Peripheral Nerve Blockade for Primary Total Knee Arthroplasty

A Population-based Cohort Study of Outcomes and Resource Utilization

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ABSTRACT

Background: Although peripheral nerve blocks decrease pain after total knee arthroplasty, the population-level impact of nerve blocks on arthroplasty resource utilization is unknown.

Methods: We conducted a population-based cohort study using linked administrative data from Ontario, Canada. We identified all adults having their first primary knee arthroplasty between 2002 and 2013. Using propensity scores to adjust for measureable confounders, we matched nerve block patients to a patient who did not receive a block. Within the matched cohort, we estimated the independent association of blocks with outcomes (length of hospital stay [primary]; and readmissions, emergency department visits, and falls [secondary]).

Results: One hundred seventy-eight thousand two hundred fourteen patients were identified; 61,588 (34.6%) had a block. The mean hospital stay was 4.6 days with a block compared to 4.8 without. After matching, there was a statistically significant decrease in the length of stay in the block group (relative risk, 0.98; 95% CI, 0.97 to 0.99; $P < 0.001$). Blocks were associated with a significant decrease in readmissions (relative risk, 0.87; 95% CI, 0.79 to 0.88; $P < 0.001$) but not emergency department visits (relative risk, 1.02; 95% CI, 0.98 to 1.05) or falls (relative risk, 1.37; 95% CI, 0.90 to 2.08). The association of blocks with length of stay after 2008 was inconsistent; overall, they were associated with longer stays; however, single-shot blocks were associated with shorter stays, while continuous techniques prolonged the length of stay.

Conclusions: Nerve blocks in total knee arthroplasty patients were associated with statistically significant reductions in length of stay and readmissions, but not emergency department visits or falls. The significance of these findings at the patient level and in contemporary practice requires further exploration in prospective randomized studies at low risk of indication bias.
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TOTAL knee arthroplasty (TKA) is one of the most common surgeries performed worldwide. In the United States alone, more than 700,000 knee replacements are performed annually,[1] a number which is increasing rapidly.[2] Despite advances in surgical and anesthetic techniques, poorly controlled pain after TKA continues to be an important issue for patients, clinicians, and the healthcare system.[3–5] While poor postoperative pain control can negatively affect patient-centered outcomes, including experience and satisfaction, it can also increase hospital length of stay (LOS)[6] and subsequent hospital readmissions and emergency department (ED) visits.[7]

Multiple strategies exist to optimize pain control after TKA including systemic opioids, intrathecal opioids, multimodal analgesia, local infiltration analgesia, and peripheral nerve blockade (PNB).[8] Recent Cochrane reviews of

What We Know about This Topic

- Peripheral nerve blocks reduce pain, but their effect on resource utilization after total knee arthroplasty remains unknown.
- In a propensity-matched retrospective cohort of 178,214 patients from Ontario, Canada, the authors estimated the independent association of peripheral nerve blocks with hospital length of stay, readmissions, emergency department visits, and falls.

What This Article Tells Us That Is New

- The length of stay was reduced in the nerve block group (relative risk [RR] 0.98; 95% CI, 0.97 to 0.99; $P < 0.001$). Nerve blocks were associated with a significant decrease in readmissions (RR, 0.87; 95% CI, 0.79 to 0.88; $P < 0.001$) but not emergency department visits (RR, 1.02; 95% CI, 0.98 to 1.05) or falls (RR, 1.37; 95% CI, 0.90 to 2.08).
- Peripheral nerve blocks very slightly reduced the hospital length of stay and reduced readmissions.

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randomized trials demonstrate that PNB for knee surgery is associated with improved postoperative pain control up to 72 h after surgery.[9] Small randomized trials show that femoral nerve blocks for TKA decrease time to meet discharge criteria,[10] improve early adherence to physical therapy, and accelerate rehabilitation.[11] However, no meta-analysis or large multicenter studies exist to estimate the impact of PNB on hospital LOS or healthcare resource utilization.[12] Based on the improved analgesia and accelerated recovery associated with PNBs, we hypothesized that the receipt of a PNB for TKA would decrease resource utilization and improve outcomes after surgery including decreased hospital LOS, decreased rates of hospital readmission, and fewer ED visits. We also investigated the association between PNBs and in-hospital falls.

