International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Comparative Evaluation of Ultrasound-Guided Transversus Abdominis Plane Block and Intraperitoneal Bupivacaine Instillation for Postoperative Pain Relief after Laparoscopic Cholecystectomy: A Randomized Controlled Trial

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Received: 20-04-2026
Accepted: 21-05-2026
Available online: 24-07-2026

ABSTRACT

Background: Effective postoperative pain control following laparoscopic cholecystectomy is essential for early recovery and improved patient satisfaction. Ultrasound-guided transversus abdominis plane (TAP) block and intraperitoneal instillation of bupivacaine are commonly used analgesic techniques; however, their comparative efficacy remains uncertain.
Methods: This prospective, randomized, double-blinded controlled trial included 140 patients undergoing elective laparoscopic cholecystectomy. Patients were randomly allocated into two equal groups: Group I received intraperitoneal instillation of 0.25% bupivacaine, while Group II received ultrasound-guided bilateral TAP block with 0.25% bupivacaine. Postoperative pain was assessed using the Numerical Rating Scale (NRS) at 30 minutes, 2, 6, and 12 hours. Time to first rescue analgesia, total analgesic consumption, postoperative complications, hemodynamic parameters, and patient satisfaction were compared.
Results: Baseline characteristics were comparable between the groups. TAP block produced significantly lower postoperative NRS pain scores at all assessment intervals ($p<0.001$), prolonged the time to first rescue analgesia (8.43 ± 1.82 vs. 5.62 ± 1.46 hours; $p<0.001$), reduced paracetamol consumption (1.42 ± 0.56 vs. 2.34 ± 0.69 g; $p<0.001$), and decreased rescue analgesic doses ($p<0.001$). The incidence of shoulder tip pain and port-site pain was significantly lower, while patient satisfaction was significantly higher in the TAP block group. Intraoperative hemodynamic parameters were comparable between the groups.
Conclusion: Ultrasound-guided TAP block provided superior postoperative analgesia, reduced analgesic requirements, and improved patient satisfaction compared with intraperitoneal bupivacaine, making it an effective and safe component of multimodal analgesia following laparoscopic cholecystectomy.

Keywords: *Laparoscopic cholecystectomy; Transversus abdominis plane block; TAP block; Intraperitoneal bupivacaine; Postoperative analgesia; Numerical Rating Scale; Ultrasound-guided regional anesthesia; Randomized controlled trial.*

INTRODUCTION

Laparoscopic cholecystectomy (LC) is the gold-standard procedure for the management of symptomatic cholelithiasis and other benign gallbladder disorders. Compared with open cholecystectomy, LC offers several advantages, including reduced surgical trauma, less blood loss, shorter hospital stay, faster recovery, and improved cosmetic outcomes [1]. Despite these benefits, postoperative pain remains a significant concern, particularly during the first 24 hours after surgery, delaying early ambulation, discharge, and recovery[2]. Consequently, effective postoperative pain control is a key component of enhanced

recovery after surgery (ERAS) protocols and is essential for improving patient satisfaction while reducing perioperative morbidity [3,4].Pain after laparoscopic cholecystectomy is multifactorial, comprising somatic pain from trocar insertion sites, visceral pain due to gallbladder bed dissection and peritoneal stretching, and referred shoulder-tip pain caused by diaphragmatic irritation from residual carbon dioxide pneumoperitoneum. Inadequate pain control may impair respiratory function, delay mobilization, increase postoperative nausea and vomiting (PONV), prolong hospital stay, and increase healthcare costs. Therefore, multimodal analgesia targeting both somatic and visceral pain has become the preferred strategy for postoperative pain management [4].Conventional analgesia relies mainly on systemic opioids and non-steroidal anti-inflammatory drugs (NSAIDs). Although opioids are effective, they are associated with adverse effects such as nausea, vomiting, respiratory depression, sedation, urinary retention, and delayed mobilization. NSAIDs may cause gastrointestinal irritation, renal dysfunction, and bleeding in susceptible patients. These limitations have encouraged the adoption of opioid-sparing regional analgesic techniques that provide effective pain relief with fewer systemic adverse effects [4].Among these techniques, the ultrasound-guided transversus abdominis plane (TAP) block has gained widespread acceptance. By depositing local anesthetic between the internal oblique and transversus abdominis muscles, the TAP block anesthetizes the thoracolumbar nerves (T6–L1) supplying the anterior abdominal wall. Ultrasound guidance improves the accuracy and safety of the procedure, and several randomized studies have demonstrated reduced postoperative pain scores, opioid consumption, and opioid-related complications following laparoscopic surgery [5–9]. However, because TAP block primarily provides somatic analgesia, its effect on visceral pain is limited [8,9].Intraperitoneal instillation of bupivacaine is another commonly used regional analgesic technique. Instillation over the gallbladder bed and subdiaphragmatic region reduces visceral pain and diaphragmatic irritation by blocking peripheral nociceptors within the peritoneum. The technique is simple, safe, inexpensive, and widely practiced, although published studies have reported variable analgesic efficacy [10–12].Comparative studies evaluating TAP block and intraperitoneal bupivacaine have shown inconsistent results. While a recent systematic review demonstrated that TAP block provides superior analgesia compared with conventional systemic analgesia, its advantage over other local anesthetic techniques remains uncertain [7]. Individual randomized trials have reported lower postoperative pain scores with TAP block, whereas others found only modest differences in analgesic outcomes [12,13].

