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# PROSPECTIVE OBSERVATIONAL STUDY TO ASSESS TWO DIFFERENT DOSES OF BUPRENORPHINE (30 µG AND 75 µG) GIVEN INTRATHECALLY ALONG WITH HYPERBARIC BUPIVACAINE AS ANALGESIC IN PATIENTS UNDERGOING LOWER LIMB ORTHOPEDIC SURGERIES

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## ABSTRACT

**Background:** Effective postoperative pain management is essential following lower limb orthopedic surgeries, as inadequate analgesia may delay mobilization, prolong hospital stay, and adversely affect patient recovery. Intrathecal buprenorphine is a commonly used opioid adjuvant that enhances the duration and quality of spinal anesthesia. However, the optimal dose capable of providing prolonged analgesia while maintaining safety remains uncertain.

**Methods:** This prospective observational study was conducted among 60 patients undergoing elective lower limb orthopedic surgeries under spinal anesthesia. Patients were allocated into two groups of 30 each. Group A received 30 µg intrathecal buprenorphine with 0.5% hyperbaric bupivacaine, while Group B received 75 µg intrathecal buprenorphine with 0.5% hyperbaric bupivacaine. Sensory and motor block characteristics, duration of postoperative analgesia, Visual Analogue Scale (VAS) scores, rescue analgesic requirements, hemodynamic parameters, and adverse effects were evaluated and compared between groups.

**Results:** The onset of sensory block was significantly faster in Group B than Group A (3.2 ± 0.7 vs 3.8 ± 0.9 minutes; $p=0.02$). The duration of sensory block was significantly prolonged in Group B (280 ± 30 vs 220 ± 25 minutes; $p<0.001$). Similarly, motor block duration was significantly longer in Group B (250 ± 25 vs 200 ± 20 minutes; $p<0.001$). The duration of postoperative analgesia was significantly greater in patients receiving 75 µg buprenorphine (520 ± 50 minutes) compared with those receiving 30 µg buprenorphine (360 ± 40 minutes; $p<0.001$). Time to first rescue analgesia was prolonged (525 ± 48 vs 365 ± 42 minutes; $p<0.001$), and rescue analgesic requirements were significantly lower in Group B. Postoperative VAS scores remained significantly lower in Group B from the second postoperative hour onward. Hemodynamic parameters were comparable between groups, and no significant differences were observed in adverse effects. No patient developed respiratory depression.

**Conclusion:** Intrathecal buprenorphine at a dose of 75 µg provided superior sensory and motor block characteristics, prolonged postoperative analgesia, lower postoperative pain scores, and reduced rescue analgesic requirements compared with 30 µg buprenorphine. Both doses demonstrated comparable hemodynamic stability and safety profiles. Therefore, 75 µg intrathecal buprenorphine appears to be a more effective adjuvant to hyperbaric bupivacaine for lower limb orthopedic surgeries.

**KEYWORDS:** Buprenorphine; Spinal anesthesia; Hyperbaric bupivacaine; Postoperative analgesia; Orthopedic surgery; Intrathecal opioid; Visual Analogue Scale; Regional anesthesia.

## 1. INTRODUCTION

Regional anesthesia has become an integral component of modern perioperative care owing to its ability to provide effective intraoperative anesthesia and prolonged postoperative analgesia while minimizing systemic opioid requirements and associated adverse effects [1]. Advances in anatomical knowledge, pharmacology, and imaging modalities have significantly improved the safety and precision of regional anesthetic techniques, leading to their widespread adoption across various surgical specialties [2]. Among these techniques, spinal anesthesia remains one of the most commonly performed neuraxial blocks worldwide because of its rapid onset, dense sensory and motor blockade, technical simplicity, and cost-effectiveness [3,4]. Continuous refinements in procedural techniques and a better understanding of neuraxial anatomy have further enhanced the safety profile and reliability of spinal anesthesia in routine clinical practice [5].

Despite substantial advancements in perioperative medicine, postoperative pain continues to be a major clinical challenge. Inadequately controlled postoperative pain has been associated with delayed ambulation, prolonged hospitalization, increased healthcare costs, impaired functional recovery, and reduced patient satisfaction [6]. The burden of postoperative pain is particularly evident in orthopedic surgery, where extensive tissue trauma and prolonged rehabilitation often necessitate effective and sustained analgesic strategies. Similar concerns have been reported in pediatric surgical populations, where inadequate pain control may adversely affect recovery and increase postoperative opioid consumption [7]. Effective perioperative analgesia is therefore essential not only for patient comfort but also for improving overall surgical outcomes and facilitating early rehabilitation [8].

