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Original Research Article

COMPARATIVE STUDY OF LIPOSOMAL BUPIVACAINE VS. STANDARD BUPIVACAINE IN ULTRASOUND-GUIDED ADDUCTOR CANAL BLOCKS FOR PROLONGED ANALGESIA FOR TOTAL KNEE ARTHROPLASTY

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ABSTRACT

Background: Early mobilization and recovery after undergoing a total knee arthroplasty (TKA) depends on effective postoperative analgesia. Liposomal bupivacaine (LB) has emerged as a long-term local anesthetic with potential advantages in comparison to the standard bupivacaine (SB). The current study was aimed to investigated the effectiveness and the safety of the use of LB and SB in adductor canal block in TKA performed using an ultrasound.

Materials and Methods: This prospective randomized study was conducted on 40 cases undergoing TKA. They were randomly allotted to two groups. In this prospective, randomized study, 40 patients undergoing TKA LB (n=20) and SB (n=20). Relevant data of age, gender, BMI, ASA status and operative were recorded. The primary outcomes included were duration of analgesia, time to first rescue analgesia, and 72-hour tramadol consumption. Secondary outcomes were assessed by pain scores at various intervals, functional recovery parameters, and adverse events.

Results: The analysis of the study showed that LB group demonstrated significantly prolonged analgesia as compared to SB group (35.2 ± 6.8 vs. 16.4 ± 4.1 hours and $p < 0.001$) and the requirement of first rescue analgesia was delayed in this group (36.1 ± 7.2 vs. 17.0 ± 4.3 hours and $p < 0.001$). Rescue analgesic tramadol use in 72 hours was significantly lower in the LB group (110.5 ± 45.2 vs. 225.0 ± 60.3 mg and $p < 0.001$). VAS scores were found to be significantly lower in LB group at 12, 24 and 48 hours respectively. Overall patients' satisfaction in LB group was found to be superior then SB group. Adverse events were minimal and comparable in both groups.

Conclusion: This study found that Liposomal bupivacaine is superior to standard bupivacaine in providing sustained analgesia in adductor canal blocks for TKA without increase risk of adverse effects. It therefore enhances the patient's satisfaction and shortens recovery time.

Keywords: Liposomal Bupivacaine, Standard Bupivacaine, Ultrasound-Guided Adductor Canal Blocks.

INTRODUCTION

Total knee arthroplasty (TKA) is among the most frequently performed orthopedic surgeries. This is done to bring a considerable amount of pain and disability alleviation due to severe osteoarthritis. Despite being a successful procedure, TKA is associated with significant postoperative pain. When pain control is not adequate it will lead to slow rehabilitation, long hospital stays, and poor patient satisfaction and outcome. [1,2] Peripheral nerve blocks and regional anesthesia have become an important addition and constituent of multimodal pain relief in

TKA. One such method is the adductor canal block (ACB), which is preferred because of the quality analgesia it provides with minimal quadriceps muscle weakness, and allows early mobilization.[3] In the past, ACB was performed with regular bupivacaine, a long-acting amide anesthetic agent that tends to provide analgesia within 12 to 18 hours.[4] Nevertheless, the significant constraint includes the short duration of single-injection nerve blocks which necessitate additional analgesics or catheter-based infusions. This could result in potential complications.[5]

Liposomal bupivacaine is a novel analgesic, which is a long-acting version of bupivacaine encapsulated in multivesicular liposomes. It is formulated to release drugs extendedly and thus provides pain relief up to 72-96 hours after the inception of injection.[6] This property has the advantage of increasing the duration of analgesia without a need for continuous infusions or frequent repetitions. Although the drug has been approved by the FDA to be used in the local administration of wound infiltration and certain nerve blocks, its usefulness and safety in peripheral nerve blocks such as ACB are currently being explored.[7] Few preliminary studies with this drug have indicated that liposomal bupivacaine could offer better pain relief and minimize the use of opioids after surgery.[8] Some of the other trials however have shown mixed results and there are concerns about its cost-effectiveness, variability in clinical outcomes, and optimal dosing techniques.[9,10] Moreover, the pharmacokinetic behavior of liposomal bupivacaine in the limited area of the adductor canal and its interplay with the standard bupivacaine (which many times are administered simultaneously to ensure the early starting effect) remains to be clarified.[11] With the growing need to implement enhanced recovery after surgery (ERAS) protocols and the shift towards outpatient joint arthroplasty, there is a need to find analgesic techniques that are effective, safe, and durable. The current study aimed to determine the efficacy of liposomal bupivacaine versus standard bupivacaine in ultrasound-guided ACBs for patients undergoing TKA.

