

The Impact of Analgesic Modality on Early Ambulation Following Total Knee Arthroplasty

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Introduction: Total knee arthroplasty is associated with moderate to severe pain, and effective analgesia is essential to facilitate postoperative recovery. This retrospective cohort study examined the analgesic and rehabilitation outcomes associated with 48-hour continuous femoral nerve block, local infiltration analgesia, or local infiltration analgesia plus adductor canal nerve block.

Methods: Patients undergoing total knee arthroplasty under spinal anesthesia, during an 8-month period, were retrospectively assessed with a targeted review of 100 patients per group. Records of eligible patients were reviewed to identify the analgesic technique used and the primary outcome of distance walked on postoperative day 1. Secondary outcomes included ambulation on days 2 and 3, numeric rating scale pain scores, opioid consumption, and adverse effects and discharge disposition.

Results: Two hundred ninety-eight eligible patients were reviewed. Local infiltration analgesia and local infiltration plus adductor canal block were associated with longer distances walked on postoperative day 1 than continuous femoral nerve block (median values of 20, 30, and 0 m, respectively; $P < 0.0001$). The addition of adductor canal block was associated with further improvement in early ambulation benchmarks and a higher rate of home discharge compared with only local infiltration (88.2% vs 73.2%, $P = 0.018$). Local infiltration with or without adductor canal block was associated with lower pain scores at rest and during movement for the first 24 hours and lower opioid consumption than continuous femoral nerve infusion.

Conclusions: Local infiltration analgesia was associated with improved early analgesia and ambulation. The addition of adductor canal nerve block was associated with further improvements in early ambulation and a higher incidence of home discharge.

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Total knee arthroplasty (TKA) is often associated with moderate to severe pain.^{1,2} Effective analgesic modalities are essential to facilitate early rehabilitation and postoperative recovery.³ In the past 2 decades, multimodal analgesic regimens including both regional anesthesia and systemic analgesics have been the mainstay of pain therapy after TKA, with continuous femoral nerve blocks (CFNBs) the regional technique of choice in many centers.^{3–5}

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Despite superior analgesia, CFNBs have potential pitfalls. Femoral blocks often result in significant quadriceps weakness, reducing strength by at least 50% of baseline even with low infusion rates.⁶ This effect may impair early ambulation and rehabilitation in the immediate postoperative period.^{1,7} Some recent studies have reported a higher rate of falls in patients attempting early ambulation before complete resolution of motor blockade.⁸ Because of these shortcomings, alternative analgesic methods are being examined. Recent research has focused on more distal sites of administration of local anesthetics in an attempt to maintain adequate analgesia while minimizing quadriceps muscle weakness.

The Toronto Western Hospital (TWH) is an academic tertiary-care center with an active orthopedic program performing approximately 800 elective primary knee arthroplasties yearly. In the past year, we have introduced new locoregional analgesic modalities with the primary aim of supporting early ambulation and rehabilitation. Our previous standard analgesic management consisted of a CFNB for 48 hours, a single-dose sciatic nerve block, and low-dose intrathecal morphine within the context of oral multimodal analgesia. Over the past year, we sequentially introduced local infiltration analgesia (LIA) and adductor canal block (ACB) to replace femoral and sciatic nerve blocks. Spinal anesthesia with low-dose intrathecal morphine continues to be our preferred anesthetic modality. Surgical techniques, perioperative oral multimodal analgesia, physiotherapy protocols, and discharge criteria remained unchanged during this time.

We elected to retrospectively examine the impact of these 3 distinct methods of loco-regional anesthesia for TKA from our institution: (1) continuous femoral nerve infusion for 48 hours (plus single-dose sciatic block), (2) LIA, and (3) LIA plus ACB. Our primary outcome measure was the distance walked on postoperative day 1 (POD1). Secondary outcomes of the study included ambulation on days 2 and 3, numerical pain rating scale scores, opioid consumption, adverse effects, and discharge disposition.

METHODS

After Institutional Research Ethics Board approval, all patients undergoing unilateral primary TKA at the TWH from November 2011 through June 2012 were considered for inclusion. Patients were identified using the TWH Regional Anesthesia Patient Database, and a retrospective patient chart review was conducted to obtain outcome data.

