 1	31 (37.4%)	31 (40.8%)	
2	22 (26.5%)	20 (26.3%)	
≥3	30 (36.1%)	25 (32.9%)	
Smoker†			0.420
Never	43 (51.8%)	47 (61.8%)	
Current	7 (8.4%)	6 (7.9%)	
Previous	33 (39.8%)	23 (30.3%)	
Diabetes†			0.099
No	65 (78.3%)	67 (88.2%)	
Yes	18 (21.7%)	9 (11.8%)	
Procedure†			0.595
Total hip arthroplasty	34 (41.0%)	28 (36.8%)	
Total knee arthroplasty	49 (59.0%)	48 (63.2%)	

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the percentage in parentheses.

TABLE II Patient Outcomes for the Control and Intervention Groups

	Control Group*	Intervention Group*	Difference†	P Value
Time exercising per day *(min)*	37.7 ± 16.3	46.4 ± 17.4	8.6 (4.9 to 12.4)	<0.001
VAS mood score *(points)*	6.5 ± 1.7	7.5 ± 1.8	0.9 (0.5 to 1.3)	<0.001
Time taking narcotics *(days)*	32.4 ± 11.8	22.5 ± 13.4	−10.0 (−14.2 to −5.7)	<0.001
Extension‡ *(deg)*				
3-week follow-up	3.5 ± 4.4	1.8 ± 3.3	−1.7 (−3.3 to −0.9)	0.038
6-week follow-up	2.6 ± 5.5	1.6 ± 2.8	−1.0 (−2.8 to 0.9)	0.295
Flexion‡ *(deg)*				
3-week follow-up	93.8 ± 14.5	101.2 ± 11.2	7.4 (2.0 to 12.7)	0.008
6-week follow-up	108.0 ± 12.8	111.9 ± 13.3	3.9 (−1.6 to 9.3)	0.161
Total calls to the office	2.6 ± 3.4	0.6 ± 0.8	−2.1 (−2.9 to −1.2)	<0.001

*The values are given as the mean and the standard deviation. †The values are given as the mean difference, with the 95% confidence interval (CI) in parentheses. The statistical interpretation of the 95% CI of the difference is that there is a significant association if the 95% CI excludes 0, but there is no significant association if the 95% CI includes 0. ‡These analyses included only patients who underwent total knee arthroplasty; there were 49 control patients and 48 intervention patients in each of these analyses.

Patients in the intervention group placed a mean of 2 fewer calls to the surgeon's office: 0.6 ± 0.8 call compared 2.6 ± 3.4 calls in the control group ($p < 0.001$). Patients in the intervention group who underwent a total knee arthroplasty had greater knee range of motion 3 weeks after the surgical procedure compared with the control group. The mean extension was 1.8° ± 3.3° for the intervention group and 3.5° ± 4.4° for the control group ($p = 0.038$), and the mean flexion was 101.2° ± 11.2° for the intervention group and 93.8° ± 14.5° for the control group ($p = 0.008$). However, this difference in range of motion was not present 6 weeks after the surgical procedure; the mean extension was 1.6° ± 2.8° for the intervention group and 2.6° ± 5.5° for the control group ($p = 0.295$), and the mean flexion was 111.9° ± 13.3° for the intervention group and 108.0° ± 12.8° for the control group ($p = 0.161$) (Table II). Four patients from the control group presented to the emergency department for pain-related concerns, and no patients from the intervention group presented to the emergency department for any reason. There were no reoperations performed within 6 weeks of the surgical procedure for either group.

Patients in the intervention group were more likely (98.6%) than those in the control group (51.4%) to agree that postoperative instructions were clear (relative risk [RR], 1.9; $p < 0.001$). Patients in the intervention group were also more likely to agree that the health-care team motivated them through their recovery (78.6% compared with 31.1% [RR, 2.5]; $p < 0.001$) and that they felt more encouraged by the health-care team (90.0% compared with 40.5% [RR, 2.2]; $p < 0.001$). Lastly, patients in the intervention group were more likely to make it a priority to perform their rehabilitation exercises (92.9% compared with 55.4% [RR, 1.7]; $p < 0.001$) (Table III). There were no unintended harms to the patients in the control group or intervention group.

For the sensitivity analysis of the primary outcome, when all missing data were assumed to have a poor score (bottom 10th percentile overall, which was 20.0 minutes), the patients in the intervention group exercised for 7.3 minutes more per day: a mean time of 42.9 ± 18.5 minutes compared with 35.6 ± 16.4 minutes for the control group ($p < 0.001$). Similarly, when all missing data were assumed to have an excellent score (top 10th

TABLE III Six-Week Postoperative Patient Survey Responses for the Control and Intervention Groups

	Control Group* (N = 80)	Intervention Group* (N = 73)	P Value†
1. I was provided with clear instructions on how to recover from surgery.	38 (47.5%)	69 (94.5%)	<0.001
2. I felt a personal connection to my surgeon throughout my recovery.	25 (31.3%)	39 (53.4%)	0.008
3. My surgeon motivated me throughout my recovery.	23 (28.8%)	55 (75.3%)	<0.001
4. I felt encouraged to meet my daily rehabilitation goals.	30 (37.5%)	63 (86.3%)	<0.001
5. I made it a priority to do my rehabilitation exercises daily.	41 (51.3%)	65 (78.3%)	<0.001

*The values are given as the number of patients, with the percentage in parentheses, stating that they "strongly agree" with the statement. †Pearson chi-square test.

percentile overall, which was 60.0 minutes), the patients in the intervention group exercised for 7.7 minutes more per day: a mean time of 40.4 ± 16.9 minutes compared with 48.2 ± 16.9 minutes for the control group ($p < 0.001$).

