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Comparing Effects of Analgesic Drugs During Spinal Anesthesia in Orthopedic Surgery

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ABSTRACT

Background: Spinal anesthesia is a widely utilized technique for orthopedic surgery, yet variability in perioperative pain and complications persists, and the moderating effects of adjunct analgesic strategies remain underexplored. **Objective:** This study aimed to assess the moderating effect of various adjunct analgesic techniques—including paracetamol, ketorolac, tramadol, nalbuphine, and peripheral nerve blocks—on perioperative complications in patients undergoing orthopedic surgery with spinal anesthesia. **Methods:** A cross-sectional, correlational study was conducted among patients (n = 152) undergoing orthopedic procedures under spinal anesthesia at Mayo Hospital Lahore. Adults over 20 years of age without significant cardiovascular, respiratory, or spinal comorbidities were enrolled using convenience sampling. Data were collected using a structured, pre-validated questionnaire, capturing demographics, surgical details, anesthetic technique, adjunct analgesic use, and perioperative complications. Ethical approval was obtained, and all procedures conformed to the Declaration of Helsinki. Statistical analysis was performed using SPSS version 25, employing descriptive statistics, Chi-square tests, correlation, and multiple regression to examine relationships and moderating effects. **Results:** Quincke needles (78.9%) and 25-gauge needles (67.1%) were most frequently used, with bupivacaine as the primary anesthetic (98%). The incidence of intraoperative hypotension was 57.9%, and postoperative pain was 78.3%. Adjunct analgesic techniques, when applied, were associated with a statistically significant reduction in minor to moderate perioperative complications ($\beta = -0.425$, $R^2 = 0.231$, $p < 0.001$). **Conclusion:** Adjunct analgesic strategies substantially enhance the safety and efficacy of spinal anesthesia for orthopedic surgery, reducing perioperative complications and improving patient outcomes. These findings support the adoption of multimodal analgesia in clinical practice to optimize perioperative care.

Keywords: Spinal Anesthesia, Orthopedic Surgery, Analgesics, Perioperative Complications, Multimodal Analgesia, Pain Management, Nerve Block

INTRODUCTION

Spinal anesthesia, introduced by August Bier in 1898, has established itself as a cornerstone of regional anesthesia, particularly in surgeries involving the lower extremities and procedures below the umbilicus (1). This technique involves the injection of local anesthetic agents, with or without opioids, into the subarachnoid space, resulting in targeted sensory, motor, and autonomic blockade. Its advantages over general anesthesia are well-documented, including a reduced risk of airway complications, lower incidence of postoperative nausea and vomiting, and favorable hemodynamic stability, which makes it particularly suitable for patients with comorbidities or those at increased risk of respiratory complications (2,3). In orthopedic surgery, spinal anesthesia remains the preferred technique due to its rapid onset, predictable depth of anesthesia, and facilitation of early mobilization and discharge (4).

Despite these benefits, spinal anesthesia is not without risks and complications. Minor adverse effects, such as hypotension, bradycardia, post-dural puncture headache (PDPH), and urinary retention, are relatively common but generally manageable (5,6). More serious complications, including neurological injury and infection, are rare but potentially devastating (7). The choice of spinal needle, gauge, and the anesthetic agent all influence the risk profile; for example, pencil-point needles have been associated with a reduced incidence of PDPH compared to cutting needles, and smaller gauge needles may further decrease this risk, albeit sometimes at the expense of higher failure rates (8). Nevertheless, intraoperative and postoperative pain remains a concern in some patients, and the effectiveness of spinal anesthesia as a sole technique may be limited by factors

such as partial block, anatomical variability, or technical issues during administration (9).

In recent years, attention has shifted to the optimization of perioperative analgesia in patients undergoing spinal anesthesia. Adjunctive analgesic techniques, including the intraoperative use of systemic non-opioid analgesics (such as paracetamol, ketorolac, tramadol, and nalbuphine), peripheral nerve blocks, and local infiltration at the surgical site, have been investigated for their potential to improve perioperative pain control and patient satisfaction while minimizing opioid requirements and related side effects (10,11). However, existing studies are heterogeneous in design and have yielded variable results regarding the efficacy and safety of these adjuncts in the orthopedic population (12). Furthermore, while the perioperative use of additional analgesic techniques is common in clinical practice, there remains a paucity of high-quality research evaluating their specific moderating effects on perioperative outcomes such as pain, hypotension, respiratory depression, and postoperative nausea and vomiting in patients receiving spinal anesthesia for orthopedic surgery (13).