Inclusion criteria were age between 18 and 85 years, American Society of Anesthesiology (ASA) physical status classification I through III, and unilateral primary TKA under spinal anesthesia with intrathecal morphine. Exclusion criteria included chronic opioid use (>30 mg of oral morphine equivalents per day), revision or bilateral TKA, and general anesthesia. Demographic data including age, height, weight, body mass index (BMI), sex, and ASA physical status classification were collected. Anesthetic technique and analgesic interventions were identified from a clinical regional anesthesia database. Institutional electronic patient records were accessed to review all clinical notes in the Acute Pain Service data, physiotherapy, and medication records. The primary

outcome measure of this study is early postoperative ambulation, defined as the distance walked, on POD1. Secondary outcomes include distance walked on postoperative days 2 and 3 (POD2, POD3) and the type of walking aid required (high or low walker), pain scores assessed by a numeric rating scale (NRS) at various predetermined intervals, total daily opioid consumption (expressed in intravenous morphine equivalents), the incidence of opioid-related adverse effects, the length of the patient's hospital stay, and discharge destination (home or rehabilitation facility). The occurrence of any major concurrent medical event requiring special diagnostic or therapeutic interventions was also documented.

Analgesic Modalities

Continuous Femoral Nerve Blockade

Patients receiving CFNB had indwelling catheters placed preoperatively under ultrasound guidance in a designated regional anesthesia room. Ultrasound equipment was either Philips CX50 (Philips, Andover, Massachusetts), SonoSite M-Turbo (SonoSite, Bothell, Washington), or Flex Focus 400 (BK Medical, St Laurent, Quebec, Canada) with linear high-frequency transducers (5–12, 6–13, or 6–18 MHz, respectively). Following full aseptic precautions and local anesthesia skin infiltration, the perineural space was accessed using a 17-gauge Tuohy needle under real-time ultrasound guidance using an in-plane or out-of-plane approach at the discretion of the attending anesthesiologist. Following perineural catheter placement (Stimucath Continuous Nerve Block Set; Arrow International Inc, Reading, Pennsylvania), an initial bolus injection of 30 mL of 0.2% ropivacaine was followed by a continuous infusion of ropivacaine 0.2% at 5 mL/h and on-demand patient bolus of 5 mL with a 30-minute lock-out period. The infusion rate was adjusted daily by the Acute Pain Service physician to optimize analgesia and minimize motor blockade and was discontinued 48 hours postoperatively. In addition, patients received a single-dose sciatic nerve block in the subgluteal area with 20 mL of 0.2% ropivacaine with 1:400,000 epinephrine, unless contraindicated.

Local Infiltration Analgesia

The joint was infiltrated by the attending surgeon intraoperatively under direct visualization with 300 mg of ropivacaine (150 mL of 0.2% ropivacaine), 30 mg of ketorolac, and 0.6 mg of epinephrine. The posterior capsule was infiltrated before placement of the prosthesis, and the peri-articular and superficial soft tissues were infiltrated after the prosthesis was in place and before wound closure.

Local Infiltration Analgesia Plus Adductor Canal Blockade

Patients in this group received an ACB preoperatively in addition to LIA. Under ultrasound guidance, the femoral artery and the saphenous nerve were identified in the middle one-third of the thigh, deep to the sartorius muscle in the adductor canal. The sartorius and adductor muscles form the roof and the floor of the canal, respectively. Following skin infiltration 20 mL of 0.5% ropivacaine was injected through an 80-mm, 22-gauge, short-bevel echogenic needle (SonoPlex; Pajunk, Norcross, Georgia) to surround the saphenous nerve within the neurovascular compartment. An inverted U-shaped spread of local anesthetic was sought superficial to the femoral artery.

Standard Anesthetic and Systemic Analgesics

All patients received a standard spinal anesthetic for surgical anesthesia with 15 mg of bupivacaine and 100 µg of morphine

injected through a 25-gauge Whitacre needle at the L2-3 or L3-4 levels as per routine institutional practice. Standardized perioperative systemic analgesics included acetaminophen 3 to 4 g orally daily for 5 days, celecoxib 100 to 200 mg orally twice a day, and opioids orally as needed. Intravenous patient-controlled analgesia was prescribed only as a “rescue” modality if oral analgesics failed to achieve an NRS pain score of less than 5. Analgesic outcomes were recorded upon arrival to the surgical ward and at 24, 48, and 72 hours postoperatively.

