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ORIGINAL RESEARCH

# Association of Liposomal Bupivacaine with Postoperative Pain, Opioid Consumption and Early Functional Exercise in Tibial Plateau Fracture: A Retrospective Cohort Study

Wenhao Song[1,2], Jun Su[3]

[1]Department of Orthopedic Surgery, Shandong Provincial Hospital Affiliated to Shandong First Medical University, Jinan, Shandong, People's Republic of China; [2]Shandong Yuhuang Chemical Co., Ltd, Heze, Shandong, People's Republic of China; [3]Department of Orthopedic Surgery, The 960th Hospital of the PLA Joint Logistics Support Force, Jinan, People's Republic of China

Correspondence: Jun Su, Department of Orthopedic Surgery, The 960th Hospital of the PLA Joint Logistics Support Force, Jinan, People's Republic of China, Email sdsujun90@163.com



**Purpose:** To investigate the association of local infiltration with liposomal bupivacaine (LB) on postoperative pain, opioid consumption, and early functional recovery in patients undergoing open reduction and internal fixation (ORIF) for tibial plateau fracture.

**Patients and Methods:** A retrospective cohort study was conducted including 252 patients aged 18–80 years treated between 2022 and 2024. Patients were divided into LB group (n=142) and non-LB group (n=110). Primary outcomes were resting visual analogue scale (VAS) pain scores at 24, 48, and 72 hours postoperatively and total opioid consumption. Secondary outcomes included time to first opioid use, time to first functional exercise, length of hospital stay, and adverse events. Normal distribution was tested using the Shapiro–Wilk test. Continuous variables were compared using independent *t*-test or Mann–Whitney *U*-test as appropriate. Categorical variables were analyzed using $\chi^2$ or Fisher exact test. Repeated measures VAS data were analyzed using linear mixed-effects models (LMM). A two-sided P<0.05 was considered statistically significant.

**Results:** The LB group showed significantly lower resting VAS scores at 24, 48, and 72 hours, lower total and time-dependent opioid consumption, delayed time to first opioid use, earlier initial functional exercise, and shorter hospital stay (all P<0.05). No significant intergroup differences were observed in non-opioid analgesic use, adverse events, PCA application, fracture healing time, or final Hospital for Special Surgery (HSS) knee scores (all P>0.05).

**Conclusion:** In this retrospective cohort study, perioperative local infiltration with LB was associated with reduced postoperative pain, lower opioid consumption, earlier functional exercise, and shorter hospital stay among patients undergoing ORIF for tibial plateau fracture, with a favorable safety profile. LB may be considered a valuable component of multimodal analgesia in this clinical setting.

**Keywords:** liposomal bupivacaine, tibial plateau fracture, open reduction and internal fixation, postoperative analgesia, opioid consumption, retrospective cohort study

## Introduction

Postoperative pain represents one of the most prevalent adverse events following surgical intervention. It causes significant physical distress for patients and substantially reduces overall satisfaction with care. Optimal postoperative analgesic strategies effectively enhance early mobilization, lower complication rates, and improve patient satisfaction, while also shortening hospital length of stay and reducing medical costs.[1] Opioid analgesia has been integral in the management of postoperative pain for decades. Unfortunately, postoperative opioid use is associated with increased risk of complications, such as atelectasis and ileus.[2–4] In recent years, multimodal analgesia (MMA) programs have been

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developed rapidly, which can significantly reduce the use of opioids and related adverse reactions.[5,6] Agents such as acetaminophen, gabapentin, and local anesthetics have been shown to be effective for pain management, some studies suggest opioids should be reserved for refractory pain when multiple analgesic modalities fail.[7–9]

In multimodal analgesia program, the most common method is local anesthesia.[10] However, the main limitation of local anesthesia is that it rarely lasts more than 24 hours. Liposomal bupivacaine (LB), a long-acting analgesia formulation, uses a novel DepoFoam drug delivery system involving encapsulation of immediate-release bupivacaine within multivesicular liposomes. Liposomes have the advantage of slowly losing their integrity in the body, which results in the continuous release of bupivacaine into surrounding tissues.[11,12] Based on this mechanism, LB could decrease post-operative pain and opioid requirements in patients after surgery. It has been reported that the duration of analgesia is up to 72 hours.[11,12]

