Journal of Pain Research

Dovepress

Open Access Full Text Article

ORIGINAL RESEARCH

Continuous Adductor Canal Block Compared to Epidural Anesthesia for Total Knee Arthroplasty

Isaac G Freedman[1,2], Michael R Mercier[3,4], Anoop R Galivanche[3,5], Mani Ratnesh S Sandhu[6], Mark Hocevar[7], Harold Gregory Moore[8], Jonathan N Grauer[3], Lee E Rubin[3], Jinlei Li[2]

[1]Department of Anesthesiology, Critical Care & Pain Medicine, Massachusetts General Hospital and Harvard Medical School, Boston, MA, USA; [2]Department of Anesthesiology, Yale School of Medicine, New Haven, CT, USA; [3]Department of Orthopaedics and Rehabilitation, Yale School of Medicine, New Haven, CT, 06511, USA; [4]Division of Orthopaedic Surgery, University of Toronto, Toronto, ON, Canada; [5]Department of Orthopaedic Surgery, University of California, San Francisco, CA, USA; [6]Department of Neurosurgery, Carver College of Medicine, University of Iowa, Iowa City, IA, USA; [7]Warren Alpert School of Medicine, Brown University, Providence, RI, USA; [8]Department of Orthopaedic Surgery, University of Texas Southwestern Medical Center, Dallas, TX, USA

Correspondence: Isaac G Freedman, Department of Anesthesiology, Critical Care & Pain Medicine, Massachusetts General Hospital, Harvard Medical School, 55 Fruit St, Boston, MA, 02114, Email igfreedman@mgh.harvard.edu

Aim: To compare the efficacy of a postoperative continuous adductor canal block (cACB) with and without a steroid adjuvant to that of epidural analgesia (EA).

Methods: Patients who underwent primary total TKA at a single institution between July 2011-November 2017 were included for retrospective analysis. TKA patients were stratified into one of the three analgesia approaches: EA, cACB without steroid adjuvant, and cACB with steroid adjuvant. Hospital length of stay (LOS), discharge disposition, incidence of postoperative adverse events, and total milligram morphine equivalents (MME) requirements were compared between strata. Logistic regressions were performed to assess the independent effect of analgesia approach on prolonged LOS greater than 3 days (pLOS), non-home discharge, and total and daily MME requirements (tMME and dMME) following TKA.

Results: Of the 4345 patients undergoing TKA, 1556 (35.83%) received EA, 2087 (48.03%) received cACB without steroids, and 702 (16.13%) cACB with steroids. cACB patients experienced lower rates of pLOS, higher rates of discharge to home than EA patients, and lower tMME and dMME. On multivariable analysis, cACB groups were at a lower odds of experiencing a pLOS compared to EA patients without steroids (OR = 0.64; 95% CI 0.49–0.84; with steroids: OR = 0.54; 95% CI 0.38–0.76). cACB groups had lower odds of a non-home discharge when compared to EA patients (without steroids OR = 0.42; 95% CI 0.36–0.48; with steroids: OR 0.22; 95% CI 0.18–0.27). On multivariable analysis, cACB groups required less tMME compared to the EA group (without steroids β= −290 mmE; 95% CI: −313 to −268 mmE; with steroids: β=−261 mmE; 95% CI: −289 to −233 mmE) as well as lower dMME (without steroids: β=−66 mmE/day; 95% CI −72 to −60 mmE/day; with steroids: β=−48 mmE/day; 95% CI −55 to −40 mmE/day).

Conclusion: cACB was associated with greater discharge to home rates, lower rates of pLOS, and lower tMME and dMME consumption.

Level of Evidence: Level III

Plain Language Summary: Anesthesia practice for TKA in the inpatient setting varies widely. Retrospectively compared outcomes for EA and cACB with or without steroids in TKA. cACB is associated with superior perioperative outcomes vs EA. cACB is associated with reduced opioid analgesia requirements vs EA. cACB with steroids was superior to cACB without steroids.

Keywords: adductor canal block, knee arthroplasty, complications, length of stay, pain control, milligram morphine equivalents, dexamethasone, methylprednisolone acetate, steroid, NSQIP, MME

Introduction

Achievement of adequate analgesia is a crucial component of post-operative care following total knee arthroplasty (TKA). Current approaches to analgesia following TKA are generally multimodal. While all approaches aim to minimize opioid

Received: 10 March 2024
Accepted: 29 October 2024
Published: 13 November 2024

consumption and accelerate postoperative ambulation, no universally accepted protocol for postoperative analgesia following TKA exists. In the present study, a retrospective observational design was used to compare the efficacy of postoperative continuous adductor canal block (cACB) with and without steroid adjuvant to that of epidural analgesia (EA).

A comparable alternative to femoral nerve block (FNB), cACB has been utilized for postoperative analgesia following TKA in several prior studies. Kim et al found ACB to be noninferior to FNB in analgesic efficacy, with ACB associated with less quadriceps muscle weakness than FNB.[1] This early sparing of quadriceps muscle function by adductor canal block (ACB) relative to FNB was theorized to mitigate the increased risk of falls associated with FNB. More recently, Borys et al demonstrated that cACB was associated with earlier mobilization but had worse analgesic efficacy compared to FNB.[2]

When investigating the efficacy of cACB, FNB represents a "best-available-therapy" control group. To obtain maximal treatment separation, however, it is desirable to estimate the efficacy of cACB using a control group without any peripheral nerve block.[3] To this end, prior studies have sought to compare the efficacy of cACB to that of epidural analgesia for postoperative TKA patients.[4–6] Kayupov et al found that cACB provided earlier ambulation, lower length of hospital stay, better analgesia, and greater satisfaction than epidural analgesia.[4] The trial did not investigate the efficacy of steroid adjuvants.

Other studies have investigated the benefit of steroid adjuvants to cACB in prolonging the duration of analgesia and improving the overall efficacy of cACB through a variety of postulated mechanisms including direct effects on nerve conduction and indirect effects including anti-inflammatory effects.[7] Wang et al found that use of a dexamethasone adjuvant increased the duration of a single-shot ACB.[8] To our knowledge, no studies have evaluated whether steroid adjuvants are effective for continuous ACB. Likewise, there has been limited evidence comparing cACB with steroid adjuvants to epidural analgesia. Filling this gap in knowledge in the comparative effectiveness of these three therapies has the potential to guide clinical practice and personalize anesthetic care.