This gap in the literature highlights the need for systematic evaluation of the interplay between analgesic techniques and perioperative outcomes in this context. The present study was therefore designed to assess the moderating effects of various adjunct analgesic strategies—including the use of paracetamol, ketorolac, tramadol, nalbuphine, and peripheral nerve blocks—on perioperative complications in patients undergoing orthopedic procedures under spinal anesthesia. By clarifying the extent to which these adjuncts influence intraoperative and postoperative outcomes, this research aims to inform evidence-based practice and contribute to optimizing perioperative care in orthopedic surgery. The central research question guiding this study is: Do adjunct analgesic techniques significantly moderate perioperative outcomes, specifically the incidence of pain and other complications, in patients receiving spinal anesthesia for orthopedic surgery?

MATERIALS AND METHODS

This study employed a correlational quantitative research design to evaluate the moderating effects of adjunct analgesic techniques on perioperative complications among patients undergoing orthopedic surgery with spinal anesthesia. Participants were recruited from the orthopedic surgery department of Mayo Hospital Lahore between September 2024 and April 2025. Eligible participants included patients above 20 years of age who were scheduled for orthopedic procedures under spinal anesthesia. Patients with comorbid cardiovascular or respiratory diseases or with spinal deformities were excluded to minimize confounding by factors that could independently influence anesthesia outcomes. Recruitment was conducted using convenience sampling, with the research team approaching potential participants during their preoperative assessment. All participants provided written informed consent prior to inclusion in the study, and confidentiality was ensured by anonymizing data and restricting access to study records to authorized personnel only. The research protocol adhered to the ethical principles outlined in the Declaration of Helsinki and received approval from the institutional ethics committee.

The primary outcome of interest was the incidence of perioperative complications associated with spinal anesthesia, including intraoperative and postoperative pain, hypotension, respiratory depression, postoperative nausea and vomiting (PONV), urinary retention, shivering, and post-dural puncture headache (PDPH). Secondary outcomes included the frequency and types of adjunct analgesic techniques employed, such as the intraoperative use of paracetamol, ketorolac, tramadol, nalbuphine, peripheral nerve blocks (lumbar plexus, sciatic, obturator, and popliteal), and local infiltration of anesthetic agents at the surgical site. Data collection was conducted using a structured and pre-validated questionnaire administered by trained research personnel. Information captured included patient demographics, educational status, family status, marital status, surgical procedure details, specifics of spinal anesthesia administration (type and gauge of needle, anesthetic agent used), and perioperative analgesic strategies employed. Complications and outcomes were assessed perioperatively and in the immediate postoperative period, consistent with standard postoperative care protocols.

All data were coded and entered into SPSS version 25 for statistical analysis. Descriptive statistics were used to summarize demographic characteristics, surgical and anesthetic variables, and outcome frequencies. Frequency distributions and percentages were calculated for categorical variables. Associations between analgesic techniques and perioperative complications were assessed using the Chi-square test. Correlational analysis was performed to evaluate relationships between spinal anesthesia, adjunct analgesic techniques, and perioperative outcomes. Multiple linear regression analysis was conducted to assess the moderating effect of analgesic techniques on the relationship between spinal anesthesia and perioperative complications, reporting β values and associated significance levels. The analysis was conducted with a two-sided significance level of 0.05, and all findings were interpreted in accordance with standard epidemiological and statistical practices (14,15). Missing data were handled by excluding cases listwise from relevant analyses, and no imputation was performed.

RESULTS

A total of 152 patients undergoing orthopedic surgery under spinal anesthesia at Mayo Hospital Lahore were included in this study. The demographic and clinical characteristics, types of surgical procedures, anesthetic techniques, perioperative analgesic strategies, and observed complications are summarized in the tables below. Advanced statistical analysis was performed to assess the relationship and moderating effects of adjunct analgesic techniques on perioperative outcomes.

