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Patterns and predictors of persistent opioid use following hip or knee arthroplasty

S.C. Kim † ‡ *, N. Choudhry †, J.M. Franklin †, K. Bykov †, M. Eikermann §, J. Lii †, M.A. Fischer †, B.T. Bateman † §

† Division of Pharmacoepidemiology and Pharmacoeconomics, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
‡ Division of Rheumatology, Immunology and Allergy, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
§ Department of Anesthesia, Critical Care, and Pain Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

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SUMMARY

Objective: The relationship between arthroplasty and long-term opioid use in patients with knee or hip osteoarthritis is not well studied. We examined the prevalence, patterns and predictors of persistent opioid use after hip or knee arthroplasty.

Method: Using claims data (2004–2013) from a US commercial health plan, we identified adults who underwent hip or knee arthroplasty and filled ≥1 opioid prescription within 30 days after the surgery. We defined persistent opioid users as patients who filled ≥1 opioid prescription every month during the 1-year postoperative period based on group-based trajectory models. Multivariable logistic regression was used to determine preoperative predictors of persistent opioid use after surgery.

Results: We identified 57,545 patients who underwent hip or knee arthroplasty. The mean ± SD age was 61.5 ± 7.8 years and 87.1% had any opioid use preoperatively. Overall, 7.6% persistently used opioids after the surgery. Among patients who used opioids in 80% of the time for ≥4 months preoperatively ($n = 3023$), 72.1% became persistent users. In multivariable analysis, knee arthroplasty vs hip, a longer hospitalization stay, discharge to a rehabilitation facility, preoperative opioid use (e.g., a longer duration and greater dosage and frequency), a higher comorbidity score, back pain, rheumatoid arthritis, fibromyalgia, migraine and smoking, and benzodiazepine use at baseline were strong predictors for persistent opioid use (C-statistic = 0.917).

Conclusion: Over 7% of patients persistently used opioids in the year after hip or knee arthroplasty. Given the adverse health effects of persistent opioid use, strategies need to be developed to prevent persistent opioid use after this common surgery.

Introduction

Osteoarthritis (OA) is a highly prevalent, chronic condition, affecting nearly one-third of adults aged 65 years and older in the US[1] and its prevalence continues to rise. Hip and knee OA is the most common type of OA, generally treated with a combination of non-pharmacologic interventions such as exercise, patient education and physical therapy, and medications including acetaminophen, non-steroidal anti-inflammatory drugs (NSAIDs), and intra-articular glucocorticoids[2]. For patients with moderate to severe symptomatic OA resistant to the aforementioned drugs or those who cannot tolerate NSAIDs, opioid analgesics can be prescribed with caution. For patients with severe OA unrelieved by medical treatment, total joint replacement (TJR) is often considered[2], as TJR is an effective surgical intervention leading to significant improvement in quality of life, pain and function in most patients with severe hip or knee OA[3,4]. Between 2010 and 2011, there were an estimated 1.3–1.4 million inpatient joint replacement procedures including total knee or hip replacement or arthroplasty in the US[5].

Over the past two decades, overuse of prescription opioid medications in the US has become a serious public health concern[6]. Compared to the years between 1988 and 1994, when 3.4% of US adults had any use of opioid analgesics, the use of these agents has more than doubled[6,7]. In older patients such as those with OA, due to the known cardiovascular risks of NSAIDs, the threshold for using opioids has decreased; opioids have been used more frequently

* Address correspondence and reprint requests to: S.C. Kim, 1620 Tremont Street, Suite 3030, Boston, MA 02120, USA. Fax: 1-617-232-8602.
E-mail address: skim62@partners.org (S.C. Kim).

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in the elderly or those with cardiovascular risk factors[8]. A recent study using the Medicare Current Beneficiary Survey showed that 40% of a cohort of elderly patients with mean age of 77 received an opioid prescription in 2009[9]. However, in a Cochrane systematic review of 22 randomized controlled trials, opioids were noted to have only a small clinical benefit but a high risk of side effects, including opioid dependency and withdrawal in patients with hip and knee OA[10]. Furthermore, preoperative use of opioids may lead to persistent opioid use and poor clinical outcomes including pain, stiffness, and requirement of additional surgery following TJR[11–14]. The objective of this study was to examine the prevalence, patterns and predictors of persistent opioid use after hip or knee arthroplasty in a population-based cohort of patients who underwent hip or knee arthroplasty.