The present study used data from a single institution to compare the efficacies of epidural analgesia, cACB without steroid adjuvant, and cACB with steroid adjuvant. The endpoints of interest were length of stay, discharge disposition, and MME requirements between three separate postoperative analgesia protocol cohorts.

Methods

Study Approval

Due to the retrospective nature of the study and de-identification of patient information, the need for further ethical approval was exempted by the Yale University Institutional Review Board (IRB). Given the retrospective, comparative design of the study, the requirement for written informed consent was waived by the Yale University IRB. The analysis was performed in accordance with applicable STROBE guidelines. All the methods in the study are in accordance with relevant institutional guidelines and regulations.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to their including patient information but are available in a deidentified format from the corresponding author on reasonable request.

Patient Inclusion/Exclusion Criteria

All patients who underwent, inpatient, elective, and primary total TKA at a single institution between July 2011 and November 2017 were selected for retrospective inclusion and analysis. Patients were identified using the Current Procedural Terminology (CPT) code for primary total knee arthroplasty (27447). Patients less than 18 years of age or undergoing revision partial, or bilateral knee arthroplasty were excluded from the study.

Patient Cohort Stratification by Analgesia Protocol

Intraoperatively, all patients during the study period were administered spinal anesthesia with plain 0.5% bupivacaine. TKA patients that met the aforementioned inclusion criteria were stratified into one of the three sequential analgesia

cohorts based on the time period of their date of surgery. Per institutional protocol, all TKA patients who underwent surgery from July 2011 and April 31st, 2014, received EA. Patient-controlled EA utilized 0.2% ropivacaine with 5 mcg/mL fentanyl, typically at a basal rate 8–10 mL per hour with a bolus rate of 4–5 mL and a lockout time of 20 minutes. Administration of EA was titrated to a visual analog scale (VAS) pain score less than or equal to 5 out of 10. The catheter was removed after 36 hours, before the initiation of postoperative venous thromboembolism (VTE) prophylaxis.

Similarly, all TKA patients who underwent surgery from May 1st, 2014, and October 31st, 2016, received a cACB without a steroid adjuvant. Patients receiving cACB were given 0.2% ropivacaine at a rate 5–12 cc per hour, titrated to VAS pain score less than or equal to 5 out of 10. Absence of major motor weakness to the extent of interfering with routine physical therapy, the catheter was removed after 48 hours. A single injection of sciatic nerve block with 0.1% ropivacaine 10 mL was used in conjunction with the cACB.

Lastly, all patients who underwent surgery from November 1st, 2016, and November 15th, 2017, received a cACB with a steroid adjuvant. This patient cohort included patients receiving a single injection ACB (sACB) and an infiltration between the popliteal artery and capsule of the knee (iPACK) block, with 30 mL of 0.2% ropivacaine and 5 mg of dexamethasone in each block. Approximately one-third of patients in this cohort were also administered 40 mg methylprednisolone acetate (Depo-Medrol) in addition to dexamethasone in each nerve block.

Data Elements

Patient demographic data, in addition to preoperative and 30-day postoperative outcome data is recorded systematically by our institution's National Surgical Quality Improvement Program (NSQIP) team for all TKA patients. This team consists of trained clinical reviewers that follow patients for 30 days after surgery to characterize patient characteristics and procedures, as well as document the incidence of postoperative complications, readmissions, and additional surgeries.[9] NSQIP-furnished data has become a well-validated and accepted instrument for evaluating surgical outcomes in orthopedic surgery.[10,11]

Demographic variables included: patient age, sex, height, and weight [used to calculate body mass index (BMI)], American Society of Anesthesiologists (ASA) physical status, and race. ASA class data was used as a composite marker for patient comorbidity, as is often done in the anesthesia and orthopedics literature.[12]

Postoperative adverse events were similarly tabulated and were categorized as major or minor. Major adverse events included: deep infection, sepsis and septic shock, ventilator use greater than 48 hours, unplanned intubation, acute renal failure, pulmonary embolism, deep vein thrombosis, cardiac arrest, myocardial infarction, and stroke. Minor adverse events included: superficial infection, wound dehiscence, pneumonia, urinary tract infection, and renal insufficiency. Any adverse event was defined as the occurrence of either a major or minor adverse event.

In addition to the aforementioned postoperative events, several other variables were collected. Readmission within 30 days was assessed. Discharge disposition from index hospitalization was categorized as home or other. Prolonged hospital length of stay was defined as greater than 3 days.

Oral milligram morphine equivalents (MME) were calculated for each patient as follows: All administrations of any medication during the index hospitalization were considered. Any administration of an opioid was assigned an MME based on standard MME conversions for the given medication, dosage, and route of administration. Total MME consumption during the index hospitalization (tMME) was calculated by summing over all opioid administrations for each patient over the entire hospitalization. Daily MME consumption during the index hospitalization (dMME) was calculated for each patient by dividing tMME by LOS. All patients given EA were treated with a dose of 8 mg/mL epidural fentanyl at a rate of 5 mL/hr for 36 hours postoperatively.

Statistical Analysis

Patient demographics, comorbidities, surgical variables, and perioperative outcomes were compared between patients in each of the analgesia cohorts. MME continuous variables (ie, tMME and dMME) were tested for normality using Shapiro–Wilkes tests, then compared using analysis of variance or Kruskal–Wallis tests. Categorical demographic and surgical variables were compared between the groups using chi-squared or Fisher's exact tests. Any, major, and minor

postoperative adverse events; readmission; and prolonged length of stay were also compared between the groups using a chi-squared test.

Several studies investigating perioperative analgesia total knee arthroplasty have identified length of stay as a crucial endpoint to examine.[13–15] Furthermore, pain control has been demonstrated to be a key factor in reducing hospital length of stay.[16] Therefore, a binary logistic regression was performed to assess the independent effect of analgesia protocol on patients' likelihood of experiencing a long hospital length of stay. The initial regressions included the following patient factors: age, race, sex, BMI, ASA class, and the occurrence of any adverse event (AAE). Regressions were optimized using recursive feature elimination (RFE) with an elimination threshold of $p > 0.20$, where age and sex were included in all models as universal covariates.