Physiotherapy Protocol

An active physiotherapy protocol was as follows: patients were visited twice daily by a physiotherapist to provide support and instruction. On the morning of POD1, patients were assisted to sit and stand by the bed, followed by transfer to a chair. They were also assisted to start walking with either a high, upright, platform, 4-wheel walker or a standard, low, 2-wheel walker (if able, as judged by the physiotherapists' assessment). Transition to a low walker is documented on the patient chart as an important benchmark as it implies a lower level of assistance and greater patient effort. The distance walked (in meters) was also documented daily.

Discharge Destination

Home discharge milestones included (1) ability to rise from bed and ambulate to bathroom independently, (2) walk along a hallway either independently or with a standard low walker, and (3) ability to climb stairs safely as per their home environment. If a higher level of ongoing support was required, the patient was transferred to a rehabilitation facility.

Sample Size and Statistical Analyses

During the study interval, a sequential practice change occurred at TWH in the management of TKA postoperative analgesia from CFNB to LIA and subsequently to LIA + AC. One hundred seven patients received LIA alone. It was therefore determined that a target convenience sample of 100 consecutive eligible patients would be reviewed in each of the 3 patient groups. Collected data were summarized using percentages for discrete variables, and mean and SDs, or median and interquartile range (IQR) for continuous data. The Kolmogorov-Smirnov test was used to test normality of the data distribution. Where required, non-parametric tests were used for comparison among the 3 groups. Between-group difference was determined with the Kruskal-Wallis test, and if $P < 0.05$ was found, the Mann-Whitney U test was used for comparisons between individual groups. A 1-way analysis of variance (ANOVA) was conducted to test for differences in normally distributed continuous variables among the 3 groups. Between-group comparisons were made using χ^2 test (for categorical variables) and Student t test (for continuous variables). Significance was set at $P < 0.05$ with Bonferroni correction used for multiple comparisons.

RESULTS

Three hundred thirty-five patients were initially screened for inclusion (Fig. 1). Thirty-seven patients were excluded (high-dose opioid use = 22 patients; use of general anesthesia = 14 patients; and bilateral surgical procedure = 1 patient). The remaining 298 patients met the inclusion criteria and were included in the analysis (Fig. 1). One hundred eligible patients were identified as having received CFNB (CFNB group). Eighty-eight of these also received a single-dose sciatic nerve block. In the remaining 12 cases, there was either a contraindication for sciatic block or

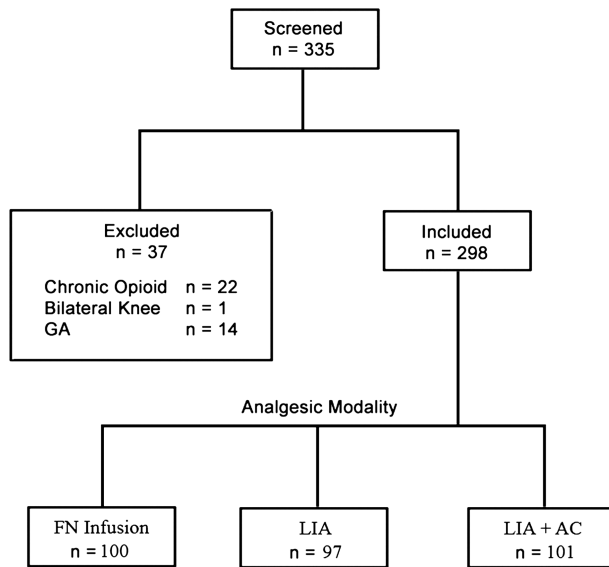


FIGURE 1. Patient inclusion flow chart.

insufficient time for the procedure. Ninety-seven patients received LIA (LIA group), and 101 patients received both LIA and ACB (LIA + ACB group). There were more females in the LIA group compared with the other 2 groups, and patients in the LIA group were marginally older and of slightly lower height than those in the FN group (Table 1). There were no differences in weight, BMI, or ASA physical status classification.

Patients in the LIA and LIA + ACB groups walked significantly more than did those in the CFNB group on POD1 (median values of 20 and 30 vs 0 m, respectively). In addition, more patients in the LIA + ACB group progressed to a standard low walker than in the other 2 groups on any given POD (Table 2). More patients in the LIA + ACB group were discharged home than in the other 2 groups (Table 2). The median length of hospital stay was 4 days for the 3 groups, with a trend toward shorter length of stay in the LIA and LIA + ACB groups (IQR, 3–4 vs 4–4).