For tibial plateau fracture with articular surface collapse more than 3mm, open reduction and internal fixation and early functional exercise are the most important therapeutic means to restore function and avoid sequelae, but post-operative pain is the main obstacle to early functional exercise. Previous studies have shown that LB can effectively relieve pain after orthopedic surgery such as knee replacement,[13,14] hip replacement,[15] total shoulder replacement[16] and lumbar fusion.[17,18] However, few studies have focused specifically on patients with tibial plateau fracture undergoing open reduction and internal fixation (ORIF). Unlike elective joint arthroplasty, tibial plateau fracture is an acute traumatic injury with severe soft tissue trauma, intense early postoperative pain, and a strong demand for early functional exercise. Evidence regarding LB in this traumatic population remains limited. This retrospective cohort study was designed to evaluate the association of LB with postoperative pain, opioid consumption, and early functional recovery in patients undergoing ORIF for tibial plateau fracture.

## Patients and Methods

Permission for this study was obtained from the Medical Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (NO.2018–242).

We retrospectively analyzed all patients with tibial plateau fractures who were treated at our institution from January 2022 to December 2024. Inclusion criteria were as follows: patients aged 18 to 80 years with closed tibial plateau fractures who underwent open reduction and internal fixation (ORIF). Exclusion criteria included: patients younger than 18 years or older than 80 years; inveterate fractures (with an interval of more than three weeks from initial injury to surgery); undergoing conservative treatment; pathological fractures and those with postoperative complications such as wound non-healing or infection. All patients were required to have a follow-up duration of more than one year.

Baseline and perioperative data were collected: gender, age, injury cause, comorbidities, fracture type, body mass index (BMI), current smoking status (yes or no), alcoholism (yes or no), time from injury to surgery, ASA physical status classification, preoperative opioid use (yes or no), operative time, anesthesia type, perioperative analgesic protocols. Resting pain assessments at different time points (Post-Anesthesia Care Unit [PACU], 24 hours, 48 hours, and 72 hours postoperatively), morphine equivalent dosage of opioids used at different postoperative time points, non-opioid medication used, time to first opioid use, length of hospital stay, time of initial exercise and corresponding pain score, as well as knee function score and pain score at the last follow-up. All patients were divided into two groups based on whether liposomal bupivacaine was used.

All opioid usage, both intravenous and oral, was converted to oral morphine milligram equivalent (MME) to normalize the data prior to statistical analysis. We used the Schatzker system to classify the fracture, in brief, it was classified six types according to the position offracture. Additionally, type I–III was considered as low-energy injury and type IV–VI was considered as high-energy injury. Alcohol consumption in excess of 13 units per week was identified as alcoholism. Body mass index (BMI) was calculated as weight divided by the square of height and was grouped according to the Chinese reference criteria: underweight, <18.5; normal, 18.5–23.9; overweight, 24–27.9; obesity, 28–31.9; morbid obesity, 32 and more. There are many scoring systems for knee joint function, and we chose the Hospital for Special Surgery (HSS) scoring system. It is a scoring system with a total score of 100 points, including six aspects: pain, function, joint range of motion, muscle strength, knee flexion deformity, and knee instability. The clinical outcomes were graded according to the HSS score as follows: excellent: 85–100 points; good: 70–84 points; fair: 60–69 points; poor: < 60 points.[19]

## Injection Technique

The knee is innervated by the sural, saphenous, tibial, and peroneal nerves; therefore, the adoption of a meticulous injection technique aimed at targeting all soft tissues is key to achieving optimal results and relieving pain in all the aforementioned nerve distributions. At the end of the procedure, all subjects in the LB group underwent local infiltration of the surgical wound. Analgesics are injected into the subcutaneous tissue through the edge of the wound before closure. A recent consensus statement issued by the Best Infiltrative Practice Working Group points out that in clinical practice, it is preferable to use a small bore needle (22-gauge or 25-gauge, 25–32 mm in length) to slowly inject liposome bupivacaine into the soft tissues at the surgical site, while frequently aspirating to check for blood, thereby minimizing the risk of intravascular injection.[20] The authors of the statement mentioned that this operation will limit the dose of a single injection by surgeons, because the method of multi-site injection with 0.5 to 1 mL aliquots per site is more appropriate. It is crucial to distribute the drug evenly throughout the entire soft tissue envelope, which is a prerequisite for achieving optimal results. In operation of tibial plateau fracture, the injection range should cover the medial capsule, lateral capsule, posterior capsule, peripatellar area, quadriceps tendon, femoral periosteum, tibial periosteum, capsulotomy incision, and the subcutaneous tissue on both sides of the incision.