Statistical significance for all analyses was set at $\alpha = 0.05$, and 95% confidence intervals [CI] were reported. Finally, because this study is a retrospective analysis, a priori power estimation could not be performed. Past studies have shown that retrospective power analyses result in biased power estimates and low precision.[17,18] Statistical analysis was performed with IBM SPSS Statistics, version 26 (IBM Corp., Armonk, N.Y., USA), Python (v3.10.8, Python Software Foundation, Wilmington, D.E., USA), and R (v4.2.1, R Foundation for Statistical Computing, Vienna, AT).

Results

Study Cohort

Of the 27,447 subjects who underwent TKA during the study period of July 2011 through November 2017 who were initially assessed for eligibility, 23,132 (84.3%) were excluded from the final analysis due to age (less than 18 years of age) or because they underwent revision, partial, or bilateral knee arthroplasty, Figure 1. In total, 4345 patients met criteria for inclusion in the sample. Of the subjects included in the final analysis cohort, 1556 patients received EA (1556/4345; 35.8%), 2087 patients received cACB without steroid adjuvant (2087/4345; 48.0%), and 702 patients received cACB with steroids (702/4345; 16.2%), Figure 1.

Demographic and Preoperative Characteristics

The mean age of EA patients was 67.0 years, while the mean ages of patients in the cACB without or with steroid groups were 67.9 years and 67.4 years, respectively, Table 1. The differences in age between the analgesia protocol groups were statistically significant by ANOVA ($p = 0.015$). Patients who received cACB without or with steroids had a greater

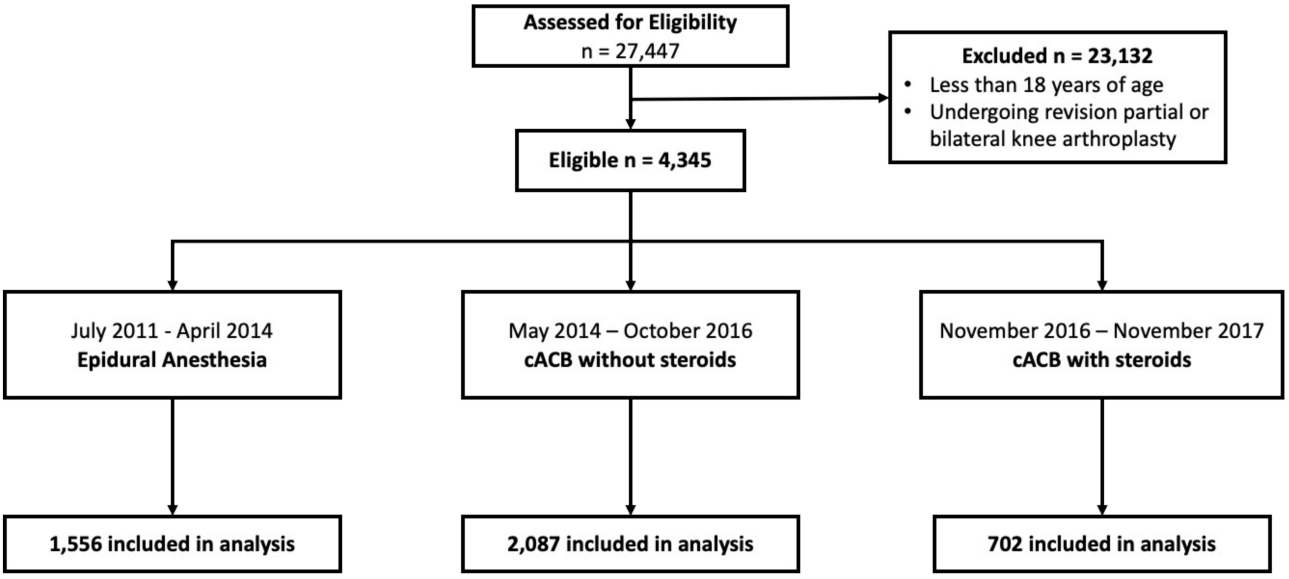

Figure 1 Flow diagram of cohort selection from July 2011 through November 2017.
Abbreviation: cACB, continuous Adductor Canal Block.

Table 1 Demographics of Patients Undergoing Primary Total Knee Replacement Organized by Nerve Block Type

Nerve Block Type	Epidural Analgesia	cACB without Steroids	cACB with Steroids	P-value
N = 4345 (100%)	**N = 1556 (35.83%)**	**N = 2087 (48.03%)**	**N = 702 (16.13%)**	
Age: Mean [SD]	**67.0 [9.7]**	**67.9 [9.6]**	**67.4 [9.4]**	**0.015**
18–54	181 (11.62%)	176 (8.43%)	60 (8.55%)	
55–64	473 (30.37%)	615 (29.47%)	218 (31.05%)	
65–74	544 (34.96%)	819 (39.24%)	270 (38.46%)	
≥ 75	358 (22.99%)	477 (22.86%)	154 (21.94%)	
Sex				0.29
Male	572 (36.73%)	741 (35.51%)	272 (38.75%)	
Female	984 (63.26%)	1346 (64.49%)	430 (61.25%)	
BMI: Mean [SD]	31.95 [6.58]	32.08 [6.46]	32.25 [6.59]	0.86
< 25	203 (13.13%)	257 (12.31%)	77 (10.97%)	
25–30	462 (30.31%)	608 (29.13%)	215 (30.63%)	
30–35	443 (27.77%)	600 (28.75%)	199 (28.35%)	
> 35	448 (28.18%)	622 (29.80%)	211 (30.06%)	
ASA				**0.001**
1	62 (3.98%)	80 (3.83%)	26 (3.70%)	
2	904 (58.10%)	1197 (57.36%)	352 (50.14%)	
3	565 (36.31%)	790 (37.85%)	319 (45.44%)	
4+	25 (1.61%)	20 (0.96%)	5 (0.71%)	
Functional Status (prior to surgery):				**0.002**
Independent	1554 (99.87%)	2066 (98.99%)	693 (98.72%)	
Partially/Totally dependent	2 (0.14%)	21 (1.00%)	9 (1.28%)	
Race				0.073
White	1297 (83.35%)	1741 (83.42%)	555 (79.06%)	
Black/African American	171 (10.99%)	249 (11.93%)	96 (13.68%)	
Asian	14 (0.89%)	13 (0.62%)	9 (1.28%)	
Not Reported	74 (4.76%)	84 (4.02%)	42 (5.98%)	

