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A Comparative Study of Intrathecal Dexmedetomidine and Fentanyl as Adjuvants to Isobaric Levobupivacaine in Segmental Spinal Anaesthesia for Elective Laparoscopic Cholecystectomy

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ABSTRACT

Introduction: Laparoscopic cholecystectomy is commonly performed under general anaesthesia, which may be unsuitable for patients with compromised cardiopulmonary function. Segmental spinal anaesthesia has emerged as a safer, targeted alternative, providing effective analgesia with fewer systemic effects. The addition of intrathecal adjuvants such as fentanyl and dexmedetomidine may enhance the quality and duration of anaesthesia while minimizing side effects.

Aim and Objective: To compare the efficacy and safety of intrathecal dexmedetomidine versus fentanyl as adjuvants to isobaric levobupivacaine in segmental spinal anaesthesia for elective laparoscopic cholecystectomy**.**

Materials & Methods: This prospective, randomized, single-centre study enrolled 60 ASA I/II patients aged 18–60 years. Patients were allocated into two groups: Group D (n=30) received 5 µg dexmedetomidine, and Group F (n=30) received 25 µg fentanyl, each combined with 1.5–1.8 ml of isobaric levobupivacaine intrathecally. Outcomes measured included sensory and motor block characteristics, duration of analgesia, postoperative analgesic consumption, intraoperative haemodynamics, and incidence of side effects**.**

Results: Dexmedetomidine significantly prolonged sensory block duration (110 ± 12.2 min vs. 86 ± 15.3 min), extended motor block (441 ± 11 min vs. 135.3 ± 12.2 min), and delayed the time to first rescue analgesia (291.7 ± 28.7 min vs. 158.99 ± 25.96 min). Postoperative analgesic requirements were significantly lower in Group D. Both groups maintained stable haemodynamics, and the incidence of side effects was minimal and statistically insignificant**.**

Conclusion: Dexmedetomidine is a more effective intrathecal adjuvant than fentanyl for SSA in laparoscopic cholecystectomy, offering longer-lasting analgesia, reduced drug requirements, and improved patient outcomes.

Keywords: Segmental spinal anaesthesia; Dexmedetomidine; Fentanyl; Laparoscopic cholecystectomy; Intrathecal adjuvants.

INTRODUCTION

Laparoscopic cholecystectomy has emerged as one of the most widely performed elective surgical procedures worldwide, primarily used for treating gallstone-related conditions such as cholelithiasis and cholecystitis. The shift toward this minimally invasive technique has been driven by several advantages over traditional open surgery, including reduced postoperative pain, shorter hospital stays, fewer wound-related complications, and quicker recovery. The standard anaesthetic approach for laparoscopic cholecystectomy has traditionally been general anaesthesia (GA), which

ensures unconsciousness, complete muscle relaxation, and airway control through endotracheal intubation. These features are particularly important during abdominal insufflation with carbon dioxide and while handling intra-abdominal organs [1,2].

Despite these well-established advantages, general anaesthesia is not without risks, especially in patients with compromised cardiopulmonary status. The requirement for airway instrumentation introduces the potential for complications such as airway trauma, aspiration, sore throat, and postoperative pulmonary issues. The pneumoperitoneum created during laparoscopy can elevate intra-abdominal pressure, push the diaphragm upward, impair pulmonary function, and cause hypercapnia, which in turn stimulates the sympathetic nervous system. These physiological responses can result in elevated heart rate and blood pressure, complicating intraoperative haemodynamic control. Consequently, patients undergoing GA for laparoscopic procedures must generally have stable cardiorespiratory function, which may not be the case in elderly individuals or those suffering from conditions like hypertension, chronic obstructive pulmonary disease, or coronary artery disease [3,4].

In an effort to minimize these risks and extend surgical options to patients who are less ideal candidates for general anaesthesia, regional anaesthetic techniques have gained attention. Among them, segmental spinal anaesthesia (SSA) represents a targeted variation of conventional spinal anaesthesia. This method involves the administration of a local anaesthetic to specific spinal segments, precisely those corresponding to the surgical area. This focused blockade reduces the likelihood of adverse effects typically associated with broader spinal blocks, such as significant hypotension, urinary retention, and prolonged motor weakness. By limiting the spread of anaesthesia to unnecessary spinal segments, SSA helps preserve sympathetic tone and motor function to a greater extent than conventional techniques [5].