Therefore, the present randomized controlled trial was undertaken to compare ultrasound-guided TAP block with intraperitoneal bupivacaine instillation for postoperative analgesia following elective laparoscopic cholecystectomy.

MATERIALS AND METHODS

This prospective, randomized, double-blinded, controlled trial was conducted A total of 140 patients scheduled for elective laparoscopic cholecystectomy were enrolled in the study, with 70 patients allocated to each group. Eligible participants were aged between 18 and 65 years and belonged to the American Society of Anesthesiologists (ASA) physical status I or II.Patients with known allergy to local anesthetics or study medications, those receiving treatment for chronic pain, and patients with morbid obesity (body mass index >40 kg/m²) were excluded from the study.

Randomization and Blinding

Participants were randomly assigned into two equal groups using a computer-generated randomization sequence.

- **Group I (Intraperitoneal Bupivacaine Group):** Received intraperitoneal instillation of 0.25% bupivacaine.
- **Group II (Ultrasound-Guided TAP Block Group):** Received bilateral ultrasound-guided transversus abdominis plane (TAP) block using 0.25% bupivacaine.

Both the patients and the postoperative outcome assessor were blinded to the group allocation throughout the study.

Anaesthetic Technique

All patients were maintained according to standard preoperative nil per oral (NPO) guidelines. Approximately 10 minutes before induction of anesthesia, patients received intravenous midazolam (1 mg), ondansetron (0.1 mg/kg), and glycopyrrolate (0.2 mg).Standard intraoperative monitoring recommended by the American Society of Anesthesiologists (ASA), including electrocardiography, non-invasive blood pressure, pulse oximetry, and capnography, was instituted in all patients.General anesthesia was induced with intravenous fentanyl (2 µg/kg), propofol (2 mg/kg), and inhalational sevoflurane in 100% oxygen. Neuromuscular blockade was achieved using intravenous atracurium (0.5 mg/kg), and endotracheal intubation was performed. Anesthesia was maintained with nitrous oxide and oxygen (66%:33%) supplemented with sevoflurane. Controlled mechanical ventilation was adjusted to maintain end-tidal carbon dioxide ($ETCO_2$) at 35 ± 5 mmHg.At the completion of surgery, all patients received intravenous paracetamol (1 g) for postoperative analgesia. Neuromuscular blockade was reversed using intravenous neostigmine (0.05 mg/kg) and glycopyrrolate (0.01 mg/kg), followed by extubation after adequate recovery.

Study Interventions

Group I: Intraperitoneal Bupivacaine

At the end of surgery and before trocar removal, 20 mL of 0.25% bupivacaine was instilled by the operating surgeon into the gallbladder bed. An additional 10 mL was instilled beneath the right dome of the diaphragm under direct vision, and

10 mL was infiltrated into the trocar insertion sites. The pneumoperitoneum was released at the end of surgery, while the intraperitoneally instilled local anesthetic was left in situ.

Group II: Ultrasound-Guided TAP Block
Following completion of surgery, a bilateral ultrasound-guided transversus abdominis plane (TAP) block was performed. A high-frequency ultrasound probe was placed beneath the xiphoid process and moved laterally along the subcostal margin toward the anterior axillary line. A 100-mm, 22-gauge block needle was advanced into the fascial plane between the internal oblique and transversus abdominis muscles. After negative aspiration, 20 mL of 0.25% bupivacaine was injected on each side using the same technique.Throughout the procedure, pneumoperitoneum pressure was maintained between 10 and 12 mmHg.