Notes: Bolding of numerical values indicates statistical significance at $p < 0.05$.
Abbreviations: ASA, American Society of Anesthesiologists classification; cACB, Continuous Adductor Canal Block.

proportion of patients with an ASA score of 3 compared to patients in the epidural analgesia group (37.85% without steroids and 45.44% with steroids, compared with 36.31% in the EA group; $p = 0.001$), Table 1. Similarly, patients who received cACB without or with steroids were more likely to have partially or totally dependent preoperative functional statuses (1.00% without steroids and 1.28% with steroids, compared with 0.14% in the EA group; $p = 0.002$), Table 1. There were no statistically significant differences in sex, BMI, or race between the analgesia protocol groups, Table 1.

Postoperative Course

Postoperatively, patients given cACB were given significantly lower postoperative opioid analgesia requirements over the entire hospitalization (tMME) than patients in the EA treatment group (tMME median [IQR]: EA 625.0 [513.0, 759.0], cACB without Steroids 318.8 [110.6, 490.1], cACB with Steroids 323.8 [287.9, 535.2]; $p < 0.001$), Table 2. This trend also held for daily opioid requirements (dMME: EA 163.3 [128.2, 192.8], cACB without Steroids 89.3 [37.7, 141.7], cACB with Steroids 103.0 [72.1, 162.7]; $p < 0.001$), Table 2. In terms of discharge disposition, cACB patients had higher rates of discharge to home than EA patients (64.40% without steroids and 75.07% with steroids, compared with 46.14% in the EA group; $p < 0.001$), Table 2. cACB patients experienced shorter hospital lengths of stay (mean of 2.69 ± 1.23 days without steroids and mean of 2.54 ± 1.64 days with steroids, compared to 3.14 ± 2.03 days in the EA

Table 2 Postoperative Analgesia and Outcomes Following Primary Total Knee Replacement Organized by Nerve Block Type

Nerve Block Type	Epidural Analgesia	cACB without Steroids	cACB with Steroids	P-value
N = 4345 (100%)	**N = 1556 (35.83%)**	**N = 2087 (48.03%)**	**N = 702 (16.13%)**	
Postoperative MME (median [IQR])				
tMME (MME)	**625.0 [513.0, 759.0]**	**318.8 [110.6, 490.1]**	**323.8 [287.9, 535.2]**	**<0.001**
dMME (MME/d)	**163.3 [128.2, 192.8]**	**89.3 [37.7, 141.7]**	**103.0 [72.1, 162.7]**	**<0.001**
Discharge Disposition				**<0.001**
Home	718 (46.14%)	1344 (64.40%)	527 (75.07%)	
Other	838 (53.86%)	743 (35.60%)	175 (24.93%)	
Mean Hospital Length of Stay (SD)	**3.14 (2.03)**	**2.69 (1.23)**	**2.54 (1.64)**	**<0.001**
Long hospital length of stay (> 3 days)	**197 (12.66%)**	**178 (8.53%)**	**59 (8.40%)**	**<0.001**
All Adverse Events	78 (5.01%)	107 (5.13%)	26 (3.70%)	0.31
Major Adverse Events	58 (3.72%)	71 (3.40%)	15 (2.13%)	0.17
Deep Infection	2 (0.13%)	2 (0.09%)	0 (0.00%)	0.64
Sepsis/Septic shock	6 (0.39%)	8 (0.38%)	3 (0.43%)	0.99
Ventilator >48 hrs	3 (0.19%)	0 (0.00%)	0 (0.00%)	0.067
Unplanned Intubation	4 (0.26%)	2 (0.09%)	0 (0.00%)	0.24
Acute Renal Failure	1 (0.06%)	0 (0.00%)	0 (0.00%)	0.41
Venothrombolic Event	**53 (3.41%)**	**68 (3.26%)**	**11 (1.57%)**	**0.049**
Cardiac Arrest	0 (0.00%)	0 (0.00%)	1 (0.14%)	0.074
Myocardial Infarction	1 (0.06%)	4 (0.19%)	1 (0.14%)	0.59
Stroke	0 (0.00%)	2 (0.10%)	1 (0.14%)	0.40
Minor Adverse Events	25 (1.61%)	45 (2.16%)	13 (1.85%)	0.52
Superficial Infection	6 (0.39%)	8 (0.38%)	5 (0.71%)	0.48
Wound Disruption	1 (0.06%)	0 (0.00%)	1 (0.14%)	0.29
Pneumonia	13 (0.84%)	15 (0.72%)	1 (0.14%)	0.16
Urinary Tract Infection	7 (0.45%)	22 (1.05%)	5 (0.75%)	0.12
Progressive Renal Insufficiency	0 (0.00%)	3 (0.14%)	0 (0.00%)	0.20
Readmissions	77 (4.95%)	113 (5.41%)	41 (5.84%)	0.67

Note: Bolding of numerical values indicates statistical significance at $P < 0.05$.
Abbreviations: cACB, Continuous Adductor Canal Block; tMME, total Milligram Morphine Equivalents (MME); dMME, daily MME.

group; $p < 0.001$), Table 2. Furthermore, cACB patients also had lower rates of prolonged hospital stay lasting longer than 3 days (8.53% without steroids and 8.40% with steroids, compared to 12.66% in the EA group; $p < 0.001$), Table 2. Lastly, cACB patients had lower rates of VTE (3.26% without steroids and 1.57% with steroids, compared to 3.41% in the EA group; $p = 0.049$, Table 2. There were no statistically significant differences in rates of any other adverse events, including major adverse events or minor adverse events, nor readmissions between analgesia cohorts, Table 2.