Methods

Data source

We used claims data from a large US commercial health insurance, United HealthCare/Optum Clinformatics® Data Mart Database, from January 1, 2004 to December 31, 2013. This database has been described in detail elsewhere[15]. Briefly, it includes, at any particular time point, more than 13 million fully-insured subscribers with medical and pharmacy coverage from across the United States and provides patients' demographic information as well as longitudinal data on inpatient and outpatient medical claims, procedure claims, and pharmacy claims. The quality of these data in accurately capturing inpatient diagnoses, procedures, health care utilization and drug dispensing as well as some outpatient diagnoses is known to be high[16]. A prior validation study reported that there was 96% agreement between medical diagnoses defined using claims data and the medical records or the patient surveys[17]. The use of this de-identified database was approved by the Institutional Review Board of the Brigham and Women's Hospital and informed consent was not required.

Study population

We selected adults aged ≥50 years who were hospitalized for a total hip or knee arthroplasty (i.e., index admission). The *index date* was defined as the fourteenth day following the hospital discharge date from the index admission. Patients were required to have a 1-year continuous enrollment period prior to the index admission date and a 1-year continuous enrollment period after the index date (Fig. 1). Patients were excluded if they had a diagnosis of any malignancy or underwent a surgery for fracture, hip or knee arthroplasty in the year prior to the index date.

Outcome definition

The primary outcome of interest was persistent use of opioids (i.e., hydrocodone, codeine, oxycodone, meperidine, hydromorphone, morphine, fentanyl, methadone, and oxymorphone) in the year following the index date. Persistent use was defined as having any use of opioid prescriptions in each of the 12 months continuously based on a group-based trajectory modeling (GBTM) and identified as Trajectory 6 in Fig. 2. We utilized this GBTM method to identify clinically distinct, dynamic patterns of opioid use over the 12-month time period. GBTM has been used to describe longitudinal trajectories and summarize long-term medication adherence[18–21].

Covariate assessment

During the baseline 365-day period prior to the index date, we assessed a number of pre-defined variables potentially related to persistent use of opioids. These variables were demographic factors (i.e., age, sex), type and characteristics of joint arthroplasty (i.e., surgical site, year of surgery, length of in-hospital stay, bilateral/unilateral, discharge type), preoperative opioid use characteristics [i.e., any use, duration of opioid use, single or multiple opioid agents, cumulative dose, number of months with a proportion of days

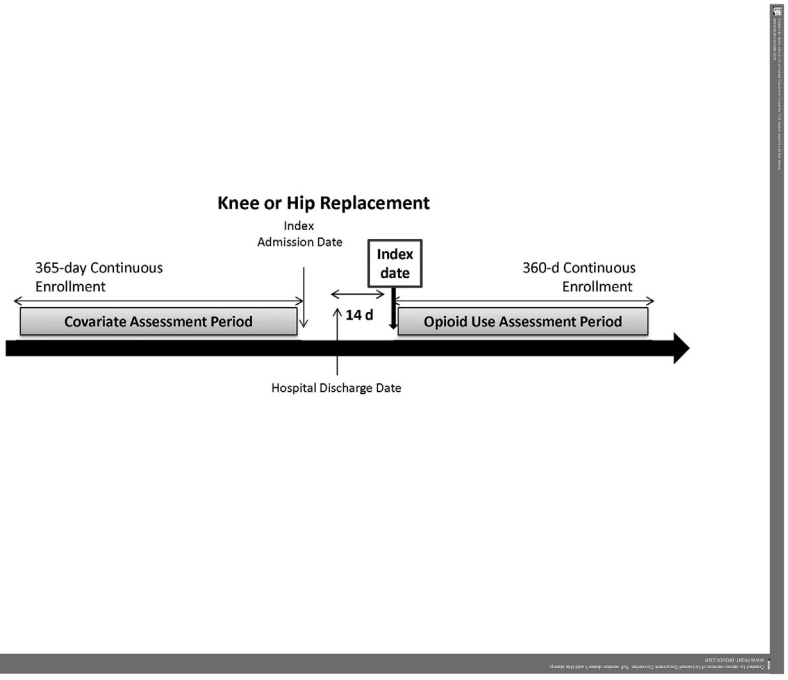

Fig. 1. Overview of study design. The index date was defined as the fourteenth day following the hospital discharge date from the index admission. Patients were required to have a 1-year continuous enrollment period prior to the index admission date and a 360-day continuous enrollment period after the index date.