Outcome Measures
Postoperative pain intensity was assessed using the Numerical Rating Scale (NRS), where 0 represented no pain and 10 represented the worst imaginable pain. Pain scores at rest were recorded at 30 minutes, 2 hours, 6 hours, and 12 hours following surgery.
The following outcome measures were recorded:

- Postoperative NRS pain scores at predefined intervals
- Time to first rescue analgesic requirement
- Total rescue analgesic consumption during the first 24 hours

Whenever the NRS score was ≥5, rescue analgesia was administered in the form of intravenous paracetamol 1 g.

Sample Size Calculation
The sample size was estimated based on the findings of a previous study that compared postoperative pain following ultrasound-guided TAP block and intraperitoneal instillation of bupivacaine after laparoscopic cholecystectomy. The reported mean NRS pain scores during the first six postoperative hours were 3.20 ± 1.09 for the TAP block group and 3.77 ± 1.25 for the intraperitoneal bupivacaine group, corresponding to a mean difference of 0.57.

Assuming a two-sided significance level (α) of 0.05, a study power of 80%, and equal allocation between groups, the required sample size was calculated for comparison of two independent means. The final sample size was 140 patients, with 70 participants in each group, which was considered adequate to detect a statistically significant difference between the two treatment groups.

Statistical Analysis
Data were entered into Microsoft Excel 2016 and analyzed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequency and percentage.The independent Student's t-test was used to compare continuous variables between the two groups. Categorical variables were compared using the Chi-square test or Fisher's exact test, whenever appropriate. A p-value <0.05 was considered statistically significant.

RESULTS
A total of 140 patients undergoing elective laparoscopic cholecystectomy were enrolled and randomized equally into two groups, with 70 patients receiving intraperitoneal bupivacaine and 70 patients receiving ultrasound-guided TAP block. All randomized patients completed the study and were included in the final analysis.The demographic and baseline clinical characteristics were comparable between the two groups. The mean age was 43.28 ± 11.42 years in the intraperitoneal bupivacaine group and 42.91 ± 10.87 years in the TAP block group ($p = 0.847$). There were no statistically significant differences in gender distribution, body mass index (BMI), ASA physical status, or duration of surgery between the groups (all $p > 0.05$), indicating successful randomization and baseline comparability (Table 1).Postoperative pain intensity, assessed using the Numerical Rating Scale (NRS), was significantly lower in the TAP block group at all postoperative assessment intervals. At 30 minutes, the mean NRS score was 2.81 ± 0.84 in the TAP block group compared with 3.72 ± 0.91 in the intraperitoneal bupivacaine group ($p < 0.001$). Similar statistically significant reductions were observed at 2 hours (3.06 ± 0.89 vs. 4.15 ± 1.02), 6 hours (2.74 ± 0.88 vs. 3.68 ± 0.94), and 12 hours (2.10 ± 0.72 vs. 2.64 ± 0.83) (all $p < 0.001$), demonstrating superior postoperative analgesia with ultrasound-guided TAP block (Table 2, Figure 1).Patients who received TAP block experienced a significantly longer duration before requiring their first rescue analgesic compared with those receiving intraperitoneal bupivacaine (8.43 ± 1.82 vs. 5.62 ± 1.46 hours; $p < 0.001$). Furthermore, the TAP block group required significantly lower total paracetamol consumption during the first 24 postoperative hours (1.42 ± 0.56 g vs. 2.34 ± 0.69 g; $p < 0.001$) and fewer rescue analgesic doses (1.36 ± 0.54 vs. 2.29 ± 0.67; $p < 0.001$) (Table 3, Figure 2).The intraoperative hemodynamic variables remained comparable between the two study groups. No statistically significant differences were observed in mean heart rate, systolic blood pressure, diastolic blood pressure, or mean arterial pressure during surgery (all $p > 0.05$), indicating that both analgesic techniques provided similar intraoperative hemodynamic stability (Table 4, Figure 3).The incidence of postoperative nausea and vomiting was lower in the TAP block group, although these differences were not statistically significant ($p = 0.196$ and $p = 0.302$, respectively). However, shoulder tip

pain and port-site pain occurred significantly less frequently among patients receiving TAP block than among those receiving intraperitoneal bupivacaine (10.0% vs. 25.7%, p = 0.015; and 14.3% vs. 30.0%, p = 0.026, respectively). No patient in either group developed local anesthetic toxicity. Overall postoperative complications were significantly lower in the TAP block group (18.6%) compared with the intraperitoneal bupivacaine group (34.3%) (p = 0.035) (Table 5).Patient satisfaction was significantly higher among patients who received ultrasound-guided TAP block. Nearly half of the patients in the TAP block group (48.6%) rated their postoperative analgesia as excellent, compared with 22.9% in the intraperitoneal bupivacaine group. Conversely, poor satisfaction was reported by only 1.4% of patients in the TAP block group compared with 7.1% in the intraperitoneal bupivacaine group. The overall distribution of satisfaction scores differed significantly between the groups (p = 0.006), favoring TAP block (Table 6).