Patient Factors Independently Associated with Prolonged Length of Stay

Multivariable logistic regression models were fitted to examine preoperative factors associated with prolonged length of hospital stay, Table 3. When controlling for all the patient factors examined in Table 1, cACB groups were at a statistically significant lower odds of experiencing a prolonged length of hospital stay, with EA patients as the referent group (without steroids: OR = 0.64; 95% CI 0.49–0.84; $p < 0.001$; with steroids: OR = 0.54; 95% CI 0.38–0.76; $p < 0.001$), Table 3.

Patient Factors Independently Associated with Discharge Disposition

A multivariable logistic regression analysis on the effects of analgesia type (ie, treatment group) and preoperative factors, including demographics and comorbidities, on discharge disposition was performed to examine the independent association between treatment groups, patient factors, and the rate of non-home discharge, Table 4. Compared to patients

Table 3 Factors Associated with pLOS Following Primary Total Knee Arthroplasty

N = 4345 (100%)	OR[a]	95% CI[a]	P-value	Q-Value[b]
Analgesia Type				
Epidural	1.00	–	–	–
cACB without steroids	**0.64**	**[0.49, 0.84]**	**<0.001**	**0.002**
cACB with steroids	**0.54**	**[0.38, 0.76]**	**<0.001**	**0.002**
Age				
18–54	1.00	–	–	–
55–64	0.73	[0.49, 1.09]	0.12	0.20
65–74	0.77	[0.53, 1.16]	0.20	0.30
≥75	0.89	[0.59, 1.36]	0.60	0.60
Sex (Female)	0.86	[0.68, 1.10]	0.20	0.30
Race				
White	1.00	–	–	–
Asian	**3.03**	**[1.10, 7.08]**	**0.017**	**0.032**
Black or African American	**2.03**	**[1.50, 2.72]**	**<0.001**	**<0.001**
Unknown/Not Reported	0.99	[0.54, 1.67]	>0.9	>0.9
ASA Class				
1	1.00	–	–	–
2	2.17	[0.96, 6.19]	0.10	0.20
3	**3.62**	**[1.61, 10.30]**	**0.006**	**0.012**
4+	**10.3**	**[3.53, 34.50]**	**<0.001**	**<0.001**
tMME (per 100mg)	**1.08**	**[1.05, 1.12]**	**<0.001**	**<0.001**

Notes: Bolding of numerical values indicates statistical significance at P < 0.05.
Abbreviations: ASA, American Society of Anesthesiologists Physical Status Classification; a OR, Odds Ratio; CI, Confidence Interval; b False discovery rate correction for multiple testing; pLOS, prolonged Length Of Stay; tMME, total Milligram Morphine Equivalents; cACB, Continuous Adductor Canal Block.

receiving EA and controlling for all patient factors examined in Table 1, cACB groups had a significantly lower odds of being discharged to a destination other than home (without steroids: OR = 0.42; 95% CI 0.36–0.48; p < 0.001; with steroids: OR = 0.22; 95% CI 0.18–0.27; p < 0.001), Table 4.

Patient Factors Associated with Postoperative Opioid Consumption

An RFE-optimized multivariable regression examining the factors associated with tMME revealed decreased opioid consumption in cACB groups (without steroids: β=−290 mmE; 95% CI −313 to −268 mmE; p < 0.001; with steroids: β=−261 mmE; 95% CI −289, −233 mmE; p < 0.001), Table 5. Similarly, dMME was also decreased in cACB groups (without steroids: β=−66 mmE/day; 95% CI −72 to –60 mmE/day; p < 0.001; with steroids: β=−48 mmE/day; 95% CI −55 to −40 mmE/day; p < 0.001), Table 5. Other factors significantly associated with tMME included older age (βs < 0, ps ≤ 0.003) and higher ASA class (βs > 0, ps ≤ 0.002). Similarly, dMME was significantly associated with older age (βs < 0, ps ≤ 0.008) and female sex (β=9.4 mmE/day, p < 0.001), Table 6.

Discussion

Pain following TKA is a major cause of patients' concern and dissatisfaction and a key determinant of LOS.[19–21] Without adequate pain control, LOS can be prolonged and discharge to a disposition with increased patient support, such as a rehabilitation center, may be necessary.[15,22] cACB with and without steroid adjuvants have been increasingly used to optimize postoperative analgesia following TKA. To date, prior studies comparing the efficacy of postoperative ACB to EA have involved treatment arm cohorts relatively limited in size (40–88 patients).[4–6] In a similar vein, past studies

Table 4 Impact of Type of Nerve Block on Non-Home Discharge

N = 4345 (100%)	OR[a]	95% CI[a]	P-value	Q-Value[b]
Analgesia Type				
Epidural	1.00	–	–	–
cACB without steroids	**0.42**	**[0.36, 0.48]**	**<0.001**	**<0.001**
cACB with steroids	**0.22**	**[0.18, 0.27]**	**<0.001**	**<0.001**
Age				
18–54	1.00	–	–	–
55–64	**1.37**	**[1.07, 1.75]**	**0.014**	**0.016**
65–74	**1.47**	**[1.15, 1.88]**	**0.002**	**0.003**
≥75	**2.62**	**[2.01, 3.42]**	**<0.001**	**<0.001**
Sex (Female)	**0.67**	**[0.58, 0.77]**	**<0.001**	**<0.001**
BMI	**1.16**	**[1.08, 1.25]**	**<0.001**	**<0.001**
Dependent Functional Status	**4.77**	**[2.06, 12.4]**	**<0.001**	**<0.001**
Race				
White	1.00	–	–	–
Asian	**2.57**	**[1.26, 5.30]**	**0.010**	**0.012**
Black or African American	**3.48**	**[2.82, 4.31]**	**<0.001**	**<0.001**
Unknown/Not Reported	**1.38**	**[1.01, 1.88]**	**0.043**	**0.046**
ASA Class				
1	1.00	–	–	–
2	1.46	[1.00, 2.17]	0.058	0.058
3	**2.79**	**[1.89, 4.19]**	**<0.001**	**<0.001**
4+	**3.13**	**[1.56, 6.37]**	**0.001**	**0.002**

Notes: Bolding indicates statistical significance at P < 0.05.
Abbreviations: cACB, Continuous Adductor Canal Block; [a] OR, Odds Ratio, CI, Confidence Interval; [b] False discovery rate correction for multiple testing; ASA, American Society of Anesthesiologists Physical Classification.

