Can J Anesth/J Can Anesth (2022) 69:963–973
https://doi.org/10.1007/s12630-022-02240-1

REPORTS OF ORIGINAL INVESTIGATIONS

Chronic opioid use after joint replacement surgery in seniors is associated with increased healthcare utilization and costs: a historical cohort study

Association entre la consommation chronique d'opioïdes après une chirurgie de remplacement articulaire chez les personnes âgées et une augmentation de l'utilisation et des coûts des soins de santé : une étude de cohorte historique

Ana Johnson, PhD · Brian Milne, MD, FRCPC · Narges Jamali, BSc · Matthew Pasquali, MSc · Ian Gilron, MD, FRCPC · Steve Mann, MD, FRCSC · Kieran Moore, MD, FRCPC · Erin Graves, MSc · Joel Parlow, MD, FRCPC

Received: 10 September 2021 / Revised: 20 December 2021 / Accepted: 24 December 2021 / Published online: 22 March 2022

Abstract

Purpose *Postoperative opioid use may be associated with increased healthcare utilization and costs. We sought to examine the relationship between duration of postoperative opioid prescriptions and healthcare costs and resource utilization in senior patients following hip and knee replacement.*

Methods *We conducted a historical cohort study evaluating postoperative opioid use and healthcare costs in patients over the age of 65 yr undergoing primary total hip or knee arthroplasty over a ten-year period from 1 April 2006 to 31 March 2016. The last follow-up date was 31 March 2017. We identified preoperative and postoperative opioid prescriptions, patient characteristics, and healthcare costs using deidentified Ontario administrative databases (Institute of Clinical Evaluative Sciences). Duration of postoperative opioid use was divided into four categories: short-term (1–90 days), prolonged (91–180 days), chronic (181–365 days), and undocumented.*

Results *The study included 49,638 hip and 85,558 knee replacement patients. Although the initial hospitalization accounted for the greatest cost in all patients, over the following year patients in the short-term opioid use group incurred the lowest average costs, and those in the chronic group incurred the highest (hip, CAD 17,528 vs CAD 26,736; knee, CAD 16,043 vs CAD 23,007), driven by increased healthcare resource utilization.*

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12630-022-02240-1.

A. Johnson, PhD
Department of Public Health Sciences, Senior ICES Scientist, Queen's University, Kingston, ON, Canada

B. Milne, MD, FRCPC · I. Gilron, MD, FRCPC · J. Parlow, MD, FRCPC (✉)
Department of Anesthesiology and Perioperative Medicine, Kingston Health Sciences Centre, Queen's University, 76 Stuart Street, Kingston, ON K7L 2V7, Canada
e-mail: parlowj@queensu.ca

N. Jamali, BSc
Queen's University, Kingston, ON, Canada

M. Pasquali, MSc
Queen's University, Kingston, ON, Canada

Western University, London, ON, Canada

S. Mann, MD, FRCSC
Division of Orthopedic Surgery, Queen's University, Kingston, ON, Canada

K. Moore, MD, FRCPC
Departments of Emergency and Family Medicine, Queen's University, Kingston, ON, Canada

E. Graves, MSc
Institute for Clinical Evaluative Sciences, Toronto, ON, Canada

Conclusion *Chronic opioid use after arthroplasty was associated with higher resource utilization and healthcare costs during the year following surgery. These results can be used to develop predictors of longer opioid use and higher costs. Further research is planned to determine whether recently implemented opioid reduction strategies can reduce healthcare resource utilization.*

Résumé

Objectif *L'utilisation postopératoire d'opioïdes peut être associée à une augmentation de l'utilisation et des coûts des soins de santé. Nous avons cherché à examiner la relation entre la durée des ordonnances d'opioïdes postopératoires, les coûts des soins de santé et l'utilisation des ressources chez les patients âgés après une arthroplastie de la hanche et du genou.*

Méthode *Nous avons réalisé une étude de cohorte historique évaluant la consommation postopératoire d'opioïdes et les coûts des soins de santé chez les patients de plus de 65 ans subissant une arthroplastie totale primaire de la hanche ou du genou sur une période de dix ans allant du 1er avril 2006 au 31 mars 2016. La dernière date de suivi était le 31 mars 2017. Nous avons identifié les ordonnances pré- et postopératoires d'opioïdes, les caractéristiques des patients et les coûts des soins de santé à l'aide de bases de données administratives de l'Ontario désidentifiées (ICES). La durée de la consommation d'opioïdes postopératoires était divisée en quatre catégories : à court terme (1 à 90 jours), prolongée (91 à 180 jours), chronique (181 à 365 jours) et non documentée.*

Résultats *L'étude a porté sur 49 638 patients ayant subi une arthroplastie de la hanche et 85 558 patients une arthroplastie du genou. Bien que l'hospitalisation initiale ait représenté le coût le plus élevé chez tous les patients, au cours de l'année suivante, les patients du groupe de consommation d'opioïdes à court terme ont encouru les coûts moyens les plus bas et ceux du groupe chronique les coûts les plus élevés (hanche, 17 528 CAD vs 26 736 CAD; genou, 16 043 CAD vs 23 007 CAD) en raison de l'utilisation accrue des ressources de soins de santé.*

Conclusion *La consommation chronique d'opioïdes après une arthroplastie a été associée à une augmentation de l'utilisation des ressources et des coûts des soins de santé au cours de l'année suivant la chirurgie. Ces résultats peuvent être utilisés pour développer des modèles de prédiction d'une consommation prolongée d'opioïdes et de coûts plus élevés. D'autres recherches sont prévues pour déterminer si les stratégies de réduction de la consommation d'opioïdes récemment mises en œuvre pourront réduire l'utilisation des ressources en soins de santé.*