Clinical studies have indicated that SSA is both practical and effective for procedures like laparoscopic cholecystectomy when appropriately executed. Achieving success with SSA requires meticulous technique, including careful positioning of the patient, the use of appropriately low doses of local anaesthetic, and vigilant intraoperative monitoring. For cholecystectomy, anaesthesia must cover the dermatomes from T4 to T8, which innervate the upper abdominal region. Limiting the blockade to these levels ensures adequate analgesia and surgical access while minimizing the risks associated with a more extensive sympathetic blockade. Because local anaesthetics have a finite duration of action, the use of adjuvants to prolong their effects and improve analgesic quality has become a common practice [6,7].

Intrathecal adjuvants enhance both the duration and intensity of spinal blocks. Opioids have long served this purpose due to their synergistic properties when combined with local anaesthetics. Fentanyl, a potent lipophilic opioid that acts primarily on μ-opioid receptors, is among the most frequently used agents in this regard. It offers a quick onset of analgesia and limited motor blockade, making it an attractive option for intraoperative use. However, its profile is not without drawbacks. Common side effects include nausea, vomiting, pruritus, and in some cases, respiratory depression. These side effects can be particularly problematic in the immediate postoperative period, potentially delaying recovery and patient discharge [8,9].

To address the limitations associated with opioids, newer pharmacological agents like dexmedetomidine have been explored as intrathecal adjuvants. Dexmedetomidine is a highly selective alpha-2 adrenergic receptor agonist with both spinal and supraspinal mechanisms of action. It modulates nociceptive transmission and suppresses sympathetic activity, resulting in prolonged sensory and motor block, deeper analgesia, and minimal respiratory depression. Its intraoperative use has been associated with improved haemodynamic stability, which is particularly beneficial during laparoscopic procedures that involve pneumoperitoneum. Furthermore, dexmedetomidine provides intraoperative sedation, enhancing patient comfort without compromising respiratory function [10,11].

Given the promising attributes of dexmedetomidine, comparing it with fentanyl as an intrathecal adjuvant in SSA offers valuable insights into optimizing anaesthesia protocols for laparoscopic cholecystectomy. An ideal adjuvant would not only prolong the duration of anaesthesia and enhance patient comfort but also maintain cardiovascular stability and reduce the physiological stress associated with surgery. Moreover, minimizing the incidence of side effects is essential for promoting early ambulation and discharge, aligning with contemporary goals of enhanced recovery after surgery (ERAS) protocols [12].

Evaluating the comparative efficacy and safety profiles of fentanyl and dexmedetomidine in this context is vital. While fentanyl provides excellent intraoperative analgesia, it carries a higher risk of postoperative side effects. In contrast, dexmedetomidine offers the benefits of prolonged analgesia, sedation, and haemodynamic control without the same level of respiratory risk. Understanding how these agents perform in clinical practice can inform anaesthetic choices, particularly in high-risk patients or settings where general anaesthesia may not be ideal [13].

As surgical and anaesthetic practices continue to evolve toward minimally invasive and patient- centered approaches, the role of SSA with appropriate adjuvants becomes increasingly relevant. Its ability to reduce the need for general

anaesthesia, maintain physiological stability, and accelerate postoperative recovery makes it a valuable option in selected patient populations. Further comparative research and clinical trials are essential to establish clear guidelines and standardize the use of SSA in laparoscopic procedures, ultimately improving outcomes and expanding anaesthetic options for a broader spectrum of surgical candidates [14].

The primary objective of this study is to compare the efficacy of fentanyl versus dexmedetomidine as adjuvants to isobaric levobupivacaine in segmental spinal anaesthesia for patients undergoing elective laparoscopic cholecystectomy. The secondary objective is to evaluate the safety, intraoperative stability, and overall postoperative outcomes associated with the use of segmental spinal anaesthesia in these patients, aiming to determine its suitability as an alternative to general anaesthesia, particularly in individuals with high-risk comorbidities.

MATERIALS AND METHODS

This prospective, randomized, single-centre, comparative study was conducted to evaluate and compare the efficacy and safety of intrathecal dexmedetomidine versus fentanyl as adjuvants to isobaric levobupivacaine in segmental spinal anaesthesia (SSA) for elective laparoscopic cholecystectomy. Sixty ASA I/II patients aged 18–60 years were randomly allocated into two groups: Group D received 5 µg dexmedetomidine, and Group F received 25 µg fentanyl with 1.5–1.8 ml isobaric levobupivacaine intrathecally. Randomization used computer-generated sequences and allocation concealment. Ethical clearance was obtained from the institutional review board, and informed written consent was obtained from all participants prior to enrolment.