Table 5 Impact of Nerve Block Type on tMME

N = 4345 (100%)	β	95% CI[a]	P-value
Analgesia Type			
Epidural	–	–	–
cACB without steroids	**−290**	**[−313, −268]**	**<0.001**
cACB with steroids	**−261**	**[−289, −233]**	**<0.001**
Age			
18–54	–	–	–
55–64	**−53**	**[−88, −18]**	**0.003**
65–74	**−106**	**[−140, −72]**	**<0.001**
≥75	**−109**	**[−145, −73]**	**<0.001**
Sex (Female)	6.1	[−13, 25]	0.70
ASA Class			
1	–	–	–
2	20	[−27, 67]	0.50
3	**78**	**[31, 126]**	**0.001**
4+	**154**	**[59, 249]**	**0.002**

Notes: Bolding indicates statistical significance at P < 0.05.
Abbreviations: cACB, Continuous Adductor Canal Block; [a] OR, Odds Ratio; CI, Confidence Interval; tMME, Total milligram morphine equivalents.

Table 6 Impact of Nerve Block Type on dMME

N = 4345 (100%)	β	95% CI	P-value
Analgesia Type			
Epidural	–	–	–
cACB without steroids	**−66**	**[−72, −60]**	**<0.001**
cACB with steroids	**−48**	**[−55, −40]**	**<0.001**
Age			
18–54	–	–	–
55–64	**-11**	**[−21, −1.2]**	**0.008**
65–74	**−25**	**[−34, −15]**	**<0.001**
≥75	**−29**	**[−39, −19]**	**<0.001**
Sex (Female)	**9.4**	**[4.1, 15]**	**<0.001**

Note: Bolding indicates statistical significance at P < 0.05.
Abbreviations: cACB, Continuous Adductor Canal Block; dMME, Daily milligram morphine equivalents.

comparing ACB with and without steroid adjuvants have also been limited in size, mostly involved single injection nerve blocks, with a focus on endpoints such as pain scores, duration of block, and patient satisfaction.[8,23]

Our institution has sequentially adopted the utilization of a postoperative cACB, later coupled with a steroid adjuvant in lieu of epidural analgesia among patients undergoing primary TKA. Drawing from a large single-institution TKA population, the present study finds that cACB with and without steroid adjuvant is associated with a significant increase in discharges to home, and reduced length of stay compared to epidural analgesia.

Our institution's TKA population demonstrated patient demographic profiles similar to other study cohorts of interest.[24,25] In our analysis, there was a statistically significant difference in age distributions of patients receiving different analgesia protocols. The mean age of patients in all analgesia groups was approximately 67 years, suggesting that the difference in ages is not clinically meaningful. Likewise, there were no clinically significant differences in cohort ASA scores or self-reported preoperative functional status (independent, vs partially or totally dependent).

There was a statistically significant increase in discharge to home from under half of patients in the epidural analgesia only group to more than three-quarters of patients in the cACB with steroid adjuvant group, Table 2. On multivariable regression analysis, patients treated with cACB with steroids had a clinically and statistically significant 78% reduced odds of discharge to a non-home location, Table 4. Discharge to home requires the achievement of better postoperative analgesia and is only implemented when deemed safe by the treating physician. Discharge disposition is an important endpoint because home discharge has been shown to be highly associated with reductions in post-operative complications, readmissions, and cost associated with care after primary TKA.[26–28]

A progressive, step-wise reduction in mean hospital length of stay was observed with each new analgesia protocol introduction, Tables 2 and 3. Likewise, fewer patients met criteria for long length of hospital stay in the cACB groups. Prior studies investigating the efficacy of other peripheral nerve blocks in arthroplasty populations have also used prolonged length of hospital stay as an endpoint to measure the success of the novel anesthesia intervention.[16,29] This reduction in the length of hospital stay remained even after controlling for preoperative variables and the incidence of complications.

There was a statistically significant decrease in VTE in the cACB with steroid group compared to the other analgesia groups, Table 2. With no other significant major or minor adverse events between the analgesia groups, it suggests that the reduction in length of stay and improved home discharge rates were due to earlier achievement of analgesia, which cACB groups required less MME to achieve adequate pain control. Reassuringly, there was no difference in readmission rates between the analgesia groups. This suggests that the increased home discharge and lower length of hospital stay were not premature or associated with more frequent return to the hospital.

Further corroborating the inference that those in the cACB groups required less MME to achieve adequate pain control, we found that cACB groups without or with steroids were associated with clinically and statistically significant

decreases in postoperative opioid consumption, Tables 2 and 5. In a study of 150 patients undergoing TKA with a multimodal pain regimen assigned to either a single-shot ACB or not, Deiter et al found total operative MME decreased significantly by 51% in the ACB relative to the no ACB group.[30] Similarly, in an analysis for 458 patients who received TKA at a single regional hospital who either did (n = 138) or did not (n = 263) receive ACB, Johns et al found that receipt of ACB was associated with significantly lower doses of opioids (7.9 mmE reduction, $p < 0.0001$).[31] These results differ from the study of Alsheikh et al of 80 patients who received either ACB or continuous EA for TKA, which found no significant difference between groups in terms of total opioid consumption.[6] However, Alsheikh et al did not tabulate opioid consumption in terms of MME. Our study shows a clinically and statistically significant decrease in both total and daily opioid consumption.

Prior studies into perineural steroid use during joint replacement surgery have focused on single injection nerve blocks, rather than continuous administration via a catheter. In a study of 95 patients who underwent unilateral TKA who received ACB with either no additional adjuvant steroid, single-dose dexamethasone, or single-dose dexamethasone and methylprednisolone acetate, Baldevet al found patients treated with a single dose had significantly lower self-administered ropivacaine use on POD1 and POD2 as well as higher likelihood of home discharge disposition, but no statistically significant difference in opioid consumption or pain scores.[32] In contrast, the present study is one of the few to demonstrate the clinical benefit of continuous catheter-delivered adjuvant steroids in an inpatient setting. Further studies may examine the generalizability of these results to other populations, such as in-home catheters with elastomeric reservoirs.