Systemic opioids have traditionally been employed for postoperative pain management; however, their use is often limited by undesirable adverse effects such as nausea, vomiting, sedation, respiratory depression, constipation, and the potential for dependence [9]. Consequently, there has been increasing interest in neuraxial opioid administration, which allows direct delivery of analgesic agents into the cerebrospinal fluid, thereby producing potent analgesia with lower systemic exposure. Intrathecal opioids have demonstrated considerable efficacy in prolonging postoperative pain relief and reducing the requirement for supplemental analgesics following surgery [10].

Among available neuraxial opioid adjuvants, buprenorphine has attracted considerable attention because of its unique pharmacological characteristics. Buprenorphine is a highly lipophilic partial μ-opioid receptor agonist and κ-opioid receptor antagonist with strong receptor affinity and slow dissociation kinetics. These properties contribute to prolonged analgesic action while simultaneously producing a ceiling effect on respiratory depression, thereby enhancing its safety profile compared with conventional opioid agonists [10]. The favorable pharmacodynamic characteristics of buprenorphine have led to its increasing use as an intrathecal adjuvant in conjunction with local anesthetics for a variety of surgical procedures.

Spinal anesthesia continues to be widely utilized in lower limb orthopedic surgeries because it provides excellent surgical conditions, reliable blockade, reduced intraoperative blood loss, and effective postoperative pain control [11]. Nevertheless, neuraxial techniques are not entirely free of complications. Post-dural puncture headache, infection, and neurological complications remain important concerns, emphasizing the need for adherence to evidence-based guidelines and meticulous procedural techniques [12]. Furthermore, successful regional anesthesia requires careful selection of adjuvants that optimize analgesic efficacy while minimizing adverse effects.

The use of adjuvants in neuraxial anesthesia has been extensively explored to prolong postoperative analgesia and improve block characteristics. Clinical evidence from pediatric and adult populations suggests that neuraxial adjuvants can significantly enhance the duration and quality of analgesia while reducing the requirement for systemic medications [13]. Comparative analyses of various regional anesthetic approaches have further highlighted the importance of balancing analgesic efficacy, safety, and feasibility when selecting an anesthetic technique [14]. In addition, strict adherence to aseptic precautions and infection control measures is essential to maintain the safety of neuraxial procedures and preserve their clinical benefits [15].

Lower limb orthopedic surgeries are frequently associated with moderate to severe postoperative pain, making effective analgesic management a priority. Although intrathecal buprenorphine has demonstrated promising analgesic efficacy, the optimal dose capable of maximizing analgesic duration while minimizing adverse effects remains uncertain. Lower doses such as 30 μg may provide satisfactory analgesia with minimal side effects, whereas higher doses such as 75 μg may further prolong postoperative pain relief but potentially increase opioid-related adverse events. Therefore, the present prospective observational study was undertaken to compare two different doses of intrathecal buprenorphine (30 μg and 75 μg) administered with 0.5% hyperbaric bupivacaine in patients undergoing lower limb orthopedic surgeries, with the aim of evaluating their effects on block characteristics, postoperative analgesia, hemodynamic stability, and adverse-effect profile.

## 2. MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Anaesthesiology, Sree Balaji Medical College and Hospital, Chennai, Tamil Nadu, India, after obtaining approval from the Institutional Ethics Committee. The study was carried out over a two-year period from January 2025 to January 2027. Adult patients undergoing elective lower limb orthopedic surgeries under spinal anesthesia were screened for eligibility. A total of 60 patients were included in the study after obtaining written informed consent.

Patients aged 20–60 years belonging to American Society of Anesthesiologists (ASA) Physical Status I and II with a body mass index (BMI) between 18 and 30 kg/m² who were scheduled for elective lower limb orthopedic surgeries were included. Patients with ASA Physical Status III and IV, emergency surgeries, known hypersensitivity to study drugs, coagulation abnormalities, local infection at the puncture site, spinal deformities, raised intracranial pressure, conversion to general anesthesia, or refusal to participate were excluded from the study.

