ANESTHESIOLOGY

Peripheral Nerve Blocks for Ambulatory Shoulder Surgery

A Population-based Cohort Study of Outcomes and Resource Utilization

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ABSTRACT

Background: Nerve blocks improve early pain after ambulatory shoulder surgery; impact on postdischarge outcomes is poorly described. Our objective was to measure the association between nerve blocks and health system outcomes after ambulatory shoulder surgery.

Methods: We conducted a population-based cohort study using linked administrative data from 118 hospitals in Ontario, Canada. Adults having elective ambulatory shoulder surgery (open or arthroscopic) from April 1, 2009, to December 31, 2016, were included. After validation of physician billing codes to identify nerve blocks, we used multilevel, multivariable regression to estimate the association of nerve blocks with a composite of unplanned admissions, emergency department visits, readmissions or death within 7 days of surgery (primary outcome) and healthcare costs (secondary outcome). Neurology consultations and nerve conduction studies were measured as safety indicators.

Results: We included 59,644 patients; blocks were placed in 31,073 (52.1%). Billing codes accurately identified blocks (positive likelihood ratio 16.83, negative likelihood ratio 0.03). The composite outcome was not significantly different in patients with a block compared with those without (2,808 [9.0%] *vs.* 3,424 [12.0%]; adjusted odds ratio 0.96; 95% CI 0.89 to 1.03; $P = 0.243$). Healthcare costs were greater with a block (adjusted ratio of means 1.06; 95% CI 1.02 to 1.10; absolute increase $325; 95% CI $316 to $333; $P = 0.005$). Prespecified sensitivity analyses supported these results. Safety indicators were not different between groups.

Conclusions: In ambulatory shoulder surgery, nerve blocks were not associated with a significant difference in adverse postoperative outcomes. Costs were statistically higher with a block, but this increase is not likely clinically relevant.

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- The use of peripheral nerve blocks after ambulatory shoulder surgery is increasing
- While short-term pain control is improved by nerve blocks in this context, the relationship with postdischarge outcomes is unclear

What This Article Tells Us That Is New

- Peripheral nerve blocks are associated with a decrease in unplanned admissions after ambulatory shoulder surgery
- There is no associated improvement in other postoperative outcomes such as emergency department visits, readmissions, mortality, or costs

Ambulatory surgeries are increasingly common.[1,2] Compared to inpatient surgery, ambulatory surgery results in lower costs with similar safety.[3,4] However, despite low incidence of serious complications after ambulatory surgery,[5] more than 3% of patients require unplanned hospital admission on the day of surgery,[6] and more than 10% of patients have an emergency department visit in the 30 days after surgery.[7] Evidence suggest that more than 25% of unanticipated admissions after ambulatory surgery are attributable to anesthesiology care and interventions.[8]

Variations in perioperative anesthesia care for shoulder surgery have been documented.[9] The majority of ambulatory shoulder surgeries are performed with general anesthesia, although there is wide variation in reported institutional practices regarding provision of peripheral nerve blocks (20 to 86%).[2,10] This may reflect a lack of comparative effectiveness evidence to guide the choice of optimal perioperative management strategies.[11] Recent systematic reviews suggest that nerve blocks provide the highest degree of acute postoperative pain relief in ambulatory shoulder surgery patients; however, high-quality evidence supporting a positive impact of regional anesthesia on longer-term outcomes is lacking.[12–14] Population-based studies could help to address this lack of data; however, available studies are at risk of bias as they have used exposures and outcomes that have not been

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previously validated, while postdischarge outcomes have not been comprehensively examined.[15,16]

Therefore, after validation of a case-ascertainment algorithm to identify nerve blocks in health administrative data (against a clinical reference standard), we hypothesized that receipt of a nerve block would reduce the odds of unplanned day of surgery admissions, emergency department visits, hospital readmissions or deaths within 7 days of surgery (combined as a composite primary outcome). We further hypothesized that nerve blocks would decrease healthcare costs and would not increase the incidence of adverse neurologic issues requiring diagnostic testing or consultation.

Materials and Methods

Design and Setting

After ethics approval by the Ottawa Health Sciences Network Research Ethics Board, Ottawa, Canada (REB #: 20160800-01H), we conducted a population-based historical cohort study in Ontario, Canada, a province of more than 13 million people that provides universal health care coverage to all residents. Written informed consent was legally waived. The administration of Ontario's universal health insurance plan produces population-based health administrative data that are collected using standardized disease classifications, procedural terminologies, and abstraction, which are stored at the Institute for Clinical Evaluative Sciences (IC/ES), Toronto, Canada, an independent research institute. The study period extended from April 2009 to December 2016. The start time was chosen to coincide with the introduction of a specific physician billing code in Ontario to identify the placement of continuous nerve catheters (this code was added in 2008; we elected to use a 1-yr washout period after implementation to promote data consistency). The end time was the latest time at which all datasets were complete.