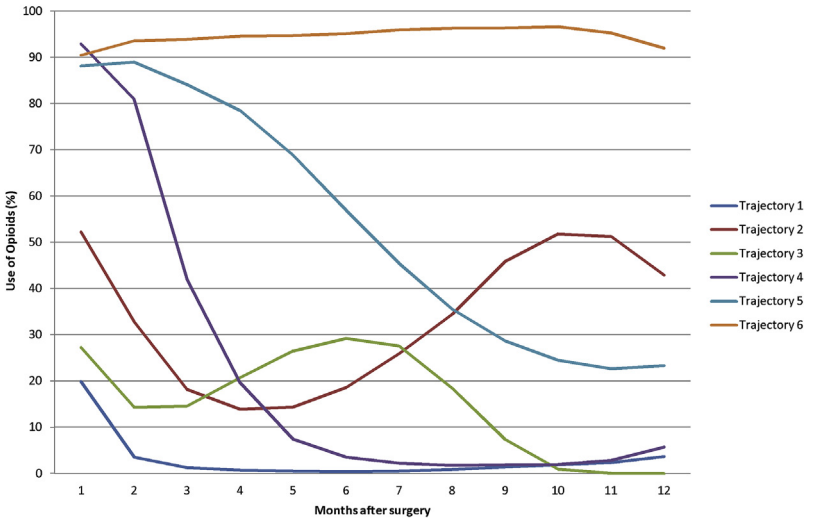

Fig. 2. Trajectories of opioid use after hip or knee arthroplasty. Among 57,545 patients who underwent hip or knee arthroplasty, 7.6% (Trajectory 6) of the study cohort had persistent opioid use in the year following surgery. Trajectories 1 (51.0%), 2 (8.1%), 3 (8.8%), 4 (16.8%), and 5 (7.6%) were considered as non-persistent users.

covered (PDC) with opioids >80%], presence of chronic pain-related comorbidities including back pain, fibromyalgia, rheumatoid arthritis, herpes zoster with neuropathy, alcoholism, other substance abuse history, and smoking, a comorbidity score that combined 20 conditions in the Charlson and Elixhauser measures[22], use of other prescription drugs including benzodiazepines, antidepressants, oral steroids, NSAIDs, gabapentin and pregabalin, and healthcare use pattern[23] listed in Table I Assuming the opioid medication was taken regularly based on the days supply and quantity dispensed, we calculated oral morphine equivalent (OME) daily dose after converting from the prescribed opioid to OME based on potency[24].

Statistical analysis

We assessed baseline characteristics of the entire study sample. To identify persistent users of opioids after hip or knee arthroplasty, we first created a 'medication diary' for each patient in our cohort indicating whether a prescription for one or more opioids was dispensed as a binary variable during each of the 12 consecutive 30-day periods after the index date. We then modeled these observed opioid dispensing patterns (i.e., 12 binary indicators) as a longitudinal response in a logistic GBTM[21,25]. In this GBTM, the log odds of having any opioid dispensing (yes/no) during each 30-day period was estimated as a smooth function of time separately within each group. The model also estimated the probability of group membership for each patient, and patients were assigned to the group with the highest membership probability. We estimated our model using six adherence groups, which have been observed in prior research to provide the best overall model fit[18]. We then defined "persistent users" as the group of patients who had any opioid dispensing in each of all twelve 30-day post-index date periods. The model was estimated using "Proc Traj," in SAS (SAS, Version 9.2, Cary, NC). Further details on the model and specific modeling choices have been previously described[18]. To determine baseline characteristics that predict persistent opioid use after the surgery, we constructed a multivariable logistic regression model with persistent opioid use (present vs absent) as the dependent variable and the aforementioned covariates as the independent variables. The c-statistic for predicting persistent opioid use was calculated. For internal validation of the model prediction performance, we performed 10-fold cross-validation[26]. In a sensitivity analysis, we assessed the predictors of persistent opioid use stratified by the presence of preoperative opioid use.