Materials and Methods

Setting and Data

After ethics approval by the Sunnybrook Health Sciences Center (Toronto, Ontario, Canada), we conducted a population-based cohort study in Ontario, Canada, where hospital and physician services are provided to all residents through a publicly funded healthcare system and recorded in health administrative datasets that are collected using standardized methods.[13,14] All data were linked deterministically using encrypted patient-specific identifiers. Datasets used for the study included the Discharge Abstract Database (DAD), which captures all hospitalizations; the Ontario Health Insurance Plan (OHIP) database, which captures physician service claims; the National Ambulatory Care Reporting System, which captures details of all emergency and outpatient care; the Continuing Care Reporting System, which records details of long-term and respite care; the Ontario Drug Benefits Database, which captures prescription drug claims for residents 65 yr and older; and the Registered Persons Database (RPDB), which captures all death dates for residents of Ontario. The analytic dataset was created by a trained data analyst independent from the study team. Because the analytic data were generated from data normally collected at Institute for Clinical Evaluative Sciences (Toronto, Ontario, Canada), no further data processing was required. Analysis was performed by the lead author and overseen by the senior author. The study protocol was registered at clinicaltrials.gov (NCT02742961), and this manuscript is reported per the STrengthening the Reporting of OBservational studies in Epidemiology and the REporting of studies Conducted using Observational Routinely-collected health Data guidelines.[15,16]

Cohort

We identified all Ontario residents who were aged 18 yr or older on the day of their elective primary knee arthroplasty. These patients were identified using Canadian Classification of Interventions code 1VG53. Reabstraction studies of the DAD show this code to have a κ statistic of 0.99, sensitivity of 100% (95% CI, 98 to 100), and positive predictive value of 99% (95% CI, 96 to 100; prevalence, 1.4%).[17] The elective status of each admission was designated in the DAD. We included only the first surgery for each individual to ensure a patient-level analysis. Participants were identified from April 2002 (the date of introduction of the *International Classification of Diseases*, Tenth Edition (ICD-10), was introduced to identify diagnoses and the Canadian Classification of Interventions to identify procedures) to March 2014 (the latest time at which all datasets were complete).

Exposure

The provision of a PNB was identified from the OHIP database using physician fee-for-service claims. We identified all plexus or major nerve blocks performed on the day of surgery using OHIP codes G260 or G060, which identify lumbar plexus or 3-in-1 blocks and femoral nerve or fascia iliaca blocks, respectively. In 2008, a separate code was introduced for the insertion of a continuous PNB catheter (CPNB; G279); therefore, CPNBs were identified in patients cared for in 2008 and later. Physician procedural codes in Ontario are highly accurate, with 88 to 95% interrater agreement in reabstraction studies.[18] We categorized the PNB exposure as present or absent.

Outcomes

The primary outcome was hospital LOS. Secondary outcomes included 30-day all-cause readmissions and 30-day ED visits. We also identified in-hospital falls during the index hospital admission. All deaths in the 30 days after surgery were recorded. Acute hospital LOS was calculated as the days from surgery to discharge from acute care in the DAD, readmissions were identified from the creation of a new DAD record within 30 days of discharge, and falls were identified from the DAD using validated ICD-10 codes with high specificity (91%) and sensitivity (96%).[19] Deaths were identified from the RPDB and ED visits from the National Ambulatory Care Reporting System.

Covariates

Demographics were identified from the RPDB and the Canadian Census, including age, gender, neighborhood income quintile, and rural residence status. Standard methods were used to identify all Elixhauser comorbidities based on ICD-9 and ICD-10 codes from the DAD in the 3-yr preceding surgery.[20] For patients aged 65 yr and older, we identified the receipt of the following prescription medications in the 6 months before surgery: immediate release opioid analgesics, extended release opioid analgesics (including fentanyl patch), angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, antiarrythmatics, anticoagulants, anticonvulsants, antidepressants, antipsychotics, insulin, oral antihyperglycemics, antiplatelet agents, benzodiazepines, β blockers, oral corticosteroids, inhaled corticosteroids, inhaled bronchodilators, donepezil, rivastigmine,

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memantine, or galantamine. All acute care hospitalizations and ED visits in the year before the index admission were identified. The anesthesia type was captured from the DAD. The receipt of a preoperative anesthesia consultation and use of an intraoperative arterial line were also identified from OHIP data.

Analysis

SAS Enterprise Guide 6.1 (SAS Institute, USA) was used for all analyses. Patient characteristics were compared between PNB categories using absolute standardized differences, which are less sensitive to sample size than *P* values. For continuous variables, standardized differences are calculated as the difference in means divided by the square root of the mean sample variance between exposure groups; for dichotomous variables, the standardized difference represents the difference in the proportion with the covariate divided by the square root of the mean variance of the proportion with the covariate between exposure groups. Although no universal threshold has been established, differences of 10% or less are considered to indicate an adequate balance of covariates.[21]