MATERIALS AND METHODS

This was a prospective observational study conducted in the Department of Anesthesia, Kakatiya Medical College and MGM Hospital, Warangal, Telangana for a period of 12 months. Ethical clearance was obtained from the Institutional Ethics Committee after duly following the protocol for human research. A written consent was obtained from all the participants of the study after explaining the nature of the study and possible outcomes in vernacular language.

Inclusion Criteria

1. Patients aged 50-80 years
2. Males and females
3. ASA I & II
4. BMI 35 kg/m2
5. undergo elective unilateral total knee arthroplasty (TKA) and in spinal anesthesia
6. Willing to participate in the study voluntarily.

Exclusion Criteria

1. Known allergies to Local anesthetics
2. Chronic opioids used
3. Coagulopathy
4. Peripheral neuropathy
5. Infections at the point of injection

A total of n=40 adult patients (aged 50-80 years) who were to undergo elective unilateral total knee arthroplasty (TKA) and spinal anesthesia were enrolled. Participants were randomized into two equal groups (n=20 each) using a computer-generated randomization number. Group LB (Liposomal Bupivacaine Group): received adductor canal block with 10 mL of liposomal bupivacaine (266 mg) diluted with normal saline to a total volume of 20 mL. Group SB (Standard Bupivacaine Group): received 20 mL of 0.25% standard bupivacaine hydrochloride. The anesthesiologist performing the block was blinded to group allocation; the drug preparation was handled by a separate investigator not involved in outcome assessments.

Procedure: All patients received standard spinal anesthesia with 15 mg of 0.5% hyperbaric bupivacaine and sedation as required. At the conclusion of surgery, an ultrasound-guided adductor canal block was performed using a high-frequency linear probe. Under aseptic precautions, a 22G insulated needle was inserted in the plane to place the injectate adjacent to the saphenous nerve within the adductor canal.

Outcome Measures

- Primary Outcome: Duration of analgesia, defined as the time from block administration to first request for rescue analgesia (VAS >4).
- Secondary Outcomes: Total opioid consumption in 72 hours, pain scores (VAS) at 6, 12, 24, 48, and 72 hours, quadriceps motor strength (graded on a 0–5 scale), time to ambulation, patient satisfaction scores, and any adverse effects (e.g., local anesthetic systemic toxicity, nausea, falls). Rescue analgesia was provided with intravenous tramadol (50 mg) as needed.

Statistical Analysis: All the available data was refined, segregated and uploaded to MS Excel spreadsheet and analyzed by SPSS version 25 in windows format. The continuous variables were represented as mean, standard deviation, frequencies and percentages. The categorical variables were calculated by Chi square test for differences between two groups. A p-value <0.05 was considered statistically significant.

RESULTS

A total of n=40 cases were randomly allotted to two groups of n=20 each. Table 1 shows the baseline demographic and clinical characteristics of the cases

in the study. A critical analysis of the table shows that the mean age of Group LB was 68.4 ± 6.2 years and 67.1 ± 7.3 years in Group SB with p values (0.52). Similarly, gender distribution was comparable in both groups confirmed by the p values of (0.76) although, there was a tendency for male dominance in both groups. The mean BMI was similar in both groups (29.1 ± 3.2 vs. 28.7 ± 3.8 kg/m²). ASA distribution of the patients also was found to be similar with p values of (0.9) and mean operative time was also found to be similar. This shows that both groups were well-matched for comparison.

