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Original Research

Combined Single-Shot Infiltration Between the Popliteal Artery and Capsule of the Knee and Adductor Canal Block With Bupivacaine, Dexmedetomidine, and Dexamethasone for Total Knee Arthroplasty: A Propensity-Matched Analysis

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ABSTRACT

Background: To investigate if combined single-shot adductor canal blockade (ACB) and infiltration between the popliteal artery and capsule of the knee (IPACK) provide better postoperative pain management compared to ACB alone for patients undergoing unilateral total knee arthroplasty (TKA).
Methods: This retrospective cohort study included adult patients who underwent primary, unilateral TKA. Patients were separated into 2 cohorts: single-shot ACB alone (performed with bupivacaine 0.25%) and combined single-shot ACB + IPACK (performed with bupivacaine 0.25%, dexmedetomidine 1 mg/kg, and dexamethasone 4 mg). Patients were propensity-matched 1:1. The primary study outcome was total opioid consumption converted to morphine milligram equivalents (MME) per eight-hour interval and postoperative day. Secondary outcomes included pain scores, length of stay, ambulation distance, return to emergency department, hospital readmission, and 30-day adverse events.
Results: One hundred eighty patients were identified, of which propensity matching used 71% to yield 64 patients receiving ACB alone and 64 receiving combined ACB + IPACK. Combined ACB + IPACK had significantly lower total summative MME throughout the entire postoperative stay ($P = .002$) and cumulatively after the first 24 hours ($P < .001$). Combined ACB + IPACK also had lower mean pain scores for 0-8 hours ($P = .005$) and 8-16 hours ($P = .009$) postoperatively. There were no significant differences in secondary outcomes.
Conclusions: Combined single-shot ACB + IPACK block was associated with lower total narcotic intake and mean pain scores during most of the immediate postoperative period following primary, unilateral TKA compared to ACB alone. Implementing longer-acting, single-shot ACB + IPACK for TKA can balance effective and more selective pain management with early rehabilitation.

Introduction

Total knee arthroplasty (TKA), one of the most common orthopaedic procedures, is regarded as the definitive treatment for chronic knee osteoarthritis. Although patients generally report long-term satisfaction, the surgery has traditionally been associated with a level of postoperative pain that prevents early mobilization, prolongs hospital length of stay, limits recovery and rehabilitation, and consequently increases the financial burden on the health care system [1]. In addition, poor pain control enforces reliance on opioids, rendering TKA an operation with one of the highest risks of chronic opioid dependence [2].

Perioperative multimodal analgesic strategies, consisting of "motor-sparing" regional anesthetic techniques combined with systemic nonopioid medications that target various pain pathways, have been developed to mitigate this risk; they confer improved

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pain scores and patient satisfaction, reduced opioid consumption and opiate-related adverse effects, early postoperative ambulation, shortened hospital stay, and fewer surgical complications [3]. Adductor canal block (ACB) has essentially replaced the femoral block by providing similar analgesic results in the anterior portion of the knee while avoiding the quadriceps muscle weakness associated with femoral blocks [4–6]. Infiltration between the popliteal artery and the capsule of the posterior knee (IPACK) block, on the other hand, has emerged for the coverage of the posterior knee pain, aiming at replacing the sciatic nerve block and the profound lower extremity motor blockade it confers [7]. IPACK provides local anesthesia to articular branches of the common peroneal, tibial, and posterior branches of the obturator nerve and spares motor branches of the common peroneal and tibial nerves. The IPACK has been shown to reduce pain scores and opioid consumption on the first day after TKA [8,9]. Furthermore, combining a single-shot IPACK block with a continuous ACB can provide analgesia to TKA patients comparable to a femoral-sciatic combination, with less motor weakness and significantly improved physical status [10,11]. So far, recent literature on regional anesthesia for TKA compares the addition of IPACK block to continuous ACB, but to our knowledge, the combination of single-shot ACB with IPACK incorporating perineural dexmedetomidine and dexamethasone has not been studied [11]. Dexmedetomidine and dexamethasone have been added to the local anesthetic as they improve the efficacy as well as the duration of regional blocks [12,13]. Therefore, the purpose of this study was to investigate if the addition of IPACK with bupivacaine, dexmedetomidine, and dexamethasone to single-shot ACB with bupivacaine has better outcomes than single-shot ACB in patients undergoing unilateral TKA in a safety-net hospital.