Statistical analysis was performed using SPSS 12.0. The Shapiro–Wilk test assessed normality. Normally distributed continuous data were presented as mean ± standard deviation (SD) and compared using independent t-test. Non-normally distributed data were presented as median (interquartile range, IQR) and compared using Mann–Whitney *U*-test. Categorical variables were presented as n (%) and analyzed using $\chi^2$ or Fisher exact test. Repeated VAS measures were analyzed using linear mixed-effects models (LMM). Multivariable regression was performed to adjust for potential confounders. A two-sided $P<0.05$ was considered statistically significant.

# Results

STROBE flowchart (Figure 1) detailing patient enrollment, exclusion, and group allocation. Eligibility screening was performed on 289 patients, with 37 excluded based on age, fracture characteristics, complications, or loss to follow-up. A total of 252 patients conformed to the inclusion criteria and were assigned to two groups based on whether liposomal bupivacaine was used. 49 females and 93 males in LB group, 44 females and 66 males in non-LB group. The average age was 42.3±13.2 and 41.8±14.5 respectively. In both groups, the right was the predominant injury side. In both groups, the leading cause of injury was identified as Electric bicycle accident. Gender, age, predominant injury side, cause of injury, and the underlying diseases including diabetes, hypertension, coronary heart disease, autoimmune disease, chronic obstructive pulmonary disease was no significant difference between two groups. Forty-five patients (31.7%) in LB group and 32 patients (29.0%) in non-LB group were current smokers, 8 patients (5.6%) in LB group and 3 patients (13%) in non-LB group were alcoholism. There was no statistically significant difference in the rates of current smoking and alcohol abuse between the two groups. Most patients in two groups had normal BMI, there was no statistical difference between two groups. Only a small number of patients had a history of preoperative opioid use: 3 in the LB group and 1 in the non-LB group, with no statistically significant difference between the two groups. Epidemiologic data are summarized in Table 1.

89 cases (62.7%) in the LB group and 64 cases (58.2%) in the non-LB group were diagnosed with type I-III fractures, whereas 53 cases (37.3%) and 46 cases (41.8%) in the two groups were identified as type IV-VI fractures, respectively. The majority of patients in both groups underwent surgical treatment within 7 days after injury, accounting for 77 cases (54.2%) in the LB group and 72 cases (65.5%) in the non-LB group. With respect to the American Society of Anesthesiologists (ASA) physical status classification, ASA 1 (healthy) was the most common grade in both groups, with 66 cases (46.5%) in the LB group and 58 cases (52.7%) in the non-LB group. The vast majority of surgical procedures in both groups were completed within 3 hours, including 125 cases (88.0%) in the LB group and 101 cases (91.8%) in the non-LB group, while 17 cases (12.0%) in the LB group and 9 cases (8.2%) in the non-LB group had an operative time of ≥3 hours. There was no significant difference between two groups in fracture type, time from injury to operation, ASA physical status classification and operative time. Moreover, there was no statistically significant difference in the mean post-anesthesia care unit (PACU) stay time between the LB group (40.5±10.7 minutes) and the