Table 1: Baseline Patient Characteristics of the cases included in the study

Characteristic	Group LB (n=20)	Group SB (n=20)	p-value
Age (years) Mean ± SD	68.4 ± 6.2	67.1 ± 7.3	0.52
Gender (Male/Female) n	8/12	9/11	0.76
BMI (kg/m2) Mean ± SD	29.1 ± 3.2	28.7 ± 3.8	0.7
ASA Status n (%)			
I	2 (10%)	3 (15%)	0.9
II	12 (60%)	11 (55%)	
III	6 (30%)	6 (30%)	
Operative Time (min)	112.5 ± 18.3	108.4 ± 20.1	0.48

[Table 2] the primary analgesia outcomes in both groups of patients. The analysis of the table shows a distinct difference between the analgesic effects of the two groups. The duration of analgesia was significantly longer in Group LB (35.2 ± 6.8) hours) then in Group SB (16.4 ± 4.1) hours) (mean difference 18.8 (95% CI 15.2 to 22.4) and p < 0.001. Similarly, time to first rescue analgesia was significantly delayed in the liposomal group (36.1 vs. 17.0 hours; p < 0.001). Tramadol consumption at 72 hours was significantly lower in Group LB (110.5 ± 45.2 mg) compared to Group SB (225.0 ± 60.3 mg), indicating a reduction of 114.5 mg (p < 0.001), showing superior sustained analgesia with liposomal bupivacaine.

Table 2: Primary Analgesia Outcomes

Outcome	Group LB (n=20)	Group SB (n=20)	p-value	Difference (95% CI)
Duration of Analgesia (h)	35.2 ± 6.8	16.4 ± 4.1	<0.001*	18.8 (15.2-22.4)
Time to First Rescue (h)	36.1 ± 7.2	17.0 ± 4.3	<0.001*	19.1 (15.3-22.9)
Tramadol Consumption (mg/72h)	110.5 ± 45.2	225.0 ± 60.3	<0.001*	-1 14.5 (-144.6 to -84.4

*Significant

The postoperative pain controls based on the VAS scale distribution at different intervals are given in Table 3. The results show that at 12 hours Group LB reported a mean VAS of 2.3 ± 1.0 versus 3.8 ± 1.2 in Group SB (p < 0.001). In addition, at 24 hours the pain was substantially lower in Group LB (2.8 ± 1.1 vs. 5.2 ± 1.3) and p < 0.001. At 48-hour intervals, the scores remained significantly lower in the liposomal group and p-values were significant. However, at 6 hours and 72 hours, the values of the LB group were lower for severity of pain but were not significant.

Table 3: Postoperative Pain Scores (VAS 0-10)

Time Point	Group LB (n=20)	Group SB (n=20)	p-value	Mean Difference
6 hours	2.1 + 0.9	2.0 ± 1.0	0.72	0.1
12 hours	2.3 + 1.0	3.8 ± 1.2	<0.001*	-1.5
24 hours	2.8 ± 1.1	5.2 ± 1.3	<0.001*	-2.4
48 hours	3.2 + 1.0	4.0 ± 1.1	0.02*	-0.8
72 hours	2.5 + 0.8	3.0 ± 1.0	0.08	-0.5

*Significant

[Table 4] depicts the functional recovery outcomes in two groups of patients. The table evaluates motor recovery and rehabilitation outcomes in both groups. The results of the table show that quadriceps strength remained similar in both groups at 24 hours and 48 hours. Similarly, the time to ambulation was almost identical in both groups (22.4 vs. 21.8 hours; p = 0.68) and not significant. However, patient satisfaction was significantly higher in the liposomal group as indicated by significant p values. The discharge readiness was achieved earlier in the LB group compared to the SB group with significant p values. These findings show that improved analgesia in the LB group led to better and faster recovery although motor strength remained unaffected by the type of bupivacaine used.

