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Ultrasound-Guided Adductor Canal Block Versus Intraoperative Transarticular Saphenous Nerve Block: A Retrospective Analysis

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ABSTRACT

Background: The ultrasound-guided adductor canal block (High-ACB) is an effective option for pain control in total knee arthroplasty (TKA), but its use can add substantial cost and preparatory time to a TKA procedure. An intraoperative adductor canal block (Low-ACB) performed by the operative surgeon has been described as an alternative. The hypothesis of this study is that the Low-ACB would achieve noninferior pain control and opioid utilization postoperatively when compared to the High-ACB.
Methods: This is a retrospective study of a prospectively maintained database comparing the High-ACB vs the Low-ACB. The primary outcome measure was morphine milligram equivalents consumed. Secondary outcome measures included Visual Analog Scale pain scores, postoperative outcomes (Patient-Reported Outcome Measurement Information System, Knee Injury and Osteoarthritis Outcome Score, knee range of motion), length of stay, postoperative speed of mobilization, and complications related to the type of block.
Results: There were 139 patients in the study. There was lower opioid use in the first 24 hours in the Low-ACB compared to the High-ACB group respectively (26.3 vs 30, $P = .29$) but this did not reach statistical significance. There was a statistically significant difference in Visual Analog Scale score on postoperative day 1 in the Low-ACB vs High-ACB groups respectively (4.6 vs 3.7, $P = .02$) but this did not reach the level of clinical significance. There was no statistical difference in the Patient-Reported Outcome Measurement Information System, Knee Injury and Osteoarthritis Outcome Score, or postoperative range of motion. There were no block-related complications in either group.
Conclusion: The Low-ACB is a safe, effective, and cost-saving alternative to the traditional High-ACB for pain control in TKA.

Modern total knee arthroplasty (TKA) has become a highly successful operation when treating patients with end-stage osteoarthritis [1,2]. As the population of the United States continues to rise, so too does the number of projected TKA procedures performed annually [3]. Although outcomes and patient satisfaction continue to improve, there has been a great deal of recent interest in perioperative pain control [3–5]. Toward this end, a variety of multimodal pain management strategies designed to disrupt the perception of pain via different mechanisms have been developed [6,7]. In addition to the combination of oral and intravenous (IV) pain medications and anti-inflammatories, spinal anesthesia, peripheral nerve blocks, and periarticular injection protocols have dramatically improved perioperative pain control [6,8–10].

While effective, some of these modalities are not without their own set of limitations. Femoral nerve blockade provides reproducible pain relief to the anterior and medial aspect of the knee, but may miss the lateral and posterior aspects of the knee [1,2,11–13]. Femoral nerve blockade may also cause quadriceps weakness which can delay mobilization and increase the risk of postoperative falls [1,14]. The adductor canal block (ACB) was developed to mitigate the motor sequelae of femoral nerve blocks [15]. Recent anatomic studies have demonstrated the presence of some motor branches to the vastus medialis within the adductor canal [11,15,16]. Study results have been

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mixed, but there has been found to be up to an 8%-9% rate of quadriceps weakness [4,12,15–17]. The ACB is typically performed under ultrasound guidance as a separate perioperative procedure, but this may add up to $2000 to the cost of a TKA [1,2,9–11,15,18].

Several authors have recently described an intraoperative ACB performed by the operating surgeon from within the joint [11,19–21]. To date, there have only been 2 published clinical studies comparing the efficacy of "High-ACB" performed under ultrasound guidance in the subsartorial adductor canal to "Low-ACB" performed intraoperatively through the existing arthrotomy [20,21]. The literature has yet to reach a consensus on the effectiveness and safety of the Low-ACB block. The hypothesis of this study is that the Low-ACB will demonstrate noninferior postoperative pain control when compared to the more traditional High-ACB based on morphine equivalents.