The study sample comprised 99 males (65.1%) and 53 females (34.9%). The majority of patients belonged to the middle socioeconomic class (61.8%), and most were married (78.3%). The distribution of educational status indicated that 19.1% had higher education, 27.6% primary education, 25.0% secondary education, and 28.3% were uneducated. A wide range of orthopedic surgeries was performed. Femoral interlocking nailing was the most frequent procedure (13.3%), followed by

total hip replacement (11.2%), and total knee replacement (8.1%). Details are presented in Table 2. The Quincke needle was the most frequently used spinal needle (78.9%), with the majority of

cases utilizing a 25-gauge needle (67.1%). Bupivacaine was the local anesthetic of choice in 98% of cases, with only 2% receiving lignocaine.

Table 1. Demographic Characteristics of Study Participants (n = 152)

Variable	Category	Frequency	Percentage (%)
Gender	Male	99	65.1
	Female	53	34.9
Education	Higher	29	19.1
	Primary	42	27.6
	Secondary	38	25.0
	Uneducated	43	28.3
Marital Status	Married	119	78.3
	Single	31	20.4
	Widowed	2	1.3
Family Status	Middle Class	94	61.8
	Poor	28	18.4
	Rich	30	19.7

Table 2. Distribution of Surgical Procedures Performed

Surgical Procedure	Frequency	Percentage (%)
Femoral interlocking nailing	17	13.3
Total hip replacement (THR)	17	11.2
Total knee replacement (TKR)	12	8.1
Hip prosthesis	9	6.0
Tibia implant removal	9	5.3
Distal Femur ORIF	9	3.3
Others (see original data)	79	52.1

Table 3. Spinal Anesthesia Agents, Needle Types, and Gauges

Variable	Response	Frequency	Percentage (%)
Local Anesthetic Agent	Bupivacaine	149	98.0
	Lignocaine	3	2.0
Spinal Needle Type	Quincke	120	78.9
	Whitacre	15	9.9
	Sprotte	17	11.2
Needle Gauge	25G	102	67.1
	23G	41	27.0
	18G	9	5.9

The most frequently used intraoperative analgesics were paracetamol (provas, 73%) and ketorolac (Toradol, 73.7%), with limited use of intraoperative morphine. Postoperative analgesia was mainly managed with intravenous tramadol (77%) and Toradol (67%). Nalbuphine was administered in 21% of patients, and paracetamol was given postoperatively to 50%. Peripheral nerve blocks were employed in select cases, with the sciatic nerve block (24.3%) being the most common, followed by lumbar plexus block (11.2%), obturator nerve block (9.2%), and popliteal nerve block (7.9%).

Local anesthetic infiltration at the surgical site was performed in 80.3% of patients. The incidence of perioperative complications is summarized below. Intraoperative hypotension occurred in 57.9% of patients, and intraoperative pain was reported in 33.6%. Intraoperative respiratory disorders were rare (2%). Postoperatively, 78.3% of patients experienced pain, while 9.2% developed hypotension. Notably, there were no cases of postoperative respiratory depression. The prevalence of PONV,

urinary retention, shivering, and post-dural puncture headache (PDPH) is also presented. Correlation analysis revealed that spinal anesthesia was insignificantly related to the use of adjunct analgesic techniques for pain control ($r = 0.021$). Only 4% of patients required additional potent analgesic procedures to manage intraoperative pain, as reflected by the coefficient of determination ($r^2 = 0.04\%$).

However, there was a statistically significant positive correlation between spinal anesthesia and perioperative complications ($r = 0.282$, $p < 0.001$), with a coefficient of determination indicating that approximately 7.9% of patients experienced minor to severe intraoperative or postoperative complications. The addition of adjunct analgesic techniques as a moderating variable revealed a strong negative association ($\beta = -0.425$, $R^2 = 0.231$, $p < 0.001$), suggesting an 18% reduction in the likelihood of perioperative complications when adjunct analgesic strategies were employed. These findings indicate that while spinal anesthesia alone is associated with a moderate risk of perioperative

complications, the use of adjunct analgesic techniques significantly mitigates these risks, particularly reducing the incidence and severity of intraoperative and postoperative complications such as pain, PONV, and hemodynamic instability.