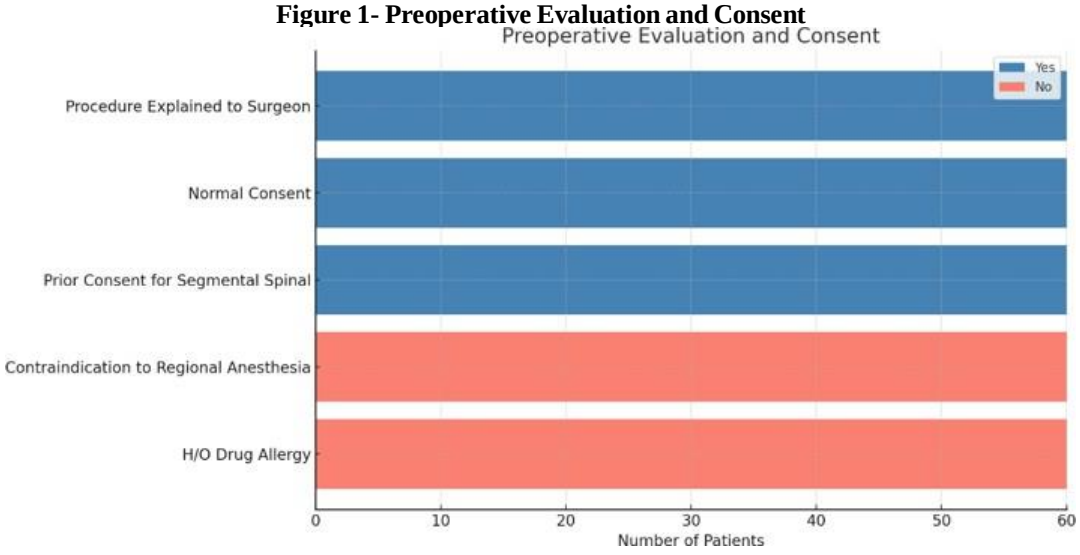
RESULTS

Table 1: Demographic status by Anaesthesia Type

Anesthesia Type	Count	Mean Age (± SD)	Heigh t (cm) (± SD)	Min Age (years)	Max Age (years)	P Value	Female (F) Count (%) / Male (M) Count (%)
Dexmedetomidine: 5 µg	30	45.07 ± 9.56	155.58 ± 4.88	28.0	60.0	> 0.05	20 (69.0%) / 10 (31.0%)
Fentanyl: 25 µg	30	45.97 ± 11.48	152.22 ± 8.78	29.0	60.0	> 0.05	22 (73.3%) / 8 (26.7%)

The table compares the demographic characteristics of two groups receiving different intrathecal adjuvants. Both groups (Dexmedetomidine and Fentanyl, n=30 each) had similar mean ages (~45 years) and no significant difference in height ($p > 0.05$). Gender distribution was comparable, with a slight female predominance in both groups. The p-value (> 0.05) indicates that the demographic variables (age, height, gender) were statistically similar between groups, ensuring baseline comparability for outcome analysis.

Figure 1- Preoperative Evaluation and Consent



The chart shows that all 60 patients underwent complete preoperative evaluation, including explanation to the surgeon, normal consent, and specific consent for segmental spinal anaesthesia. None had contraindications to regional

anaesthesia or a history of drug allergy. This indicates thorough screening and documentation before enrolment.