The present study has several limitations within the scope of which the results should be interpreted. First, the present study is retrospective in nature, specific endpoints of interest such as opioid utilization, range of motion measurements, and other validated instruments for pain control were not collected, and it included data from only a single institution. These factors all limit the generalizability of the findings. However, the study's retrospective design allows for the examination of a large cohort of patients not previously seen in the literature, more representative of the general population, and over a longer time span. Furthermore, the current study was unable to factor in the duration of the nerve block each patient received. It is technically challenging to have an accurate assessment of the duration of motor-sparing analgesic blocks such as ACB and iPACK block using low concentration of local anesthetics; therefore, the duration of nerve block was not followed. Next, the present study did not track the utilization of adjunctive non-opioid pain medications such as non-steroidal anti-inflammatory medications, the use of which may have led to decreased analgesia requirements in some patients.

The present study is the first of its kind of simultaneously evaluate the efficacy of EA, cACB without steroids, and cACB with steroids. The findings reported here suggest that cACB is significantly associated with greater discharge to home rates, lower rates of prolonged length of total hospital stay, and lower total MME requirements. The present study finds that steroid adjuvants to cACB may additionally improve discharge to home rates and further reduce prolonged lengths of hospital stay. Finally, our study showed a significant and dramatic reduction in both daily and total post-operative opioid consumption, indicating that when compared to EA, cACB with or without the addition of steroids has analgesic benefit and suggests its use may also reduce postoperative opioid use and opioid dependence. These findings may be used to inform clinical practice as well as in power calculations for prospective studies evaluating these analgesic protocols head-to-head.

Abbreviations

TKA, total knee arthroplasty; cACB, continuous adductor canal block; EA, epidural analgesia; FNB, femoral nerve block; ACB, adductor canal block; VAS, visual analog scale; VTE, venous thromboembolism; sACB, single injection ACB; iPACK, infiltration between the popliteal artery and capsule of the knee; HCAHPS, Hospital Consumer Assessment of Healthcare Provider Systems; CMS, Centers for Medicare and Medicaid Services; NSQIP, National Surgical Quality Improvement Program; BMI, body mass index; ASA, American Society of Anesthesiologists or ASA Physical Status Classification; AAE, any adverse event; IRB, institutional review board; MME, milligram morphine equivalents tMME, total MME; dMME, daily MME or MME per day; LOS, hospital length of stay; pLOS, prolonged LOS greater than 3 days; RFE, recursive feature elimination.

Declaration of Ethics

This study complies with the Declaration of Helsinki.

Acknowledgment

There was a pre-print publication on Research Square on this submission.

Author contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

The current study was funded by the Yale School of Medicine Medical Student Fellowship. The manuscript submitted does not contain information about medical device(s)/drug(s).

Disclosure

The following disclosures have been collected and reported per International Committee of Medical Journal Editors (ICMJE) reporting standards. Dr. Isaac G. Freedman has nothing to disclose. Dr. Michael R. Mercier has nothing to disclose. Dr. Anoop R. Galivanche has nothing to disclose. Dr. Mani Ratnesh S. Sandhu has nothing to disclose. Mr. Mark Hocevar has nothing to disclose. Dr. Harold G. Moore has nothing to disclose. Dr. Jonathan N. Grauer reports personal fees from TIDI products, personal fees from the North American Spine Society, is the Editor-in-Chief of the North American Spine Society Journal outside the submitted work. Dr. Jinlei Li has nothing to disclose. Dr. Lee E. Rubin reports personal fees from DePuy Synthes, personal fees from ConvaTec, personal fees from Innovative Medical Products, personal fees from Thompson Surgical Instruments, personal fees from SLACK, Inc. Publishers, personal fees from Johns Hopkins University Press, other from 3D Surgical, Inc., outside the submitted work. None pertaining to the subject or content of this work.

References

1. Kim DH, Lin Y, Goytizolo EA, et al. Adductor canal block versus femoral nerve block for total knee arthroplasty: a prospective, randomized, controlled trial. *Anesthesiology*. 2014;120:540–550.
2. Borys M, Domagala M, Wenclaw K, Jarczynska-Domagala J, Czuczwar M. Continuous femoral nerve block is more effective than continuous adductor canal block for treating pain after total knee arthroplasty: a randomized, double-blind, controlled trial. *Medicine*. 2019;98:e17358.
3. Castro M. Placebo versus best-available-therapy control group in clinical trials for pharmacologic therapies: which is better? *Proc Am Thorac Soc*. 2007;4(7):570–573. doi:10.1513/pats.200706-073JK
4. Kayupov E, Okroj K, Young AC, et al. Continuous adductor canal blocks provide superior ambulation and pain control compared to epidural analgesia for primary knee arthroplasty: a randomized, controlled trial. *J Arthroplasty*. 2018;33(4):1040–4e1. doi:10.1016/j.arth.2017.11.013
5. Willett A, Lew R, Wardhan R. Is continuous proximal adductor canal analgesia with a periarticular injection comparable to continuous epidural analgesia for postoperative pain after total knee arthroplasty? A retrospective study. *Rom J Anaesth Intensive Care*. 2019;26:9–15.
6. Alsheikh KA, Alkhelaifi AS, Alharbi MK, et al. Adductor canal blockade versus continuous epidural analgesia after total knee joint replacement: a retrospective cohort study. *Saudi J Anaesth*. 2020;14(1):38–43. doi:10.4103/sja.SJA_354_19
7. Zorrilla-Vaca A, Li J. Dexamethasone injected perineurally is more effective than administered intravenously for peripheral nerve blocks: a meta-analysis of randomized controlled trials. *Clin J Pain*. 2018;34:276–284.
8. Wang CJ, Long FY, Yang LQ, et al. Efficacy of perineural dexamethasone with ropivacaine in adductor canal block for post-operative analgesia in patients undergoing total knee arthroplasty: a randomized controlled trial. *Exp Ther Med*. 2017;14(4):3942–3946. doi:10.3892/etm.2017.4974
9. Bovonratwet P, Bohl DD, Russo GS, Ondeck NT, Singh K, Grauer JN. Incidence, risk factors, and impact of clostridium difficile colitis after spine surgery: an analysis of a national database. *Spine*. 2018;43(12):861–868. doi:10.1097/BRS.0000000000002430
10. Belmont PJ Jr, Goodman GP, Waterman BR, Bader JO, Schoenfeld AJ. Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. *J Bone Joint Surg Am*. 2014;96(1):20–26. doi:10.2106/JBJS.M.00018
11. Kishawi D, Schwarzman G, Mejia A, Hussain AK, Gonzalez MH. Low preoperative albumin levels predict adverse outcomes after total joint arthroplasty. *J Bone Joint Surg Am*. 2020;102(10):889–895. doi:10.2106/JBJS.19.00511

