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ORIGINAL ARTICLE • KNEE - ARTHROPLASTY

Additive effect of continuous adductor canal block and liposomal bupivacaine periarticular injection in total knee arthroplasty

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Abstract

Background Novel methods of postoperative analgesia for total knee arthroplasty (TKA) have demonstrated improved functional outcomes and decreased narcotic consumption. These approaches include continuous adductor canal blocks (CACB) and periarticular injection (PAI). There is a lack of current understanding regarding the effect of these modalities on narcotic usage, functionality, and pain when both PAI and CACB are utilized compared to PAI alone.

Methods TKAs were performed unilaterally by a single surgeon with a standardized protocol. Patients were divided into two groups: those receiving PAI alone ($n=54$) and those receiving PAI and CACB ($n=37$). Patient outcomes including, narcotics usage, pain scale, and distance walked, were recorded on postoperative day (POD) zero through three.

Results When compared with PAI alone, it was identified that concurrent use of PAI and CACB results in a statistically significant decrease in narcotics usage on POD 0, 1, 3, and total narcotic usage while admitted. Patients in the PAI and CACB group walked significantly farther than patients in the PAI only group on POD 1, 2, and 3. On POD 0, patients in the PAI and CACB reported significantly less pain with activity when compared to the PAI only group.

Conclusion Here we identify an additive effect when utilizing both PAI and CACB for postoperative TKA analgesia. Our findings demonstrate significant decrease in patient total narcotic usage, pain scores, and an increase in walking distance when utilizing PAI and CACB compared with PAI alone. This analgesic technique may help reduce patients' narcotic use while also increasing functional outcomes.

Keywords Total knee arthroplasty · Pain management · Periarticular injection · Continuous adductor canal block · Perioperative management

Introduction

Adequate analgesia following total knee arthroplasty (TKA) continues to be a topic of interest. Early mobilization is highly encouraged following TKA, and the severity of a patient's level of pain can be a deterrent to their participation in physical therapy which can delay the inpatient rehabilitation process and discharge. Furthermore, patient satisfaction surveys currently assess pain control in their outcome measures affecting both hospital scoring and reimbursement. As many as 60% of patients undergoing TKA may experience severe postoperative pain and 30% may experience moderate postoperative pain [1].

Currently, it is commonplace that management for acute relief of severe pain relies on morphine and associated mu-opioid-receptor agonists. However, these medications come with undesirable side effects including nausea, vomiting, constipation, and respiratory depression. Increased use of

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these medications can lead to tolerance and potential addiction [2, 3]. Pain management can be particularly difficult in patients who have developed a dependency on these medications. With the current opioid crisis, a greater focus should be directed toward preventing dependency in postoperative patients. For these reasons, multimodal approaches to analgesia are currently employed.

Peripheral nerve blocks (PNB) can provide regional anesthesia targeted to a specific nerve distribution. These are typically performed under ultrasound guidance postoperatively in the operative suite or in the post-anesthesia care unit. The duration of pain control is dictated by the type of anesthetic used, the dose, and whether or not a continuous anesthetic delivery device is used. While the use of an intra-articular bupivacaine-epinephrine pain pump has been associated with postarthroscopic glenohumeral chondrolysis, this has not been demonstrated with extra-articular use [4, 5]. Two extra-articular anatomic regions frequently anesthetized following TKA include the femoral canal and the adductor canal.

Femoral nerve blocks (FNB) have been one of the most commonly used PNBs following TKA. The sensory branches anesthetized by this block include the middle cutaneous, medial cutaneous, and saphenous nerves, which supply sensation to the skin and muscles of the thigh, and to the femur and knee. This block also affects motor branches to the quadriceps and sartorius muscles. When combined with intravenous pain control, femoral nerve blocks have demonstrated better pain control, a lower incidence of postoperative complications, and a quicker time to functional recovery when compared to IV pain control alone [6]. However, because the femoral nerve is comprised of both sensory and motor branches, this block can lead to quadriceps weakness thus delaying mobilization and presenting an increased risk of falls [7–10].