Methods

This study is a retrospective analysis of a prospectively maintained database performed by 2 surgeons at a large academic hospital. Prior to initiating the study, Institutional Review Board approval was obtained by our institution's Institutional Review Board. Consecutive adults over the age of 18 years of age scheduled to undergo elective primary unilateral TKA for osteoarthritis were enrolled between March 2020 and December 2020 and randomized to one of the 2 study groups. Exclusion criteria included >90 consecutive days of narcotic use in the 6 months prior to surgery, bilateral procedure, nonprimary arthroplasty, workman's compensation status, inability to have spinal anesthesia, failure of attempted spinal anesthesia, inflammatory or post-traumatic arthritis, American Society of Anesthesiologists score of 4, and pregnancy [20–24]. Patients who met inclusion criteria and agreed to participate were provided with detailed description of the risks, benefits, and alternatives to each intervention and gave signed informed consent during their preoperative clinic visit.

Standard Perioperative Protocol

All patients received the same perioperative regimen regardless of which arm of the study they were randomized to. Prior to leaving the preoperative area, all patients received 30 mg of IV ketorolac (15 mg if history of renal disease) and 1000 mg of oral acetaminophen. In the operating room (OR), standard monitoring equipment was used by anesthesia staff and a thigh tourniquet was applied. Patients received spinal anesthesia using 5-10 mL of 0.5% bupivacaine as well as 8 mg IV dexamethasone (4 mg in diabetic patients). Light sedative and anxiolytic agents (propofol and midazolam) were used at the discretion of anesthesia staff throughout the procedure. During the procedure, all patients received a cocktail described by Dalury et al [6] containing ropivacaine, epinephrine, ketorolac, and clonidine infiltrated in the posterior capsule and along the distal femur and proximal tibia. Postoperatively, patients received 30 mg (15 mg for patients older than 60 or with renal disease) IV ketorolac Q6 hours for 4 doses. Patients who discharged within 24 hours of surgery only received ketorolac until the time of discharge. Patients also received 1000 mg scheduled oral acetaminophen Q8 hours, tramadol 50 mg oral Q8 hours *pro re nata*, meloxicam 7.5 mg daily, and cryotherapy. Narcotics included oral oxycodone, hydrocodone/acetaminophen, or tramadol based on patient pain levels and medication allergies. Additionally, patients were given a proton pump inhibitor beginning 1 week prior to surgery until they were off all non-steroidal anti-inflammatory drugs and deep vein thrombosis prophylaxis, a probiotic also beginning 1 week preoperatively until 3 weeks postoperatively, and a stool softener (docusate) until off all narcotics.

Randomization

Patients were randomized in a consecutive grouped fashion. The first half of the patients operated on by each surgeon received the High-ACB. The second half of the patients operated on by each surgeon received the Low-ACB. This randomization method was chosen after discussion with the anesthesia department in order to prevent confusion and to prevent the possibility of a patient receiving both High-ACB and Low-ACB.

Surgeon-Administered Group (Low-Adductor Canal Block)

In the intraoperative cohort, the block was administered after the final components were in place and cement debris was removed. The knee joint was irrigated with dilute betadine followed by pulsatile lavage per institutional protocol. A periarticular and posterior capsular block was then administered as above. The location of the saphenous nerve as it exits the adductor canal was estimated to be 1.5× the transepicondylar axis proximal to the medial epicondyle in men and 1.3× the transepicondylar axis proximal in women as described by Kavolus et al [19]. A blunt tip 1.5 in 18 gauge needle was then used to administer 15 cc of 0.5% ropivacaine. This was injected through the vastus medialis musculature in a field extending from 1 cm proximal to 1 cm distal to the assumed location of the nerve with the needle directed in approximately 30° laterally (Figs. 1-4). The wound was then irrigated with pulsatile lavage one final time and closed in a layered fashion.