The study population was divided into two groups comprising 30 patients each. Group A received 3 mL of 0.5% hyperbaric bupivacaine with 30 μg intrathecal buprenorphine, while Group B received 3 mL of 0.5% hyperbaric bupivacaine with 75 μg intrathecal buprenorphine. A detailed pre-anesthetic evaluation was performed one day before surgery, and baseline demographic characteristics including age, sex, BMI, ASA physical status, and relevant clinical history were documented. Upon arrival in the operating room, standard monitoring including electrocardiography, non-invasive blood pressure, pulse oximetry, and heart rate monitoring was established. Baseline hemodynamic parameters were recorded. Intravenous access was secured and patients received crystalloid preloading according to institutional protocol. Under strict aseptic precautions, spinal anesthesia was administered in the sitting position at the L3–L4 or L4–L5 intervertebral space using a 25-gauge Quincke spinal needle. Following confirmation of free cerebrospinal fluid flow, the study drug was injected

intrathecally according to the allocated group, after which patients were placed in the supine position and monitored throughout the perioperative period.

Sensory blockade was assessed using the pinprick method, and the onset of sensory block, time to achieve maximum sensory level, highest sensory level attained, and duration of sensory block were recorded. Motor blockade was evaluated using the Modified Bromage Scale, and the onset, maximum grade achieved, and duration of motor block were documented. Postoperative pain intensity was assessed using the Visual Analogue Scale (VAS), with scores recorded at 1, 2, 4, 6, 12, and 24 hours after surgery.

The primary outcome measure was the duration of postoperative analgesia, defined as the time interval between intrathecal drug administration and the first request for rescue analgesia. Secondary outcome measures included sensory block characteristics, motor block characteristics, postoperative VAS scores, time to first rescue analgesia, number of patients requiring rescue analgesia, total rescue analgesic consumption during the first 24 postoperative hours, perioperative hemodynamic parameters, and adverse effects. Hemodynamic monitoring included heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and oxygen saturation. Patients were also observed for adverse events such as nausea, vomiting, pruritus, sedation, bradycardia, hypotension, and respiratory depression.

Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. Intergroup comparisons of continuous variables were performed using the independent Student's t-test, while categorical variables were analyzed using the Chi-square test or Fisher's exact test wherever appropriate. A p-value of less than 0.05 was considered statistically significant.

## 3. RESULTS

**TABLE 1. Baseline Demographic and Clinical Characteristics of the Study Participants**

| Characteristic | Group A (30 µg) (n=30) | Group B (75 µg) (n=30) | Total (N=60) | p-value |
|---|---|---|---|---|
| Age (years) | 38.2 ± 9.1 | 37.5 ± 8.7 | 37.9 ± 8.9 | 0.72 |
| 20–30 years | 8 (26.7%) | 9 (30.0%) | 17 (28.3%) | 0.84 |
| 31–40 years | 10 (33.3%) | 11 (36.7%) | 21 (35.0%) | |
| 41–50 years | 7 (23.3%) | 6 (20.0%) | 13 (21.7%) | |
| 51–60 years | 5 (16.7%) | 4 (13.3%) | 9 (15.0%) | |
| Male | 18 (60.0%) | 16 (53.3%) | 34 (56.7%) | 0.65 |
| Female | 12 (40.0%) | 14 (46.7%) | 26 (43.3%) | |
| BMI (kg/m²) | 24.5 ± 3.2 | 25.1 ± 2.9 | 24.8 ± 3.0 | 0.54 |
| Normal BMI | 17 (56.7%) | 15 (50.0%) | 32 (53.3%) | 0.77 |
| Overweight | 13 (43.3%) | 15 (50.0%) | 28 (46.7%) | |
| ASA I | 20 (66.7%) | 18 (60.0%) | 38 (63.3%) | 0.81 |
| ASA II | 10 (33.3%) | 12 (40.0%) | 22 (36.7%) | |
| Fracture fixation | 12 (40.0%) | 11 (36.7%) | 23 (38.3%) | 0.89 |
| Arthroscopy | 8 (26.7%) | 9 (30.0%) | 17 (28.3%) | |
| Implant removal | 5 (16.7%) | 4 (13.3%) | 9 (15.0%) | |
| Other orthopedic procedures | 5 (16.7%) | 6 (20.0%) | 11 (18.3%) | |

The mean age of the study population was 37.9 ± 8.9 years. Most participants belonged to the 31–40-year age group. Male participants constituted 56.7% of the study population. The mean BMI was comparable between groups, with the majority having normal BMI. Most patients belonged to ASA Physical Status I. The distribution of demographic and clinical characteristics was similar between the two groups with no statistically significant differences ($p > 0.05$), indicating baseline comparability.