An alternative to the FNB is the adductor canal block (ACB). The adductor canal spans from the middle third of the thigh to the adductor hiatus. Targeting the adductor canal provides anesthesia to sensory branches of the saphenous and obturator nerves, as well as the nerve to vastus medialis. This provides analgesia to the medial aspect of the knee but not to the lateral or posterior aspects [6, 11]. The femoral nerve is not targeted allowing this block to spare the quadriceps and preserves immediate postoperative function for early rehabilitation. When compared to the FNB, the use of an ACB has demonstrated better patient performance with physical therapy in terms of feet walked [12]. Furthermore, while a rare diagnosis, use of a continuous ACB has not been associated with a delay in identifying anterior thigh compartment syndrome [13].

Both ACB and FNB can be administered as a single shot or a continuous analgesic pump. The use of continuous ACB in TKA has been shown to decrease pain scores and opioid use while increasing ambulation and quadriceps strength testing when compared with placebo in the initial two postoperative days [14]. When comparing continuous ACB and continuous FNB for postoperative TKA analgesia, it has been identified that while there is minimal difference in opioid consumption and pain scale, continuous ACB affords significant superiority in ambulatory outcomes and faster return to functionality [15].

A multimodal periarticular injection (MPI) is a local form of anesthesia that is administered intraoperatively. It is a mixture of medications that typically includes, but is not limited to, a local anesthetic, morphine, and Toradol [16, 17]. Commercially available options include a lipophilic form of bupivacaine that may extend the active duration of the anesthetic up to 96 h after administration, which has not been demonstrated as superior to local anesthetic mixtures [18]. Meta-analysis comparing the efficacy of peripheral nerve block modalities and MPI in TKA has identified that when compared with FNB, periarticular injection has significantly superior perioperative pain control [19].

In light of novel techniques for analgesic management of TKA, there remains a sparsity in the understanding of their optimal utilization. Although there are many studies regarding the application of peripheral nerve blocks and multimodal periarticular injections, in this retrospective analysis we attempt to identify the effects of peripheral nerve block and liposomal bupivacaine periarticular injection on patient functionality, narcotic consumption, and pain scores.

Materials and methods

Following protocol approval by the institutional review board, we performed a retrospective review of medical records for patients who underwent unilateral TKA at our institution between 2015 and 2017. As this is a retrospective study, we divided the patients into two groups based upon whether or not they had received and continuous adductor canal block. This was at a specific time point when the surgeon began using CACB for all of his patients, in addition to continuing the periarticular injection. We looked at patients 2 years before and 2 years after this time point. We were able to review the charts on patients pre-CACB, at which time the surgeon was using primary periarticular injections alone, and after the addition of CACB to the periarticular injections. Patients were assigned to a group based on whether or not they had received a CACB.

Exclusion criteria included bilateral and revision TKA, ipsilateral knee surgery within 1 year, preoperative opioid dependence and/or history of illicit drug abuse. Criteria used to classify opioid dependence included current daily opioid requirement exceeding the equivalent of 15 mg morphine. All study records were contained on the electronic medical record used at our institution. Of the 91 eligible patients, 37 patients received continuous adductor canal block (CACB), while the remaining patients underwent standard total knee procedure receiving a periarticular injection (PAI) alone without placement of an ACB.

In our retrospective review, perioperative including average daily pain scores using visual analogue scale (VAS), average daily narcotic usage, total stay narcotic usage, average number of feet walked with physical therapy per day, and length of hospital stay were extracted and compared between the two groups.

All total knee arthroplasties were performed by a single surgeon using a standard medial parapatellar approach with the patient in the supine position. A tourniquet was applied on the proximal thigh. Before cementation of components, 20 cc of 1.3% liposomal bupivacaine was diluted with sterile normal saline and injected intraoperatively to the posterior capsule, collateral ligaments, quadriceps tendon, and retinaculum. Following the procedure, a sterile dressing was applied over the closed incision.