Keywords analgesics · arthroplasty · economics · opioids · postoperative pain

Between January 2016 and March 2020, there were an estimated 16,364 opioid-related deaths and 20,523 opioid-related hospitalizations in Canada.[1] The estimated cost of opioid abuse in Canada totalled 3.5 billion Canadian dollars (CAD) in 2014, including healthcare, lost productivity, criminal justice, and other direct costs.[2] It has been recognized that opioids prescribed for postsurgical pain are often the precursors for chronic opioid use.[3] Our group previously found that 24.3% of hip surgery and 29.4% of knee surgery patients aged over 65 yr in Ontario were still using opioids six to 12 months after surgery, regardless of whether they were using opioids preoperatively.[4] Other investigators have similarly shown that patients without prior opioid use are at risk for developing chronic opioid use following surgery.[5–8]

Preoperative opioid use has been associated with postsurgical adverse outcomes, high costs, and persistent opioid use in total joint arthroplasty patients.[9] Recent priority setting for perioperative research in Canada included a focus on perioperative opioid use.[10] An increase in healthcare costs and resource utilization has been shown to be associated with complications caused by heavy opioid use after total joint arthroplasty, such as opioid-induced constipation[11] and postoperative opioid use disorder.[12] The fiscal impact of persistent postoperative opioid use has also been examined in the general population,[13] in patients undergoing surgery for neurodegenerative diseases,[14] and in patients undergoing other major and minor surgeries.[14] Nevertheless, few studies have examined the relationship between the duration of postoperative opioid use and healthcare costs, particularly in an elderly population and in a public healthcare system.[11–15] The purpose of this study was to examine the relationship between duration of opioid use and resource utilization and costs after joint replacement surgery in a senior population.

Methods

Cohort and data sources

We conducted a historical study using administrative databases from the Institute for Clinical Evaluative Sciences (ICES, www.ices.on.ca). The ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze healthcare and demographic data,

without consent, for health system evaluation and improvement. The use of the data in this project is authorized under section 45 of Ontario's Personal Health Information Protection Act. The databases reflect Ontario's provision of public universal access to physician and hospital healthcare services to its 14.7 million inhabitants (2021). These data sets were linked using unique encoded identifiers and analyzed at ICES. Many comorbidities, outcomes and exposures have been previously coded and validated.[16–19] Patients aged 66 yr and older who underwent total hip or knee arthroplasty between 1 April 2006 and 31 March 2016 were included in the study cohort and followed for 365 days after surgery (or date of death, if earlier), with the last follow-up date being 31 March 2017. This ten-year window was chosen to ensure robustness of the results over an extended period of time. The two procedures were selected because they are common in seniors and are associated with high costs as well as frequent need for postoperative opioids.[20] Patients were identified using Ontario Health Insurance Plan (OHIP) billing codes and corresponding hospital admission data (Canadian Institute for Health Information – Discharge Abstract Database [CIHI-DAD], and Canadian Institute for Health Information – Same Day Surgery Database [CIHI-SDS]). Drugs prescribed to patients were tracked through the Ontario Drug Benefit (ODB) database. A complete list of databases used has previously been published.[4] Only the first arthroplasty procedure for each patient that occurred during the one-year follow-up period was considered. Exclusion criteria were diagnosis of cancer in the year before admission or in the year after discharge, provision of palliative care in the year before admission date to one year after discharge, hip or femur fracture one month before index admission, osteomyelitis or septic arthritis one year after index admission, and diagnosis of a pre-existing pain disorder from unrelated causes. These confounders have been previously described in the literature.[4] Ethics approval was obtained from the Queen's University Health Sciences Research Ethics Board.

Patient characteristics, outcomes, covariates

The following patient characteristics were identified: age, sex, socioeconomic status (neighborhood median income), rurality, region of residence within Ontario (by Local Health Integration Network [LHIN]),[21] Charlson comorbidity index with a two-year look-back window, residence in a long-term care facility (LTC) in the previous two years, and type of hospital for the index surgery (teaching *vs* nonteaching). In addition, comorbidities, including diabetes and hypertension,[17] heart failure, malignancy, chronic renal insufficiency or dialysis, and pulmonary, peripheral vascular, cerebrovascular, and coronary artery disease (using International Classification of Diseases, 10th revision [ICD-10 codes][22] were included if they were documented within two years prior to surgery. Postoperative opioid prescriptions were categorized by the number of days that the last prescription was filled after discharge: short-term opioid use (1–90 days), prolonged opioid use (91–180 days), chronic opioid use (181–360 days), or undocumented opioid use. Additionally, we created two patient cohorts: no preoperative opioids (no prescription for opioids 90 days prior to index admission) and preoperative opioids (at least one opioid prescription filled within 90 days prior to index admission).[5, 7, 8, 23, 24]

Analyses were performed from the payer's perspective, and costs are reported in 2017 CAD (http://www.statcan.gc.ca). Resource utilization included the following: number of unique episodes of care; number of repeat hospitalizations and days of stay; number of repeat surgeries; number of emergency department visits; opioid-related hospitalizations or emergency department visits; number of admissions to rehabilitation, chronic care, long-term care, or mental health facilities; number of physician visits; lab claims; and home care visits for nursing, physiotherapy, occupational therapy, respiratory services, nutrition consultant/dietitian, speech language pathology, social work, psychology, case management, home-making/personal support, placement services, and respite care. The ICD-10 revision was used to identify opioid-related diagnoses (T40.0, T40.2, T40.3, T40.4, and T40.6). Mortality data (death in and out of hospital) were also presented.