Results

Study population

After applying inclusion and exclusion criteria, we included a total of 57,545 patients who underwent either hip or knee joint replacement between 2004 and 2013 (Fig. 3). The mean (SD) age was 61.5 (7.8) years and 57.0% were female. Of these, 68.5% had a knee surgery and 31.5% had a hip surgery (Table I). Prior to the surgery, 50,120 patients (87.1%) had at least one opioid dispensing and 10,148 (17.6%) used opioids for at least 4 months. There were 3023 patients (5.2%) who used opioids in 80% of the time (i.e., PDC $\geq$ 80%) for at least 4 months prior to the surgery. The mean (SD) duration of opioid use prior to the surgery was 2.3 (2.7) months. More than one type of opioid prescriptions were used by 41.5% of the patients. Back pain (40.8%) and fibromyalgia (8.2%) were common comorbidities. Use of NSAIDS including coxibs (56.1%) and benzodiazepines (19.0%) was also common.

Persistent opioid use

As illustrated in Fig. 2, GBTM identified six distinct trajectories of post-TJR opioid use. There were 29,352 (51.0%) patients who

Table I
Baseline characteristics of study patients in 365 days prior to joint replacement surgery

	All ($n = 57,545$)	Persistent opioid users ($n = 4394$)	Non-persistent opioid users ($n = 53,151$)
Percentage or mean ± standard deviation			
Demographic factors			
Age, years	61.5 ± 7.8	59.7 ± 7.3	61.7 ± 7.9
50–59	45.5	56.0	44.6
60–69	39.1	33.5	39.5
70+	15.4	10.5	15.9
Female	57.0	61.8	56.6
Surgical factors			
Bilateral surgery	0.7	0.5	0.7
Knee surgery	68.5	72.4	68.1
Year of surgery			
2004	0.3	0.2	0.3
2005	8.6	7.8	8.6
2006	10.4	9.8	10.5
2007	11.4	10.7	11.5
2008	14.1	13.7	14.1
2009	13.4	14.0	13.3
2010	13.9	14.7	13.8
2011	14.2	15.0	14.2
2012	13.8	14.2	13.7
No. of days for in-hospital stay			
1–2	3.7	2.5	3.8
3–5	85.5	82.7	85.8
6–8	7.7	10.4	7.5
9–10	1.3	1.7	1.3
11+	1.8	2.7	1.7
Discharge to a rehabilitation facility	14.5	17.3	14.3
Preoperative opioid use			
Any opioid use	87.1	98.9	86.1
No. of months with opioid use	2.3 ± 2.7	8.0 ± 3.8	1.8 ± 1.9
No. of months with mean OME dose > 100 mg/day	0.1 ± 1.1	1.4 ± 3.4	0.0 ± 0.4
No. of months with PDC >80%			
0	88.7	31.2	93.4
1–3	6.1	19.2	5.0
4+	5.2	49.6	1.6
Single opioid agent	45.6	23.4	47.5
Multiple opioid agents	41.5	75.5	38.7
Comorbidities			
Alcoholism	1.6	2.7	1.5
Back pain	40.8	63.8	38.9
Fibromyalgia	8.2	17.9	7.4
Migraine	7.9	14.8	7.3
Osteoarthritis	99.9	99.8	99.9
Rheumatoid arthritis	5.1	10.4	4.6
SLE	1.3	2.4	1.2
Herpes zoster with neuropathy	0.2	0.3	0.1
Tobacco use	12.3	19.4	11.7
Substance abuse	0.7	4.2	0.4
Comorbidity score	0.5 ± 1.4	0.9 ± 7.8	0.5 ± 1.4
Medications			
Antidepressants	25.8	50.2	23.8
Benzodiazepines	19.0	44.1	16.9
NSAIDs/Coxibs	56.1	65.4	55.4
Oral steroids	25.9	38.0	24.9
Gabapentin/pregabalin	3.3	10.0	2.7
Healthcare utilization			
No. of acute hospitalizations			
1	87.5	77.6	88.3
2	10.5	17	10.0
3+	2.0	5.4	1.7