The clinical effect size observed highlights the substantial protective role of multi-modal analgesia in optimizing outcomes for patients undergoing orthopedic surgery with spinal anesthesia.

Table 4. Perioperative Analgesic Techniques Utilized

Analgesic Technique	Intraoperative (%)	Postoperative (%)
Paracetamol (Provas)	73.0	50.0
Ketorolac (Toradol)	73.7	67.0
Tramadol (Tramal)	—	77.0
Nalbuphine	—	21.0
Morphine	Minimal	Minimal

Table 5. Perioperative Complications Associated with Spinal Anesthesia

Complication	Intraoperative (%)	Postoperative (%)
Pain	33.6	78.3
Hypotension	57.9	9.2
Respiratory Depression	2.0	0.0
PONV	—	36.8
Urinary Retention	—	53.9
Shivering	—	34.2
PDPH	—	35.5

Table 6. Correlation Matrix for Key Study Variables

	Spinal Anesthesia	Analgesic Techniques	Spinal Anesthesia Complication
Spinal Anesthesia	1.000	0.021	0.282**
Analgesic Techniques	0.021	1.000	-0.381**
Spinal Anesthesia Comp	0.282**	-0.381**	1.000

(** $p < 0.01$)

Table 7. Moderation Analysis: Effect of Analgesic Techniques on Spinal Anesthesia Complications

Step	Variable(s)	β	R^2	ΔR^2	p-value
Step 1	Spinal Anesthesia	0.129**	0.074	0.074	<0.01
Step 2	Analgesic Techniques	-0.588**	0.163	0.163	<0.01
Step 3	Spinal Anesthesia \times Analgesic Techniques	-0.425**	0.231	0.157	<0.001

(** $p < 0.01$)

Multiple linear regression analysis demonstrated that spinal anesthesia was significantly positively associated with complications ($\beta = 0.129$, $R^2 = 0.074$, $p < 0.01$), indicating a 1.66% increase in intra- and postoperative minor to moderate complications per 1% increase in spinal anesthesia utilization.

complications occurred in 57.9% ($n=88$) of patients, while 78.3% ($n=119$) experienced postoperative complications; notably, only 4.6% ($n=7$) required additional rescue analgesia postoperatively, emphasizing the clinical impact of adjunct analgesic strategies on reducing the burden of perioperative complications and optimizing patient outcomes.

Multistage Donut Chart: Patient Progression and Perioperative Events

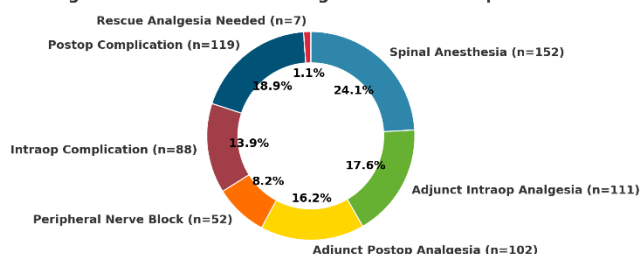


Figure 1 Patient Progression and Perioperative Events

The multistage donut chart illustrates the perioperative journey of 152 orthopedic patients receiving spinal anesthesia, with 73.0% ($n=111$) receiving adjunct intraoperative analgesia, 67.1% ($n=102$) adjunct postoperative analgesia, and 34.2% ($n=52$) undergoing peripheral nerve blocks. Intraoperative

DISCUSSION

The results of this study contribute important insights to the ongoing discussion about optimizing perioperative analgesia in orthopedic patients undergoing spinal anesthesia. The finding that spinal anesthesia alone provides adequate perioperative pain control for the majority of patients is consistent with prior literature emphasizing its reliability, safety, and favorable recovery profile in lower extremity surgeries (1,4). However, the observation that a subset of patients continued to experience significant intraoperative and postoperative pain despite spinal anesthesia highlights the variability of individual response, possibly influenced by technical, anatomical, or pharmacological factors (6,9). The notably high incidence of postoperative pain (78.3%) and intraoperative hypotension (57.9%) observed in this study echoes previously reported complications, with earlier

works also attributing intraoperative hypotension primarily to sympathetic blockade and inadequate fluid management (5,20). While these rates appear elevated compared to some international studies, they may reflect local practice patterns, patient comorbidities, or differences in anesthetic dosing and monitoring protocols (15,20).