Patients in groups LIA and LIA + ACB had lower NRS pain scores than did those in the CFNB group both at rest and with movement on POD0 and upon movement on POD1 (Table 3). In addition, patients in both LIA and LIA + ACB groups used 30% to 50% less opioid analgesics on the first 3 postoperative days (Table 4). A greater proportion of patients in the CFNB group required intravenous opioid “rescue” (Table 4).

There were no differences in the rates of opioid-related adverse effects including nausea, vomiting, dizziness, sedation, hallucination, respiratory depression, or pruritus. There were no documented cases of major or minor symptoms suggestive of local anesthetic systemic toxicity (LAST), and there were no documented complications directly attributable to the nerve blocks, such as local bleeding, infection, or postoperative neuropathy.

DISCUSSION

The moderate to severe postoperative pain of TKA is frequently managed with multimodal analgesic regimens that include regional anesthesia and systemic analgesics. Despite providing effective analgesia, CFNB may impair early ambulation and rehabilitation^{1,7} and contribute to a higher rate of falls if ambulation is pursued before complete block resolution.⁸ The ideal analgesic regimen following TKA should offer a balance between adequate pain levels and sufficient lower motor function to allow for safe early ambulation.

Although other authors had previously reported the use of intra-articular injections of local anesthetics, the first detailed description of this technique for TKA was by Kerr and Kohan.⁹ Prospective randomized controlled studies have shown that LIA is effective in decreasing pain scores and opioid consumption when compared with intravenous opioids alone, but in the absence of intrathecal morphine or other regional anesthetic technique.^{2,10–12} When LIA is maintained via indwelling catheter with subsequent boluses, it may provide better analgesia than a single dose of 100 µg of intrathecal morphine preoperatively¹³ but has only demonstrated reductions in opioid consumption on the day of surgery.¹⁴ Two studies have compared LIA with continuous femoral nerve infusion with differing results. Affas et al¹ reported similar analgesic outcomes in the first 24 hours, whereas Toftdahl et al¹⁵ reported improved analgesia with LIA compared with continuous femoral nerve infusions in the first 48 hours. These latter 2 studies

TABLE 1. Patient Demographics and Preoperative Functional Status

	CFNB (n = 100)	LIA (n = 97)	LIA + ACB (n = 101)	P
Female/male, n	49/51	65/32*	61/40	0.034
Age, y	63.2 ± 9.7	67.6 ± 9.3‡	64.6 ± 10.1	0.007
Height, cm	167.4 ± 9.8	163.4 ± 9.5†	164.9 ± 11.3	0.026
Weight, kg	87.9 ± 17.5	84.2 ± 17.7	89.2 ± 19.1	0.099
BMI, kg/m ²	31.3 ± 5.2	31.5 ± 6.0	32.7 ± 6.1	0.289
ASA physical status I/II/III, n	5/47/48	3/49/45	2/50/49	0.813
Leg-raise ability, n (%)	92 (92)	91 (93.8)	98 (97)	0.450
Cane, n (%)	32 (32)	23 (23.7)	27 (26.7)	0.894
Walker, n (%)	0	16 (16.5)*	9 (8.9)	0.012
Unassisted ambulation, n (%)	67 (67)	58 (59.8)	66 (65.3)	0.615

Values are mean ± SD or n and percentage.

P was obtained from 1-way ANOVA for continuous variables or χ^2 for categorical variables. When statistical significance was achieved for any given variable ($P < 0.05$), then a Bonferroni correction was applied to *t* test or χ^2 for individual intergroup comparisons respectively.

* $P < 0.05$ compared with CFNB.

† $P < 0.05$ compared with both CFNB and LIA + ACB.

TABLE 2. Early Ambulation, LOS, and Discharge Destination

	CFNB (n = 100)	LIA (n = 97)	LIA + ACB (n = 101)	P
Ambulation POD1 (m), median (IQR)	0 (0–0)	20 (6–50)*	30 (7–50)*†	<0.001
Ambulation POD2 (m), median (IQR)	40 (18–60)	50 (26–60)	50 (27–62)	0.103
Ambulation POD3 (m), median (IQR)	55 (45–80)	50 (40–70)	60 (40–80)	0.410
Low walker POD1, n (%)	0	6 (6.2)*	20 (19.8)*†	<0.001
Low walker POD2, n (%)	3 (3)	39 (40.2)*	50 (49.5)*†	<0.001
Low walker POD3, n (%)	10 (10)	36 (37.1)*	51 (50.5)*†	<0.001
LOS, median (IQR), d	4 (4–4)	4 (3–4)*	4 (3–4)*	0.018
LOS (range), d	3–17	2–7*	2–7*	0.018
Discharge home, n (%)	77 (77)	71 (73.2)	89 (88.2)*†	0.012
Discharge to rehabilitation center, n (%)	23 (23)	26 (26.8)	12 (11.8)*†	0.012

Unless indicated, values are presented as mean ± SD or n and percent.