Unadjusted analyses were performed for all outcomes. Because the indication for a PNB could be confounded by patient factors that are also related to the likelihood of experiencing our outcomes of interest, we also performed propensity score–matched analyses. We developed a nonparsimonious logistic regression model to predict the likelihood of receiving a PNB. Our propensity score model included patient gender, age (represented as a restricted cubic spline with five knots), year of surgery (represented as a restricted cubic spline with three knots), rural residence (binary), neighborhood income quintile (five-level categorical variable), all Elixhauser comorbidities (as binary variables), acute care hospitalizations in the year before admission (binary), ED visits in the year before surgery (binary), anesthesia type (categorized as general anesthesia [which included combined spinal or epidural plus general] or neuraxial anesthesia [spinal or epidural alone]), receipt of a preoperative anesthesia consult (binary), use of an intraoperative arterial line (binary), and each prescription medication described in the Covariates (each coded as three-level categorical variables representing no prescription drug coverage, drug coverage but no prescription for the medication, or drug coverage with a prescription for the medication). Because CPNBs could not be identified across the study period, the propensity score model grouped single-shot PNBs and CPNBs into a single exposure level.

A propensity score was assigned to each patient; individuals who received a PNB were matched 1 to 1 without replacement using a greedy matching algorithm that accounted for their propensity to receive a PNB (with caliper width equal to 0.2 SDs of the propensity score logit) to a patient with a similar propensity score who did not receive a PNB and who was operated on in the same hospital. Matching 1:1 has been shown to reduce bias relative to 1: many matching.[22] By matching on the propensity score between patients within the same hospitals, we were able to account for unobserved hospital-level characteristics and the hierarchal nature of population-based health administrative data. Studies demonstrate that within-cluster matching decreases bias and error compared to matching only on the propensity score.[23] Propensity score match success was assessed by (1) achieving a balance of all measured covariates between groups defined by a standardized difference of less than or equal to 10%; (2) visual inspection of pre- and postmatch propensity score distributions; and (3) ensuring that a large number of matched pairs were created to support the precision and generalizability of our findings.[24]

For our primary analysis, unadjusted and propensity score match–adjusted analyses measured the association between PNB and LOS using a generalized linear model with negative binomial distributed errors and a log link to account for the skewed LOS distribution.[25] For our secondary analyses (risk of readmission, ED visits, and falls), we used chi-square tests. For all outcomes, we calculated absolute differences, as well as relative risk and 95% CI.

We performed three-subgroup analyses to test the robustness of our primary findings. For each subgroup analysis, a new propensity score was generated for each member of the specified subgroup and a new match performed within the specific subgroup (*i.e.*, we generated three new sets of propensity scores and three specific matched subgroup cohorts). Our subgroups of interest were patients 66 yr or older (all of whom had complete prescription drug data), patients operated on in the first half of the study period (2002 to 2007), and patients operated on in the second half of the study period (2008 to 2013/2014, the period where CPNBs could be identified). Matching and outcome analyses within each subgroup were done as described for the primary and secondary analyses.

To explore the impact of CPNBs on outcomes, we preformed *post hoc* sensitivity analyses using multivariable regression in the subgroup of patients whose surgery was in 2008 or later (generalized linear models with γ distributed errors and a log link for LOS, logistic models for all other binary outcomes) with a three-level categorical variable as the exposure of interest (no PNB [reference], PNB no nerve catheter, and PNB plus nerve catheter). All models controlled for gender, age, year of surgery, rural residence, neighborhood income quintile, all Elixhauser comorbidities, acute care hospitalizations in the year before admission, ED visits in the year before surgery, anesthesia type, receipt of a preoperative anesthesia consult, use of an intraoperative arterial line, and preoperative opioid use.

Missing Data

Main outcome and exposure variables were complete for all participants. Neighborhood income quintile was imputed for with the group median for 0.4% of patients; rurality was imputed with the most common value (nonrural residence) for 0.1% of patients. No other data were missing, and all linkages were complete.

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Results

We identified 234,884 episodes of elective primary TKA between 2002 and 2014 (fig. 1). After excluding subsequent knee replacements in the same patient (*i.e.*, future operations on the other knee), we were left with 178,214 patients for analysis. Peripheral nerve blocks were performed in 61,588 (34.6%) patients. CPNBs were placed in 7,685 individuals (7.9% of all patients in 2008 and later, 16.4% of all patients receiving a PNB in this time period). Patient characteristics are described in table 1. Before matching, standardized differences were less than 10% for most covariates. Patients who received a block were less likely to live in a rural setting, had a higher American Society of Anesthesiology score, and were more likely to be seen preoperatively in consultation with an anesthesiologist.