Healthcare costs included inpatient hospitalizations, outpatient clinics, same day surgeries, emergency department visits, National Ambulatory Care Reporting System (NACRS) dialysis visits, NACRS cancer clinics, prescription drugs (ODB), rehabilitation, complex continuing care, long-term care, inpatient mental health, physician visits, laboratory claims, home care visits, nonphysician billings, and physician capitation costs. Data from primary/specialist physician visits, nonphysician visits, and laboratory services were calculated as fees paid from the Claims History Database of the OHIP.[25] Costs associated with short episodes of care were estimated from the NACRS by multiplying the assigned Day Procedure Group resource intensity weight (RIW) for each visit by the provincial average cost per weighted case.[25] Similarly, hospital admission costs were estimated from CIHI-DAD, using the RIW method, a measure of resource utilization intensity whereby each hospital inpatient is assigned a RIW value representing an average utilization of hospital resources (administration, staff, supplies, technology, equipment); for

example, twice as many resources are utilized by an individual with RIW = 2.0 than by an individual with RIW = 1.0. Individuals classified with particular RIWs have similar resource utilization patterns fitting into statistically and clinically homogeneous groups dependent on clinical/administrative data profiles.[18,25–27]

Data analysis

Postoperative opioid prescriptions were displayed using descriptive statistics, continuous variables using mean and standard deviation (SD), and categorical variables as frequency and percentages. Duration of opioid prescriptions was compared across LHIN regions and hospitals (teaching *vs* nonteaching centers).

Power was estimated given the sample size of our current data, based on a generalized linear model with a log link, using G*Power software.[28] A type I error of 0.05 and a squared multiple correlation coefficient (R^2) of 0.5 were assumed. Data are presented as individual costs (mean cost per patient). Generalized linear models with log link and gamma family (i.e., gamma regression models) were performed to determine the association between total costs and opioid utilization (with short-term utilization as the reference category) adjusted for other characteristics (i.e., age, sex, and comorbidities); *P* values were derived from Wald Chi square statistics. Gamma regression models have been shown to be appropriate for modeling cost data.[29] These models were performed separately for hip and knee surgery groups. Proportional increases in costs, as indicated by the exp(coefficient), were modeled using regression coefficients with corresponding Wald 95% confidence intervals (CIs), with $P < 0.0001$ indicating significance. Population costs (total cost per annum for all individuals during the course of the study) and resource utilization data were presented as mean and SD. We used SAS software version 9.2 (SAS Institute, Cary, NC, USA) for the analyses.

Results

Characteristics of the cohort

In total, 49,638 patients undergoing hip replacement and 85,558 patients undergoing knee replacement met the criteria for inclusion in the study. Demographic characteristics were previously published.[4] With these sample sizes, there was over 99% power to detect a regression coefficient of at least 0.18 (i.e., exp[coefficient] = 1.2) for both hip surgery and knee surgery cohorts.

Following surgery, 24.3% of hip and 29.4% of knee arthroplasty patients were still being prescribed opioids at six to 12 months (i.e., chronic users). Preoperatively, 17.8% of hip surgery and 20.5% of knee surgery patients had been receiving opioids. On average, preoperative opioid users incurred 3.1% (hip) and 2.3% (knee) higher costs postoperatively than nonopioid users did.

Resource utilization, mortality, and costs

Short-term opioid use was associated with the lowest average costs, and chronic opioid use with the highest average costs (CAD 17,528 *vs* CAD 26,736 for hip surgery; CAD 16,043 *vs* CAD 23,007 for knee surgery) (Table 1). Total costs over the study period are displayed in the Electronic Supplementary Material (ESM) eTable 1. Average annual incremental costs incurred by chronic opioid users, compared with short-term opioid users, were CAD 11,090,262 for hip and CAS 17,504,640 for knee surgery patients (calculated as the difference in cost per patient per year between chronic and short-term users, multiplied by the number of chronic users). The initial hospitalization accounted for the greatest cost in all patients (average of 59.7% of total costs per patient). Chronic opioid users incurred higher costs in complex continuing care, long-term care, equipment/assistive devices, and dialysis compared with short-term opioid users (Table 1).

Higher costs in chronic than in short-term opioid users were associated with: older age, female sex (hip surgery only), lower income quintile group, higher comorbidity score, teaching *vs* community hospital, provincial health region, congestive heart failure, chronic renal failure, chronic renal disease, chronic obstructive pulmonary disease, cerebrovascular disease, and coronary artery disease (Tables 2 and 3, presenting adjusted values). Chronic postoperative opioid users were more likely to incur higher costs than short-term opioid users were (hip: exp(coefficient), 1.43; 95% CI, 1.42 to 1.45; knee: exp(coefficient), 1.41; 95% CI, 1.40 to 1.42). Similarly, prolonged postoperative opioid users were also more likely to incur higher costs than short-term opioid users were (hip: exp[coefficient], 1.41; 95% CI, 1.39 to 1.44; knee: exp[coefficient], 1.30; 95% CI, 1.28 to 1.31). Residence in an LTC was a significant predictor of higher costs (hip: exp[coefficient], 1.86; 95% CI, 1.76 to 1.97; knee: exp[coefficient], 2.10; 95% CI, 1.97 to 2.23). (Detailed resource utilization data can be found in ESM eTable 2, and mortality data [death in and out of hospital] in ESM eTable 3).