Material and methods

Patients

After receiving institutional review board approval, we conducted a retrospective cohort study of patients (age $\geq$18 years) who underwent primary, unilateral TKA performed by a single orthopaedic surgeon at an academic, tertiary care, safety-net hospital between January 2015 and February 2020. Patients who received exclusively single-shot ACB with bupivacaine 0.25% comprised the historic ACB cohort. Patients who received both single-shot ACB with bupivacaine 0.25% and IPACK with bupivacaine 0.25%, dexmedetomidine 1mg/kg (up to 100 mcg), and dexamethasone 4 mg comprised the intervention (ACB + IPACK) cohort. All patients received intraoperative intraarticular injection of local anesthetic (bupivacaine 0.25% w/1:200.000 epinephrine) by the surgical team, while ensuring bupivacaine levels remained within therapeutic range.

Exclusion criteria were bilateral TKA, unicompartmental (partial) knee arthroplasty, ipsilateral revision TKA, usage of peripheral nerve block other than ACB and/or IPACK, allergy to local anesthetic, active infection at site of injection (before block placement), pre-existing neurological abnormalities, and inability to comprehend the visual analog scale (VAS) pain score (determined by nursing and chart review). Intraoperative anesthetics included either general anesthesia or spinal anesthesia.

Block information

Single-shot adductor canal block

In the supine position, ACB was performed under ultrasound guidance with a 10 MHz linear probe using a 21-gauge, 4-inch echogenic block needle. Board-certified anesthesiologists identified the femoral artery in the adductor canal, deep into the sartorius muscle, in a short-axis view. The needle was inserted lateral to medial via an in-plane approach, with the tip under the vastoadductor membrane. A total of 20 mL of bupivacaine 0.25% was delivered incrementally after repeated negative heme aspirations around the femoral artery, encompassing the 9 o'clock to 5 o'clock positions of the artery, ensuring spread to the saphenous nerve and the nerve to the vastus medialis.

Infiltration between the popliteal artery and capsule of the knee

After its implementation in our institution in 2019, the IPACK block was performed under ultrasound guidance with a 10 MHz linear probe using a 21-gauge 4-inch echogenic block needle and the patient in the lateral decubitus position contralaterally to the operative side. A board-certified anesthesiologist identified the popliteal artery in a short-axis view, at the popliteal crease, and moved cephalad just beyond the femoral condyles, at the level where the condyles merge with the shaft of the femur. The tibial and peroneal nerves were visualized superficially to the popliteal artery. After identifying the space between the femur and popliteal artery, the needle was advanced in-plane from lateral to medial. The tip positioned in the middle of the femur and near the lateral border near the periosteum is injected to ensure adequate spread to the lateral end of the femur. Bupivacaine 0.25% (20 ml) with 1 mcg/kg of dexmedetomidine (up to 100 mcg) and 4 mg of dexamethasone were injected incrementally.

Outcomes

Baseline preoperative characteristics included age, sex, body mass index, American Society of Anesthesiologists (ASA) level, preoperative opioid usage within 3 months of TKA, and use of neuraxial anesthesia (spinal). Postoperative outcomes included opioid consumption in morphine milligram equivalents (MME) and VAS pain scores at 0-8, 8-16, 16-24, 24-48, and 48-72 hours, length of hospital, maximum ambulation distance on postoperative days 1 and 2, anesthesia and surgically-related postoperative complications, and emergency department (ED) presentation/hospital readmission within 30 days of discharge.