Table 2- Comparison of Preoperative Vitals Between Anesthesia Groups

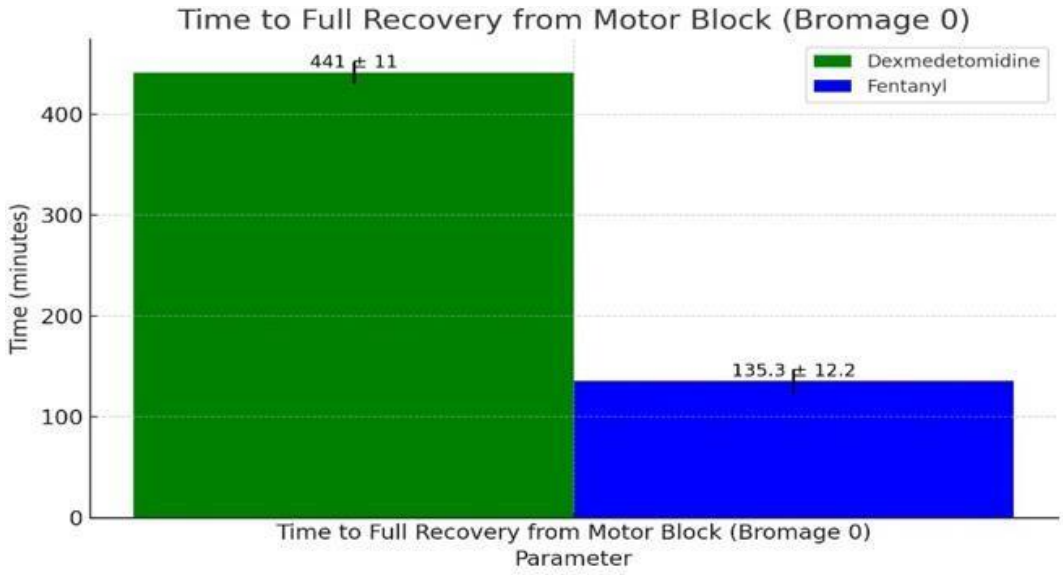
Anesthesia Group	Systolic BP	Diastolic BP	Pulse (mean ± SD)	SPO2 (Mean ± SD)	RR (Mean ± SD)
Dexmedetomidine: 5 µg	110.57 ±5.21	73.28 ± 5.30	80.55 ± 6.95	99.9 ± 0.31	14.14 ± 0.52
Fentanyl: 25 µg	106.57 ±3.81	71.28 ± 6.30	78.73 ± 6.61	99.93 ± 0.25	14.2 ± 0.61

The preoperative vital parameters (systolic/diastolic BP, pulse, SPO2, and respiratory rate) were comparable between the dexmedetomidine and fentanyl groups, with only minor variations and overlapping standard deviations. This indicates that baseline physiological status was similar across groups. Such comparability ensures unbiased evaluation of intraoperative and postoperative outcomes.

Table 3- Characteristics of sensory block in Dexmedetomidine and Fentanyl group

Parameter	Group D (n=30)	Group F (n=30)	P value
Highest Sensory Level Reached	T5 (T4–T8)	T6 (T4–T7)	> 0.05
Time to Reach Highest Sensory Level (minutes)	15.3 ± 2.8	17.1 ± 1.7	> 0.05
Time to Drop by 2 Sensory Levels (minutes)	110 ± 12.2	86 ± 15.3	< 0.001
Total Painkiller Dose in 24 Hours (mg)	70 ± 6.7	165 ± 20	< 0.001
Time to Need More Analgesia (minutes)	291.7 ± 28.69	158.99 ± 25.96	< 0.001

Both groups achieved comparable highest sensory block levels and onset times ($p > 0.05$). However, the dexmedetomidine group had significantly longer sensory block duration, lower 24- hour analgesic requirement, and delayed need for additional analgesia ($p < 0.001$). This indicates superior analgesic efficacy and prolonged block with dexmedetomidine.