Postoperatively, an attending anesthesiologist with specific training in regional anesthesia placed the ACB. The ACB catheters were positioned under ultrasound guidance into the medial thigh, halfway between the inguinal ligament and patella, under the sartorius muscle and just lateral and superficial to the femoral artery. After confirming the appropriate location, a 25 cc bolus of 0.25% liposomal bupivacaine was given. The anesthetic delivery device contained a 400 cc of ropivacaine, and the ACB group received continuous local infusion at a rate of 4–12 cc/hr. These pumps were removed once the fixed volume was depleted.

During the study period, all patients were offered a PCA preoperatively by the attending anesthesiologist at our institution. If the patient elected to receive a PCA, protocol was to discontinue use by 0700 on POD 1. After this, the patient was given a standard opioid regimen on a PRN basis for the rest of their hospital course. Pain score was checked in routine fashion by the patient's nurse every 3 h and was recorded in the chart. In addition, the patient's pain was assessed by the physical therapist prior to starting their session and after completion of therapy. For any patient that elected to use a PCA, the lock-out dosage and patient usage were recorded.

Throughout each patient's hospital stay, self-rated pain scores (VAS) were gathered every 4–6 h or with routine vitals as part of standard nursing protocol on the orthopedic floor. Pain scores were also recorded by therapists with and without activity. Daily average pain scores were obtained from postoperative day zero through discharge. Oral and intravenous opioids were administered postoperatively without standardized dosages between the comparison groups. The postoperative pain regimen consisted mostly of narcotic medications administered on an as needed basis. These medications included tramadol, oxycodone, morphine, hydromorphone. In order to comparatively assess the oral and intravenous opioid administration between patients, all administered opioids were converted to oral morphine equivalents (Meq) based on the following conversions as reported by the Royal College of Anaesthetists whereby 30 mg of oral morphine is equivalent to 10 mg IV morphine, 20 mg oral hydro/oxycodone IR, 10 mg oxycodone ER, 200 mg tramadol, 1.5 mg IV dilaudid, 7 mg oral dilaudid, or 15 mcg/h fentanyl.

Postoperative rehabilitation commenced on postoperative day zero and continued daily until discharge. Patients were encouraged to ambulate the same day of surgery. Each patient typically received two sessions of physical therapy daily, once in morning and once in the evening. Patient activity level was analyzed by number of steps taken with physical therapy per day. Length of hospital stay was calculated from time of surgery to discharge. Patients were discharged once both pain and physical therapy requirements were met.

VAS pain scores were averaged for each POD until discharge. An unpaired student t test was used to compare between the two groups. Average feet walked per day was used as an assessment of activity level per day. Opioid consumption based on milliequivalents of morphine was used for daily opioid consumption. This was calculated from the summation of the PRN medications, breakthrough, in addition to the volume used daily from the patient-controlled analgesia pump. These were converted to morphine equivalents. The mean opioid consumption per day was analyzed between the groups. The mean values of the continuous secondary variables were analyzed and compared using an unpaired student t test. Significance was defined as $p < 0.05$.

A post hoc power analysis was performed because this was a non-randomized retrospective review of patient charts 2 years before and 2 years following the surgeon's implementation of the CACB. Based on the average narcotic usage (in mg morphine equivalents) and standard deviation of both groups, post hoc power analysis with an α of 0.05 resulted in a β of 79.5%.

Results

This study included 91 patients undergoing unilateral TKA with 54 receiving PAI injection only and 37 patients receiving PAI and CACB. Patient demographics are indicated no significant differences between the two groups (Table 1).

VAS pain scores

When considering VAS pain scales, it was determined that patients in the PAI + CACB reported significantly less pain only on POD 0 for both pain at rest ($p = 0.009$) and pain

Table 1 Demographics

	PAI only	PAI + CACB	*p* value
Total patients (*n*)	54	37	
Male	20 (37%)	17 (46%)	
Female	34 (63%)	20 (54%)	
Average age (years)	65	64	
Average length of stay (days)	4.43	3.81	0.047*

*Indicates significance at 95% confidence interval

Table 2 Pain at rest (VAS: 0–10)

Pain at rest (VAS: 0–10)	PAI only	PAI + CACB	*P* value
POD 0	4.78	3.09	0.009*
POD 1	5.47	5.04	0.262
POD 2	4.5	4.68	0.656
POD 3	3.86	4.36	0.432