The use of PNBs increased substantially over the course of our study (fig. 2). Major plexus blocks (which would represent a lumbar plexus or a 3-in-1 block) were billed in 48,791 (79%) of patients receiving a PNB with the remainder being billed as a major nerve block (femoral or fascia iliaca block). All CPNBs were placed in conjunction with a major nerve block.

Propensity score matching resulted in 38,557 PNB patients (62.6% of all PNB patients) being matched to a similar patient from the same hospital who did not receive a PNB. The balance of covariates assessed by a standardized difference of 10% or less was achieved across all measured confounders (table 1), and propensity score distribution overlap improved noticeably (Appendix).

In the 30 days after surgery, 438 (0.25%) patients died (282 in the no PNB group and 156 in the PNB group). The overall rate of falls was 0.7 per 1,000 in-hospital patient days.

Unadjusted and propensity score match–adjusted results of our primary and secondary analyses are described in table 2. LOS was shorter in the PNB group before and after adjustment. The risk of readmission was lower in the PNB group in both crude and adjusted analyses. Before propensity score adjustment, the risk of an ED visit was lower in the PNB group; however, the adjusted association was nonsignificant. PNBs were not associated with the risk of falling before or after propensity score adjustment, although the total number of falls in the study was small.

The findings of the subgroup analysis are provided in table 3 In patients more than 65 yr old, adjusted results mirrored the findings of the primary analysis, except that ED visits were more likely in the PNB group. However, the associations between PNBs with decreased LOS and readmission risk were not consistent over time. Before 2008, findings across outcome measures were similar to the results of the primary analysis, including a significant reduction in LOS and readmissions; after 2008, we found that PNBs were associated with a small but statistically significant increase in LOS, while their association with a decreased risk of readmission was no longer present.

Our sensitivity analyses demonstrated that compared to no block, CPNBs were associated with significant increases in LOS, no difference in readmission risk, decreased risk of ED visits, and no difference in fall risk (table 4). Single-shot PNBs were significantly associated with decreases in LOS, readmissions, and ED visits. Although our regression model analyzing postoperative falls did converge, due to the small number of outcomes (*i.e.*, falls) relative to degrees of freedom in the model, these results must be interpreted with greater caution as this model may overfit our available data.

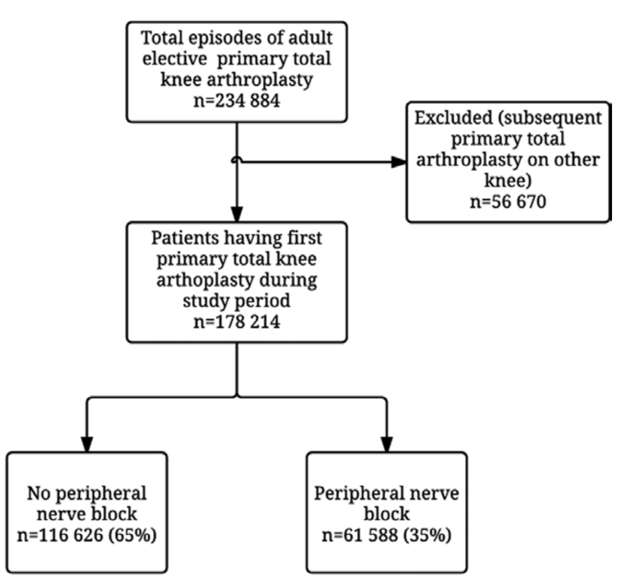

Fig. 1. Creation of analytical dataset.

DISCUSSION

In this population-based cohort study of peripheral nerve blocks for primary TKA, the receipt of a PNB was associated with significantly decreased postoperative LOS and decreased risk of 30-day hospital readmission. However, these positive impacts of PNBs on postoperative resource utilization were not entirely consistent over time and across subgroups. This heterogeneity may reflect a variety of factors, including different impacts of single-shot *versus* continuous nerve block techniques, or changes in the application of perioperative multimodal analgesia strategies over time. Given this heterogeneity and the finding that our primary outcome of LOS was statistically, but possibly not clinically, significant at the individual patient level, randomized evaluations of continuous *versus* single-shot PNBs in high-priority patient populations are needed to inform the optimized provision of perioperative care for TKA patients, including the study of patient-reported outcome measures.