Data Sources

All data were linked deterministically using encrypted patient-specific identifiers. Datasets used included the Same Day Surgery Database, which records all ambulatory surgical procedures performed (*i.e.*, those with planned hospital stays of less than 24 h) and present on admission diagnoses; the National Ambulatory Care Reporting System, which records all emergency department visits; the Discharge Abstract Database, which records all inpatient hospital admissions and present on admission diagnoses; the Ontario Health Insurance Plan database, which captures physician service claims; the Ontario Drug Benefits Database, which captures prescription drug claims for residents 65 yr and older; and the Registered Persons Database, which captures 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 the IC/ES, no further data processing was required. The analysis was performed by an independent analyst following an analysis plan prespecified by the lead and senior author. The study protocol was registered at clinicaltrials.gov (NCT03544775), and the 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.[17,18]

Cohort

We included Ontario residents, aged 18 yr and older, who underwent elective ambulatory shoulder surgery. Participants were identified using the Same Day Surgery Database through application of previously studied Canadian Classification of Interventions codes to identify the following shoulder surgeries: rotator cuff repair, shoulder arthroplasty or joint repair, and other repair of shoulder muscles (see specific codes in Supplemental Digital Content, appendix 1, http://links.lww.com/ALN/B993).[7] We compiled a patient-level cohort by including only the first surgery for any participant in the study period.

Exposure

Our primary exposure was receipt of a nerve block. Before any outcome analysis, we validated the exposure definition by measuring the accuracy and validity of a case ascertainment algorithm to identify receipt of a nerve block in health administrative data (see full description in Supplemental Digital Content, appendix 2, http://links.lww.com/ALN/B993). Briefly, our algorithm consisted of physician billing codes in Ontario Health Insurance Plan (G260-major plexus block, G060-major nerve block, G061-minor nerve block, or G279-percutaneous nerve block catheter for continuous infusion analgesia) compared to a reference standard of nested clinical data from a single hospital linked to the IC/ES. Full validation is described in the Supplemental Digital Content, appendix 2 (http://links.lww.com/ALN/B993), but briefly, we defined our reference standard from The Ottawa Hospital Data Warehouse, a peer-reviewed central data repository that stores a combination of administrative and clinical data for all patients cared for at The Ottawa Hospital, Ottawa, Canada, and includes all electronic anesthesia medical records (which are the medico-legal standard for anesthesia data collection). The validation data contained all adult ambulatory shoulder surgery patients at The Ottawa Hospital from January 2013 to December 2016. The algorithm was highly accurate (positive likelihood ratio 16.83, negative likelihood ratio 0.03; sensitivity 97%, specificity 94%) for correctly identifying the true presence (or absence) of a nerve block.

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For our main outcome study we compared (1) no nerve block (*i.e.*, no physician billing codes) to (2) nerve block (*i.e.*, presence of a nerve block billing code). We also identified any patient who had a continuous catheter inserted to allow for a sensitivity analysis using the billing code G279.

Outcomes

Our primary outcome was a composite including (1) unplanned admissions on the day of surgery (from the Discharge Abstract Database), (2) postdischarge emergency department visits within 7 days of surgery (from National Ambulatory Care Reporting System), (3) readmission within 7 days of surgery (from the Discharge Abstract Database), and (4) death from any cause (from the Registered Persons Database). We included mortality, even though it is a rare after ambulatory surgery, as it is a competing risk.[19] The most responsible diagnosis, as defined by the treating physician, for all emergency department visits was identified. Our secondary outcome was total health system costs from the perspective of the payer (*i.e.*, the Ontario Ministry of Health and Longterm Care, Toronto, Ontario, Canada), calculated from the day of surgery to 7 days after surgery. To calculate these costs, we used standardized patient-level costing algorithms that include all direct health system costs (*i.e.*, those directly attributable to the patient such as physician service claims, diagnostic and laboratory testing, pharmaceuticals, equipment or medical devices, home care) as well as indirect costs (*i.e.*, health system utilization of inpatient and outpatient hospital care, emergency care, inpatient rehabilitation, complex continuing care and long-term-care). The indirect costs are calculated by accounting for an individual's resource intensity weight, case-mix group, and duration of care in each location. This approach does include the cost of surgery, but lacks the granularity to specifically account for materials used in the operating room (such as regional anesthesia supplies), although the fee paid to the anesthesiologist for placing the block is included.[20] Costs incurred by the individual patient that are not covered by the health system (*e.g.*, private physiotherapy, custom slings or braces, or opportunity costs such as missed time at work) are not included. Costs were standardized to 2016 Canadian dollars. We also evaluated the composite outcome and health system costs in the 30 days after surgery.