12. Bovonratwet P, Nelson SJ, Ondeck NT, Geddes BJ, Grauer JN. Comparison of 30-day complications between navigated and conventional single-level instrumented posterior lumbar fusion: a propensity score matched analysis. *Spine*. 2018;43(6):447–453. doi:10.1097/BRS.0000000000002327
13. Husted H, Hansen HC, Holm G, et al. What determines length of stay after total hip and knee arthroplasty? A nationwide study in Denmark. *Arch Orthop Trauma Surg*. 2010;130(2):263–268. doi:10.1007/s00402-009-0940-7
14. Beaupre LA, Johnston DB, Dieleman S, Tsui B. Impact of a preemptive multimodal analgesia plus femoral nerve blockade protocol on rehabilitation, hospital length of stay, and postoperative analgesia after primary total knee arthroplasty: a controlled clinical pilot study. *ScientificWorldJournal*. 2012;2012:273821. doi:10.1100/2012/273821
15. Eccles CJ, Swiergosz AM, Smith AF, Bhimani SJ, Smith LS, Malkani AL. Decreased opioid consumption and length of stay using an IPACK and adductor canal nerve block following total knee arthroplasty. *J Knee Surg*. 2021;34(07):705–711. doi:10.1055/s-0039-1700840
16. Carvalho Junior LH, Temponi EF, Paganini VO, Costa LP, Soares LF, Goncalves MB. Reducing the length of hospital stay after total knee arthroplasty: influence of femoral and sciatic nerve block. *Rev Assoc Med Bras*. 2015;61:40–43.
17. Bovonratwet P, Bohl DD, Malpani R, et al. Cardiac complications related to spine surgery: timing, risk factors, and clinical effect. *J Am Acad Orthop Surg*. 2019;27(7):256–263. doi:10.5435/JAAOS-D-17-00650
18. Bovonratwet P, Webb ML, Ondeck NT, et al. Definitional differences of 'outpatient' versus 'inpatient' THA and TKA can affect study outcomes. *Clin Orthop Relat Res*. 2017;475:2917–2925.
19. Gunaratne R, Pratt DN, Banda J, Fick DP, Khan RJK, Robertson BW. Patient dissatisfaction following total knee arthroplasty: a systematic review of the literature. *J Arthroplasty*. 2017;32(12):3854–3860. doi:10.1016/j.arth.2017.07.021
20. Baker PN, van der Meulen JH, Lewsey J, Gregg PJ, National Joint Registry for E, Wales. The role of pain and function in determining patient satisfaction after total knee replacement. Data from the national joint registry for England and Wales. *J Bone Joint Surg Br*. 2007;89(7):893–900. doi:10.1302/0301-620X.89B7.19091
21. Jacobs CA, Christensen CP. Factors influencing patient satisfaction two to five years after primary total knee arthroplasty. *J Arthroplasty*. 2014;29(6):1189–1191. doi:10.1016/j.arth.2014.01.008
22. Sharareh B, Le NB, Hoang MT, Schwarzkopf R. Factors determining discharge destination for patients undergoing total joint arthroplasty. *J Arthroplasty*. 2014;29(7):1355–8e1. doi:10.1016/j.arth.2014.02.001
23. Hu X, Li J, Zhou R, et al. Dexmedetomidine Added to Local Anesthetic Mixture of Lidocaine and Ropivacaine Enhances Onset and Prolongs Duration of a Popliteal Approach to Sciatic Nerve Blockade. *Clin Ther*. 2017;39:89–97e1.
24. Pehora C, Pearson AM, Kaushal A, Crawford MW, Johnston B. Dexamethasone as an adjuvant to peripheral nerve block. *Cochrane Database Syst Rev*. 2017;11:CD011770.
25. Schnabel A, Reichl SU, Weibel S, et al. Adductor canal blocks for postoperative pain treatment in adults undergoing knee surgery. *Cochrane Database Syst Rev*. 2019;2019(10). doi:10.1002/14651858.CD012262.pub2
26. Tarity TD, Swall MM. Current trends in discharge disposition and post-discharge care after total joint arthroplasty. *Curr Rev Musculoskelet Med*. 2017;10:397–403.
27. Bozic KJ, Wagie A, Naessens JM, Berry DJ, Rubash HE. Predictors of discharge to an inpatient extended care facility after total hip or knee arthroplasty. *J Arthroplasty*. 2006;21(6):151–156. doi:10.1016/j.arth.2006.04.015
28. Keswani A, Tasi MC, Fields A, Lovy AJ, Moucha CS, Bozic KJ. Discharge destination after total joint arthroplasty: an analysis of postdischarge outcomes, placement risk factors, and recent trends. *J Arthroplasty*. 2016;31(6):1155–1162. doi:10.1016/j.arth.2015.11.044
29. Lenart MJ, Wong K, Gupta RK, et al. The impact of peripheral nerve techniques on hospital stay following major orthopedic surgery. *Pain Med*. 2012;13(6):828–834. doi:10.1111/j.1526-4637.2012.01363.x
30. Deiter J, Ponzio D, Grau L, et al. Efficacy of adductor canal block protocol implementation in a multimodal pain management protocol for total knee arthroplasty. *J Clin Orthop Trauma*. 2020;11:118–121.
31. Johns N, Noye N, Wall C, Martin G, Loch A. Efficacy of adductor canal blocks in total knee arthroplasty. *J Knee Surg*. 2021;35(13):1491–1494. doi:10.1055/s-0041-1726417
32. Baldev K, Dai F, Barrett C, et al. Glucocorticoid minimizes local anesthetic infusion requirement through adductor canal block and improves perioperative prosthetic joint range of motion in total knee arthroplasty. *PLoS One*. 2022;17:e0261949.