Discussion

Brief summary

This historical cohort study evaluated healthcare costs and utilization associated with duration of postoperative opioid use in senior patients undergoing hip and knee arthroplasty

Table 1 Average costs per patient during one year following surgery (in 2017 CAD)

Event	Hips (no preoperative opioids)				Hips (preoperative opioids within 90 days)			
	Undocumented (N = 7,423)	Short-term (N = 20,865)	Prolonged (N = 2,478)	Chronic (N = 10,019)	Undocumented (N = 1,733)	Short-term (N = 4,488)	Prolonged (N = 607)	Chronic (N = 2,025)
Acute hospitalization	13,795	11,100	15,788	15,250	14,409	11,302	14,976	15,536
Outpatient	1,348	1,185	1,617	1,671	1,441	1,248	1,621	1,725
Same day surgery	178	179	295	296	268	188	321	328
Emergency department	205	169	301	329	244	185	333	363
Rehabilitation	3,812	1,369	3,081	3,047	4,054	1,620	2,828	2,747
Complex continuing care	1,071	106	583	596	1,284	190	641	577
Long-term care home	486	165	465	688	411	144	482	389
Inpatient mental health	104	18	9	21	184	34	-	104
Physician capitation	210	212	200	199	205	203	191	195
Laboratory claims	131	125	145	159	138	135	149	172
Home care visits	1,711	1,317	1,734	2,037	1,835	1,395	1,831	1,915
Equipment/assisted devices	20	9	26	30	33	7	25	33
NACRS dialysis visits	142	38	263	140	182	72	143	117
NACRS cancer clinics	28	40	45	105	22	31	10	51
ODB prescription drugs	1,323	1,261	1,596	2,156	1,547	1,490	1,743	2,018
Nonphysician visits	87	66	81	90	76	67	78	86
Total costs per patient	24,652	17,360	26,229	26,813	26,333	18,311	25,372	26,358
Event	Knees (no preoperative opioids)				Knees (preoperative opioids within 90 days)			
	Undocumented (N = 7,707)	Short-term (N = 34,819)	Prolonged (N = 5,563)	Chronic (N = 19,920)	Undocumented (N = 1,743)	Short-term (N = 8,793)	Prolonged (N = 1,796)	Chronic (N = 5,217)
Acute hospitalization	12,900	10,120	13,464	13,830	12,910	10,357	12,459	13,754
Outpatient	1,417	1,199	1,654	1,687	1,479	1,262	1,582	1,711
Same day surgery	217	201	269	302	346	231	322	364
Emergency department	230	180	269	306	240	206	268	320
Rehabilitation	2,881	1,120	1,857	2,259	2,926	1,319	1,933	2,126
Complex continuing care	830	67	150	267	772	111	152	245
Long-term care home	261	70	119	217	353	75	97	213
Inpatient mental health	77	28	10	18	78	17	20	5
Physician capitation	211	198	182	184	196	185	175	177
Laboratory claims	135	137	153	161	164	150	159	169
Home care visits	1,325	998	1,287	1,475	1,406	1,095	1,319	1,400
Equipment/assisted devices	21	8	10	19	22	10	7	15

Table 1 continued

Event	Knees (no preoperative opioids)				Knees (preoperative opioids within 90 days)			
	Undocumented ($N = 7,707$)	Short-term ($N = 34,819$)	Prolonged ($N = 5,563$)	Chronic ($N = 19,920$)	Undocumented ($N = 1,743$)	Short-term ($N = 8,793$)	Prolonged ($N = 1,796$)	Chronic ($N = 5,217$)
NACRS dialysis visits	101	29	21	62	67	89	80	112
NACRS cancer clinics	24	32	26	37	41	38	27	62
ODB prescription drugs	1,481	1,388	1,622	2,158	1,670	1,598	1,757	2,012
Nonphysician visits	81	71	85	88	90	77	91	90
Total costs per patient	22,191	15,848	21,179	23,068	22,762	16,819	20,448	22,775

ODB = Ontario Drug Benefits; NACRS = National Ambulatory Care Reporting System

in Ontario. Patients who were still receiving opioids at six to 12 months postoperatively incurred the highest average healthcare costs. Annually, over CAD 28 million in incremental healthcare costs were incurred by the public healthcare system in chronic *vs* short-term opioid users.

Resource utilization and duration of postoperative opioid use

Chronic postsurgical opioid users incurred high incremental costs from the Ontario healthcare system compared with those in the short-term opioid use group. In addition, short-term opioid use was associated with lower costs than no outpatient opioid prescriptions. Since opioids prescribed in hospital or rehabilitation facilities are not captured in the ODB database, a potential explanation for the higher costs in the "undocumented" group is that these patients required more rehabilitation services or longer hospitalization.

Determining the sources of increased costs in the chronic opioid group is important for resource planning and policy makers. The current study showed that for both the short-term and chronic opioid use groups, the highest total costs were related to acute hospitalization. Nevertheless, the chronic opioid use patients, who continued to fill opioid prescriptions for six to 12 months after surgery, had higher utilization of expensive resources, including complex continuing care, long-term care, assistive devices, and dialysis. Previous studies have shown that persistent postsurgical opioid use was associated with significantly higher total healthcare spending in the months following surgery.[11,12,15] It is also possible that some patients who used opioids for a longer period following surgery had sustained significant perioperative complications, thereby incurring more costs. Some studies have focused on healthcare costs associated with stand-alone opioid-related complications. Wittbrodt *et al.* found that patients with opioid-induced constipation incurred significantly higher costs than patients without this complication.[11] We also found that a strong predictor for higher costs in the chronic use group, compared with the short-term group, was residence in an LTC. Nevertheless, it is important to note that patients residing in LTCs are more likely to possess other characteristics that were found to be predictors of higher costs, such as older age and more comorbidities.[30]