**TABLE 2. Comparison of Sensory Block Characteristics**

| Variable | Group A (30 µg) | Group B (75 µg) | p-value |
|---|---|---|---|
| Onset of sensory block (min) | 3.8 ± 0.9 | 3.2 ± 0.7 | 0.02 |
| Time to peak sensory level (min) | 7.5 ± 1.4 | 6.4 ± 1.2 | <0.01 |
| T6 sensory level achieved | 8 (26.7%) | 18 (60.0%) | 0.03 |
| T8 sensory level achieved | 22 (73.3%) | 12 (40.0%) | |
| Duration of sensory block (min) | 220 ± 25 | 280 ± 30 | <0.001 |

The onset of sensory block was significantly faster in Group B than Group A. Patients receiving 75 µg buprenorphine achieved higher sensory block levels more frequently and attained peak sensory block earlier. The duration of sensory blockade was significantly prolonged in Group B compared to Group A, demonstrating enhanced sensory block characteristics with the higher dose.

**TABLE 3. Comparison of Motor Block Characteristics**

| Variable | Group A (30 µg) | Group B (75 µg) | p-value |
|---|---|---|---|
| Onset of motor block (min) | 4.5 ± 0.8 | 3.9 ± 0.6 | 0.01 |

| | | | |
|---|---|---|---|
| Bromage Grade 2 | 6 (20.0%) | 2 (6.7%) | 0.12 |
| Bromage Grade 3 | 24 (80.0%) | 28 (93.3%) | |
| Duration of motor block (min) | 200 ± 20 | 250 ± 25 | <0.001 |

Motor block onset occurred significantly earlier in patients receiving 75 µg buprenorphine. Although a greater proportion of patients achieved complete motor blockade (Bromage Grade 3) in Group B, the difference was not statistically significant. However, the duration of motor block was significantly prolonged in the higher-dose group.

**TABLE 4. Comparison of Postoperative Analgesic Outcomes**

| Variable | Group A (30 µg) | Group B (75 µg) | p-value |
|---|---|---|---|
| Duration of analgesia (min) | 360 ± 40 | 520 ± 50 | <0.001 |
| Time to first rescue analgesia (min) | 365 ± 42 | 525 ± 48 | <0.001 |
| Patients requiring rescue analgesia | 18 (60.0%) | 9 (30.0%) | 0.01 |
| Mean rescue doses in 24 hours | 2.1 ± 0.6 | 1.2 ± 0.4 | <0.001 |

Postoperative analgesia lasted significantly longer in Group B compared to Group A. The time to first rescue analgesic requirement was also significantly delayed in patients receiving 75 µg buprenorphine. Furthermore, fewer patients required rescue analgesia and the mean number of rescue doses administered during the first 24 postoperative hours was significantly lower in Group B.

**TABLE 5. Comparison of Postoperative Pain Scores (VAS)**

| Time After Surgery | Group A | Group B | p-value |
|---|---|---|---|
| 1 hour | 0.8 ± 0.5 | 0.6 ± 0.4 | 0.08 |
| 2 hours | 1.5 ± 0.7 | 1.0 ± 0.5 | 0.02 |
| 4 hours | 2.8 ± 0.8 | 1.8 ± 0.6 | <0.001 |
| 6 hours | 4.5 ± 0.9 | 2.5 ± 0.7 | <0.001 |
| 12 hours | 5.8 ± 1.0 | 3.2 ± 0.8 | <0.001 |
| 24 hours | 3.2 ± 0.7 | 2.1 ± 0.6 | <0.001 |

Postoperative pain scores were comparable during the first postoperative hour. However, from the second postoperative hour onwards, VAS scores were significantly lower in Group B. The greatest difference was observed at 6 and 12 hours postoperatively, reflecting the prolonged analgesic effect of the higher buprenorphine dose.