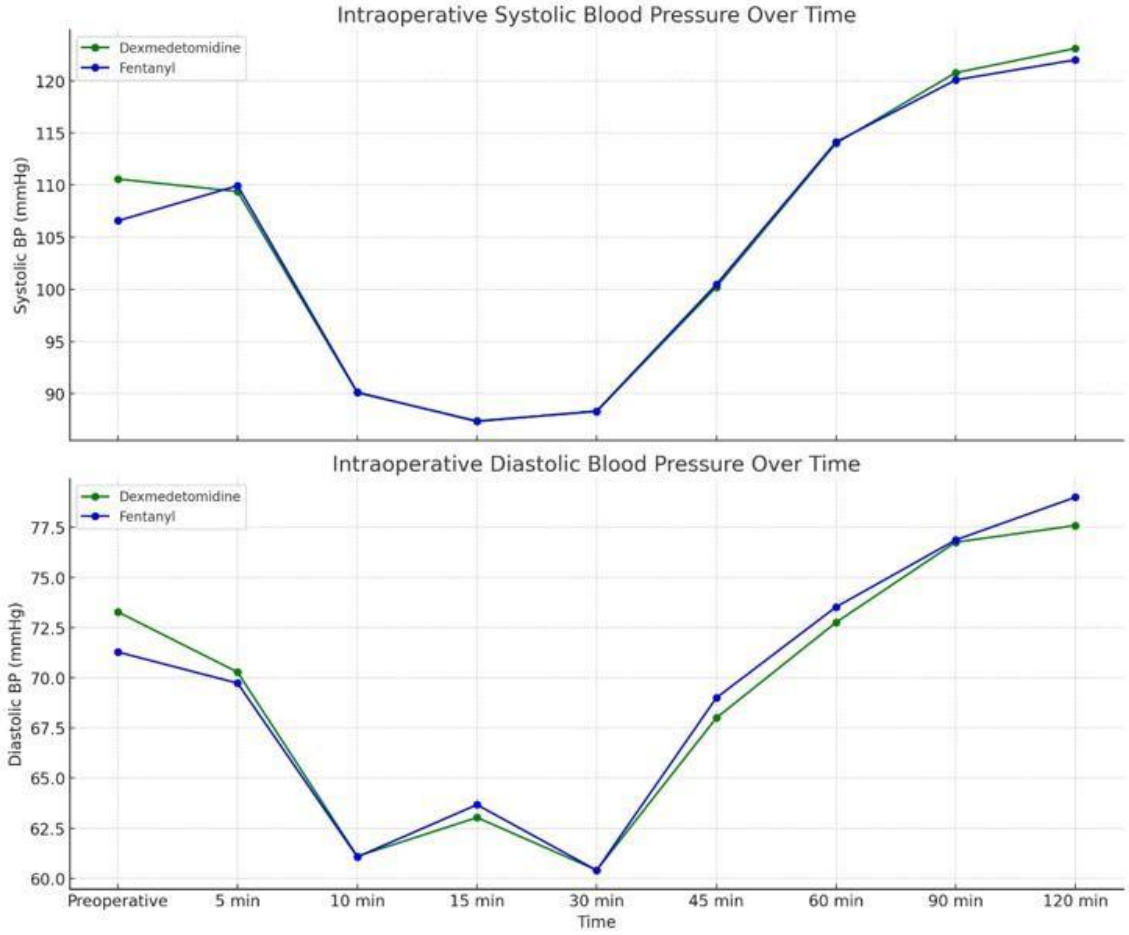
The chart shows that the dexmedetomidine group had a significantly longer time to full motor block recovery (441 ± 11 minutes) compared to the fentanyl group (135.3 ± 12.2 minutes). This indicates prolonged motor blockade with dexmedetomidine. The extended duration may benefit postoperative analgesia but could delay early ambulation.

Table 4- Intraoperative pulse rate comparison by time and anesthesia group

Time (Minutes)	Pulse Dexmedetomidine (mean ± SD)	Pulse Fentanyl (mean ± SD)	P-value
5	71.66 ± 3.21	71.53 ± 3.31	0.8864
10	67.10 ± 4.49	67.00 ± 4.45	0.9295
15	61.86 ± 3.02	62.07 ± 2.90	0.7918
30	68.28 ± 2.76	68.27 ± 2.77	0.9899
45	70.21 ± 1.95	70.07 ± 2.00	0.7862
60	70.21 ± 1.72	70.13 ± 1.66	0.8677
90	70.90 ± 2.93	70.70 ± 2.78	0.7927
120	70.28 ± 1.98	70.47 ± 2.08	0.7195

The intraoperative pulse rates between the dexmedetomidine and fentanyl groups remained comparable at all measured time points (5 to 120 minutes), with no statistically significant differences ($p > 0.05$). This indicates both adjuvants maintained stable heart rates intraoperatively. Dexmedetomidine's mild bradycardic effect did not lead to clinically significant changes.

Both groups showed a transient intraoperative drop in systolic and diastolic blood pressures, reaching the lowest values



around 10–30 minutes, followed by gradual recovery to near-baseline by 120 minutes. The trends were nearly identical between dexmedetomidine and fentanyl groups, indicating comparable haemodynamic stability. No significant intergroup differences were observed throughout the procedure.