As an indicator of possible nerve injury or complication from the nerve block, we examined the rate of neurology consults (Ontario Health Insurance Plan physician billing code A180-special neurology consultation, A/C188-neurology partial assessment or concurrent care, or A/C385-neurology limited consultation) and nerve conduction studies (code G455-G456–complete electromyography study, both technical/professional component, or G466/G457–limited electromyography study, both technical/professional component) in the 90 days after surgery. A time frame of 90 days was chosen to ensure late presentations of peripheral nerve injuries would not be missed. Electromyography has improved diagnostic utility if performed more than 3 weeks after injury, which may not have been captured if a shorter time frame was used.[21]

Covariates

Patient demographics, comorbidities, and preoperative patterns of healthcare resource use could confound the association between receipt of a nerve block and outcomes. Therefore, we collected detailed baseline data on all participants: age (restricted cubic spline with five knots), gender (binary), rural residence (binary), neighborhood income quintile (five-level categorical), year of surgery (restricted cubic spline with three knots), validated chronic disease status for asthma[22] (binary), chronic obstructive pulmonary disease[23] (binary), diabetes mellitus[24] (binary), acute coronary syndrome[25] (binary), heart failure[26] (binary) and hypertension[27] (binary), all Elixhauser comorbidities (using a 3-yr lookback, each as a binary variable),[28] American Society of Anesthesiologists score (2 or lower *vs.* 3 or higher), baseline 1-yr mortality risk using the Johns Hopkins Adjusted Clinical Groups score (continuous linear; derived using Adjusted Diagnosis Groups[29] from each individuals' inpatient and outpatient contact with the health system). The Johns Hopkins Adjusted Clinical Groups scores were then assigned points to produce a measure of baseline mortality risk that has been validated across the full Ontario population (c-statistic 0.92, well-calibrated across the risk spectrum),[30] acute care hospitalization in the previous year (binary), emergency department visits in the previous year (categorical: 0, 1, 2 or greater); and predicted healthcare utilization based on the Johns Hopkins Adjusted Clinical Groups Resource Utilization Band (six-level categorical),[29] which accounts for patterns of preoperative inpatient and outpatient health resource use. Last, all prescriptions for oral and transdermal opioids (short- and long-acting) were identified from the Ontario Drug Benefits Database for all people older than 65 yr in the 6 months before surgery.

Data Analysis

The dataset was created, manipulated, and analyzed using SAS version 9.4 (SAS Institute, Cary, North Carolina). After reviewer feedback, absolute standardized differences were used to compare baseline characteristics between exposure groups instead of tests of significance; values greater than 10 are felt to represent substantial differences.[31]

We calculated the unadjusted and adjusted association between nerve blocks and outcomes. Generalized linear mixed models (PROC GLIMMIX) were used to account for clustering of patients within hospitals (which was the highest level of hierarchy in our data)[32] using a random intercept term in all adjusted analyses. Dichotomous outcomes (our primary outcome and its components, safety outcomes) were analyzed using logistic regression. Cost data, which are typically skewed, were analyzed using a gamma

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distribution and a log link.[33] Adjusted differences in attributable costs were calculated by estimating the predicted adjusted cost from the log-gamma cost model, followed by creation of 1,000 bootstrap samples with replacement. We then calculated the median adjusted cost difference across the bootstrap samples as the effect size and CI using the percentile method.[34] All adjusted models included the variables listed in the Covariates section, plus a categorical variable for the specific type of shoulder surgery based on the type of surgery (three-level categorical) and a binary indicator for open *versus* arthroscopic approach (derived from the Canadian Classification of Interventions code). All analyses were conducted using two-tailed hypothesis testing with a P value of less than 0.05 as statistically significant. Adjustment for multiple testing was not specified; however, a conservative adjustment for the fact that we had two main primary analyses (*i.e.*, the composite outcome and costs), such as a Bonferroni corrected P value of 0.025, would not have changed the significance threshold interpretation for either result.

Sensitivity Analyses

We performed several prespecified sensitivity analyses to test the robustness of our primary analysis. First, we recalculated the adjusted associations for our primary outcome restricting the cohort to people older than 65 yr to evaluate whether addition of preoperative opioid drug data impacted our estimated associations. Next, we tested whether our choice of analytic approach impacted our primary findings. We used a nonparsimonious logistic regression model to assign a propensity score for receipt of a nerve block to each person based on covariates used in the primary analysis. We then matched patients who received a nerve block one-to-one without replacement exactly on the index hospital (to account for clustering), and then using a greedy matching algorithm based on a caliper width of 0.2 times the logit of the SD of the propensity score. Within this propensity score matched cohort, we estimated the impact of nerve blocks on the primary outcome. Finally, to assess the impact of catheters, we reran our primary analysis, but specified our independent variable as a three-level categorical variable (no nerve block, nerve block only, nerve block plus catheter).