The current study provides important and generalizable information that enhances the current body of knowledge regarding PNBs for TKA. In a real-world setting, PNBs were significantly associated with a decrease in LOS and readmissions after surgery, outcomes that are both important drivers of healthcare resource utilization. An independent decrease in LOS of 0.1 days may not be highly relevant at the individual

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Table 1. Baseline Characteristics of Study Population

	PNB, n = 61,588	No PNB, n = 116,626	Standardized Difference	Propensity Score–matched Cohort PNB, n = 38,557	Propensity Score–matched Cohort No PNB, n = 38,557	Propensity Score–matched Cohort Standardized Difference
Demographics						
Age, mean (SD)	68 (10)	68 (10)	0.0	68 (10)	68 (10)	0.0
Female, %	62.3	64.9	5.4	61.6	61.9	0.6
Rural, %	13.1	19.2	16.6	15.9	13.2	7.7
Neighborhood income quintile, median (IQR)	3 (4–2)	3 (4–2)	0.0	3 (4–2)	3 (4–2)	0.0
Comorbidities						
Alcohol abuse, %	0.4	0.5	1.5	0.5	0.5	0.0
ASA score, < 3	42.4	51.4	18.1	46.5	49.1	5.2
Atrial arrhythmia, %	1.8	2.1	2.2	2.1	2.0	0.7
Blood loss anemia	2.8	3.5	4.0	3.2	3.3	0.6
Cardiac valvular disease, %	1.1	1.2	0.9	1.2	1.2	0.0
Cerebrovascular disease, %	1.0	1.1	1.0	1.1	1.1	0.0
Chronic obstructive pulmonary disease, %	4.5	4.8	1.4	4.6	5.2	2.8
Coagulopathy, %	0.7	1.1	4.2	0.9	1.0	1.0
Deficiency anemia	0.2	0.3	2.0	0.3	0.4	1.7
Dementia, %	0.2	0.2	0.0	0.2	0.2	0.0
Depression, %	1.4	1.4	0.0	1.2	1.4	1.8
Diabetes mellitus without complications, %	12.9	12.2	2.1	12.6	12.6	0.0
Diabetes mellitus with complications, %	4.2	3.8	2.0	4.4	3.4	5.2
Dialysis, %	0.1	0.2	2.6	0.2	0.2	0.0
Disease of pulmonary circulation, %	1.1	1.0	1.0	1.1	1.0	1.0
Drug abuse, %	0.2	0.2	0.0	0.2	0.2	0.0
Heart failure, %	1.7	1.9	1.5	1.9	2.0	0.7
Hemiplegia, %	0.1	0.1	0.0	0.1	0.1	0.0
Hypertension without complications, %	30.3	27.9	5.3	30.3	29.5	1.7
Hypertension with complications, %	0.6	0.5	1.4	0.6	0.5	1.4
Liver disease, %	0.2	0.3	2.0	0.2	0.2	0.0
Malignancy, %	1.7	1.9	1.5	1.8	1.8	0.0
Metastases, %	0.2	0.2	0.0	0.2	0.2	0.0
Obesity, %	6.1	5.1	4.4	4.8	5.2	1.8
Peptic ulcer disease, %	0.4	0.4	0.0	0.5	0.5	0.0
Peripheral vascular disease, %	0.5	0.5	0.0	0.6	0.5	1.4
Psychoses, %	0.2	0.3	2.0	0.2	0.2	0.0
Renal disease, %	0.6	0.6	0.0	0.6	0.6	0.0
Rheumatic disease, %	0.7	0.8	1.2	0.8	0.9	1.1
Venous thromboembolism, %	0.3	0.3	0.0	0.3	0.4	1.7
Healthcare resource use						
Hospitalization in the last year	7.6	8.6	3.7	7.9	8.4	1.8
Emergency department visit in the last year, %	28.9	30.9	4.4	29.5	29.2	0.7
Anesthesia care						
Arterial line, %	2	2.9	5.8	2.8	2.3	3.2
Preoperative anesthesiology consult, %	79	63.6	34.5	71.9	73.6	3.8
General anesthesia, %	28.7	32.9	9.1	37.2	34.1	6.5
Prescription drugs*						
ACE-I/ARB, %	28.5	28.1	0.9	28.8	28.4	0.9
Antiarrythmatic, %	1.1	1.1	0.0	1.1	1.2	0.9
Insulin, %	1.7	1.7	0.0	1.7	1.6	0.8
Anticoagulant, %	4.9	5	0.5	5.1	5	0.5
Oral diabetes agent, %	8.9	8.4	1.8	8.9	8.6	1.1
Antiplatelet agent, %	2.1	1.9	1.4	2.1	1.9	1.4
β-blocker, %	15	15.5	1.4	15.9	15.8	0.3
Inhaled bronchodilator, %	6.5	6.4	0.4	6.6	6.7	0.4
Inhaled corticosteroid, %	6.2	6	0.8	6.1	6.3	0.8
Oral corticosteroid, %	2.2	2.4	1.3	2.4	2.3	0.7
Immediate release opioid, %	17.5	18.1	1.6	18.2	18.8	1.5
Extended release opioid, %	1.9	1.8	0.7	2.0	1.9	0.7

*This proportion indicated the proportion of the total sample who received a prescription for this drug.