PDC: proportion of days covered; SLE: systemic lupus erythematosus, NSAID: non-steroidal anti-inflammatory drug, Coxib: selective cyclooxygenase-2 inhibitor, OME: oral morphine equivalent.

had no or minimal opioid use beyond 3 months postoperatively (Trajectory 1). 4,683 (8.1%) patients had a decrease in opioid use in the first 6 months after TJR but then they had an increase in opioid use in the 6–12 month post-TJR period (Trajectory 2). Patients seen in Trajectories 3 (8.8%), 4 (16.8%) and 5 (7.6%) gradually had a decrease in the use of opioids over time. There were 4,394 (7.6%, Trajectory 6) persistent opioid users in the year following the surgery. Compared to non-persistent users (Trajectories 1 through 5), persistent opioid users (Trajectory 6) were younger, more likely to be female and have a greater preoperative use of opioids, more painful comorbidities and prescription drug use (Table I). In both persistent and non-persistent opioid users, hydrocodone was the most commonly used opioid agent (55.2%) preoperatively, followed by oxycodone (21.8%). After the surgery, oxycodone (50.9% in persistent opioid users and 48.2% in non-persistent users) was the most commonly used opioid at the time of hospital discharge followed by hydrocodone (42.9% in persistent opioid users and 35.1% in non-persistent users).

Preoperative characteristics predicting persistent opioid use

Multivariable logistic regression analysis (Table II) showed a number of significant predictors of persistent opioid use after surgery. Patients who underwent a knee arthroplasty versus hip [adjusted odds ratio (aOR) 1.75, 95% confidence interval (CI) 1.59–1.93], who were discharged to an acute rehabilitation facility versus others (aOR 1.26, 95% CI 1.12–1.42) and who had a longer length of stay during the index admission (aOR 1.04 for an additional day of stay, 95% CI 1.02–1.06) were more likely to use opioids persistently after surgery. Preoperative opioid use patterns were strong predictors of persistent opioid use following surgery: any preoperative opioid use (aOR 1.72, 95% CI 1.27–2.33), a longer duration of opioid use preoperatively (aOR 1.47, 95% CI 1.45–1.50), ≥1 month with a OME dose ≥100 mg per day (aOR 1.44, 95% CI 1.19–1.73), and a greater number of months with PDC ≥80% for opioids (aOR 4.54 for more than 7 months versus none, 95% CI 3.79–5.45). Among other medications, benzodiazepine use during the baseline period was also a predictor of persistent opioid use (aOR 1.42, 95% CI 1.29–1.56). A higher comorbidity score (aOR 1.03, 95% CI 1.00–1.06), smoking (aOR 1.20, 95% CI 1.07–1.35) and presence of chronic pain-related comorbidities such as back pain (aOR 1.28, 95% CI 1.17–1.40), fibromyalgia (aOR 1.22, 95% CI 1.07–1.39), migraine (aOR 1.19, 95% CI 1.04–1.36) and rheumatoid arthritis (aOR 1.40, 95% CI 1.20–1.65) were also significant predictors of persistent opioid use. The c-statistic of the multivariable logistic model was 0.917, indicating that the model could accurately identify persistent opioid users. The 10-fold cross-validated C statistic for the prediction model was 0.915, suggesting excellent internal validity.

In a sensitivity analysis stratified by the preoperative use of opioids, 50,120 (87.1% of the total cohort) prior opioid users and 7,425 (12.9%) opioid-naïve patients were analyzed. After the surgery, 4,346 (8.67%) prior opioid users and 48 (0.65%) opioid-naïve patients became persistent opioid users. In patients who used opioids in 80% of the time for ≥4 months preoperatively ($n = 3,023$), 72.1% became persistent users. Among patients with prior opioid use, multivariable logistic regression (c-statistic = 0.917) showed similar significant predictors of persistent opioid use as noted in the main analysis (Table III). Among the opioid-naïve subgroup, a greater comorbidity score (aOR 1.25, 95% CI 1.08–1.44) and discharge to an acute rehabilitation facility (aOR 2.24, 95% CI 1.21–4.13) were significant predictors of persistent opioid use. The c-statistic of the multivariable logistic model in the opioid-naïve subgroup was 0.752.