*Indicates significance at 95% confidence interval

Table 3 Pain with activity (VAS: 0 – 10)

Pain with activity (VAS: 0–10)	PAI only	PAI + CACB	*p* value
POD 0	5.22	3.6	0.02*
POD 1	6.81	6.31	0.115
POD 2	6.04	6.02	0.953
POD 3	4.1	5.48	0.584

*Indicates significance at 95% confidence interval

with activity ($p = 0.02$). Differences in patient reported pain scales were not significantly different on POD 1, POD 2, or POD 3 (Tables 2, 3; Fig. 1)

Length of stay

The difference in length of stay was determined to be significantly different between the PAI only group (4.43 days) and PAI + CACB group (3.81 days), ($p = 0.047$) (Table 1).

Opioid consumption

Narcotic consumption, measured in morphine equivalents, was determined to be significantly less for the PAI + CACB group compared to PAI alone on POD 0 (17.25 mg less), POD 1 (20.01 mg less), and POD 3 (18.77 mg less), ($p < 0.05$). On POD 2, on average, the PAI + CACB received 12.34 mg less of morphine equivalents than the PAI only, but this difference was not significant ($p = 0.171$) (Table 4, Fig. 2). When total narcotic consumption in morphine equivalents from POD 0

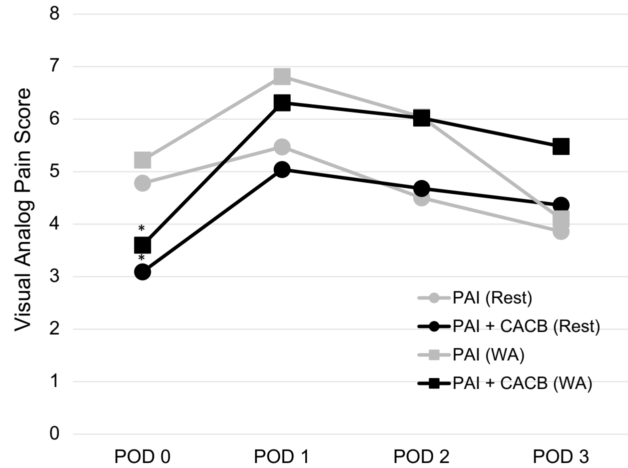

Fig. 1 Daily average numeric pain scores at rest and with activity for patients with periarticular injection alone versus periarticular injection and continuous adductor canal block. *Indicates significantly less pain ($p < 0.05$) (*WA* with activity)

Table 4 Average daily narcotic use

Average daily narcotic use (morphine equivalents* in mg)	PAI Only	PAI + CACB	*p* value
Day 0	44.83	27.58	0.005*
Day 1	72.67	52.66	0.045*
Day 2	57.95	45.61	0.171
Day 3	43.15	24.38	0.014*

*Indicates significance at 95% confidence interval

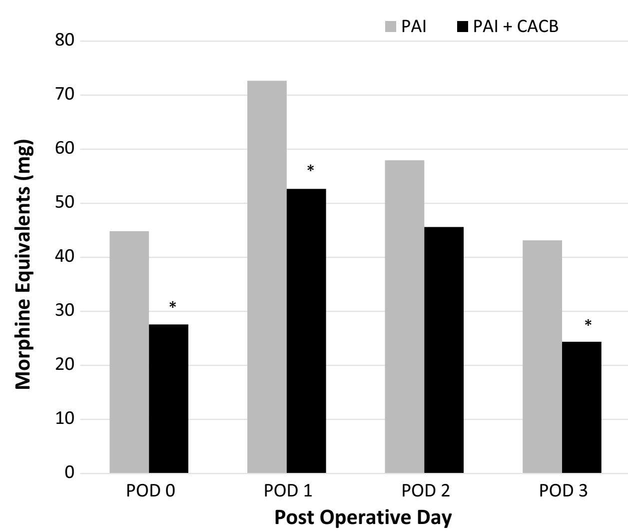

Fig. 2 Morphine equivalent administration per postoperative day with PAI versus PAI + CACB. *Indicates significantly less narcotic usage ($p < 0.05$)