Post Hoc Subgroup Analyses

After protocol registration, we identified that there could be effect modification based on (1) the type of surgery performed (shoulder arthroplasty or joint repair *vs.* rotator cuff repair), and (2) surgery being performed before, or after, 2014 (as in 2014, two key systematic reviews of dexamethasone prolonging duration of brachial plexus blocks were published[35,36]). To test for effect modification, we added a multiplicative interaction term to our primary multilevel multivariable model to test whether the interaction between nerve block and procedure, or nerve block and time period, was significant ($P < 0.05$).

Reviewer-requested Sensitivity Analyses

During peer review, the following *post hoc* sensitivity analyses were requested: (1) excluding data from 2009 when utilization of nerve blocks was substantially lower, (2) providing an adjusted cost difference, (3) adjusting for procedural risk using the full Canadian Classification of Interventions code, (4) adjusting for hospital-level variation using hospital identifier as a categorical fixed effect, (5) adjusting for the Johns Hopkins Adjusted Clinical Groups score as a five-knot restricted cubic spline, and (6) rerunning our cost analysis after subtracting the physician billing cost of the block (estimated at $60 of anesthesia time plus $80 for G260, $55 for G060, $30 for G061, $80 G279). The methods employed and results of these analyses are provided in Supplemental Digital Content, appendix 4 (http://links.lww.com/ALN/B993).

Sample Size

This was a population-based cohort, so all eligible participants were included. With more than 6,000 outcomes, we conservatively had 600 degrees of freedom to support logistic regression modeling.[37] We did not prespecify a clinically important difference in the primary outcome.

Missing Data

Main outcome and exposure variables were complete for all participants.

Results

We identified 59,644 people who underwent shoulder surgery in Ontario from January 2009 to December 2016 (fig. 1) at one of 118 different hospitals. Overall, nerve blocks were placed in 31,073 patients (52.1%), 1,508 (4.9%) of which were catheters. In the first year of the study, 626 of 6,487 (9.7%) of patients received a nerve block for their shoulder surgery; subsequent years had an increasingly greater proportion of patients who received a nerve block (fig. 2). Patient characteristics are described in table 1.

In the total cohort, 6,234 of 59,644 (10.4%) experienced the primary outcome (no patients died in the 30 days after surgery). Specifically, 4.9% of patients had an unplanned admission after their surgery, 0.3% of patients were readmitted to the hospital within 7 days of their surgery, and 5.9% of patients were seen in the emergency department within 7 days of their surgery.

Primary Outcome

Of people with a nerve block, 2,808 of 31,073 patients (9.0%) had an admission, readmission, or emergency department visit within 7 days of surgery compared to 3,424 of 28,571 patients (12.0%) without a nerve block (unadjusted odds ratio 0.73;

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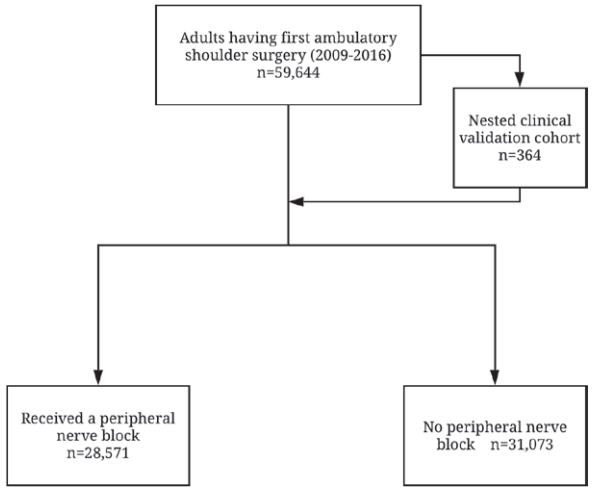

Fig. 1. Flow diagram depicting the creation of the analytical dataset.

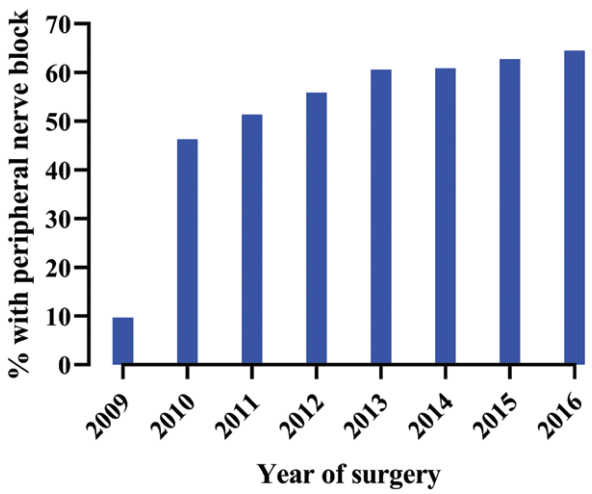

Fig. 2. Graph displaying the number of peripheral nerve blocks placed by year of study.