Table 4: Functional Recovery Outcomes

Outcome	Group LB (n=20)	Group SB (n=20)	p-value
Quadriceps Strength (24h)	4.2 ± 0.5	4.3 ± 0.4	0.45
Quadriceps Strength (48h)	4.5 ± 0.3	4.4 ± 0.5	0.42
Time to Ambulation (h)	22.4 ± 4.8	21.8 ± 5.2	0.68
Patient Satisfaction (0-10)	8.9 ± 0.8	7.1 ± 1.2	<0.001*
Discharge Readiness (days)	2.8 ± 0.6	3.2 ± 0.7	0.04*
Quadriceps Strength by Oxford Scale (0-5), where 5 = full strength			

*Significant

[Table 5] shows the adverse events and postoperative complications. A critical analysis of the table shows both groups demonstrated a low incidence of adverse events, with no major complications reported. Nausea occurred in 15% of Group LB and 25% of Group SB patients (p = 0.43). Vomiting and pruritus were infrequent, seen in 1–2 patients in Group SB and none or one in Group LB (p > 0.3). Moreover, no cases of motor block, fall, local anesthetic systemic toxicity (LAST), or neurological symptoms were observed in either group. This shows the excellent safety profile of both, with liposomal bupivacaine not associated with increased adverse effects.

Table 5: Adverse Events and Complications

Adverse Event	Group LB (n=20)	Group SB (n=20)	p-value
Nausea	3 (15%)	5 (25%)	0.43
Vomiting	1 (5%)	2 (10%)	0.55
Pruritus	0 (0%)	1 (5%)	0.31
Motor Block	0 (0%)	0 (0%)	-
Falls	0 (0%)	0 (0%)	-
LAST	0 (0%)	0 (0%)	-
Neurological Symptoms	0 (0%)	0 (0%)	-

DISCUSSION

Adequate pain management during the postoperative period following total knee arthroplasty (TKA) is crucial to improve patient survival, space early mobilization, and shorten hospitalization periods. In such investigation, liposomal bupivacaine (LB) revealed better pain alleviation and better postprocedural measures than standard bupivacaine (SB) in ultrasound-guided adductor canal block (ACB). In our study, we found the duration of analgesia was comparatively longer in the LB group (35.2 ± 6.8 hours) than in the SB group (16.4 ± 4.1 hours) with a mean difference of approximately 19 hours. This superiority was also reflected in the time to first rescue analgesia. These findings are in agreement with previous studies where they reported that liposomal formulations of bupivacaine provided pain management over 3 days after surgery due to slow, sustained release from the injection site. [6,8] Our study showed that tramadol consumption in 72 hours was significantly lower in the LB group (110.5 ± 45.2 mg) as compared to the SB group (225.0 ± 60.3 mg). This shows the opioid-sparing effect of prolonged local analgesia. Our findings are consistent with Ilfeld et al,[4] who reported that there was reduced opioid usage in patients receiving long-acting local anesthetic formulations. This reduction is especially important in terms of postoperative safety. Our study showed that pain scores based on visual analog scale (VAS) were statistically less at 12, 24, and 48 hours in the LB group, indicating a pattern of effectiveness of the analgesics throughout the critical post-surgical period. At the 72-hour mark, Group LB had a favorable pattern, yet the difference in the ratings of the pain was not significant. These outcomes confirm the impression that liposomal bupivacaine provides a stronger pain control without the risk of motor blockade as the groups did not differ in the quadriceps strength during recovery. The time to ambulation and the motor power showed no difference in either group which is in line with the sensory-selectivity of ACBs. Nevertheless, the LB group had a higher patient satisfaction score (8.9 ± 0.8) than the SB group (7.1 ± 1.2), which could be explained by the fact that there was extended pain duration and less dependability on anti-inflammatory narcotic drugs on the systemic level. In addition, the LB group achieved discharge readiness faster which also implies a shortened postoperative recovery pattern. Similar findings have been shown in the research of Schroer et al. and Mont et al., who emphasized the role of liposomal bupivacaine in promoting recovery during joint arthroplasty. [12,13] The analysis of adverse events in both groups showed that the incidence of adverse events was similar in both groups and no serious complications such as local anesthetic systemic toxicity (LAST) or neurological sequelae were reported in either group. The safety profile of LB shows that it is one of the analgesics to be considered in orthopedic surgeries especially where prolonged postoperative pain control is crucial for patients.

CONCLUSION

In conclusion, within the limitations of our study, we found that liposomal bupivacaine, when used in adductor canal blocks for TKA, provides prolonged analgesia, reduces opioid requirements, improves

patient satisfaction, and may expedite functional recovery, all without compromising safety. Future larger-scale randomized trials are warranted to validate these results across broader populations.

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