Anesthesia-Administered Group (High-Adductor Canal Block)

In the preoperative cohort, the ACB was administered by either board-eligible or board-certified anesthesia staff immediately prior to patient transport to the OR. This was a single shot, with no catheter left in place after the injection. The thigh was prepped with chlorhexidine at the midpoint between the anterior superior iliac spine and the patella and sterile drapes were applied. An ultrasound probe was then used to localize the adductor canal and confirm that the femoral artery, femoral vein, and saphenous nerve could be visualized deep to the sartorius. The probe was moved

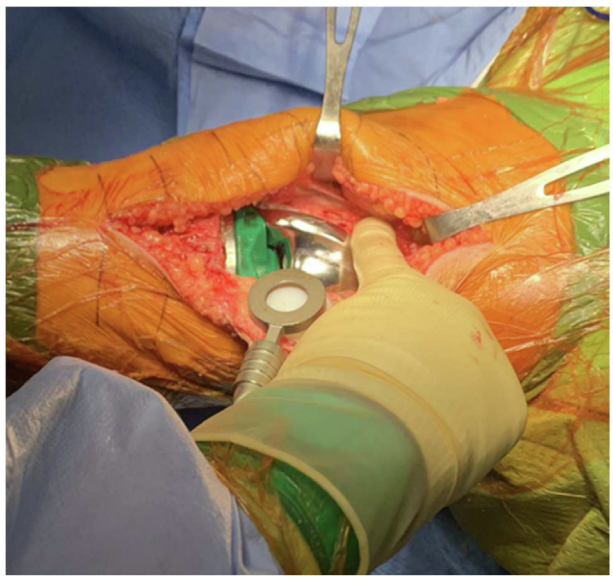

Fig. 1. Surgeon measures medially one fingerbreadth above the anterior flange of the femoral component.

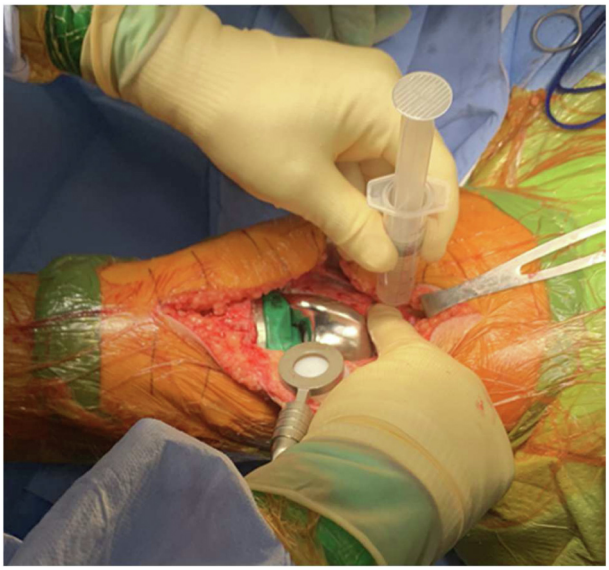

Fig. 2. The needle is inserted down to the hub at the appropriate location and directed approximately 30° laterally.

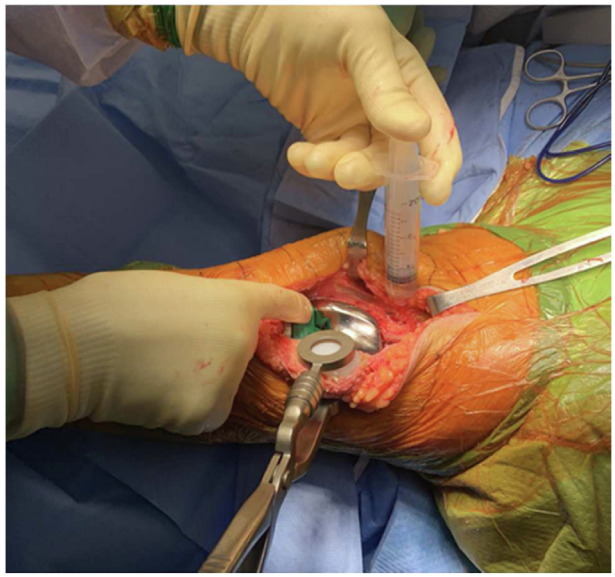

Fig. 4. The contents of the syringe are emptied surrounding the saphenous nerve.

proximally or distally until the neurovascular bundle was centered under the sartorius. A 20 cc syringe with a blunt tip 1.5 in 18 gauge needle was then used to inject 15 cc of 0.5% ropivacaine. Following this, the wound was prepped and draped in usual sterile fashion for the arthroplasty procedure.