95% CI 0.69 to 0.77; $P < 0.0001$). After multilevel, multivariable adjustment, no significant difference remained (odds ratio 0.96; 95% CI 0.89 to 1.03; $P = 0.243$). The fully specified model is provided in Supplemental Digital Content, appendix 3 (http://links.lww.com/ALN/B993), including the calibration plot, which demonstrated good agreement between observed and expected outcomes across the risk spectrum.

When evaluating the individual components of the composite outcome, there was a significant adjusted decrease in unplanned admissions for patients with a nerve block (adjusted odds ratio 0.88; 95% CI 0.79 to 0.98; $P = 0.020$). There was no significant adjusted difference in readmissions or emergency department visits within 7 days between the two groups, although the directional associations for these postdischarge associations did not favor nerve blocks (table 2). Table 3 describes the most common

Table 1. Characteristics of the Study Cohort

	No PNB (n = 28,571)	PNB (n = 31,073)	ASD
Demographics			
Age, yr, mean ± SD	51 ± 13	52 ± 12	8.0
Female, %	32.7	33.9	0.9
Rural, %	18.7	13.0	10.7
Neighborhood income quintile, median (IQR)	3 (4–2)	3 (4–2)	0.0
Surgery type, %			
Shoulder arthroplasty or joint repair	40.8	36.5	2.0
Rotator cuff repair	58.0	63.1	2.2
Other shoulder repair	1.2	0.4	8.9
Surgical approach, %			5.1
Arthroscopic	71.1	75.9	
Open	28.9	24.1	
Healthcare resource use, %			
Hospitalization in the last year	5.8	4.9	3.6
Emergency department visit in the last year	43.9	39.2	1.6
Comorbidities			
ACG score, mean ± SD	8 ± 3	8 ± 3	0.0
ASA score, < 3	68.7	64.3	3.1
Cerebrovascular disease, %	0.3	0.3	0.0
Chronic renal disease, %	0.2	0.1	2.6
Dialysis, %	0.1	0.1	0.0
Dementia, %	0	0	N/A
Primary malignancy, %	0.7	0.7	0.0
Metastatic solid tumor, %	0.1	0.0	4.5
Peripheral vascular disease, %	0.2	0.2	0.0
History of peptic ulcer disease, %	0.2	0.1	2.6
Liver disease, %	0.1	0.1	0.0
Rheumatologic disease, %	0.2	0.1	2.6
Hemiplegia or paraplegia, %	0.1	0.0	4.5
Atrial arrhythmia, %	0.4	0.4	0.0
History of venous thromboembolism, %	0.1	0.1	0.0
History of heart failure, %	1.3	1.2	0.9
History of hypertension, %	33.6	36.0	1.5
History of diabetes mellitus, %	14.7	15.6	1.8
Chronic obstructive pulmonary disease, %	12.3	12.2	0.2
Asthma, %	17.8	18.2	0.7
Myocardial infarction, %	1.5	1.6	0.8
Cardiac valvular disease, %	0.1	0.1	0.0
Disease of the pulmonary circulation, %	0.1	0.1	0.0
Coagulopathy, %	0.1	0.1	0.0
Obesity, %	0.5	0.6	1.3
Weight loss, %	0.1	0.0	4.5
Blood loss anemia, %	0.5	0.6	1.3
Deficiency anemia, %	0.0	0.0	N/A
Alcohol abuse, %	0.4	0.3	1.7
Drug abuse, %	0.2	0.1	2.6
Psychosis, %	0.0	0.0	N/A
Depression, %	0.4	0.4	0.0

ACG, Johns Hopkins Adjusted Clinical Groups score; ASD, adjusted standardized difference; ASA, American Society of Anesthesiologists; IQR, interquartile range; N/A, not applicable; PNB, peripheral nerve block.