**TABLE 6. Comparison of Hemodynamic Parameters**

| Parameter | Group A | Group B | p-value |
|---|---|---|---|
| Baseline HR (beats/min) | 82 ± 9 | 81 ± 8 | 0.76 |
| Lowest HR (beats/min) | 74 ± 7 | 73 ± 6 | 0.68 |
| Baseline SBP (mmHg) | 124 ± 10 | 123 ± 9 | 0.72 |
| Lowest SBP (mmHg) | 108 ± 8 | 106 ± 9 | 0.54 |
| Baseline DBP (mmHg) | 78 ± 6 | 79 ± 5 | 0.61 |
| Lowest DBP (mmHg) | 68 ± 5 | 67 ± 6 | 0.63 |
| Baseline MAP (mmHg) | 93 ± 7 | 94 ± 6 | 0.54 |
| Lowest MAP (mmHg) | 84 ± 6 | 83 ± 5 | 0.58 |
| Baseline $SpO_2$ (%) | 99 ± 1 | 99 ± 1 | 0.92 |
| Lowest $SpO_2$ (%) | 98 ± 1 | 98 ± 1 | 0.88 |

Hemodynamic parameters remained stable throughout the perioperative period in both groups. No statistically significant differences were observed in heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, or oxygen saturation. These findings indicate that both doses of intrathecal buprenorphine were hemodynamically safe.

**TABLE 7. Comparison of Adverse Effects**

| Adverse Effect | Group A n (%) | Group B n (%) | p-value |
|---|---|---|---|
| Nausea | 2 (6.7%) | 4 (13.3%) | 0.39 |
| Vomiting | 1 (3.3%) | 2 (6.7%) | 0.55 |
| Pruritus | 1 (3.3%) | 3 (10.0%) | 0.30 |
| Sedation | 2 (6.7%) | 5 (16.7%) | 0.22 |
| Bradycardia | 1 (3.3%) | 2 (6.7%) | 0.55 |
| Hypotension | 2 (6.7%) | 3 (10.0%) | 0.64 |
| Respiratory depression | 0 | 0 | — |

The incidence of adverse effects was low in both study groups. Although nausea, pruritus, and sedation were more frequent

in patients receiving 75 µg buprenorphine, the differences did not reach statistical significance. No patient experienced respiratory depression, indicating an acceptable safety profile for both doses.