Statistics

Preoperative characteristics were summarized between ACB + IPACK vs ACB cohorts after propensity-score matching using the covariates of age, gender, opioid usage within 3 months before surgery, ASA, and use of spinal anesthesia. Postoperative outcomes were analyzed and compared between cohorts utilizing chi-squared for categorical variables and t-test for quantitative variables. Statistical analysis was performed using R (R Foundation for Statistical Computing, Vienna, Austria). *P*-values less than 0.05 were deemed statistically significant.

Results

One hundred eighty patients who underwent unilateral TKA and met inclusion criteria were identified. Propensity matching (1:1) used 71% of the set to yield 64 patients who underwent ACB + IPACK and 64 patients who underwent ACB only. There were no statistically significant differences between ACB + IPACK and ACB cohorts in age, sex, ASA score, use of opioid within 3 months before surgery, and spinal anesthesia usage (Table 1).

The ACB + IPACK cohort had significantly lower total summative MME throughout the entire postoperative stay (160.1 vs 268.8, $P = .002$) and cumulatively after the first 24 hours (53.2 vs 100.8, $P < .001$) compared to the ACB cohort. The ACB + IPACK cohort had significantly lower MME in the 0-8 hour (23.7 vs 54.2, $P < .001$),

Table 1
Patient and treatment characteristics by anesthesia method.

Characteristic	ACB alone (n = 64)		ACB + IPACK (n = 64)		*P* value
	Freq.	(%)	Freq.	(%)	
Age at surgery (years)					
Mean (SD)	63.6	(9.02)	64.5	(9.12)	.54
Sex (% male)	22	(34.40)	24	(37.50)	.85
ASA					.72
2	27	(42.19)	30	(46.88)	
3	37	(57.81)	34	(50.75)	
BMI					
Mean (SD)	32.0	(5.72)	32.5	(5.84)	.58
Race					.67
Black	32	(50.00)	24	(37.50)	
White	14	(21.88)	18	(28.13)	
Hispanic	12	(18.75)	13	(20.31)	
Asian	1	(1.56)	1	(1.56)	
Not provided	5	(7.80)	8	(12.50)	
Spinal anesthesia used	23	(35.94)	21	(32.81)	.85
Opiate usage within 3 mo before current admission	16	(25.00)	16	(25.00)	1

ACB, adductor canal block; IPACK, infiltration between popliteal artery and capsule of the knee.

16-24 hour (14.25 vs 25.8, $P = .003$), and 24-48 hour (36.0 vs 59.7, $P = .04$) intervals (Table 2, Fig. 1). In addition, the ACB + IPACK cohort had lower mean VAS scores for the 0-8 hour (4.34 vs 5.51, $P = .005$) and 8-16 hour (4.62 vs 5.69, $P = .009$) intervals (Table 2, Fig. 2). There were no differences in rates of anesthesia-related or surgically-related complications between cohorts. No differences were found between cohorts for length of postoperative anesthesia care unit stay, length of hospital stay, return to ED, hospital readmission, or ambulation distance after operation (Table 3).

Discussion

Utilizing an anesthetic modality that provides reduced pain and narcotic usage without increasing complication rates is crucial for optimizing patient outcomes after TKA. Our results show that patients in the ACB + IPACK cohort required lower narcotic intake compared to the ACB cohort within the first 24 hours postoperatively and during the entire hospital stay. The ACB + IPACK cohort also had lower mean VAS scores for the first 16 hours postoperatively. There were no significant differences in anesthesia or surgical complications, ambulation distance, ED returns, readmissions, or length of stay.

Previous literature has shown that IPACK can provide decreased pain scores and opioid consumption when compared to no infiltration on the first day after TKA [8,9]. There have also been reports that, when combined with a regimen of low-dose oral and parenteral opioids, as well as nonopioid analgesics perioperatively, many patients can be comfortable and mobile enough to be discharged home within a matter of hours [14].