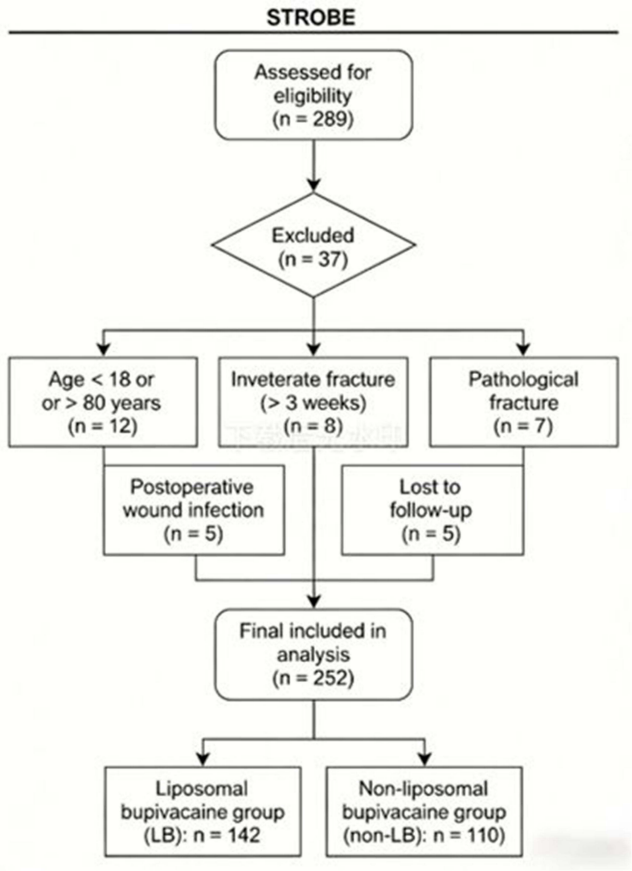


**Figure 1** STROBE-compliant flowchart of patient enrollment. 289 patients were screened, 37 were excluded, and 252 were included in the study and divided into the LB group (n = 142) and the non-LB group (n = 110).

non-LB group (42.8±12.6 minutes). Notably, the average hospital length of stay was 11.2±3.5 days in the LB group and 13.8±1.9 days in the non-LB group, there was a statistically significant difference between the two groups. These data were detailed in Table 2.

**Table 1** Demographic Characteristics

| Variables | LB Group (n=142) | Non-LB Group (n=110) | P |
|---|---|---|---|
| Age | 42.3±13.2 | 41.8±14.5 | 0.766 |
| Gender | | | 0.697 |
| Male | 93, 65.5% | 66, 60% | |
| Female | 49, 34.5% | 44, 40% | |
| Injury side | | | 0.824 |
| Left | 40, 28.2% | 31, 28.2% | |
| Right | 102, 71.8% | 79, 71.8% | |
| Cause of injury | | | 0.664 |
| Fall | 32, 22.5% | 28, 25.4% | |
| Fall from height | 15, 10.6% | 12, 10.9% | |
| Pedestrian-vehicle collision | 35, 24.6% | 30, 27.3% | |
| Electric bicycle accident | 60, 42.3% | 40, 36.4% | |

(*Continued*)

**Table 1** (Continued).

| Variables | LB Group (n=142) | Non-LB Group (n=110) | P |
|---|---|---|---|
| Underlying disease | | | 0.866 |
| Hypertension | 19, 13.4% | 19, 17.3% | |
| Coronary heart disease | 33, 23.2% | 25, 22.7% | |
| Diabetes mellitus | 24, 16.9% | 21, 19.1% | |
| Autoimmune disease | 8, 5.6% | 3, 2.7% | |
| Chronic obstructive pulmonary disease | 22, 15.5% | 15, 13.6% | |
| Current smoking | | | 0.665 |
| Yes | 45, 31.7% | 32, 29.1% | |
| No | 97, 68.3% | 78, 70.9% | |
| Alcoholism | | | 0.534 |
| Yes | 8, 5.6% | 3, 2.7% | |
| No | 134, 94.4% | 107, 97.3% | |
| Body mass index | | | 0.804 |
| <18.5 | 17, 12% | 14, 12.7% | |
| 18.5–23.9 | 52, 36.6% | 40, 36.4% | |
| 24–27.9 | 34, 23.9% | 36, 32.7% | |
| 28–31.9 | 32, 22.5% | 18, 16.4% | |
| >32 | 7, 4.9% | 2, 1.8% | |
| Opioid use PTA | | | 0.591 |
| Yes | 3, 2.1% | 1, 0.1% | |
| No | 139, 97.9% | 109, 99.9% | |