Figure 1. Sensory and Motor Block Duration

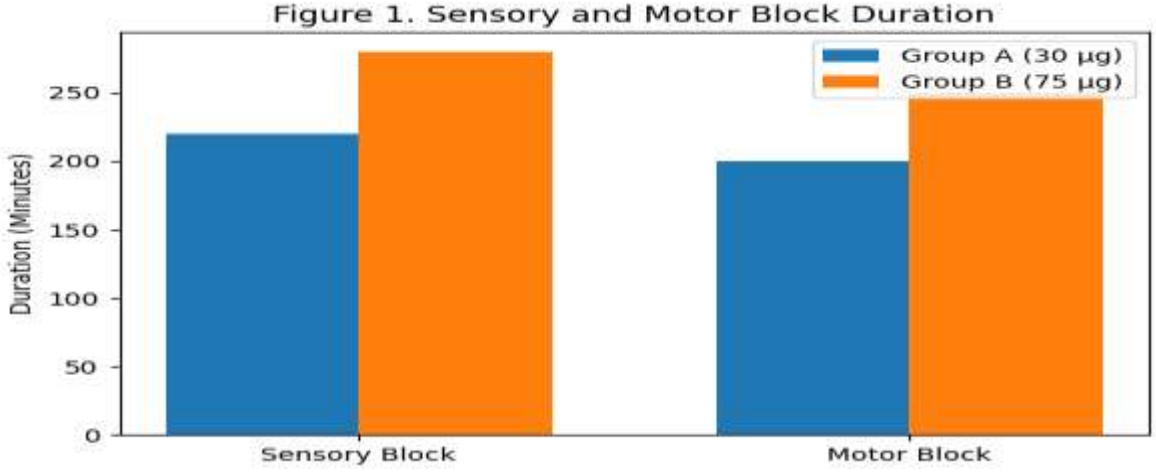



Figure 2. Duration of Postoperative Analgesia

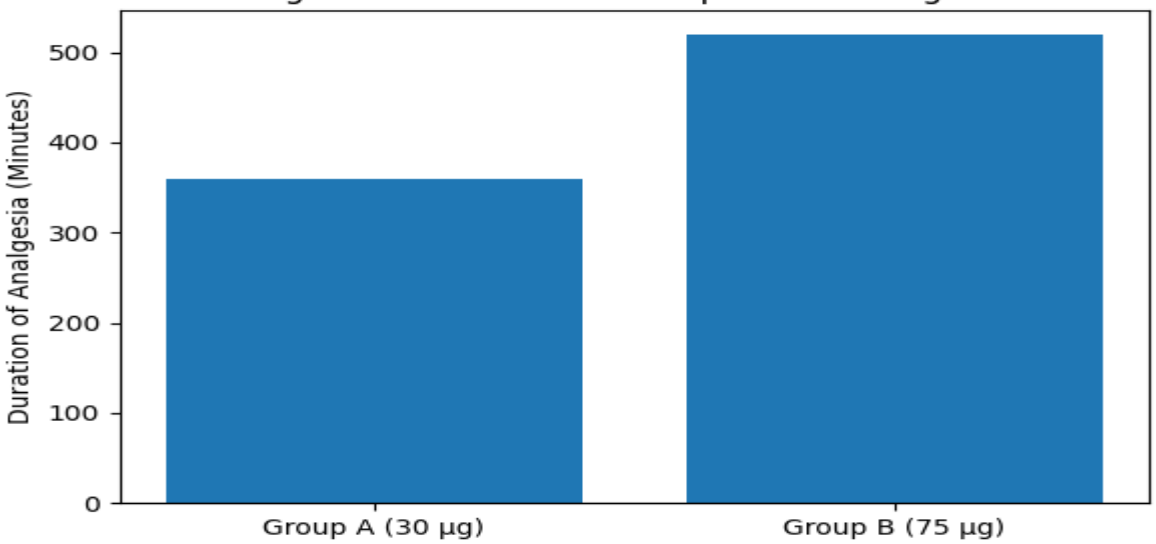
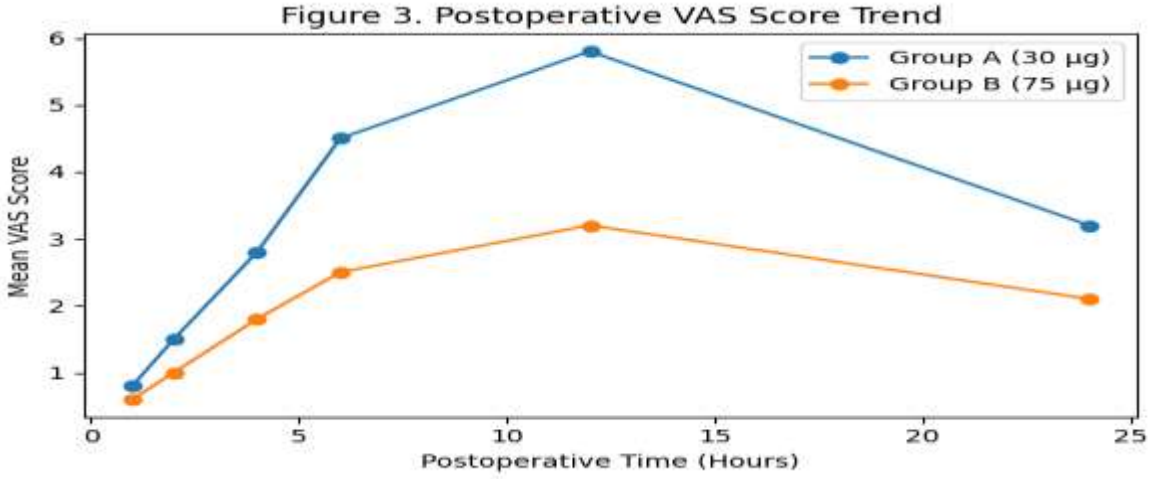



Figure 3. Postoperative VAS Score Trend




## 4. DISCUSSION

The present prospective observational study compared two different doses of intrathecal buprenorphine (30 µg and 75 µg) administered with 0.5% hyperbaric bupivacaine in patients undergoing lower limb orthopedic surgeries. The study demonstrated that administration of 75 µg intrathecal buprenorphine resulted in significantly superior sensory and motor block characteristics, prolonged postoperative analgesia, lower postoperative pain scores, and reduced rescue analgesic requirements without increasing clinically significant adverse effects. These findings suggest that increasing the dose of intrathecal buprenorphine enhances the quality and duration of spinal anesthesia while maintaining an acceptable safety profile.