Discussion

Preoperative use of opioids in patients with hip or knee OA was highly prevalent as over 87% of the study population received at

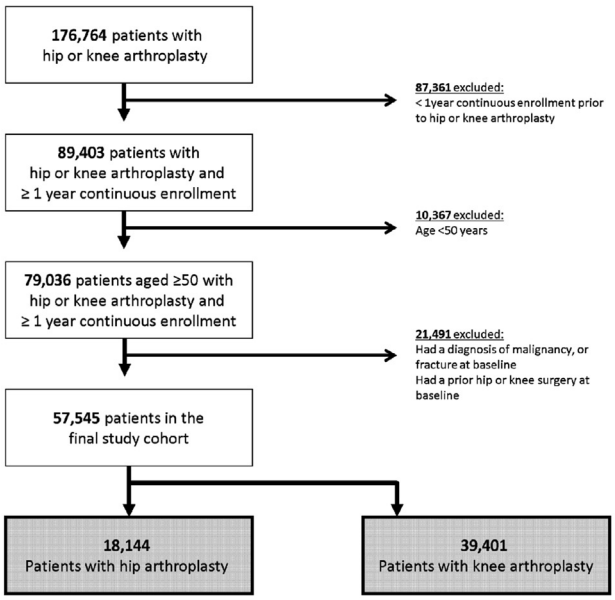

Fig. 3. Cohort selection flow. The final study cohort included 57,545 patients who underwent either hip or knee arthroplasty.

least one opioid dispensing in the year prior to undergoing hip or knee arthroplasty. However, intensive preoperative opioid use was uncommon as only 5.2% of the cohort used opioids in ≥80% of the time (PDC ≥80%) for at least 4 months prior to the arthroplasty. In general, joint replacement surgery is highly effective in moderate-to-severe hip or knee OA and 51% of our study patients had no or minimal use of opioids 3 months after the surgery. However, 7% of the study population had persistent use of opioids in the year following the surgery. It is particularly important to note that among patients who had intensive opioid use preoperatively for at least 4 months, over 72% were persistent users following the surgery. Presence of chronic pain-related comorbidities and use of benzodiazepines prior to the surgery were also significant predictors of persistent opioid use following the surgery.

This study highlights several important issues in the management of moderate-to-severe hip or knee OA and pre- and post-operative pain management in patients undergoing hip or knee arthroplasty in the US Similar to what has been noted in the overall US population, the use of opioids even in the older age group is highly prevalent. A recent Australian-cohort study (n = 9,525) showed that 44% of their patients used any opioid analgesics prior to total hip replacement compared with 87% in our study[27]. Opioids are effective in reducing acute pain, but in a Cochrane systematic review of 22 randomized controlled trials in patients with hip and knee OA they were shown to have only a small clinical benefit with a high risk of side effects as well as opioid dependency[10]. Similarly, no significant differences in pain reduction were found between opioids and NSAIDs and between less potent and potent opioids in patients with knee OA, based on a systematic review of 17 randomized controlled trials[28]. In response to the current prescription opioid crisis in the US, the Centers for Disease Control and Prevention (CDC) developed and published recommendations for prescribing opioids in patients with chronic non-cancer pain[29]. While it is important that patients receive appropriate pain treatment, the CDC guideline emphasizes the need to improve communication between clinicians and patients about the risks and benefits of opioid therapy for chronic pain to improve the safety and effectiveness of pain treatment, and reduce the risks associated with long-term opioid therapy, including opioid use disorder, overdose, and death. Given the limited utility of opioids for chronic management of patients with OA, use of intensive, long-term and/or high-potency opioids should be minimized in these patients. Furthermore, concurrent use of opioids and benzodiazepines which was seen in 19% of the total cohort should be avoided or at least minimized as use of both drugs at the same time put patients at greater risk for persistent opioid use as well as potentially fatal overdose.