**Abbreviation**: PTA, prior to admission.

**Table 2** Surgical Related Data

| Variables | LB Group (n=142) | Non-LB Group (n=110) | P |
|---|---|---|---|
| Fracture type | | | 0.171 |
| I-III | 89, 62.7% | 64, 58.2% | |
| IV-VI | 53, 37.3% | 46, 41.8% | |
| Time from injury to operation | | | 0.341 |
| <7 days | 77, 54.2% | 72, 65.4% | |
| 7–14 days | 49, 34.5% | 30, 27.3% | |
| >14 days | 16, 11.3% | 8, 7.3% | |
| ASA | | | 0.192 |
| 1 (Healthy) | 66, 46.5% | 58, 52.7% | |
| 2 (Mild disease) | 62, 43.7% | 34, 30.9% | |
| 3 (Severe disease) | 12, 8.5% | 16, 14.5% | |
| 4 (Severe life-threatening disease) | 2, 1.4% | 2, 1.8% | |
| Operative time | | | 0.355 |
| <3 hours | 125, 88% | 105, 95.5% | |
| ≥3 hours | 17, 12% | 5, 4.5% | |
| PACU time (minutes) | 40.5±10.7 | 42.8±12.6 | 0.139 |
| Length of stay (days) | 11.2±3.5 | 13.8±1.9 | *<0.001* |

**Abbreviations**: ASA, American Society of Anesthesiologists; PACU, post-anesthesia care unit.

Perioperative analgesic-related indices were also compared between the LB group and non-LB group, with data detailed in Table 3. The LB group had significantly lower total opioid consumption than the non-LB group. At 0–24h, 24–48h, 48–72h and 72–120h, opioid consumption in the LB group was markedly lower than that in the non-LB group.


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**Table 3** Postoperative Opioid Consumption and Non-Opioid Analgesic Use

| Variables | LB Group (n=142) | Non-LB Group (n=110) | P |
|---|---|---|---|
| Total opioid consumption (mg) | 185.6±120.2 | 266.9±144.1 | *<0.001* |
| Opioid consumption | | | |
| 0–24 hours | 68.5 | 98.3 | *<0.001* |
| 24-48 hours | 52.6 | 104.1 | *<0.001* |
| 48–72 hours | 33.5 | 50.6 | *<0.001* |
| 72–120 hours | 23.3 | 27.6 | *0.001* |
| Time to first opioid use (hours) | 22.3±3.6 | 7.9±10.8 | *<0.001* |
| Non-opioid analgesics used | | | |
| PACU | 102, 71.8% | 93, 84.5% | 0.444 |
| PACU-24 hours | 113, 79.6% | 104, 94.5% | 0.664 |
| 24-48 hours | 60, 42.3% | 57, 51.8% | 0.640 |
| 48-72 hours | 62, 43.7% | 66, 60% | 0.420 |
| 72–96 hours | 48, 33.8% | 38, 34.5% | 0.279 |
| Opioid-related adverse events | | | |
| Nausea/vomiting | 29, 20.4% | 13, 11.8% | 0.173 |
| Constipation | 13, 9.2% | 7, 6.4% | 0.357 |
| Ileus | 0, 0 | 0, 0 | - |
| Pruritus | 0, 0 | 0, 0 | - |
| Respiratory depression | 0, 0 | 0, 0 | - |
| Over-sedation | 1, 0.1% | 0, 0 | 0.364 |
| PCA use postoperatively | | | 0.345 |
| Yes | 101, 71.1% | 88, 80% | |
| No | 41, 28.9% | 22, 20% | |

**Abbreviations**: PACU, post-anesthesia care unit; PCA, patient-controlled analgesia.

Postoperative opioid use was 0.93±0.4 d, however, it was initiated significantly earlier in the non-LB group (0.32±0.5 d). Non-opioid analgesic use showed no intergroup differences at all time points (PACU, PACU-24h, 24–48h, 48–72h, 72–96h). Nausea/vomiting and constipation were the main opioid-related adverse events in both groups, only 1 case of over-sedation occurred in the LB group, and no ileus, pruritus or respiratory depression was observed in either group. Postoperative PCA use was no statistically significant difference between the two groups.