ACE-I/ARB = angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; ASA = American Society of Anesthesiology; IQR = interquartile range; PNB = peripheral nerve block.

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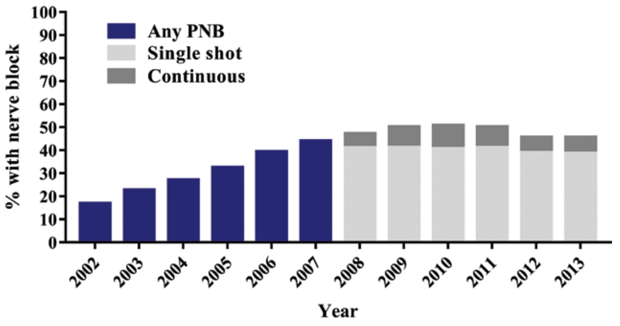

Fig. 2. Yearly proportion of patients receiving any peripheral nerve block (PNB) or a continuous PNB (continuous techniques could only be identified from 2008 onward; data are aggregated by administrative years. For example, the 2002 year includes patients from April 2002 to March 2003).

patient level and is substantially less than the 1.7-day decrease in time to discharge readiness found in a recent randomized trial.[10] However, when extrapolated across the 719,000 TKAs performed in the United States in 2010,[26] this equates to a 79,000-hospital bed days per year decrease. At an average cost of $1,600 per hospital bed day,[27] this could translate into annual savings of over $100 million. With an average readmission cost of approximately $10,200, a 0.6% decrease in readmission rates could also be projected to save millions of dollars per year.[28] However, the lack of consistent association between PNBs and decreased resource since 2008 requires that these projections be tempered and underlying changes in practice be considered when explaining this temporal trend.

Overall, changes in the utilization of PNBs, as well as in postoperative resource utilization, were clear across our study period. Patients cared for between 2002 and 2007 had

Table 2. Study Outcomes

	No PNB	PNB	Relative Risk (95% CI)	*P* Value
Unadjusted	n = 116,626	n = 61,588		
Length of stay, mean (SD)	4.8 (4.3)	4.6 (3.7)	0.95 (0.94–0.96)	< 0.001
Readmission, n (%)	3,787 (4.1)	2,277 (3.4)	0.83 (0.79–0.88)	< 0.001
Emergency department visit, n (%)	16,073 (15.2)	9,643 (13.3)	0.85 (0.83–0.89)	< 0.001
In-hospital fall, n (%)	157 (0.2)	103 (0.1)	0.96 (0.75–1.23)	0.72
Propensity score match adjusted	n = 38,557	n = 38,557		
Length of stay, mean (SD)	4.8 (4.1)	4.7 (3.9)	0.98 (0.97–0.99)	< 0.001
Readmission, n (%)	1,421 (4.4)	1,334 (3.8)	0.87 (0.81–0.94)	< 0.001
Emergency department visit, n (%)	5,223 (13.6)	5,312 (13.8)	1.02 (0.98–1.05)	0.35
In-hospital fall, n (%)	38 (0.05)	52 (0.07)	1.37 (0.90–2.08)	0.14

PNB = peripheral nerve block.

Table 3. Outcomes of Subgroup Analyses

	No PNB	PNB	Crude* RR (95% CI)	PS-adjusted RR (95% CI)	PS-adjusted *P* Value
> 65 yr old					
Propensity score match adjusted	n = 38,557	n = 38,557			
Length of stay, mean (SD)	5.2 (4.8)	5 (4.5)	0.94 (0.93–0.95)	0.97 (0.96–0.98)	< 0.001
Readmission, n (%)	1,536 (6.8)	1,145 (5.1)	0.86 (0.81–0.92)	0.91 (0.84–0.98)	0.013
Emergency department visit, n (%)	3,081 (13.7)	3,203 (14.2)	0.88 (0.86–0.91)	1.05 (1.01–1.09)	0.02
In-hospital fall, n (%)	67 (0.2)	75 (0.2)	0.93 (0.72–1.19)	1.12 (0.90–2.08)	0.51
2002–2007					
Propensity score match adjusted	n = 15,812	n = 15,812			
Length of stay, mean (SD)	5.2 (4.1)	5 (3.9)	0.95 (0.93–0.97)	0.97 (0.96–0.98)	< 0.001
Readmission, n (%)	909 (5.1)	815 (4.3)	0.86 (0.79–0.93)	0.84 (0.77–0.92)	< 0.001
Emergency department visit, n (%)	2,335 (13.1)	2,433 (12.8)	0.89 (0.86–0.93)	0.98 (0.93–1.03)	0.39
In-hospital fall, n (%)	53 (0.2)	41 (0.2)	1.15 (0.82–1.62)	1.26 (0.84–1.90)	0.27
2008–2013					
Propensity score match adjusted	n = 18,119	n = 18,119			
Length of stay, mean (SD)	4.3 (3.8)	4.4 (3.5)	1.02 (1.01–1.03)	1.03 (1.02–1.04)	< 0.001
Readmission, n (%)	579 (3.2)	590 (3.3)	0.9 (0.84–0.96)	1.02 (0.91–1.14)	0.77
Emergency department visit, n (%)	2,689 (15)	2,609 (14.5)	0.82 (0.80–0.85)	0.97 (0.92–1.02)	0.23
In-hospital fall, n (%)	23 (0.1)	33 (0.1)	0.95 (0.70–1.28)	1.43 (0.84–2.44)	0.23