Table 5- Post operative side effects in Dexmedetomidine and Fentanyl group

Side Effect	Group D (n=30)	Group F (n=30)	P value
Nausea	2	3	>0.05
Vomiting	0	1	>0.05
Pruritus	0	1	>0.05
Respiratory depression	0	0	—
Hypotension	1	2	>0.05

Bradycardia	0	1	>0.05
Urinary retention	1	3	>0.05

Postoperative side effects such as nausea, vomiting, pruritus, hypotension, bradycardia, and urinary retention were slightly more frequent in the fentanyl group, but none of the differences were statistically significant ($p > 0.05$). No cases of respiratory depression occurred in either group. Overall, both adjuvants demonstrated a favorable safety profile

DISCUSSION

Segmental spinal anaesthesia (SSA) has recently emerged as a favorable alternative to general anaesthesia (GA), particularly for high-risk patients with compromised cardiopulmonary status. SSA allows for targeted blockade of specific spinal segments, using reduced doses of local anaesthetics with or without adjuvants, thereby minimizing hemodynamic instability and preserving respiratory function. Compared to conventional spinal techniques, SSA produces a more confined sensory and motor block, which enhances postoperative recovery, reduces hospital stays, and aligns with enhanced recovery protocols. With the growing interest in adapting SSA for procedures like laparoscopic cholecystectomy, traditionally performed under GA, there is a need to assess its efficacy and safety [15].

This study compared dexmedetomidine and fentanyl as intrathecal adjuvants in SSA during laparoscopic cholecystectomy. Fentanyl, a potent opioid, provided rapid onset and effective analgesia but was associated with a shorter block duration and mild side effects like nausea. Dexmedetomidine, a selective α2-adrenergic receptor agonist, showed superior analgesic efficacy, minimal side effects, and better patient satisfaction. Its sympatholytic properties contributed to intraoperative haemodynamic stability—an essential factor during laparoscopic procedures that elevate intra-abdominal pressure and stimulate sympathetic responses [16].

Demographically, both groups were comparable in age, height, and sex distribution, ensuring minimal confounding factors. The mean age and height differences were statistically insignificant ($p > 0.05$), and the female predominance in both groups was consistent with previous findings indicating slightly higher cephalad spread in women. Baseline vitals, including systolic and diastolic blood pressure, pulse rate, and oxygen saturation, were similar in both groups, confirming homogeneity [17].

Intraoperatively, both groups maintained comparable haemodynamics. Blood pressure and heart rate remained stable across all measured time points, with no significant intergroup differences ($p > 0.05$). Notably, dexmedetomidine's known bradycardic and hypotensive potential was not clinically evident at the administered low dose (5 µg). Similarly, pulse rates decreased mildly during the onset phase in both groups but normalized without the need for pharmacological intervention, demonstrating cardiovascular safety for both agents [18].

Postoperative side effects were mild and infrequent. Dexmedetomidine showed fewer incidents of nausea, vomiting, and pruritus compared to fentanyl, though differences were not statistically significant. Importantly, no respiratory depression occurred in either group, reinforcing the safety of SSA with these adjuvants. Dexmedetomidine's non-opioid mechanism likely contributed to its better tolerability profile [19].

In terms of sensory block characteristics, both groups achieved adequate levels (T5 in dexmedetomidine, T6 in fentanyl; $p > 0.05$) with similar onset times. However, dexmedetomidine provided a significantly longer duration of sensory block (110 ± 12.2 min vs. 86 ± 15.3 min, $p < 0.001$), consistent with Kanazi et al.'s findings [20]. Postoperative analgesic needs were significantly lower in the dexmedetomidine group (70 ± 6.7 mg vs. 165 ± 20 mg, $p < 0.001$), and the time to first rescue analgesia was longer (291.7 ± 28.7 vs. 158.99 ± 25.96 min), supporting earlier observations by Al-Mustafa et al. [21].

Motor block lasted significantly longer in the dexmedetomidine group (441 ± 11 min vs. 135.3 ± 12.2 min), as previously reported by Shukla et al. While prolonged motor blockade may delay early ambulation, it offers extended immobility and comfort in longer surgeries. Overall, dexmedetomidine demonstrated superior analgesic efficacy, prolonged block duration, and fewer side effects, making it a valuable adjuvant in SSA for laparoscopic procedures [22].

CONCLUSION

Dexmedetomidine, as an intrathecal adjuvant in segmental spinal anaesthesia for laparoscopic cholecystectomy, demonstrates superior efficacy compared to fentanyl by providing longer-lasting analgesia, extended sensory and motor block, and reduced postoperative analgesic requirements, all while maintaining haemodynamic stability and a favorable safety profile. Patients receiving dexmedetomidine reported fewer side effects and higher satisfaction, highlighting its potential to enhance perioperative care. These findings support the use of dexmedetomidine as a reliable alternative to fentanyl in suitable cases. However, larger, multicentre studies are needed to confirm these benefits and enable broader implementation in diverse surgical and patient populations.

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