Postoperative pain intensity and functional recovery outcomes are summarized in Table 4. The LB group exhibited significantly lower Visual Analogue Scale (VAS) scores at 24 h, 48 h, and 72 h postoperatively compared with the non-

**Table 4** Postoperative Pain and Function Evaluation

| Variables | LB Group (n=142) | Non-LB Group (n=110) | P |
|---|---|---|---|
| Postoperative 0–24h | | | |
| Maximum VAS | 5.69±2.78 | 7.80±3.66 | *<0.001* |
| Average VAS | 4.80±1.39 | 7.13±2.04 | *<0.001* |
| Postoperative 24–48h | | | |
| Maximum VAS | 5.02±1.73 | 7.36±3.14 | *<0.001* |
| Average VAS | 3.90±2.54 | 6.62±1.94 | *<0.001* |
| Postoperative 48–72h | | | |
| Maximum VAS | 3.24±1.05 | 5.83±2.63 | *<0.001* |
| Average VAS | 3.15±1.78 | 5.02±2.33 | *<0.001* |

(*Continued*)

**Table 4** (Continued).

| Variables | LB Group (n=142) | Non-LB Group (n=110) | P |
|---|---|---|---|
| Postoperative 0–72h | | | |
| Maximum VAS | 4.65±2.19 | 7.00±2.57 | *<0.001* |
| Average VAS | 3.95±1.97 | 6.26±2.07 | *<0.001* |
| Time to first FE (day) | 2.66±0.98 | 5.23±1.96 | *<0.001* |
| VAS at first functional exercise | 4.73±3.61 | 4.98±2.76 | 0.561 |
| Follow-up time (month) | 12.36±0.56 | 12.43±0.37 | 0.261 |
| HSS score | 95.66±10.34 | 96.21±12.76 | 0.705 |
| Fracture healing time (month) | 3.32±0.45 | 3.28±0.32 | 0.467 |

**Abbreviations**: VAS, visual analogue scale; FE, functional exercise.

LB group whether for the maximum VAS or the average VAS. The time to first functional exercise was 2.66±0.98 days in the LB group versus 5.23±1.96 days in the non-LB group, with the former being significantly shorter than the latter. However, the VAS at the first functional exercise was similar in two groups. No statistically significant differences were observed between the LB and non-LB groups in terms of follow-up duration, and fracture healing time. The knee function was to be elevated at the last follow up, HSS score was lower in the LB group than in the non-LB group, but there was no significant difference.

## Discussion

More than 80% of surgical patients will experience postoperative pain, among which about 75% will have moderate to severe pain.[21] Postoperative pain not only causes physical discomfort and psychological burden to patients, but also impairs their gastrointestinal and cardiopulmonary functions, triggers various complications. Postoperative analgesia can improve patients' mobility, reduce the incidence of complications, enhance patient satisfaction, shorten hospital stays, and lower hospitalization costs. Pain management is an important part of postoperative rehabilitation.[21] Previously, postoperative analgesia mainly relied on opioid drugs administered when pain occurred. However, the disadvantages of opioid analgesia include a high incidence of nausea and vomiting, excessive sedation, and possible respiratory depression when the dosage is too large.[22] Therefore, reducing the dosage of opioids is the core issue in the treatment of acute pain. For orthopedic surgeons, it is a challenge to reduce opioid use while still controlling pain in patients after tibial plateau fracture surgery, thereby enabling patients to undergo early functional exercises.

Multimodal analgesia refers to the use of analgesic drugs and methods with different mechanisms of action to achieve optimal analgesic effects while reducing opioid consumption;[23] among these approaches, multimodal analgesia incorporating local anesthesia has been widely adopted for postoperative pain management and is associated with decreased postoperative opioid use and fewer opioid-related adverse events (ORALs). However, the efficacy of local anesthetics is limited by their short duration of action. The 0.50% and 0.75% bupivacaine can provide effective analgesia for 4–6 hours and 5–7 hours, respectively, while the 0.75% and 1.00% ropivacaine can maintain effective analgesia for 3–4 hours and 9.5–22.0 hours.[23,24] However, postoperative pain usually lasts for 48–72 hours, and pain during this period is typically the most difficult to control. Therefore, how to prolong the duration of action of local anesthetics remains a key concern for clinicians.