Preoperative opioid use and postsurgical costs

In this study, in a publicly funded healthcare system, preoperative opioid use was associated with a small increase in healthcare costs in the year following surgery. Previous studies, conducted in private healthcare

Table 2 Adjusted opioid utilization and total one-year postoperative costs model for the hip surgery group (generalized linear model with log link and gamma family)

Variables/models	Coefficient	Standard error	Wald 95% CI		*P* value*
Opioid utilization (reference: early use (1–90 days))					
No opioid use	1.2639	0.0057	1.2499	1.2781	< 0.001
Prolonged use (91–180 days)	1.4116	0.0087	1.3876	1.4358	< 0.001
Chronic use (181–365 days)	1.4310	0.0051	1.4168	1.4454	< 0.001
Age at index date (continuous, no reference category)	1.0196	0.0003	1.0189	1.0202	< 0.001
Sex F (reference = "M")	1.0437	0.0043	1.0351	1.0524	< 0.001
Income quintile (ref = 1, lowest)					
2	0.9844	0.0070	0.9710	0.9979	0.02
3	0.9735	0.0070	0.9603	0.9868	< 0.0001
4	0.9578	0.0069	0.9451	0.9708	< 0.0001
5 (highest)	0.9286	0.0067	0.9165	0.9409	< 0.0001
Rural N (reference = "Y")	1.0057	0.0060	0.9938	1.0177	0.35
LHIN (reference = LHIN 1)					
2	0.9912	0.0110	0.9703	1.0128	0.42
3	0.9794	0.0120	0.9567	1.0027	0.08
4	1.0217	0.0102	1.0014	1.0425	0.04
5	1.0988	0.0143	1.0683	1.1301	< 0.001
6	1.0699	0.0117	1.0457	1.0948	< 0.001
7	1.1248	0.0119	1.0989	1.1513	< 0.001
8	1.1233	0.0107	1.1000	1.1472	< 0.001
9	1.0453	0.0105	1.0241	1.0669	< 0.001
10	0.9648	0.0122	0.9420	0.9882	0.003
11	1.0379	0.0108	1.0162	1.0601	0.001
12	0.9869	0.0129	0.9623	1.0121	0.30
13	1.0405	0.0121	1.0161	1.0655	< 0.001
14	1.0763	0.0167	1.0415	1.1120	< 0.001
Charlson comorbidity index (ref = 0, lowest group)					
1	1.1439	0.0059	1.1308	1.1572	< 0.001
2	1.2169	0.0096	1.1942	1.2400	< 0.001
3	1.4853	0.0139	1.4453	1.5264	< 0.001
Residence in long-term care facility: Yes (ref = No, 0)	1.8604	0.0281	1.7607	1.9658	< 0.001
Hospital type: teaching (reference: not teaching)	1.0497	0.0049	1.0398	1.0597	< 0.001
Diabetes: Yes (ref = No, 0)	0.9999	0.0095	0.9815	1.0188	0.99
Hypertension: Yes (ref = No, 0)	0.9941	0.0066	0.9814	1.0070	0.37
Congestive health failure (ref = No, 0)	1.2012	0.0124	1.1723	1.2308	< 0.001
Malignancy (ref = No, 0)	1.0139	0.0134	0.9877	1.0408	0.30
Chronic renal failure (ref = No, 0)	1.1475	0.0282	1.0858	1.2128	< 0.001
Chronic renal disease (ref = No, 0)	1.1566	0.0249	1.1014	1.2145	< 0.001
Chronic obstructive pulmonary disease (ref = No, 0)	1.0806	0.0106	1.0583	1.1033	< 0.001
Peripheral vascular disease (ref = No, 0)	0.9882	0.0188	0.9524	1.0254	0.53
Cerebrovascular disease (ref = No, 0)	1.2994	0.0267	1.2331	1.3693	< 0.001
Coronary artery disease (ref = No, 0)	1.0887	0.0076	1.0725	1.1052	< 0.001
One-year survival	1.4764	0.0197	1.4205	1.5343	< 0.001

Note: No interaction is considered in the model. Quintiles (1 = poorest; 5 = wealthiest)

**P* values were derived from Wald Chi-square statistics (cf. body text, Methods section, paragraph *Data analysis*)

CI = confidence interval; LHIN = Local Health Integration Network (http://www.lhins.on.ca/); Pr = probability

Table 3 Adjusted full opioid utilization and total one-year postoperative costs model for the knee surgery group (generalized linear model with log link and gamma family)