Early ambulation data were not normally distributed according to a Kolmogorov-Smirnov test. Nonparametric tests were used for comparison among the 3 groups. *P* was obtained with Kruskal-Wallis test, and when *P* < 0.05, then Mann-Whitney *U* test was used for comparisons between individual groups. The remaining variables were compared with 1-way ANOVA or χ^2 and if *P* < 0.05, then a Bonferroni correction was applied to Student *t* test or χ^2 for comparisons between individual groups.

**P* < 0.05 compared with CFNB.

†*P* < 0.05 compared with LIA.

LOS indicates length of stay.

did not report any significant difference in early ambulation or length of hospital stay.

An alternative site of local anesthetic administration that has sparked recent interest is the ACB, although clinical data of its effectiveness for TKA are still limited. The adductor canal is an aponeurotic space in the thigh, extending from the apex of the femoral triangle to the adductor hiatus.^{16,17} It contains several nerve branches that supply sensory innervations to the knee, including consistently the saphenous nerve (which innervates the infratellar skin and the anterior knee capsule) and a distal branch of the motor nerve to the vastus medialis (which provides sensory innervation to the superomedial aspect of the knee and the knee capsule).¹⁸ In addition, other small sensory nerves involved in analgesia of the knee course frequently, although not consistently, through this space. The adductor canal is therefore an attractive location to provide sensory anesthesia to the knee with potentially limited effect on motor function. A small case series of 8 patients reported significant postoperative analgesia.¹⁹ A

placebo-controlled randomized trial on 71 patients suggested that the administration of 30 mL of 0.75% ropivacaine into the canal provides effective analgesia, significantly reducing pain and improving postoperative mobility assessed by the Timed Up and Go Test when compared with placebo.²⁰ It has been suggested that ACB does not result in significant quadriceps weakness.^{21,22} In healthy volunteers, ACB is associated with a mild degree of weakness (8% decrease from baseline vs 49% decrease after femoral nerve block).²³ One of the limitations of the current literature on both LIA and ACB is that each intervention has been studied in isolation, compared with placebo alone, and in the setting of general anesthesia and intravenous opioids.

In this study, we compared the 3 different analgesic regimens in the setting of spinal anesthesia with intrathecal morphine and oral multimodal systemic analgesics. Our results suggest that LIA is associated with improved early ambulation versus CFNB. The addition of ACB to LIA was associated with further improvements in early ambulation (greater distance walked on POD1 than the

TABLE 3. Pain Scores According to a Numeric Rating Scale (0 = No Pain to 10 = Maximal Pain)

	CFNB (n = 100)	LIA (n = 97)	LIA + ACB (n = 101)	P
POD0 at rest	1.9 ± 3.3	0.4 ± 1.4*	0.5 ± 1.6*	<0.001
POD0 on movement	1.7 ± 3.3	0.4 ± 1.7*	0.5 ± 1.6*	0.005
POD1 at rest	4.1 ± 2.7	3.8 ± 2.7	4.1 ± 2.9	0.752
POD1 on movement	6.7 ± 2.5	5.4 ± 2.9*	6.1 ± 2.9	0.008
POD2 at rest	3.6 ± 2.7	3.3 ± 2.5	3.9 ± 2.4	0.243
POD2 on movement	6.2 ± 2.6	5.1 ± 2.7*	5.9 ± 2.4	0.013
POD3 at rest	2.3 ± 2.5	2.7 ± 2.2	3.3 ± 2.6	0.064
POD3 on movement	4.9 ± 2.9	4.2 ± 2.4	5.1 ± 2.8	0.165

Values are presented as mean ± SD.

P was obtained from 1-way ANOVA. When statistical significance was achieved for a given variable (*P* < 0.05), then a Bonferroni correction was applied to *t* test for individual intergroup comparisons.