Table 5 Average total narcotic usage

	PAI only	PAI + CACB	*p* value
Average total narcotic usage (Day 0–day 3) (morphine equivalents* in milligrams)	213.00	146.93	0.009*

*Indicates significance at 95% confidence interval

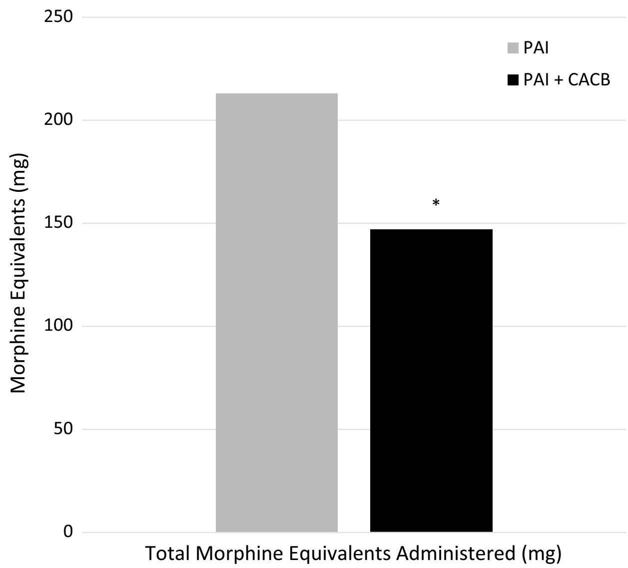

Fig. 3 Total morphine equivalents administered in periarticular injection alone versus periarticular injection and continuous adductor canal block. *Indicates significantly less narcotic usage ($p < 0.01$)

Table 6 Average feet walked daily

Average feet walked daily	PAI Only	PAI + CACB	*p* value
POD 0	2.91	3.57	0.591
POD 1	30.09	44.16	0.041*
POD 2	55.35	84.11	0.046*
POD 3	43.15	78.91	0.015*

*Indicates significance at 95% confidence interval

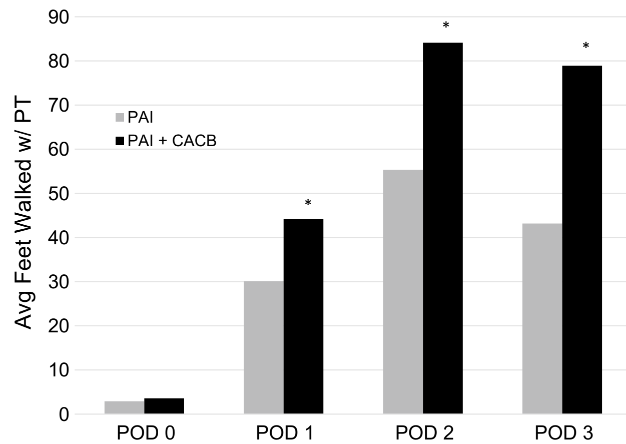

Fig. 4 Total daily feet walked with physical therapy in patients with periarticular injection alone versus periarticular injection and continuous adductor canal block. *Indicates significantly more feet walked ($p < 0.05$)

to POD 3 was compared, PAI + CACB patients on average received significantly less medication (66.07 mg) than the PAI only group ($p = 0.009$) (Table 5, Fig. 3).

Physical therapy activity level

When considering postoperative ambulation, it was identified that patients in the PAI + CACB group walked significantly more steps than the PAI alone group on POD 1 (14.07 ft farther), POD 2 (28.76 ft farther), and POD 3 (35.76 ft farther), ($p < 0.05$). On POD 0, the PAI + CACB group walked on average 0.66 feet farther than the PAI only group, which was not significant (Table 6, Fig. 4).