Persistent opioid use before and after surgery may be associated with poor clinical outcomes including pain, stiffness, and revision surgery following TJR[11–14,30]. A cohort study of 12,859 patients who had total hip replacement showed that higher OME doses in days 91–180 post-surgery were significantly associated with a greater risk of 1-year and 5-year revision[30]. Similar findings were also reported in the aforementioned Australian cohort of total hip replacement patients[31], although whether persistent opioid use is a causative factor for revision TJR surgery or TJR failure, or a surrogate or intermediate endpoint of TJR failure needs to be further studied. Nevertheless, it would be clinically crucial to identify patients who are at risk of persistent opioid use following TJR so that clinicians can provide individualized pain management to those high-risk patients pre- and post-operatively. Particular attention needs to be paid in the preoperative evaluation and/or postoperative pain

Table II
Predictors of persistent opioid users in the entire cohort ($n = 57,545$)

	Multivariable odds ratio*	95% Confidence interval
Demographics		
Age 50–59	1.02	0.88–1.17
Age 60–69	0.95	0.83–1.10
Age ≥ 70	Reference	–
Female vs. male	1.03	0.94–1.13
Surgery characteristics		
Knee surgery vs. hip	1.75	1.59–1.93*
Discharge to a rehabilitation facility	1.26	1.12–1.42*
No. of days for in-hospital stay	1.04	1.02–1.06*
Preoperative opioid use		
Any opioid use	1.72	1.27–2.33*
No. of months with opioid use	1.47	1.45–1.50*
≥1 month with a mean OME dose > 100 mg/day	1.44	1.19–1.73*
No. of months with PDC > 80%		
0	Reference	–
1–3	2.53	2.25–2.84*
4–6	3.31	2.79–3.94*
7+	4.54	3.79–5.45*
Multiple opioid agents	1.04	0.95–1.15
Comorbidities		
Alcoholism	0.93	0.70–1.25
Cocaine use	3.59	0.95–13.5
Marijuana use	1.14	0.33–3.98
Fibromyalgia	1.22	1.07–1.39*
Migraine	1.19	1.04–1.36*
Rheumatoid arthritis	1.40	1.20–1.65*
SLE	1.11	0.81–1.53
Back pain	1.28	1.17–1.40*
Tobacco use	1.20	1.07–1.35*
Substance abuse	1.17	0.84–1.64
Comorbidity score	1.03	1.00–1.06*
Medications		
Antidepressants	1.08	0.99–1.19
Benzodiazepines	1.42	1.29–1.56*
NSAIDs/Coxibs	1.01	0.92–1.10
Oral steroids	1.02	0.93–1.12
Gabapentin/pregabalin	1.10	0.93–1.31
Healthcare utilization		
No. of acute hospitalizations	0.93	0.87–1.00*

OME: oral morphine equivalent, NSAID: non-steroidal anti-inflammatory drug, Coxib: selective cyclooxygenase-2 inhibitor, PDC: proportion of days covered, SLE: systemic lupus erythematosus.
*P-value < 0.05.
* Additionally adjusted for the index year.

Table III
Predictors of persistent opioid users in the subgroup with preoperative opioid use ($n = 50,120$)

	Multivariable odds ratio*	95% Confidence interval
Demographics		
Age 50–59	1.00	0.86–1.15
Age 60–69	0.94	0.81–1.08
Age ≥ 70	Reference	–
Female vs male	1.03	0.94–1.13
Surgery characteristics		
Knee surgery vs hip	1.75	1.59–1.93*
Discharge to a rehabilitation facility	1.23	1.09–1.39*
No. of days for in-hospital stay	1.04	1.02–1.06*
Preoperative opioid use		
No. of months with opioid use	1.48	1.45–1.50*
≥1 month with a mean OME dose>100 mg/day	1.44	1.20–1.74*
No. of months with PDC > 80%		
0	Reference	–
1–3	2.54	2.26–2.85*
4–6	3.32	2.79–3.95*
7+	4.54	3.79–5.44*
Multiple opioid agents	1.05	0.95–1.16
Comorbidities		
Alcoholism	0.92	0.68–1.23
Cocaine use	3.74	0.99–14.1
Marijuana use	1.15	0.33–4.02
Fibromyalgia	1.21	1.06–1.38*
Migraine	1.19	1.05–1.37*
Rheumatoid arthritis	1.42	1.21–1.67*
SLE	1.11	0.81–1.53
Back pain	1.27	1.16–1.39*
Tobacco use	1.21	1.08–1.36*
Substance abuse	1.19	0.85–1.66
Comorbidity score	1.02	0.99–1.05
Medications		
Antidepressants	1.08	0.98–1.18
Benzodiazepines	1.43	1.30–1.57*
NSAIDs/Coxibs	1.00	0.91–1.09
Oral steroids	1.02	0.93–1.12
Gabapentin/pregabalin	1.11	0.93–1.32
Healthcare utilization		
No. of acute hospitalizations	0.93	0.86–1.00*