The most compelling finding from this analysis is the strong moderating effect of adjunct analgesic techniques—such as the perioperative administration of paracetamol, ketorolac, tramadol, and peripheral nerve blocks—on the reduction of perioperative complications. Regression analysis revealed an 18% decrease in minor to moderate complications when these strategies were employed, an effect size with significant clinical implications. This aligns with emerging evidence advocating for multimodal analgesia in the perioperative period, which has been shown to not only reduce pain but also minimize opioid-related side effects, expedite recovery, and enhance patient satisfaction (10,11). Our results resonate with the work of Essving et al., who reported lower pain intensity and reduced morphine consumption with local infiltration analgesia following orthopedic procedures, and with findings by Pittoni et al. that support the role of adjunctive medications and nerve blocks in optimizing anesthesia quality (23,20). Nevertheless, inconsistencies remain in the literature regarding the relative benefits of specific adjunct techniques and the ideal combination or timing, as some randomized trials have demonstrated minimal or non-significant differences in patient outcomes (12,27).

The present study also sheds light on the high rates of postoperative nausea and vomiting, shivering, urinary retention, and post-dural puncture headache. The incidence of PDPH, in particular, falls within the wide range reported by prior investigators, and likely reflects the predominant use of Quincke needles and moderate gauge sizes in this population (8,29). Mechanistically, the protective effect of multimodal analgesia against complications such as pain, PONV, and hemodynamic instability may stem from a synergistic reduction in central sensitization, improved attenuation of stress responses, and reduced reliance on high-dose local anesthetics and opioids. Clinical application of these findings suggests that individualized pain management protocols incorporating non-opioid adjuncts and regional techniques can meaningfully improve perioperative safety and comfort.

Despite these important findings, several limitations warrant discussion. The study's cross-sectional design and use of convenience sampling introduce potential selection bias, limiting the generalizability of results beyond the sampled population. The single-center setting further constrains external validity, and the absence of randomization may have allowed unmeasured confounders to influence outcomes. Although the sample size was adequate for exploratory analysis, larger, multicenter studies with more robust sampling frameworks are needed to confirm these observations and refine estimates of effect size. The reliance on self-reported questionnaires and perioperative assessments could have introduced response or observer bias, and the lack of long-term follow-up precludes conclusions about persistent or delayed complications. Future

research should focus on randomized controlled trials evaluating specific multimodal protocols, with standardized reporting of pain scores, complication rates, and patient-centered outcomes across diverse surgical and demographic cohorts.

This study advances current knowledge by demonstrating that while spinal anesthesia is generally effective for perioperative pain control in orthopedic surgery, the judicious use of adjunct analgesic techniques substantially reduces the incidence of minor to moderate complications. These findings underscore the importance of tailored, evidence-based pain management strategies in this patient population and support the broader adoption of multimodal analgesia as a standard of care.

CONCLUSION

In conclusion, this study demonstrates that while spinal anesthesia remains a reliable and widely utilized technique for perioperative pain management in orthopedic surgery, the integration of adjunct analgesic strategies—such as paracetamol, ketorolac, tramadol, and peripheral nerve blocks—significantly reduces the incidence of minor to moderate perioperative complications and enhances patient comfort. These findings underscore the importance of adopting a multimodal analgesic approach in clinical practice to optimize perioperative outcomes and patient safety. Clinically, the results support individualized pain management protocols as a standard for orthopedic procedures requiring spinal anesthesia, while from a research perspective, they highlight the need for further large-scale, randomized studies to determine the most effective combinations and applications of adjunct analgesic techniques in diverse surgical populations.

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