Liposomal bupivacaine is an amide-type local anesthetic composed of multivesicular liposomes. After local injection, it releases bupivacaine slowly over time; a single dose can provide local analgesia for postoperative wounds for up to 72 hours. Because of LB's novel formulation and ability to extend the duration of action of bupivacaine up to 72 hours, its usage has dramatically increased across various surgical procedures for patients to prolong analgesic effects. It has been incorporated into multimodal pain management regimens.[25–28] Liu et al[29] and Ma et al[30] conducted a meta-analysis, concluding that local infiltration with liposomal bupivacaine achieves comparable efficacy to femoral nerve block (FNB) in postoperative pain management for patients undergoing total knee replacement (TKA). Dysart et al found that during

total knee replacement (TKA) surgery, patients who received combined local infiltration of liposomal bupivacaine had a significant decrease in pain intensity.[31] Finkel et al did a prospective, two-arm, double-blinded randomized controlled trial and concluded that LB significantly reduced postoperative pain between 24 and 96 hours and at postoperative day 60 for total shoulder replacement[17] However, Previous studies focused on elective arthroplasty, while tibial plateau fracture represents acute traumatic injury with distinct pain and rehabilitation needs. Our findings fill this evidence gap. Similarly, in our study, we found that LB can effectively reduce pain in patients with tibial plateau fractures within 72 hours postoperatively.

Meanwhile, previous studies have shown that LB can also reduce postoperative opioid consumption. Relevant studies have confirmed that patients who underwent hemorrhoidectomy or augmentation mammoplasty and were treated with liposomal bupivacaine had a significant reduction in opioid consumption within 24 hours postoperatively.[32,33] The use of local injection of liposomal bupivacaine after orthopedic surgery can also reduce opioid use. Dysart et al demonstrated that during total knee arthroplasty, patients administered liposomal bupivacaine experienced a 91% reduction in opioid consumption within 24 hours postoperatively.[31] Gannon's E study demonstrated that among patients undergoing one-level and two-level posterior lumbar interbody fusion, those who received liposomal bupivacaine injection just before surgical closure had a significantly lower total opioid consumption than the control group.[34] A meta-analysis showed that periarticular injection (PAI) of liposomal bupivacaine can reduce opioid consumption in patients undergoing total hip arthroplasty (THA).[35] Similarly, in our study, it was also found that in patients with tibial plateau fractures, delaying the time to first opioid administration, shortening the duration of opioid use, could significantly reduce opioid consumption within 72 hours postoperatively, while also decreasing the use of non-opioid analgesics.

For patients with tibial plateau fractures, one of the goals of surgery is to enable early functional exercise, thereby maximizing the recovery of knee joint function. However, postoperative pain is the main factor limiting early post-operative functional exercise. Therefore, how to alleviate postoperative pain is the key to determining whether patients can perform early functional exercise. Several studies showed that another potential therapeutic advantage of liposomal bupivacaine is its ability to relieve postoperative pain without compromising patients' mobility.[36,37] In our study, it was found that the time to first postoperative functional exercise was earlier in patients who received liposomal bupivacaine than in those who did not. Although there was no significant difference in knee joint function scores between the two groups at the last follow-up, patients who received liposomal bupivacaine had higher knee joint function scores than those in the non-LB group at one month postoperatively. This indicates that the use of LB is beneficial for the early functional recovery of patients.

## Limitation

We recognize several limitations of our study. This was a single-center study, and differences in institutional surgical practices and patient populations may limit external validity of our results. Our study was retrospective rather than prospective, differences in surgical protocols and patient populations across institutions may limit the external validity of the study results. Future multicenter, large sample randomized controlled trials are needed to assess the efficacy of liposomal bupivacaine in postoperative analgesia after tibial plateau fracture surgery.

## Conclusion

In summary, for tibial plateau fracture patients which undergoing open reduction and internal fixation (ORIF), perio-perative local infiltration with liposomal bupivacaine was associated with reduced postoperative pain, lower opioid consumption, earlier functional exercise, and shorter hospital stay, with good safety as no significant differences were found in opioid-related adverse events, fracture healing time, or final knee function scores between the LB group and non-LB group. LB may serve as a useful component of multimodal analgesia in this population optimize postoperative pain management and promote recovery.

## Data Sharing Statement

Please contact author for data requests.

## Ethics Approval and Consent to Participate

The experimental protocol was established according to the ethical guidelines of the Declaration of Helsinki and was approved by the Human Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University (NO.2018–242). All the patients were informed of the purpose of this study and signed the informed consent form.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors report no conflicts of interest in this work.

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