It is important to note that our study revealed similar findings as previous literature, namely that the ACB + IPACK group had lower pain scores and reduced narcotic intake compared to ACB alone. Contrary to previous studies that utilized primarily continuous ACB catheters with IPACK, our study combined IPACK with single-shot ACBs in both cohorts. At our institution, single-shot blocks are preferred over continuous catheters as they use lower anesthetic volume, are less labor-intensive, do not require follow-up checks, and do not confer the risk of catheter-associated infection, catheter-related hematoma due to dislodgement, and muscle weakness from prolonged local anesthetic affecting the femoral nerve. Meta-analyses comparing single-shot and continuous ACB present varying results regarding which provides superior pain management [12]. In addition, in our study, the IPACK injectate included not only bupivacaine 0.25% but also dexmedetomidine and dexamethasone, which makes the comparison of outcomes among previous IPACK studies not applicable.

A Cochrane review showed dexamethasone to be helpful for upper-limb surgeries but stated there is not enough evidence to conclude if it is useful for lower-limb surgeries [13]. Dexamethasone has been shown to increase duration of the ACB in anterior cruciate ligament surgery [15], and a recent randomized controlled trial revealed that 2 doses of dexamethasone reduced postoperative pain and narcotic intake post-TKA [16]. Dexmedetomidine seems to reduce postoperative pain and narcotic intake after TKA prolonging the duration of sufficient pain control [17]. A case report showed that the IPACK + ACB block was prolonged with the use of perineural dexmedetomidine and dexamethasone for TKA [18]. Considering these recent studies, our institution has utilized both dexmedetomidine and dexamethasone to prolong the effect of regional blocks.

Although our findings reveal reduced opioid intake associated with the use of IPACK when combined with ACB, others have reported increased opioid intake in patients with IPACK + ACB in comparison to IPACK combined with periarticular injection (PAI) [19,20]. These discordant findings may be attributed to institutional practices, such as using dexmedetomidine and dexamethasone to prolong the regional blockade, but also to the technique itself. The IPACK is a relatively new approach, so experience of the

Table 2
Visual analog scale and morphine milligram equivalents by anesthesia method.

Characteristic	ACB alone (n = 64)		ACB + IPACK (n = 64)		*P* value
	Mean	SD	Mean	SD	
MME (0-8 h postoperation)	54.17	−46.29	23.68	−23.63	**<.001**
MME (8-16 h postoperation)	20.81	−17.11	15.27	−36.22	.27
MME (16-24 h postoperation)	25.83	−26.03	14.25	−15.99	**.003**
MME (24-48 h postoperation)	59.69	−72.65	36.01	−55.27	**.04**
MME (sum of 0-24 h postoperation)	100.81	−70.94	53.2	−58.19	**<.001**
MME (sum of entire stay postoperation)	268.77	−215.25	160.11	−164.05	**.002**
VAS (0-8 h postoperation)	5.51	−2.36	4.34	−2.2	**.005**
VAS (8-16 h postoperation)	5.69	−2.4	4.62	−2.12	**.009**
VAS (16-24 h postoperation)	5.35	−1.89	5.05	−1.71	.362
VAS (24-48 h postoperation)	5.38	−1.64	5.26	−1.51	.734

ACB, adductor canal block; IPACK, infiltration between popliteal artery and capsule of the knee; MME, morphine milligram equivalents; VAS, visual analog scale.
Bold indicate statistical significance.