OME: oral morphine equivalent, NSAID: non-steroidal anti-inflammatory drug, Coxib: selective cyclooxygenase-2 inhibitor, PDC: proportion of days covered, SLE: systemic lupus erythematosus.
*P-value < 0.05.
* Additionally adjusted for the index year.

management of patients who have almost daily opioid use for more than a few months prior to the arthroplasty.

The strengths of this study include the large cohort size and use of comprehensive and longitudinal data on patients' comorbidities, prescription drug use and health care utilization patterns. In addition, we used GBTM to determine different patterns of post-TJR opioid use and to define persistent opioid users. This modeling method estimated probabilities for multiple trajectories simultaneously and showed dynamic patterns of opioid use over time. This method shows more informative patterns of medication use over time than reporting only the proportion of patients taking opioids either as a binary or categorical variable at a given time point[32].

This study has several limitations. First, we did not have disease or pain severity specific to knee or hip OA. Furthermore, we were unable to determine the indication for opioids. In other words, it is possible that some patients used opioids not for hip or knee OA but for a different health condition preoperatively. We included a number of common chronic-pain related conditions as baseline covariates to address this issue. Second, although the model has high predictability for persistent opioid use, our data do not include information on patients' functional status, pain level, socioeconomic status, or other behavioral factors related to opioid use. Third, even though our study database has detailed and longitudinal data on any prescription drug dispensing before and after surgery without risk of recall bias, our study cannot assess whether or how often patients actually took the medication as prescribed. However, it is likely that patients with a monthly dispensing of a prescription drug have high adherence or persistence. Fourth, since we relied on diagnosis or procedure codes to define preoperative characteristics, there is a potential for misclassification. Lastly, our findings may not generalize to uninsured patients or those who switched to a different commercial or publicly available (e.g., Medicare) health plans because our cohort is based on a commercially insured patient population and we required patients to be continuously enrolled for at least 1 year prior to surgery.

Conclusion

In this population-based cohort of patients with hip or knee OA, over 7% of patients persistently used opioids in the year after hip or knee arthroplasty. The proportion of persistent opioid users after the surgery was much higher at 72.1% among patients who used opioids in ≥80% of the time (PDC ≥ 80%) for at least 4 months

preoperatively. Patterns of preoperative opioid use and presence of other painful comorbidities such as back pain, rheumatoid arthritis, fibromyalgia and migraine and use of benzodiazepines were significant predictors of persistent opioid use following the surgery. Better preoperative pain management for both OA and other painful conditions may reduce the risk of persistent opioid use following hip or knee arthroplasty. Future study should evaluate potential strategies to minimize persistent opioid use, particularly in patients taking these drugs chronically in the preoperative period and study the impact of persistent opioid use on clinical and safety outcomes following hip or knee arthroplasty.

Authors' contributions

All authors conceived and designed the study, interpreted the data, and critically revised the manuscript for important intellectual content. SCK drafted the paper. SCK has full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Conflict of interest

No specific funding was given for this study.

Kim receives salary support from unrelated grants to Brigham and Women's Hospital from Lilly, Genentech, Pfizer, Bristol-Myers Squibb, Merck and AstraZeneca for unrelated studies.

Bateman is an investigator on grants to the Brigham and Women's Hospital from Lilly, Baxalata, GlaxoSmithKline, and Pfizer unrelated to the topic of this manuscript. Bateman consults for Optum for unrelated projects.

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Choudhry, Bykov, Eikermann and Lii have nothing to disclose.

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