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Table 2. Association of Peripheral Nerve Blocks with Outcomes in Ambulatory Shoulder Surgery (Primary and Secondary)

	No PNB	PNB	Unadjusted Relative Effect* (95% CI)	*P* Value	Adjusted† Relative Effect‡ (95% CI)	*P* Value
Primary analysis	n = 28,571	n = 31,073				
Composite outcome (7 days), n (%)	3,424 (12.0)	2,808 (9.0)	0.73 (0.69–0.77)	< 0.0001	0.96 (0.89–1.03)	0.243
Unplanned admission §, n (%)	1,784 (6.2)	1,132 (3.6)	0.57 (0.53–0.61)	< 0.0001	0.88 (0.79–0.98)	0.020‖
Readmission within 7 days, n (%)	85 (0.3)	98 (0.3)	1.06 (0.79–1.42)	0.693	1.00 (0.73–1.39)	0.987
ED visits within 7 days, n (%)	1,779 (6.2)	1,732 (5.6)	0.89 (0.83–0.95)	< 0.001	1.02 (0.94–1.12)	0.583
Secondary analysis						
Composite outcome (30 days), n (%)	4,400 (15.4)	3,754 (12.1)	0.76 (0.72–0.79)	< 0.0001	0.95 (0.89–1.02)	0.137
Unplanned admission§, n (%)	1,784 (6.2)	1,132 (3.6)	0.57 (0.52–0.61)	< 0.0001	0.88 (0.79–0.98)	0.020‖
Readmission within 30 days, n (%)	229 (0.8)	207 (0.7)	0.83 (0.69–1.00)	0.053	1.00 (0.73–1.39)	0.987
ED visits within 30 days, n (%)	2,837 (9.9)	2,727 (8.8)	0.87 (0.83–0.92)	< 0.0001	1.00 (0.93–1.07)	0.983
Cost after surgery‡ (7 days)	4,391 (3,910–4,836)	4,681 (4,337–5,066)	1.07 (1.07–1.07)§	< 0.0001	1.06 (1.02–1.10)§	0.005‖
Cost after surgery‡ (30 days)	4,528 (4,014–5,019)	4,840 (4,451–5,258)	1.07 (1.07–1.08)§	< 0.0001	1.06 (1.02–1.10)§	0.007‖
Neurology consultations in the 90 days after surgery	74 (0.3)	92 (0.3)	1.14 (0.84–1.55)	0.391	1.04 (0.71–1.53)	0.839
Nerve conduction studies in the 90 days after surgery	235 (0.8)	274 (0.9)	1.07 (0.9–1.28)	0.432	1.02 (0.84–1.24)	0.834

Weighted frequencies of outcomes for the "No PNB" group are presented.

*All relative effect measures represent odds ratios, except for costs which are ratios of means. †Variables included in the model include patient demographics, surgery location, surgery type, healthcare resource use, and comorbidities as outlined in table 1. ‡Cost after surgery includes the day of surgery costs. §Unplanned admission refers to admission on the day of surgery only. ‖ $P < 0.05$ is statistically significant.

ED, emergency department; PNB, peripheral nerve block.

Table 3. Most Common Etiologies of Unplanned Admissions and ED Visits within 7 Days of Surgery

Etiology of ED Visits	No PNB (n = 28,571) n (%)	PNB (n = 31,073) n (%)
Acute pain	302 (1.1)	434 (1.4)
Surgical dressing or suture	168 (0.6)	102 (0.3)
Bleeding	94 (0.3)	69 (0.2)
Pain in joint	50 (0.2)	68 (0.2)
Urinary retention	76 (0.3)	64 (0.2)

ED, emergency department; PNB, peripheral nerve block.

physician-assigned primary diagnoses for patients who presented to the emergency department. When the primary outcome was measured over the 30 days after surgery, findings were similar to the 7-day outcomes (table 2).

Secondary Outcomes

Before adjustment, health system costs on the day of surgery to 7 days after surgery were significantly higher with a nerve block (median cost with a nerve block $4,681 *vs.* $4,391 without; ratio of means 1.07; 95% CI 1.07 to 1.07; $P < 0.0001$). After multilevel multivariable adjustment, costs remained significantly higher in those who received a nerve block (ratio of means 1.06; 95% CI 1.02 to 1.10; $P = 0.005$). We found $325 (95% CI $316 to $333) in excess health system costs attributable to provision of a nerve block. A similar cost difference was seen with the 30-day cost data (median cost with a nerve block $4,840 *vs.* $4,528 without; adjusted ratio of means 1.06; 95% CI 1.02 to 1.10; $P = 0.007$).

Evaluating safety indicators between the receipt of a nerve block *versus* no nerve block, we found that there were no differences in the odds of either neurology consultations (adjusted odds ratio 1.04; 95% CI 0.71 to 1.53; $P = 0.839$) or nerve conduction studies in the 90 days after surgery (adjusted odds ratio 1.02; 95% CI 0.84 to 1.24; $P = 0.834$).