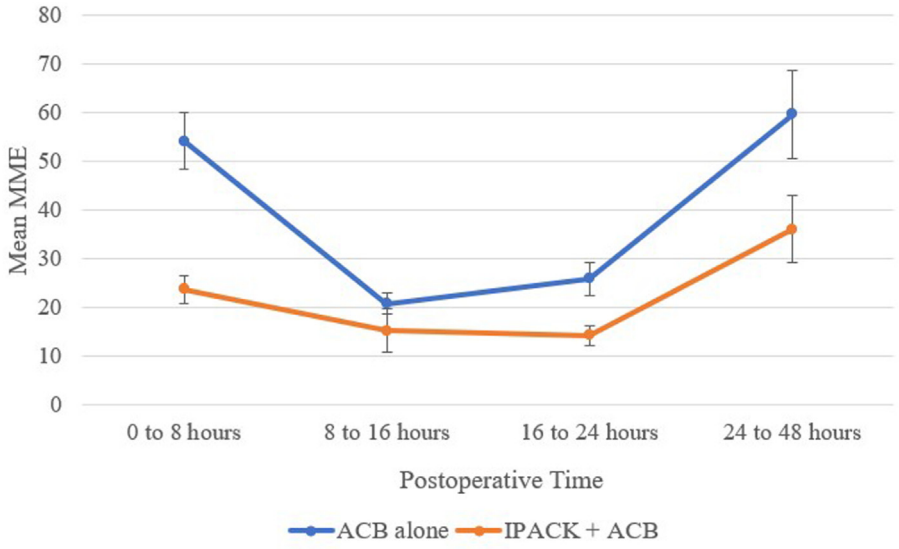

Figure 1. Mean morphine milligram equivalents (MME) during postoperative stay.

anesthesiologist may be one factor. Furthermore, there is technical variation among providers with respect to anatomic placement of the block in relation to the femoral condyles. Chan et al showed that IPACK block has been administered either proximally (distal femoral shaft) or distally (cephalad to or at femoral condyles) [21]. Distal IPACKs spread preferentially to anteromedial and posterior aspects of the knee, while the proximal IPACK primarily spread to the anterolateral area [22]. IPACKs at the level of femoral condyles have been shown to provide better pain management compared to those at the level of the distal femoral shaft [23]. These studies provide insight into a possible source of variability in IPACK's efficacy to reduce postoperative pain and have guided our institution to provide IPACKs at the level of the femoral condyles. PAIs are commonly used intraoperatively in order to reduce postoperative pain. PAI often does not reach posteriorly due to the risk of injecting in or puncturing the popliteal artery, as well as causing risk of pseudoaneurysms, and therefore there is often inadequate analgesia in the posterior knee. Furthermore, the IPACK uses ultrasound guidance, so it is more targeted and thus safer.

This study is not without limitations. Although our study tried to limit confounding by utilizing propensity-score matching, selection bias may be present as it is a retrospective cohort study. The relatively small number of patients in each cohort after matching may limit the strength of our conclusions. Prior to 2019, single-shot ACBs were primarily used at our institution. However, after 2019, our anesthesiology department started providing IPACKs in combination with single-shot ACBs to patients undergoing TKAs due to the expertise of a new regional anesthesiologist as well as favorable emerging literature on the use of IPACK in patients undergoing TKA. After discussion with members of our anesthesia team, no significant changes occurred in the department during the study time frame that we believe could influence operative course, related complications, perception of pain, or opioid administration for patients receiving a TKA. Another weakness of the study is that the experimental arm includes 3 different interventions (IPACK, dexamethasone, and dexmedetomidine). Therefore, this study cannot definitively delineate which of the specific interventions made a difference in the outcomes measured. Our study showed that VAS

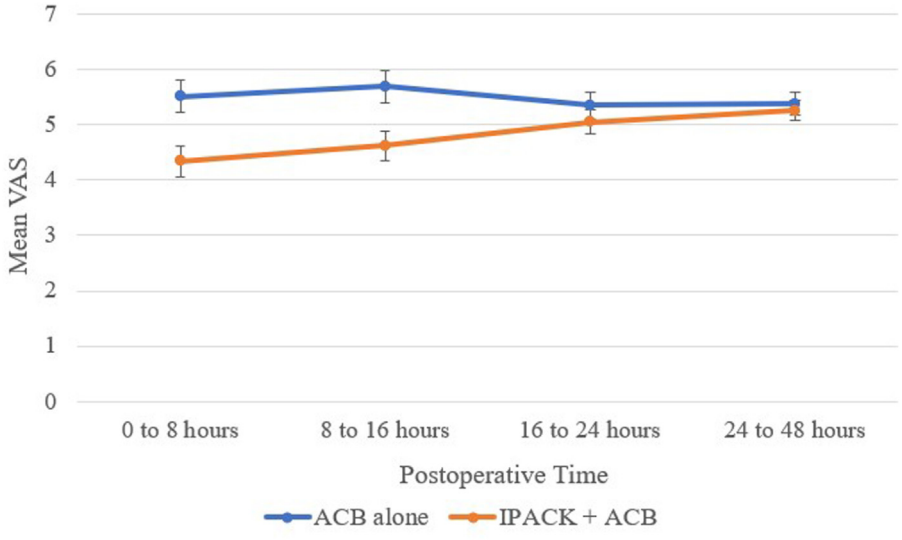

Figure 2. Mean visual analog scale (VAS) during postoperative stay.