Variables/models	Coefficients	Standard error	Wald 95% CI		*P* value*
Opioid utilization (reference: early use [1–90 days])					
No opioid use	1.2729	0.0050	1.2604	1.2856	< 0.001
Prolonged use (91–180 days)	1.2960	0.0055	1.2821	1.3101	< 0.001
Chronic use (181–365 days)	1.4059	0.0035	1.3964	1.4155	< 0.001
Age at index date (continuous, no reference category)	1.0168	0.0003	1.0163	1.0173	< 0.001
Sex F (reference = "M")	1.0042	0.0031	0.9981	1.0104	0.18
Income quintile (ref = 1, lowest)					
2	0.9803	0.0050	0.9707	0.9899	< 0.001
3	0.9584	0.0050	0.9491	0.9678	< 0.001
4	0.9597	0.0049	0.9505	0.9691	< 0.001
5 (highest)	0.9416	0.0049	0.9326	0.9508	< 0.001
Rural N (reference = "Y")	0.9917	0.0045	0.9829	1.0005	0.07
LHIN (reference = LHIN 1)					
2	0.9909	0.0081	0.9754	1.0067	0.26
3	1.0187	0.0090	1.0008	1.0370	0.04
4	1.0416	0.0075	1.0264	1.0571	< 0.001
5	1.0719	0.0091	1.0530	1.0912	< 0.001
6	1.0663	0.0085	1.0486	1.0844	< 0.001
7	1.1444	0.0089	1.1247	1.1646	< 0.001
8	1.1139	0.0077	1.0971	1.1310	< 0.001
9	1.0282	0.0075	1.0132	1.0433	< 0.001
10	0.9667	0.0089	0.9499	0.9836	< 0.001
11	1.0352	0.0079	1.0193	1.0515	< 0.001
12	0.9600	0.0097	0.9420	0.9785	< 0.001
13	0.9979	0.0088	0.9807	1.0153	0.81
14	1.0619	0.0125	1.0362	1.0883	< 0.001
Charlson comorbidity index (ref = 0, lowest group)					
1	1.1312	0.0041	1.1223	1.1403	< 0.001
2	1.2280	0.0067	1.2119	1.2443	< 0.001
3	1.4093	0.0108	1.3797	1.4396	< 0.001
Residence in long-term care facility: Yes (ref = No, 0)	2.0951	0.0318	1.9686	2.2300	< 0.001
Hospital type: teaching (reference: not teaching)	1.0450	0.0037	1.0374	1.0526	< 0.001
Diabetes: Yes (ref = No, 0)	0.9785	0.0063	0.9666	0.9906	0.001
Hypertension: Yes (ref = No, 0)	1.0086	0.0050	0.9989	1.0186	0.08
Congestive health failure (ref = No, 0)	1.1857	0.0092	1.1644	1.2074	< 0.001
Malignancy (ref = No, 0)	1.0282	0.0101	1.0080	1.0486	0.01
Chronic renal failure (ref = No, 0)	1.1258	0.0203	1.0819	1.1715	< 0.001
Chronic renal disease (ref = No, 0)	1.1093	0.0175	1.0719	1.1480	< 0.001
Chronic obstructive pulmonary disease (ref = No, 0)	1.0662	0.0082	1.0493	1.0834	< 0.001
Peripheral vascular disease (ref = No, 0)	1.0127	0.0151	0.9831	1.0430	0.40
Cerebrovascular disease (ref = No, 0)	1.3130	0.0213	1.2592	1.3690	< 0.001
Coronary artery disease (ref = No, 0)	1.0820	0.0057	1.0699	1.0941	< 0.001
Age at index date (continuous, no reference category)	1.7704	0.0178	1.7097	1.8335	< 0.001

Note: No interaction is considered in the model. Quintiles (1 = poorest; 5 = wealthiest)

**P* values were derived from the generalized linear model with log link and gamma family (cf. body text, Methods section, paragraph *Data analysis*)

CI = confidence interval; LHIN = Local Health Integration Network (http://www.lhins.on.ca/); Pr = probability

systems, have found that preoperative opioid use may be associated with higher postoperative healthcare costs and resource utilization in joint replacement[9,12] and other types of surgery.[14,31] Wilson *et al.* found that postsurgical costs were CAD 6,595 and CAD 4,623 (converted to 2017 CAD) greater in patients who were receiving opioids prior to total hip arthroplasty and total knee arthroplasty, respectively. The increase in costs was attributed to higher rates of prosthetic joint infection, wound and prosthetic complications, revision surgery, longer lengths of hospital stay, and readmission.[12] Similarly, Blevins Peratikos *et al.* found that hip, knee, and shoulder surgery patients who used opioids preoperatively had a median increase of CAD 1,314 (2017 CAD) in medical spending, as well as longer hospital stays and increased revision rates in the year after surgery, compared with those who did not use opioids preoperatively.[9] These differences may be related to varying definitions of opioid use, shorter follow-up periods, and younger populations; both studies included "opioid use disorder" in their definition of preoperative and postoperative opioid use, whereas we included any opioid prescriptions filled in the 90 days before surgery. On the other hand, Lee *et al.* examined healthcare costs in opioid-naive patients between the ages of 18 and 64 yr who developed persistent opioid use following nonorthopedic surgeries, and found that new persistent opioid use was associated with significantly higher healthcare spending in the six months after surgery.[15]

Strengths and limitations

This study analyzed data from well-validated administrative databases, thereby minimizing the risk of missing data and ensuring comprehensive capture of demographics, hospitalizations, comorbidities, medications, and procedures. These databases also enabled a large sample size, although it may not have been powered to calculate all specific subgroups and comorbidities. Data regarding prescriptions filled were not influenced by recall bias, as in studies relying on surgeon or patient self-reported accounts. The exclusion criteria may limit the generalizability of the study findings to those who have multiple surgeries in a short period of time, or other major comorbidities that were not included (e.g., advanced cancer, hip or femur fracture prior to surgery, osteomyelitis or septic arthritis, and pre-existing pain diagnoses). Nevertheless, by excluding these factors, we were able to avoid potential confounders that may have skewed the data and overestimated average healthcare costs and resource utilization in the population of interest. Admittedly, additional healthcare resources associated with second hip/knee or other surgeries, may have contributed towards added services and opioid use, which are not considered here.