Study Population

One hundred forty patients were enrolled in the study and 1 patient was dropped due to the unsuccessful administration of spinal anesthesia. Patient enrollment began in March 2020 and was completed in December 2020. Seventy patients received the High-ACB and 69 patients received the Low-ACB. Patients were followed for 6 weeks postoperatively. There was no statistical difference in the demographics between the 2 study groups (Table 1).

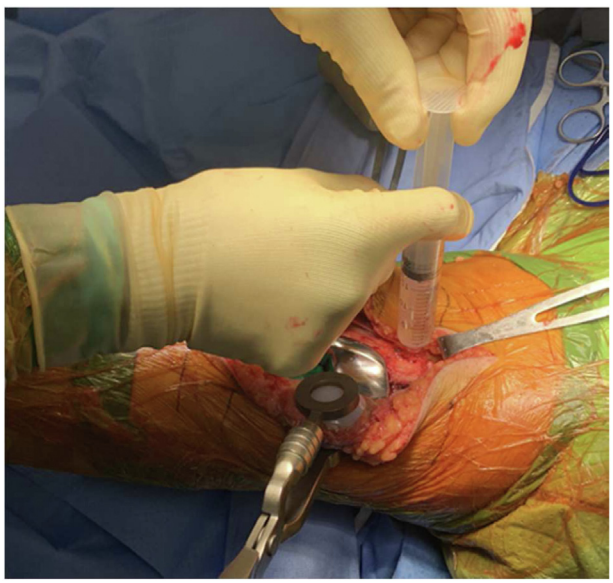

Fig. 3. The syringe is aspirated to ensure the needle has not violated the vasculature.

Outcomes

The primary outcome measure was morphine equivalents of pain medicine consumed postoperatively. The time the patient arrived to the post-anesthesia care unit was recorded as time 0 for purposes of calculating narcotic utilization. Pain scores and narcotic utilization after discharge from the hospital were recorded by patients with the use of a pain journal. Patients were instructed to record their pain scores within 30 minutes of waking up in the morning beginning on the day after discharge home. Secondary outcomes included Visual Analog Scale pain scores (VAS), Knee Injury and Osteoarthritis Outcome Score, Patient-Reported Outcome Measurement Information System, distance walked in postoperative physical therapy, knee range of motion, and postoperative hospital length of stay. All patients were also monitored for any complications related to the block including falls, intravascular injection, and allergic reaction.

Statistical Analysis

A power analysis was performed prior to enrolling patients. Prior studies specifically evaluating narcotic utilization following

Table 1
Patient Demographics Compared Between High-ACB and Low-ACB Cohorts.

Patient Demographics	High-ACB	Low-ACB	*P*-Value
Number of patients	70	69	
Gender			.31
Female	71.0%	63.0%	
Male	29.0%	37.0%	
Age (y)	70.0 ± 8.0	71.5 ± 8.3	.26
BMI (kg/m^2)	31.3 ± 4.2	30.6 ± 4.9	.38
ASA score	2.5 ± 0.5	2.4 ± 0.6	.58
Coronary artery disease	29.0%	27.1%	.81
Pulmonary disease	36.2%	25.7%	.18
Diabetes mellitus	24.6%	30.0%	.48
Chronic kidney disease	8.7%	10.0%	.79

ACB, adductor canal block; BMI, body mass index; ASA, American Society of Anesthesiologists.

ACB for TKA demonstrated a standard deviation of 20 mg of morphine equivalent consumption at 24 hours postoperatively [4,9,18]. A 10 mg morphine equivalent reduction at 24 hours has been demonstrated to be clinically relevant and a previous noninferiority study of ACB in TKA has used 30 mg morphine equivalent as their noninferiority margin which we adopted as our cut off [18]. Assuming a type I error rate of $\alpha = 0.05$ and a type II error rate of $\beta = 0.2$ (80% power), a minimum sample size of 50 patients per group was needed. Due to the longitudinal nature of postoperative outcome measures and to account for loss to follow-up or incomplete data collection, we opted to recruit 70 patients per group for a total of 140 patients enrolled. This was to ensure an adequately powered cohort even with a 30% attrition rate.