Specific post hoc power analysis for recorded variables is provided in Table 7

Table 7 Post hoc power analysis per variable

POD	Feet walked	Narcotics used
0	7.5	84.6
1	53.3	56.4
2	49.6	30
3	80.2	93.5

Discussion

Providing adequate analgesia following TKA may lead to a variety of improved patient outcomes during the postoperative inpatient period. Previous work comparing single shot ACB and continuous FNB depicted that ambulatory outcomes were significantly greater, and length of stay was significantly shorter in patients undergoing single injection ACB alone, but no difference in patient pain score or total opioid consumption [20, 21]. When comparing the efficacy of ACB and periarticular injection for TKA, one study reported that the ACB group had a significantly longer length of analgesia and lower reported pain scales with rest and activity [22]. However, another randomized clinical trial demonstrated similar efficacy between the two [23]. In regard to total narcotic usage, another study reported there is no difference in total narcotic use when comparing ACB and MPI and that there is no synergistic effect when utilizing both blocks together [24]. Our findings suggest that the addition of a CACB to address local control of pain decreases a patient's requirements on narcotic medications while also increasing their performance in physical therapy. Our study is the first to our knowledge that addresses the effects of simultaneous CACB and PAI versus PAI alone and provides useful data on the value of this analgesic modality following TKA.

Hospital stay

When evaluating length of hospital stay, patients receiving the combination PAI and CACB demonstrated a shorter average stay of 0.62 days, which reached statistical significance ($p < 0.05$). However, with the advent and adoption of bundled payments for joint replacement surgery, many hospitals (including ours) developed a multidisciplinary approach to maximizing the efficient delivery of patient care during the postoperative period. This development led to a more routine and standardized inpatient course. This is in contrast to a previous study that failed to find a difference in LOS when adding a PAI to an adductor canal block [25].

Physical therapy

Patients receiving the CACB and PAI walked significantly farther than those receiving PAI alone. Our data agree with a 2016 meta-analysis comparing the two demonstrated patients receiving the combination achieved earlier ambulation [26]. An earlier return to ambulation may lead to improved performance and progress with physical therapy during the inpatient period.

Opioid consumption

While differences in VAS pain scores between the two groups did not reach statistical significance other than on POD 0, the CACB + PAI group demonstrated significantly lower narcotic analgesia requirements on POD 0, 1, and 3 (17.25 mg, 20.01 mg, and 18.77 mg, respectively). Overall, this led to a reduction of 66.07 mg morphine equivalents during the inpatient period for the CACB + PAI group. We posit this represents a more objective indication of postoperative pain than the subjective nature of patient reported pain scores.

A recent study by Grosso et al. comparing PAI with PAI + single shot adductor canal block depicted that there is no significant decrease in opioid consumption or reported pain scores [27]. However, this study did not assess continuous administration of local anesthesia via CACB. Our study suggests that CACB may provide decrease in these measures. Therefore, we suggest a prospective study to further elucidate any potential benefit to this intervention.

Limitations

As a retrospective study, we are unable to account for changes in hospital policies or procedures that may have affected the inpatient experience and the subjective patient measured of pain. Without a standardized postoperative pain medication regimen, patients may have received dissimilar morphine equivalents for the same pain score. Our data are also limited to the inpatient postoperative period. More robust follow-up is required in order to assess whether the addition of the CACB has any long-term impact on patient outcomes. With regard to opioid consumption, the use of a PCA could have had an impact on POD 0 pain score differences and opioid consumption; however, all opioids given via PCA were recorded and included in the data analysis.

Future directions

As this is a retrospective study, we had a limitation on patients for whom we could collect data. While our data suggests significance, additional power is needed. Based on the mean values and standard deviation of the data we collected, we can more accurately design a prospective study that will enroll the appropriate number of patients to determine significance in these categories.

Conclusion

In this retrospective study, we have assessed the addition of continuous adductor canal block to the standard therapy of periarticular injection alone for the analgesic management of total knee arthroplasty. Our findings suggest that the addition of continuous adductor canal block may offer improved postoperative functional outcomes, reduced opioid equivalent consumption, reduced length of stay and slightly improved subjective pain scale. Although additional prospective studies should be pursued regarding this analgesic technique regarding later postoperative outcomes, our study suggests that this technique may be of value for patients undergoing total knee arthroplasty.

Compliance with ethical standards

Conflict of interest Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Ethical review committee statement This work has been approved and registered by the Plainview Hospital Institutional Review Board Committee—Study 17-0771.

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