Administrative databases are generally limited in their ability to identify or quantify pain, with drug prescriptions usually acting as a surrogate for pain.[32] Although chronic postoperative opioid use was associated with higher costs, a causal relationship cannot be concluded, and it is important to determine the resources that lead to the increased costs. It is possible that chronic opioid use is a marker of other conditions or surgical complications that result in increased costs, although opioid use itself can lead to significant complications.[11,12] Thus, it is not established that reducing the duration of postoperative opioid use will reduce costs and healthcare utilization. Compliance and dosing of prescriptions were not known since we only tracked prescriptions that had been filled. In addition, local practices regarding opioid prescriptions issued at discharge are likely quite variable. Finally, some patients may have been excluded or improperly classified, since opioids received from other sources, including private insurance, out-of-pocket, and illicit means, are not accounted for in the ODB.

Future directions

Chronic opioid use following surgery has been identified as a major public health problem. Future studies should investigate the impact of directed preoperative evaluation and perioperative management on opioid use following hip or knee arthroplasty. Specifically, multispecialty and multidisciplinary initiatives may influence healthcare resource utilization and costs. Of particular relevance may be those interventions that are designed to change the prescribing culture of postoperative opioids, including healthcare provider educational modules and seminars, widely disseminated brochures and posters, and consensus guidelines.[33,34]

Conclusions

Chronic opioid use after arthroplasty is associated with higher resource utilization and healthcare costs during the year following surgery. The results of this study can be used to help develop predictors of longer opioid use and higher costs. Further research is planned to determine whether recently implemented opioid reduction strategies have reduced healthcare resource utilization.

Author contributions *Ana Johnson*, *Brian Milne* and *Joel Parlow* contributed to all aspects of this manuscript, including study conception and design; acquisition, analysis, and interpretation of data; and preparation of the manuscript. *Narges Jamali*, *Matthew Pasquali*, and *Ian Gilron* contributed to the interpretation of data and

preparation of the manuscript. *Steve Mann* contributed to the design of the study, interpretation of data, and drafting the manuscript. *Kieran Moore* contributed to the conception of the study. *Erin Greaves* contributed to the acquisition and analysis of data.

Acknowledgements This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and the Ministry of Long-Term Care. The analyses, conclusions, opinions, and statements expressed herein are solely those of the authors and do not reflect those of the funding or data sources; no endorsement is intended or should be inferred. We thank IQVIA Solutions Canada Inc for use of their Drug Information File. Parts of this material are based on data and information provided by CIHI and by Cancer Care Ontario (CCO). The opinions, results, view, and conclusions reported in this paper are those of the authors and do not necessarily reflect those of CCO or CIHI. No endorsement by CCO or CIHI is intended or should be inferred. The authors wish to acknowledge Dr. Zihang Lu for his statistical expertise and contribution to the manuscript.

Disclosures None of the authors declare any competing interests related to this study.

Funding statement This project was funded by an Applied Health Research Question grant from the Institute for Clinical Evaluative Sciences, ON, Canada.

Editorial responsibility This submission was handled by Dr. Stephan K. W. Schwarz, Editor-in-Chief, *Canadian Journal of Anesthesia/Journal canadien d'anesthésie.*