Patient characteristics were summarized using descriptive statistics for the Low-ACB and High-ACB groups, respectively. Numerical variables were presented as mean (standard deviation) or median (interquartile range), with *t*-test or Mann-Whitney *U*-test for comparison. Categorical variables were reported as percentages, with chi-squared test or Fisher's exact test for comparison. *t*-Test and linear regressions were used to compare the postoperative narcotic utilization between the 2 groups of patients. Linear mixed-effect models were used to compare the pain score, knee function, and patient-reported outcomes between the 2 groups of patients over time. Statistical analysis was performed using SAS version 9.4 (SAS Institute, Cary, NC) and R version 4.0 (R-Foundation, Vienna, Austria).

Results

There was no statistical difference in the median 24-hour postoperative narcotic consumption between the High-ACB and Low-ACB groups (30 [7.5-46.9] Meq vs 26.3 [15-47.5] Meq, $P = .29$) (Table 2). The High-ACB group had significantly lower mean VAS pain score on postoperative day 1 (POD 1) compared to the Low-ACB group (3.7 vs 4.6, $P = .02$), but this did normalize on POD 2. There was no statistical difference between the groups with physical therapy participation on the day of surgery and the distance ambulated during the initial physical therapy visit. There was a statistically significant difference in length of stay, with the Low-ACB group discharging sooner (Table 3). There were no statistical differences in patient outcomes postoperatively (Table 4). There were no block-related complications in either study group.

Discussion

The High-ACB is commonly utilized in TKA to improve pain control and reduce opioid use. Although it has been shown to be effective for pain relief, its use can lead to significantly increased costs for the patients, increased resources required, decreased efficiency for the surgical team, and a risk of quadriceps weakness. Depending on the institution and payment structures the High-ACB can increase costs from $1000 to $2000, which in the era of bundled payments is not insignificant [20]. The Low-ACB has been proposed as a low cost and efficient alternative to the High-ACB, while still effectively reducing pain. The technique used for the Low-ACB in our study is based on the descriptions from previous cadaveric and magnetic resonance imaging studies [11,19]. This technique is efficient, low cost, and easily reproducible by the operative surgeon with a very simple learning curve.

This study showed no statistical difference in narcotic consumption between the High-ACB and Low-ACB groups over the first 24 hours after surgery. The results did show a statistically significant lower VAS pain score for the High-ACB vs the Low-ACB on POD 1. Although this was statistically significant, the small actual difference (3.7 vs 4.6) does not reach the level of clinical significance of 1.2-1.3 difference as defined by the literature [25,26]. The other secondary outcomes did not show any statistical differences except for the postoperative length of stay. The Low-ACB group did have a significantly shorter length of stay when compared to the High-ACB group. The data for this study were collected during the first year of the COVID-19 pandemic, and there were institutional and departmental changes regarding same-day discharge which did affect these results. Based on the nature of these changes though, they were not felt to have any effect on the other study parameters. The High-ACB data were collected on the first 70 patients of the study, and the Low-ACB data were collected on the subsequent 70 patients. Over this period of time the perioperative and postoperative protocols regarding early discharge did continue to evolve and improve. Based on these facts, while the improvement in early discharge is encouraging, it is not felt to be related to the block type.

Table 2
Narcotic and Visual Analog Scale Use Compared Between High-ACB and Low-ACB Cohorts.

Narcotics Use and VAS Postoperative Day	High-ACB	Low-ACB	*P*-Value
Narcotics (24-h postop)	30.0 (7.5-46.9) Meq	26.3 (15-47.5) Meq	.29
VAS postoperative day 1	3.7 ± 2.0	4.6 ± 2.1	**.02**[a]
VAS postoperative day 2	6.0 ± 1.8	5.3 ± 2.3	.20

ACB, adductor canal block; VAS, Visual Analog Scale.
[a] Bolded values indicate statistical significance.

Table 3
Physical Therapy and Length of Stay Compared Between High-ACB and Low-ACB Cohorts.