*Crude refers to the measure of association before propensity score matching within each subgroup.

PNB = peripheral nerve block; PS = propensity score; RR = relative risk.

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Table 4. Sensitivity Analyses (2008 to 2013)

	No PNB,* n = 50,351	PNB only, n = 39,040	CPNB, n = 7,685
Outcome			
Length of stay, adjusted RR (95% CI)	1	0.98 (0.98–0.99)	1.05 (1.04–1.07)
Readmission, adjusted OR (95% CI)	1	0.89 (0.83–0.96)	0.88 (0.76–1.01)
Emergency department visit, adjusted OR (95% CI)	1	0.82 (0.79–0.86)	0.86 (0.80–0.92)
In-hospital fall, adjusted OR (95% CI)	1	1.14 (0.83–1.57)	0.90 (0.47–1.70)

*No PNB group is reference.
CPNB = continuous peripheral nerve block; OR = odds ratio; PNB = peripheral nerve block; RR = risk ratio.

longer LOS and higher readmission rates than those cared for between 2008 and 2013, regardless of PNB exposure. Therefore, the broad focus on more efficient use of healthcare resources in the setting of constrained hospital and health system budgets, as well as the use of these outcomes as hospital quality metrics, may have driven down LOS and readmission rates to the point that the additional analgesic impact of a PNB no longer translates into expedited discharge and avoidance of readmissions at a population level. Additionally, important changes to the perioperative care of TKA patients have recently emerged, such as increased use of standard perioperative care pathways,[29] increased uptake of perioperative multimodal analgesia,[30] and routine use of local infiltration analgesia.[31] In fact, a recent systematic review found that, compared to femoral nerve blocks, LOS in local infiltration analgesia patients after TKA was not significantly different.[32]

The divergence between outcomes over time was also informed by our sensitivity analysis. When the association between PNBs and CPNBs with outcomes was looked at separately in patients from 2008 onward, single-shot PNBs continued to be associated with improved resource utilization, while CPNBs were associated with an increase in LOS and no change in readmission risk. The increase in LOS attributable to CPNBs could be related to complexities with in-hospital management of catheters and discharge planning, or it could suggest that unmeasured sources of indication bias underlying a clinician's decision to place a CPNB as opposed to a single-shot PNB (such as higher risk of poor recovery or pain tolerance) were present and inadequately captured by administrative data. However, the lack of clear resource use benefit with CPNBs in particular should be considered and requires future study. The divergence in findings related to ED visits when PNBs and CPNBs were considered separately may relate to the fact that propensity score–matched analyses provide an average treatment effect in the treated (*i.e.*, the impact of treatment is only measured in the subset of the population that can be matched) compared to a regression analysis that provides an average treatment effect (*i.e.*, the impact of moving the whole population between different interventions).[33]

Overall, it does appear that at least for single-shot PNBs, there is a consistent and generalizable association with improved resource utilization after surgery. However, as with any intervention, the risks and benefits of PNBs must be considered for each patient. In our study, we addressed two pertinent safety issues. First, in some major orthopedic surgeries, decreased LOS is associated with an increased risk of postdischarge adverse events.[34] Reassuringly, despite a reduced LOS, we found that PNB patients were less likely to be readmitted, and there was no consistent signal toward an increase in ED visits. Second, the proven efficacy of PNBs in improving pain outcomes[9,12] must be weighed against risks of adverse events (such as falls). As in previous studies,[35] our findings support a lack of statistically significant association between single-shot PNBs and fall risk after TKA. Based on our findings using a validated definition of falls in health administrative data, there also does not appear to be an association between CPNBs and falls.[36,37] However, this finding is by no means definitive. Despite the lack of statistically significant association, falls were rare in our study but were more frequent in the PNB group (37% relative risk increase). We suggest that falls should continue to be studied as an important safety issue in the setting of lower limb PNB.