Discussion

This randomized controlled trial was aimed at investigating the effects of an SMS bot in patients undergoing knee and hip arthroplasty. The most pertinent findings in this study are that patients in the intervention group spent more time on their home-based therapy exercises, discontinued their narcotic medications sooner, reported higher satisfaction and VAS mood scores, made fewer telephone calls to the office, and did not return to the emergency department during the first 6 weeks after the surgical procedure.

As arthroplasty begins to transition to fewer postoperative appointments and overall less contact with the treatment team, an opportunity exists to fill that void with digital patient engagement platforms[2,4,6,7]. The industry has seen an influx of patient engagement platforms. However, the currently available platforms have inherent disadvantages that include technical complexity and the need for downloads and logins, and they generally require a clinician to monitor inbound patient messages[3]. These disadvantages have resulted in low patient and provider adoption. Alternatively, an SMS bot can deliver automated, timely, 1-way messages directly to a user's SMS inbox[7]. It also has the theoretical advantage of automating simple clinician-like tasks and creating a natural and convenient way for patients to receive information without overburdening staff with incoming communication from patients.

Patients in the intervention group spent 8.6 additional minutes per day on their home-based therapy compared with the control group. This improvement in self-reported home therapy was paired with an increase in their objective range of motion at their 3-week postoperative visit measured by the office staff. The early improvement in range of motion dissipated by the sixth postoperative week. This finding may mean that patients can transition from outpatient therapy to an independent home-based therapy program sooner. This would reduce the cost of the care episode without potentially threatening the patient's outcome.

It has been reported that opioid use increases complication rates after joint arthroplasty and that opioid dependence can develop[8-11]. Governmental and professional organizations are addressing opioid use in the United States[12-15]. In this current study, patients enrolled in the intervention group discontinued their narcotic pain medications 10 days sooner than the control group. This finding may be related to improved patient education, as they had the opportunity to receive more information through preconfigured pain medication keyword responses (for example, oxycodone). More interestingly, this finding may have been related to the encouraging and empathetic tone of the text and video messages as well as improved mood scores and self-efficacy, which in previous reports has shown to be a very effective pain reliever[16-18].

The surgical volume of total hip arthroplasty and total knee arthroplasty is expected to increase over the next decade[19,20]. Goyal et al. reported that the average patient will call the clinic twice during the postoperative period for a total hip arthroplasty[21]. This finding is corroborated in our study, as patients in the control group called the office a mean of 2.6 times in the first 6 weeks after the surgical procedure. However, patients in the intervention group made 2 fewer telephone calls to the office (a mean of 0.6 call). The theoretical savings of 2 fewer telephone calls to the office per patient for an arthroplasty surgeon who has a mean of 350 cases per year would total around $6,125. As physicians consider the return on investment for new patient engagement platforms, the savings in fewer calls can be paired with the increased productivity generated as clinicians redirect their time to more value-added services.

The value of higher patient satisfaction scores is starting to become more clear. Right now, a portion of the reimbursement to a hospital from the Centers for Medicare & Medicaid Services (CMS) is based on the strength of their Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey, a patient survey that serves as a marker of patient satisfaction. In this study, patients in the intervention group marked "strongly agree" more often than the control group in the postoperative patient satisfaction survey questions (Table III). Additional research into the duration of engagement per care episode is warranted. In this study, 6 weeks of scheduled messages did not appear to result in fatigue or overload.

Reducing postoperative admission to the emergency department and readmissions to the hospital has become a top priority as we focus on value-based care. Four patients in the control arm presented to the emergency department during their recovery, and no patients in the intervention group presented to the emergency department. Although the power analysis showed that there were not enough numbers to be statistically reliable at this time, there appears to be a trend toward fewer postoperative visits to the emergency department for the intervention group. Interestingly, of the 4 patients who were evaluated in the emergency department, none of them were readmitted to the hospital for further treatment or evaluation, suggesting that the reason for their evaluation stemmed from signs or symptoms that were clinically normal, rather than a medical or surgical complication that necessitated admission to the hospital. The cost savings in reduced emergency department visits is substantial, especially in the era of bundled payments and financial penalties for readmissions.

Our study had some limitations. The study was completed at a single academic center and may not have been wholly representative of the patient population in other geographic areas, and it did not include a large portion of younger male patients, who are notoriously challenging to engage in patient engagement platforms. The randomization process did not protect against selection bias during patient enrollment and we were unable to conceal patient allocation by blinding the participants, which has been reported to exaggerate the estimate of the effect size of interventions[22]. The patient self-reported data within our study were also subject to response bias, introspective ability, and the inherent limitations of rating scales and questionnaires. Moreover, the data showing greater motivation and time performing rehabilitation exercises in the intervention group could potentially

have resulted because that group was trying something new. More study is needed to address this potential limitation.

In conclusion, in an era of value-based reimbursement and high-volume surgical procedures, more attention is being paid to new patient engagement platforms and services that improve patient engagement. Currently available mobile applications and web-based portal solutions have high inherent technical barriers to implementation and disrupt the clinical workflow. Thus, there is interest in patient engagement platforms that eliminate the provider and patient activation barrier, create a supportive and empathetic digital environment, and do not require clinician monitoring or follow-up. In this study, a novel, physician-specific SMS bot increased patient satisfaction, VAS mood score, and minutes spent on home therapy and also decreased narcotic pain medication use and calls to the surgeon's office in a group of patients undergoing primary total knee arthroplasty and total hip arthroplasty. ■

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