Physical Therapy Use, Feet Walked, and Length of Stay	High-ACB	Low-ACB	*P*-Value
Physical therapy on day of surgery? (Yes)	97.1%	95.7%	.99
Feet walked during initial physical therapy visit	126.5 ± 85.8	145.6 ± 105	.24
Hospital length of stay			**<.01**[a]
0-23 h	2.9%	21.4%	
24-48 h	85.5%	71.4%	
>48 h	11.6%	7.1%	

ACB, adductor canal block.
[a] The Low-ACB block was performed on patients later in the study timeline. Departmental procedures regarding same-day discharge changed due to the COVID-19 pandemic, which likely accounts for the difference in hospital length of stay. Bolded values indicate statistical significance.

Table 4
Patient-Reported Outcome Measures Compared Between High-ACB and Low-ACB Cohorts.

PROMIS, KOOS, and ROM Parameter	High-ACB	Low-ACB	*P*-Value
PROMIS (Physical)			
Preoperatively	42.1 ± 5.2	42.7 ± 6.5	.85
2-wk postoperatively	43 ± 6.2	43.3 ± 6.7	.92
6-wk postoperatively	46.9 ± 6.4	47.5 ± 6.8	.68
PROMIS (Mental)			
Preoperatively	49.5 ± 6.2	48.6 ± 7.7	.88
2-wk postoperatively	52.1 ± 6.6	53 ± 8.6	.90
6-wk postoperatively	50.9 ± 6.1	52.9 ± 6.6	.76
Knee injury and Osteoarthritis Outcome Score			
Preoperatively	48.7 ± 10.6	50 ± 12.4	.78
2-wk postoperatively	63.7 ± 8.5	60.7 ± 10	.68
6-wk postoperatively	68.5 ± 15.8	68.2 ± 12	.90
Range of motion			
Preoperatively	100.8 ± 12.3	102.2 ± 7.7	.76
2-wk postoperatively	98.9 ± 16.6	98.4 ± 14.1	.83
6-wk postoperatively	113.1 ± 13.8	112.7 ± 12.3	.74

ACB, adductor canal block; PROMIS, Patient-Reported Outcomes Measurement Information System.

Our study is in agreement with the current literature regarding clinical comparisons of the Low-ACB and the High-ACB. Peterson et al retrospectively compared a surgeon-administered intra-articular saphenous nerve block and high-dose periarticular injection with an anesthesia-administered continuous adductor canal catheter. They found that the group with the surgeon-administered block had significantly lower pain scores and required fewer narcotic pain medications on the day of surgery. There was no difference in POD 1 pain scores, overall opioid use, length of stay, or complications. Greenky et al prospectively compared an anesthesia-administered with a surgeon-administered saphenous nerve block. This study found that opioid use was equal on POD 0, 1, or 2 between the groups. The group with the anesthesia-administered block did have statistically less pain on POD 1, but this did not reach clinical significance. Our study does have larger patient cohorts than any previously published study on this topic. Although this is a retrospective study, the database was maintained in a prospective manner.

Our study does have several limitations. Although our database was prospectively maintained, this is a retrospective cohort study rather than a prospective randomized trial. In addition, we did not record VAS pain scores on POD 0 due to an inability to control for the time after surgery that it was recorded. We felt this could skew results if some patients had pain scores recorded while spinal anesthesia was still in effect. On the other hand, the duration of effect of ropivacaine when used peripherally is between 18 and 24 hours [2,27,28]. Our first VAS pain score was recorded the morning after surgery and depending on the time of surgery and the length of effect of the ropivacaine it is possible that the ACB may no longer have an effect on pain control at that time. Another limitation is the fact that the patients who discharge home on the day of surgery recorded their own pain scores on POD 1. Based on patient compliance, the variability in VAS score collection could affect the data. Finally, our study was only powered to detect noninferiority of morphine equivalents. The strength of our data would be improved if the study was powered to detect differences in the other study parameters.

Conclusion

Based on these findings, the surgeon administered Low-ACB provides noninferior perioperative pain control relative to a more traditional anesthesia administered High-ACB based on morphine equivalents. Performing the block intraoperatively has the potential to substantially decrease OR turnaround time in institutions where the block was previously performed by anesthesia in the OR. Utilizing this technique may also be associated with substantial cost savings per TKA procedure.

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