Strengths and Limitations

This study features several strengths, as well as limitations, that must be considered when appraising our findings. Our use of population-based data allowed us to study the broad range of TKA patients across a universal healthcare system; therefore, our findings may be generalizable to similar patients in similar jurisdictions. While the propensity score methods used in this study to control for indication and confounding bias are robust, account for clustering within hospitals, and include preoperative data that many studies of anesthesia interventions do not (such as longitudinal prescription drug records and a 3-yr lookback window for comorbidity data), we could control only for measured confounders. By its nature, observational research of interventions is at the risk of indication bias, and our findings must be considered in the context of this important limitation. The health administrative data used were not initially collected for research purposes and have limitations. The codes used to define our TKA cohort and to measure outcomes have been studied and are known to be accurate and reliable. Physician fee-for-service claims have been found to be highly accurate; however, the specific diagnostic accuracy of the codes

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used to identify PNBs in this study has not been formally measured. Additionally, we cannot know with certainty the specific block that was performed (3-in-1, lumbar plexus, fascia iliaca, femoral nerve, or possibly adductor canal block) although surveys suggest that over 80% of PNBs for TKA are femoral blocks.[38] It appears that most single-shot blocks for TKA in Ontario are billed as major plexus blocks, while CPNB insertion is billed in conjunction with a major nerve block. This is credible, since the physician services agreement dictates that a catheter cannot be billed in addition to a major plexus block, but billing a major nerve block plus a continuous catheter would result in a higher payment to the physician. We are also unable to control for the clinical effectiveness of the PNBs, provision of local infiltration analgesia, or systemic multimodal analgesia; however, we would predict that these missing data would bias our results toward the null (*i.e.*, decrease the impact of PNBs). Finally, our outcomes were limited to measures of healthcare resource utilization. The development of a full understanding of the value attributable to PNBs for TKA will require a prospective study, including patient-centered outcome measures.

Conclusions

The provision of a peripheral nerve block for TKA was associated with a small but significant decrease in the hospital LOS and a significant reduction in the risk of readmission. For single-shot peripheral nerve blocks, this finding was consistent over time, while the positive impact of continuous catheter techniques on outcomes was less clear. Furthermore, neither single-shot or continuous catheter techniques were significantly associated with an increased risk of in-hospital falls. Future research on the impact of peripheral nerve blocks on patient-reported outcome measures is needed.

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Competing Interests

Dr. McIsaac receives salary support from the Ottawa Hospital Anesthesiology Associates Alternate Funds Association *via* The Ottawa Hospital Department of Anesthesiology, Ottawa, Ontario, Canada. The other authors declare no competing interests.

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Appendix

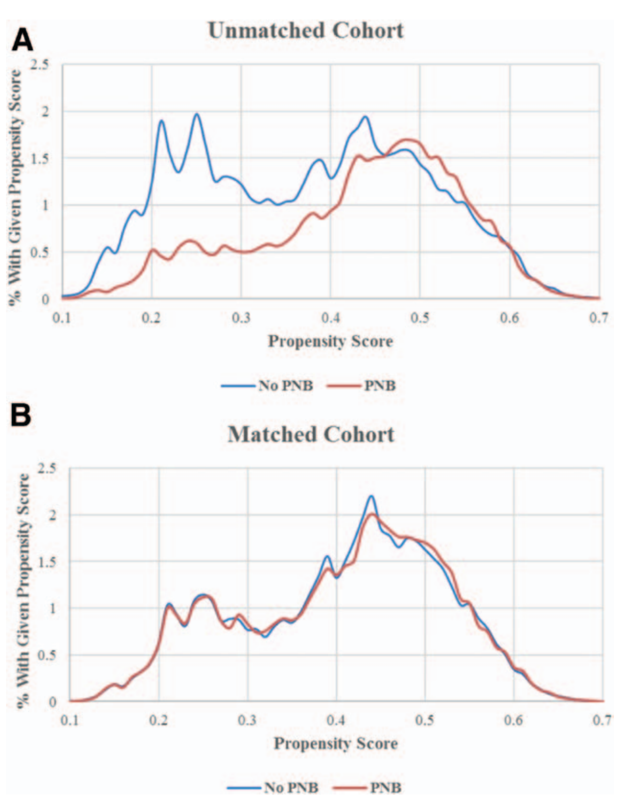

Fig. A1. Propensity score distributions before (*A*) and after (*B*) matching. Closer overlap of distributions indicates the improved balance of covariates between peripheral nerve block (PNB) and no PNB groups.

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