**P* < 0.05 compared with CFNB.

TABLE 4. Postoperative Opioid Consumption

	CFNB (n = 100)	LIA (n = 97)	LIA + ACB (n = 101)	P
Morphine equivalents POD0, mg	16.1 ± 15.2	8.3 ± 7.1*	7.8 ± 8.4*	<0.001
Morphine equivalents POD1, mg	36.7 ± 28.2	25.3 ± 20.8*	26.0 ± 23.2*	0.001
Morphine equivalents POD2, mg	35.8 ± 24.0	17.4 ± 13.5*	22.0 ± 18.1*	<0.001
Morphine equivalents POD3, mg	19.8 ± 18.1	11.6 ± 14.1*	13.1 ± 12.3*	<0.001
Rescue IV-PCA, n (%)	41 (41)	7 (7)*	9 (9)*	<0.001

Values are presented as mean ± SD.

P was obtained from 1-way ANOVA for continuous variables or χ^2 for categorical variables. When statistical significance was achieved for a given variable ($P < 0.05$), then a Bonferroni correction was applied to *t* test or χ^2 for individual intergroup comparisons respectively.

* $P < 0.05$ compared with CFNB.

IV-PCA indicates intravenous patient-controlled analgesia.

other 2 groups and earlier transition to a standard low walker). Patients who received an ACB were also less likely to require discharge to a rehabilitation facility, and hence more likely to be discharged home.

Our study has several limitations. First, it is a retrospective, observational, nonrandomized study. Differences between groups in patient or provider characteristics may have contributed to the measured outcomes in unmeasured ways. Although similar in most baseline characteristics, patients in the LIA and LIA + ACB groups were more commonly female and older. Similarly, a small percentage of patients in these groups were dependent on the support of a walker for ambulation before procedure. No attempt was made to assess outcomes based on preprocedure ambulation aid requirement, as the study was not powered for such an analysis. Finally, the outcome differences observed between groups may be in some cases mere associations, rather than due to a cause-and-effect relationship. For example, the higher incidence of home discharge documented in the ACB + LIA group could conceivably be related to social factors not specifically documented in this study. To minimize the potential influence of external factors, we included patients from a single institution with surgeries performed within a short period, by a similar group of surgeons and anesthesiologists who use standard protocols and procedures outside the analgesic intervention per se.

Second, a low infusion rate of local anesthetic was used in our patients during femoral nerve infusions (0.2% ropivacaine at 5 mL/h or 0.1% ropivacaine at 10 mL/h, with on-demand bolus options), which may explain the relatively high pain scores and opioid requirements in this group. Low concentrations and infusion rates were used in an attempt to minimize quadriceps weakness. However, the majority of patients receiving CFNB nonetheless demonstrated impaired early ambulation (Table 4). These results are consistent with previous findings.⁶ The higher concentration of ropivacaine 0.5% was chosen for administration during ACB due to an expected lack of motor effect and to be consistent with previous investigations demonstrating efficacy of this block for TKA analgesia.^{19,22,24}

Finally, the combination of LIA and ACB implies the use of a high total dose of local anesthetic with the potential for LAST. Since the recent introduction of both LIA and ACB to our practice, all patients have been closely followed in the perioperative period for signs and symptoms of LAST. Although plasma levels of local anesthetic were not tested, no changes in neurologic status, evidence of seizure activity, or evidence of cardiac toxicity were noted in any patient. Similarly, no patient-reported symptoms of LAST including altered sensorium, tinnitus, or changes in taste were documented on any of the reviewed cases. It is unlikely that any major event of LAST was missed, but minor

symptoms cannot be excluded. In addition, to minimize the potential for toxicity, the following measures are routinely taken at our institution: (1) only ropivacaine is used for both ACB and LIA; (2) epinephrine is used for both ACB and LIA; (3) ACB is performed approximately 1 hour before the surgical start (peak plasma concentration expected to occur within 20–30 minutes)²⁵; and (4) LIA is performed in stages during the surgical procedure and while a thigh tourniquet is in place. Tourniquet release occurs approximately 2.5 hours after ACB. It may be advisable that future prospective studies include a quantitative evaluation of systemic absorption and peak plasma levels of local anesthetic.

CONCLUSIONS

This retrospective study of 298 patients undergoing TKA suggests that LIA is associated with greater early ambulation (longer distance walked on POD1) and improved analgesia compared with low-dose CFNB. The addition of ACB was associated with further increases in early ambulation, a more rapid transition to use of a standard low walker, and a higher incidence of discharge to home. Further prospective comparative studies are warranted to better define the role of these new analgesic modalities, especially in the setting of spinal anesthesia and intrathecal morphine.

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