The baseline demographic and clinical characteristics were comparable between the study groups. The mean age was 38.2 ± 9.1 years in Group A and 37.5 ± 8.7 years in Group B. Male patients constituted 60.0% and 53.3% of the respective groups, while the mean BMI was 24.5 ± 3.2 kg/m² and 25.1 ± 2.9 kg/m². Most participants belonged to ASA Physical Status I. No statistically significant differences were observed in any baseline parameter, confirming that both groups were comparable before intervention and reducing the possibility of confounding factors influencing study outcomes.

Effective postoperative pain management remains a major concern following lower limb orthopedic surgeries. Aytolign et al. [16] demonstrated that regional anesthetic techniques significantly improve postoperative analgesic outcomes following orthopedic procedures. Similarly, Sapate et al. [17] reported that the addition of adjuvants to spinal anesthesia enhanced block quality and prolonged anesthetic duration in below-knee orthopedic surgeries. Kumari et al. [18] further observed that neuraxial opioid adjuvants significantly prolonged postoperative analgesia and reduced postoperative analgesic consumption. These observations support the concept that optimization of intrathecal adjuvants can substantially improve perioperative pain management.

In the present study, the onset of sensory blockade was significantly faster in patients receiving 75 µg buprenorphine (3.2 ± 0.7 minutes) than in those receiving 30 µg buprenorphine (3.8 ± 0.9 minutes; p=0.02). The time required to achieve peak sensory block was also significantly shorter in Group B (6.4 ± 1.2 minutes) than Group A (7.5 ± 1.4 minutes; p<0.01). Furthermore, 60.0% of patients in Group B achieved T6 sensory blockade compared with only 26.7% in Group A. The duration of sensory blockade was significantly prolonged in Group B (280 ± 30 minutes) compared with Group A (220 ± 25 minutes; p<0.001).

Li et al. [19] reported that improved neuraxial anesthesia techniques contribute to superior block characteristics and better perioperative outcomes in orthopedic patients. Kamel et al. [20] similarly emphasized that prolonged sensory blockade provides improved surgical conditions and enhanced postoperative comfort. The findings of the present study are also consistent with those of Shrinivas et al. [21], who demonstrated that the addition of intrathecal buprenorphine to hyperbaric bupivacaine significantly prolonged sensory blockade and postoperative analgesia compared with bupivacaine alone. Dhawale et al. [22] compared intrathecal fentanyl and buprenorphine as adjuvants to hyperbaric bupivacaine and reported superior analgesic efficacy with buprenorphine while maintaining hemodynamic stability. Ravindran et al. [23] evaluated varying doses of intrathecal buprenorphine and observed a dose-dependent prolongation of sensory blockade and postoperative analgesia, which closely parallels the dose-dependent improvements observed in the present study.

Motor block characteristics were also significantly influenced by the dose of buprenorphine. The onset of motor blockade was faster in Group B (3.9 ± 0.6 minutes) than in Group A (4.5 ± 0.8 minutes; p=0.01). Complete motor blockade (Bromage Grade 3) was achieved in 93.3% of patients receiving 75 µg buprenorphine compared with 80.0% of those receiving 30 µg buprenorphine. Additionally, the duration of motor blockade was significantly prolonged in Group B (250 ± 25 minutes) compared with Group A (200 ± 20 minutes; p<0.001).

These findings are supported by Gupta et al. [24], who demonstrated that intrathecal buprenorphine effectively prolonged motor blockade when used as an adjuvant to bupivacaine. Arora et al. [25] similarly reported improved quality of spinal anesthesia and prolonged motor blockade in patients receiving buprenorphine-containing regimens. The prolonged motor blockade observed in the present study may be attributed to synergistic interactions between buprenorphine and hyperbaric bupivacaine at the spinal cord level, resulting in enhanced neural transmission blockade.

The most clinically important finding of the present investigation was the significant prolongation of postoperative analgesia in patients receiving the higher buprenorphine dose. The mean duration of postoperative analgesia was 520 ± 50 minutes in Group B compared with 360 ± 40 minutes in Group A (p<0.001). Likewise, the mean time to first rescue analgesia was significantly delayed in Group B (525 ± 48 minutes) compared with Group A (365 ± 42 minutes; p<0.001). Only 30.0% of patients in Group B required rescue analgesia compared with 60.0% in Group A. Furthermore, the mean number of rescue analgesic doses administered during the first postoperative day was significantly lower in Group B (1.2 ± 0.4) than Group A (2.1 ± 0.6; p<0.001).