References

1. *Government of Canada*; *Special Advisory Committee on the Epidemic of Opioid Overdoses.* Opioid-and stimulant-related harms in Canada. Ottawa, ON: Public Health Agency of Canada. Available from URL: https://health-infobase.canada.ca/substance-related-harms/opioids-stimulants (accessed January 2022).
2. *Canadian Centre on Substance Use and Addiction; University of Victoria; Canadian Institute for Substance Use Research.* Canadian Substance Use Costs and Harms Scientific Working Group. Canadian substance use costs and harms 2007-2014. Ottawa, ON: Canadian Centre on Substance Use and Addiction. Available from URL: https://www.ccsa.ca/sites/default/files/2019-04/CSUCH-Canadian-Substance-Use-Costs-Harms-Report-2018-en.pdf (accessed January 2022).
3. *Bicket MC, Long JJ, Pronovost PJ, Alexander GC, Wu CL.* Prescription opioid analgesics commonly unused after surgery: a systematic review. JAMA Surg 2017; 152: 1066-71.
4. *Johnson A, Milne B, Pasquali M, et al.* Long-term opioid use in seniors following hip and knee arthroplasty in Ontario: a historical cohort study. Can J Anesth 2021. https://doi.org/10.1007/s12630-021-02091-2.
5. *Sun EC, Darnall BD, Baker LC, Mackey S.* Incidence of and risk factors for chronic opioid use among opioid-naive patients in the postoperative period. JAMA Intern Med 2016; 176: 1286-93.
6. *Alam A, Gomes T, Zheng H, Mamdani MM, Juurlink DN, Bell CM.* Long-term analgesic use after low-risk surgery: a retrospective cohort study. Arch Intern Med 2012; 172: 425-30.
7. *Clarke H, Soneji N, Ko DT, Yun L, Wijeysundera DN.* Rates and risk factors for prolonged opioid use after major surgery: population based cohort study. BMJ 2014. https://doi.org/10.1136/bmj.g1251.
8. *Raebel MA, Newcomer SR, Reifler LM, et al.* Chronic use of opioid medications before and after bariatric surgery. JAMA 2013; 310: 1369-76.
9. *Blevins Peratikos M, Weeks HL, Pisansky AJ, Yong RJ, Stringer EA.* Effect of preoperative opioid use on adverse outcomes, medical spending, and persistent opioid use following elective total joint arthroplasty in the United States: a large retrospective cohort study of administrative claims data. Pain Med 2020; 21: 521-31.
10. *McKeen DM, Banfield JC, McIsaac DI, et al.; Perioperative Anesthesia Clinical Trials Group (PACT).* Top ten priorities for anesthesia and perioperative research: a report from the Canadian Anesthesia Research Priority Setting Partnership. Can J Anesth 2020; 67: 641-54.
11. *Wittbrodt ET, Gan TJ, Datto C, McLeskey C, Sinha M.* Resource use and costs associated with opioid-induced constipation following total hip or total knee replacement surgery. J Pain Res 2018; 11: 1017-25.
12. *Wilson JM, Farley KX, Aizpuru M, Wagner ER, Bradbury TL, Guild GN.* The impact of preoperative opioid use disorder on complications and costs following primary total hip and knee arthroplasty. Adv Orthop 2019. https://doi.org/10.1155/2019/9319480.
13. *Chang H-Y, Kharrazi H, Bodycombe D, Weiner JP, Alexander GC.* Healthcare costs and utilization associated with high-risk prescription opioid use: a retrospective cohort study. BMC Med 2018. https://doi.org/10.1186/s12916-018-1058-y.
14. *Sharma M, Ugiliweneza B, Aljuboori Z, Boakye M.* Health care utilization and overall costs based on opioid dependence in patients undergoing surgery for degenerative spondylolisthesis. Neurosurg Focus 2018. https://doi.org/10.3171/2018.2.FOCUS17764.
15. *Lee JS, Vu JV, Edelman AL, et al.* Health care spending and new persistent opioid use after surgery. Ann Surg 2020; 272: 99-104.
16. *Austin PC, Daly PA, Tu JV.* A multicenter study of the coding accuracy of hospital discharge administrative data for patients admitted to cardiac care units in Ontario. Am Heart J 2002; 144: 290-6.
17. *Hux JE, Ivis F, Flintoft V, Bica A.* Diabetes in Ontario: determination of prevalence and incidence using a validated administrative data algorithm. Diabetes Care 2002; 25: 512-6.
18. *Juurlink D, Preyra C, Croxford R, et al.* Canadian Institute for Health Information Discharge Abstract Database: a validation study. Toronto: Institute for Clinical Evaluative Sciences June 2006. Available from URL: https://www.ices.on.ca/~/media/Files/Atlases-Reports/2006/CIHI-DAD-a-validation-study/Full-report.ashx (accessed January 2022).
19. *Levy AR, O'Brien BJ, Sellors C, Grootendorst P, Willison D.* Coding accuracy of administrative drug claims in the Ontario Drug Benefit database. Can J Clin Pharmacol 2003; 10: 67-71.
20. *Petersen KK, Simonsen O, Laursen MB, Nielsen TA, Rasmussen S, Arendt-Nielsen L.* Chronic postoperative pain after primary and revision total knee arthroplasty. Clin J Pain 2015; 31: 1-6.
21. *Office of the Auditor General of Ontario.* 2015 Annual Report of the Office of the Auditor General of Ontario. Chapter 3, Section 3.08: LIHNs: Local Health Integration Networks. Available from URL: https://www.auditor.on.ca/en/reports_en/en15/3.08en15.pdf (accessed January 2022).
22. *Quan H, Sundararajan V, Halfon P, et al.* Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care 2005; 43: 1130-9.
23. *Cook DJ, Kaskovich SW, Prikle SC, et al.* Benchmarks of duration and magnitude of opioid consumption after total hip and

knee arthroplasty: a database analysis of 69,368 patients. J Arthroplasty 2019; 34: 638-44.e1.
24. *Kehlet H, Rathmell JP*. Persistent postsurgical pain: the path forward through better design of clinical studies. Anesthesiology 2010; 112: 514-5.
25. *Wodchis WP, Bushmeneva K, Nikitovic M, McKillop I*. Guidelines on person-level costing using administrative databases in Ontario. Toronto, ON: University of Toronto; May 2013. Available from URL: https://tspace.library.utoronto.ca/handle/1807/87373 (accessed January 2022).
26. *Canadian Coordinating Office for Health Technology Assessment*. A guidance document for the costing process: version 1.0. Ottawa, ON: Canadian Agency for Drugs and Technologies in Health; Aug 1996. Available from URL: https://www.cadth.ca/media/pdf/costing_e.pdf (accessed January 2022).
27. *Pink GH, Bolley HB*. Physicians in health care management: 3. Case mix groups and resource intensity weights: an overview for physicians. CMAJ 1994; 150: 889-94.
28. *Faul F, Erdfelder E, Buchner A, Lang AG*. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav Res Methods 2009; 41: 1149-60.
29. *Dodd S, Bassi A, Bodger K, Williamson P*. A comparison of multivariable regression models to analyse cost data. J Eval Clin Pract 2006; 12: 76-86.
30. *Ontario Long Term Care Association.* This is long term care 2019. Ottawa, ON: Ontario Long Term Care Association; 2019. Available from URL: https://www.oltca.com/OLTCA/Documents/Reports/TILTC2019web.pdf (accessed January 2022).
31. *Gupta A, Nizamuddin J, Elmofty D, et al.* Opioid abuse or dependence increases 30-day readmission rates after major operating room procedures: a national readmissions database study. Anesthesiology 2018; 128: 880-90.
32. *Lacasse A, Cauvier Charest E, Dault R, et al*. Validity of algorithms for identification of individuals suffering from chronic noncancer pain in administrative databases: a systematic review. Pain Med 2020; 21: 1825-39.
33. *Kaafarani HM, Eid AI, Antonelli DM, et al.* Description and impact of a comprehensive multispecialty multidisciplinary intervention to decrease opioid prescribing in surgery. Ann Surg 2019; 270: 452-62.
34. *Buys MJ, Bayless K, Romesser J, et al.* Opioid use among veterans undergoing major joint surgery managed by multidisciplinary transitional pain service. Reg Anesth Pain Med 2020; 45: 847-52.