Table 3
Patient outcomes by anesthesia method.

Outcomes	ACB alone (n = 64)		ACB + IPACK (n = 64)		*P* value
	Freq.	(%)	Freq.	(%)	
Presentation to ED postoperation	8	(12.50)	13	(20.31)	.34
Readmission to hospital	4	(6.25)	8	(12.50)	.36
Anesthesia-related complications	5	(7.81)	3	(4.69)	.72
Surgery-related complications	8	(12.50)	5	(7.81)	.48
Length of stay (hours)					
Mean (SD)	73.54	32.85	75.55	41.38	.76
PACU stay (hours)					
Mean (SD)	3.41	1.5	3.15	1.51	.32
Maximum ambulation distance POD 1 (m)[a]	131.08	117.17	135.15	91.31	.836
Maximum ambulation distance POD 2 (m)[b]	174.35	126.32	168.68	100.84	.826

ED, emergency department; PACU, postoperative anesthesia care unit; POD, postoperative day.
[a] 62 patients in the ACB alone group and 55 patients in the IPACK + ACB group had ambulation data POD1; remaining refused, were unable to be seen by physical therapy, or no documentation reported
[b] 43 patients in the ACB alone group and 38 patients in the IPACK + ACB group had ambulation data POD2; remaining refused, were unable to be seen by physical therapy, or no documentation reported.

scores at various postoperative intervals were above the minimum clinically important difference [24].

Conclusions

Despite these limitations, our results show that single-shot ACB with bupivacaine 0.25% combined with IPACK with bupivacaine 0.25%, dexmedetomidine, and dexamethasone are associated with lower narcotic intake than ACB alone in patients undergoing unilateral TKA. This study helps broaden the base of literature investigating regional anesthesia for TKA by introducing an analgesic combination that provides successful pain management, thus assisting anesthesiologists and orthopaedic surgeons in anesthetic decision-making. Furthermore, this study may serve as the springboard for a multicenter, randomized trial comparing pain management and outcomes of the single-shot ACB + IPACK with and without dexmedetomidine and dexamethasone in TKA.

Conflicts of interest

The authors declare the following financial interests/personal relationships that may be considered as potential competing interests: A. Abdeen is a board member/committee appointment for American Association of Hip and Knee Surgeons Quality Measures Committee and American Academy of Orthopaedic Surgeons Exams and Assessments Committee. D. Freccero has stock or stock options (equity in ROMTech), research support from Depuy, Conformis, and is a board member/committee appointment for AAHKS Patient and Public Relations Education Committee, AAOS Committee Hip, Knee and Adult Reconstruction Evaluation Committee, and AAOS Adult Reconstruction Knee Program Committee; all other authors declare no potential conflicts of interest.

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Author contributions

Melina Shoni contributed to data curation, methodology, writing – original draft, writing – review and editing. David Freccero contributed to conceptualization, investigation, methodology, supervision, writing – original draft, writing – review and editing. Ayesha Abdeen contributed to methodology, project administration, supervision, writing – review and editing. Nikhil Mikkilineni contributed to data curation, methodology, writing – original draft, writing – review and editing. Allen Wang contributed to data curation, formal analysis, writing – review and editing. Aneesh Samineni contributed to data curation, investigation, methodology, writing – original draft, writing – review and editing. Seroos Salavati contributed to conceptualization, investigation, methodology, project administration, supervision, writing – original draft, writing – review and editing.

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