These observations are in agreement with Shah et al. [26], who demonstrated significant improvement in postoperative pain relief following the addition of intrathecal buprenorphine to bupivacaine-based spinal anesthesia. Kaushal et al. [27] compared intrathecal nalbuphine and buprenorphine in lower limb orthopedic surgeries and concluded that buprenorphine produced prolonged postoperative analgesia with reduced rescue analgesic requirements. Similarly, Ture et al. [28] reported that buprenorphine-containing spinal anesthesia regimens provided superior analgesic efficacy and prolonged pain relief. The findings of the present study reinforce the role of buprenorphine as an effective intrathecal opioid adjuvant capable of substantially extending postoperative analgesia.

Assessment of postoperative pain using the Visual Analogue Scale further supported the analgesic superiority of the higher-dose group. VAS scores were similar during the first postoperative hour (0.8 ± 0.5 versus 0.6 ± 0.4; p=0.08). However, from the second postoperative hour onward, pain scores remained significantly lower in Group B. At 4 hours, the mean VAS score was 1.8 ± 0.6 in Group B compared with 2.8 ± 0.8 in Group A. At 6 hours, VAS scores were 2.5 ± 0.7 and 4.5 ± 0.9, respectively. The greatest difference was observed at 12 hours postoperatively, where Group B demonstrated a mean VAS score of 3.2 ± 0.8 compared with 5.8 ± 1.0 in Group A. Even at 24 hours, pain scores remained lower in Group B (2.1 ± 0.6 versus 3.2 ± 0.7; p<0.001).

The improved pain scores observed in the present study are comparable to findings reported by Dahm et al. [29], who demonstrated effective and sustained pain relief following intrathecal buprenorphine administration. Yousef et al. [30] also reported enhanced postoperative analgesia and reduced analgesic consumption when opioid adjuvants were incorporated into neuraxial anesthesia techniques. Collectively, these studies support the ability of buprenorphine to provide prolonged postoperative pain control and improved patient comfort.

Hemodynamic stability is an important consideration when evaluating intrathecal opioid adjuvants. In the present study, baseline and intraoperative heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and oxygen saturation remained comparable between groups. No statistically significant differences were observed in any hemodynamic parameter, indicating that both buprenorphine doses maintained cardiovascular stability throughout the perioperative period. These findings are consistent with previously published studies demonstrating the hemodynamic safety of intrathecal buprenorphine and support its use in routine orthopedic anesthesia practice.

The incidence of adverse effects was low in both groups. Nausea occurred in 6.7% and 13.3% of patients in Groups A and B, respectively, while vomiting occurred in 3.3% and 6.7%. Pruritus was observed in 3.3% and 10.0% of patients, and sedation occurred in 6.7% and 16.7%, respectively. Although adverse effects were numerically more frequent in the higher-dose group, none of these differences reached statistical significance. Importantly, no patient in either group experienced respiratory depression. The absence of severe respiratory complications supports the known pharmacological advantage of buprenorphine, namely its ceiling effect on respiratory depression. This favorable safety profile further strengthens the clinical applicability of intrathecal buprenorphine in orthopedic surgical patients.

Overall, the present study demonstrates that 75 µg intrathecal buprenorphine administered with hyperbaric bupivacaine provides significantly faster sensory and motor block onset, prolonged sensory and motor blockade, longer postoperative analgesia, lower postoperative pain scores, and reduced rescue analgesic requirements compared with 30 µg buprenorphine. These benefits were achieved without clinically significant hemodynamic instability or increased adverse effects. Therefore, 75 µg intrathecal buprenorphine appears to be a more effective dose for enhancing postoperative analgesia in patients undergoing lower limb orthopedic surgeries.

## 5. CONCLUSION

The present study demonstrated that 75 µg intrathecal buprenorphine administered with 0.5% hyperbaric bupivacaine produced significantly superior sensory and motor block characteristics compared with 30 µg buprenorphine in patients undergoing lower limb orthopedic surgeries. The higher dose resulted in prolonged postoperative analgesia, delayed rescue analgesic requirement, lower postoperative pain scores, and reduced analgesic consumption during the first 24 postoperative hours. Importantly, these benefits were achieved without clinically significant hemodynamic instability or increased adverse effects. Based on these findings, 75 µg intrathecal buprenorphine may be considered an effective and safe adjuvant for enhancing postoperative analgesia in lower limb orthopedic surgical procedures.

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