Sensitivity Analyses

In people more than 65 yr of age (n = 8,653 or 15% of total cohort), for whom we could add additional adjustment for receipt of preoperative opioids, there was no difference in the adjusted odds of the composite outcome between nerve blocks compared to those without a nerve block (adjusted odds ratio 0.87; 95% CI 0.75 to 1.03; $P = 0.110$).

The propensity score analysis resulted in successful matching of 12,699 people with a nerve block to 12,699 people without (42.6% of total cohort; characteristics in Supplemental Digital Content, appendix 5, http://links.lww.com/ALN/B993). The presence of a nerve block was not associated with a difference in the composite outcome at 7 days (10.8%) compared with those without a nerve block (10.5%; adjusted odds ratio 1.04; 95% CI 0.95 to 1.13; $P = 0.382$).

When we compared no nerve block (reference category) *versus* nerve block with no catheter *versus* nerve block with a catheter, the presence of a catheter was associated with a significant increase in the adjusted odds of the 7-day

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composite outcome (odds ratio 1.92; 95% CI 1.55 to 2.38; $P < 0.0001$) compared to no nerve block; there was no difference in the adjusted odds of composite outcome between no nerve block and nerve blocks without a catheter (odds ratio 0.93; 95% CI 0.87 to 1.00; $P = 0.059$).

Subgroup Analyses

There was no evidence of significant effect modification on the multiplicative scale between nerve block receipt and surgery type ($P = 0.067$), or nerve block and time period ($P = 0.314$).

Reviewer-requested Sensitivity Analyses

Results of the requested analyses are provided in Supplemental Digital Content, appendix 4 (http://links.lww.com/ALN/B993). No substantive changes in our results were identified for the primary composite outcome or 7-day health system costs. The association of increased costs persisted (although attenuated) after subtracting physician billing charges for block placement (ratio of means 1.03; 95% CI 1.03 to 1.04; $P < 0.001$).

Discussion

In this retrospective study examining nerve blocks in ambulatory shoulder surgery, there was no association between nerve blocks (measured using validated billing codes) and the composite outcome of unplanned admissions or readmissions, emergency department visits, or death within 7 days. These data suggest that the early benefits of decreased pain scores with nerve blocks, proven in randomized trials, may not translate into postdischarge health system benefits. Additionally, nerve blocks were associated with a $325 increase in health system costs up to 7 postoperative days; however, despite statistical significance, this may not be clinically significant. These findings suggest that pragmatic randomized trials focused on postdischarge patient-reported outcomes, and evaluation of processes, are needed to help extend the early benefits of nerve blocks into the postdischarge phase and to address important knowledge gaps around nerve block use in ambulatory shoulder surgery.

Two previous studies using administrative data have attempted to address health system outcomes associated with nerve blocks for shoulder surgery.[15,16] However, both studies had significant limitations. Importantly, both lacked a validated exposure measure (*i.e.*, manner to identify true receipt or nonreceipt of a nerve block). This can bias results,[38,39] as misclassification bias can improperly categorize patients as having had, or not had, a given exposure in unpredictable ways.[39] Furthermore, the study by Danninger *et al.*[15] of rotator cuff repairs, which found nerve blocks to be associated with decreased day of surgery admissions, was limited to outcomes happening up to the time of hospital discharge and did not specify whether surgeries were planned as ambulatory or inpatient cases (which could also misclassify their outcome variable). Ding *et al.*[16] found nerve blocks used in the absence of general anesthesia to be associated with decreased rates of 90-day readmissions compared to general anesthesia (with or without a nerve block). As the study was limited by grouping all people who received general anesthesia (including those with a nerve block) in a single level, outcome differences may not be due to the nerve block altering postoperative pain, but rather an avoidance of general anesthesia. Furthermore, causally relating a block on the day of surgery to 90-day readmissions may be difficult. In contrast, we used a validated nerve block exposure and collected data on a combination of key health system outcomes from surgery to postoperative day 7. Importantly, we captured emergency department visits, which are common after ambulatory surgery but not routinely studied. Using this robust approach, we found no difference associated with receipt of a nerve block and a combination of unplanned admissions, emergency department visits, hospital readmissions, or deaths.

While using a composite outcome allowed us to assess a combination of pertinent outcomes in a manner relevant to patients and the health system, the individual components of the composite outcome warrant closer examination. Unplanned day of surgery admissions were significantly lower in the nerve block group, which is consistent with the trial data demonstrating improved early pain control and shorter postanesthesia care unit stays with nerve blocks.[13] However, this early benefit did not impact postdischarge outcomes, as emergency department visits and readmissions did not differ between groups. The reasons for emergency department visits may provide some insight into this finding. In the nerve block group, acute pain was more common as the primary emergency department diagnosis (table 3). This could reflect rebound pain, a phenomenon in which profound initial analgesia from a block leads to inadequate oral analgesic consumption as the block wears off.[40] These findings could inform a possible prevention strategy focusing on greater patient education or process optimization around systemic analgesia as nerve blocks wear off. In people without a block, emergency department diagnoses were more commonly related to surgical issues, which is consistent with previous research.[41] Across both nerve block and no nerve block groups, it is also important to note that approximately 6% of adults having ambulatory shoulder surgery return to the emergency department or are readmitted to hospital within 7 days.

Our sensitivity analyses also provide insights into the relationship between nerve blocks and outcomes. As indication and confounding bias are also important considerations in database research,[39] we assessed whether a propensity score match (as opposed to our regression model) would lead to differing results (as matching allows one to estimate the effect of an intervention in the section of the population that is most comparable at baseline, whereas regression provides an estimate of what would happen if the whole population

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switched from no block to a block).[42] However, the results were similar (no significant difference associated with nerve blocks). Unmeasured confounders can also bias results, and in the case of nerve blocks, baseline chronic pain could influence both receipt of a nerve block and risk of an adverse outcome. However, in those older than 65 yr, where prescription opioid data was available, again we found no primary outcome difference. Finally, as an exploratory analysis, we compared no block with isolated blocks or blocks with a catheter. While we found that receipt of a catheter was associated with a 92% relative increase in the odds of unplanned admissions, readmissions, or emergency department visits, caution is needed in interpreting the result of a secondary analysis. There is little published evidence regarding postdischarge outcomes with catheters *versus* single shot nerve blocks.[43] This finding could reflect complications specific to the catheter, or patient uncertainty associated with continuous catheters. Unmeasured confounding may contribute to this effect size; however, using the E-value[44] to estimate how strong a missing variable would need to be to explain away the measured effect suggests that this is unlikely (we estimate that a missing variable would need to have an odds ratio of 3.25 to decrease the association between catheters and adverse outcomes to no effect).

Finally, our analysis also addressed the association of nerve blocks with health system costs and safety indicators. We found a statistically significant association between nerve blocks and a small increase in health system costs on the day of surgery to 7 days afterward (approximately $325). Some of this cost is attributable to the cost of the physician service in placing the block and the additional anesthesia care time (in Ontario, anesthesiologists are fee-for-service and bill for specific procedures as well as time-based billing); however, even after accounting for these charges, a 3% relative increase in costs remained. Whether these costs represent a clinically important increase is questionable. For example, one must consider whether this increased cost may still represent value in providing a nerve block. While we were unable to identify any valuation data specific to pain avoidance after ambulatory surgery, avoiding postoperative pain has been identified as the third highest priority outcome for patients after surgery, and chronic pain patients have identified that they would be willing to pay $56 to $145 per day to avoid pain; therefore, the higher cost associated with nerve block placement may well provide value at the patient level.[45–47] In terms of safety, we are not aware of validated means to identify nerve injuries in administrative data; however, we did not find any differences between groups in the number of neurologic consultations or nerve conduction studies in the 90 days after surgery. While this outcome can only be considered a proxy for true nerve injury, it is important to note that there was no strong signal that nerve blocks were associated with increased nerve injuries significant enough to require specialist consultation of diagnostic testing.

Limitations

Our findings are at risk of several types of bias. First, there is risk of misclassification bias. We validated our exposure to confirm that blocks were accurately identified, but only know that a block was placed, not how well it worked. Therefore, our findings reflect a pragmatic approach as opposed to an explanatory study.[48] Confounding bias may influence receipt of specific interventions and outcomes; if unmeasured confounders led to higher risk of adverse events and increased likelihood of a block, our findings would be biased to the null. However, we controlled for prespecified confounders, and results were consistent across all analyses that were prespecified in our protocol. We were unable to measure patient-reported outcomes such as quality of life, quality of recovery, experience/satisfaction, or return to work. Our findings do not preclude benefit, as our 95% CI included values below the null value; however, despite a large sample, we found no statistically significant impact. Cost were captured at the health system level, but were not adequately granular to capture operating room supplies, and partly rely on indirect techniques that could be associated with estimation error. We did not have specifics of each nerve block technique (*e.g.*, ultrasound *vs.* landmark, dose or type of local anesthetic or additives) that may impact nerve block efficacy. Findings may not generalize to all jurisdictions.

Implications

Receipt of a nerve block for ambulatory shoulder surgery was not associated with a difference in unplanned admissions, emergency department visits, readmissions, or deaths in the 7 days after surgery; unplanned admission rates were lower in the presence of a nerve block. Pragmatic randomized trials powered for patient-centered postdischarge outcomes, as well as process evaluation, are needed to understand how the early benefits of blocks may extend after discharge and to fully inform anesthetic care.

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Competing Interests

The authors declare no competing interests.

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