Table 1. Baseline Demographic and Clinical Characteristics of the Study Participants

Variable	Intraperitoneal Bupivacaine (n = 70)	TAP Block (n = 70)	p-value	Statistical test
Age (years), Mean ± SD	43.28 ± 11.42	42.91 ± 10.87	0.847	Independent t-test
Male, n (%)	28 (40.0)	30 (42.9)	0.728	Chi-square test
Female, n (%)	42 (60.0)	40 (57.1)		
BMI (kg/m²), Mean ± SD	25.11 ± 3.14	24.86 ± 3.38	0.653	Independent t-test
ASA Grade I, n (%)	44 (62.9)	46 (65.7)	0.726	Chi-square test
ASA Grade II, n (%)	26 (37.1)	24 (34.3)		
Duration of surgery (minutes), Mean ± SD	58.62 ± 12.41	59.84 ± 11.76	0.551	Independent t-test

Table 2. Comparison of Postoperative Pain Scores (NRS) Between the Two Groups

Time after surgery	Intraperitoneal Bupivacaine (n = 70) Mean ± SD	TAP Block (n = 70) Mean ± SD	p-value	Statistical test
30 minutes	3.72 ± 0.91	2.81 ± 0.84	<0.001	Independent t-test
2 hours	4.15 ± 1.02	3.06 ± 0.89	<0.001	Independent t-test
6 hours	3.68 ± 0.94	2.74 ± 0.88	<0.001	Independent t-test
12 hours	2.64 ± 0.83	2.10 ± 0.72	<0.001	Independent t-test

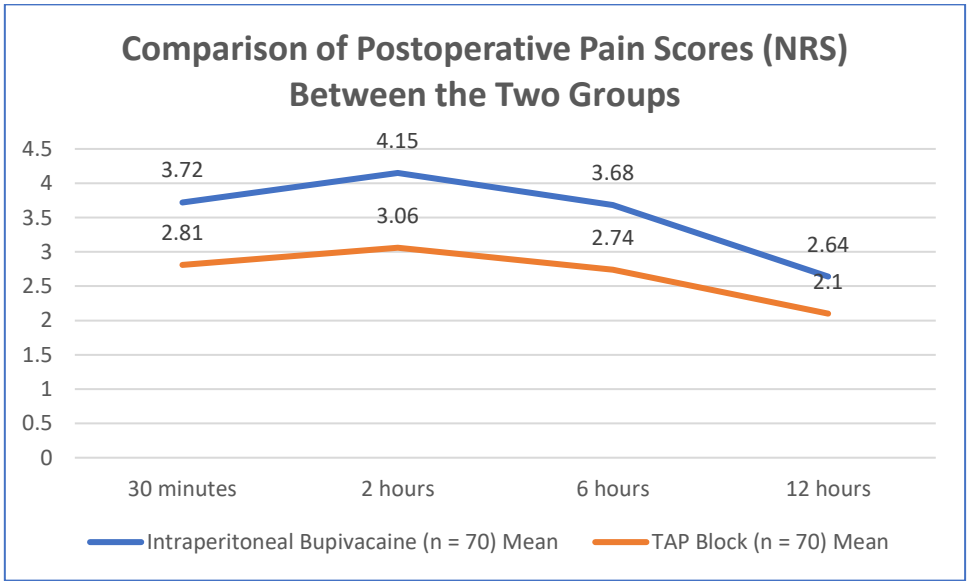

Figure 1 Comparison of Postoperative Pain Scores (NRS) Between the Two Groups

Table 3. Comparison of Rescue Analgesia

Variable	Intraperitoneal Bupivacaine (n = 70) Mean ± SD	TAP Block (n = 70) Mean ± SD	p-value	Statistical test

Time to first rescue analgesia (hours)	5.62 ± 1.46	8.43 ± 1.82	<0.001	Independent t-test
Total paracetamol consumption in first 24 hours (g)	2.34 ± 0.69	1.42 ± 0.56	<0.001	Independent t-test
Rescue analgesic doses (24 h)	2.29 ± 0.67	1.36 ± 0.54	<0.001	Independent t-test

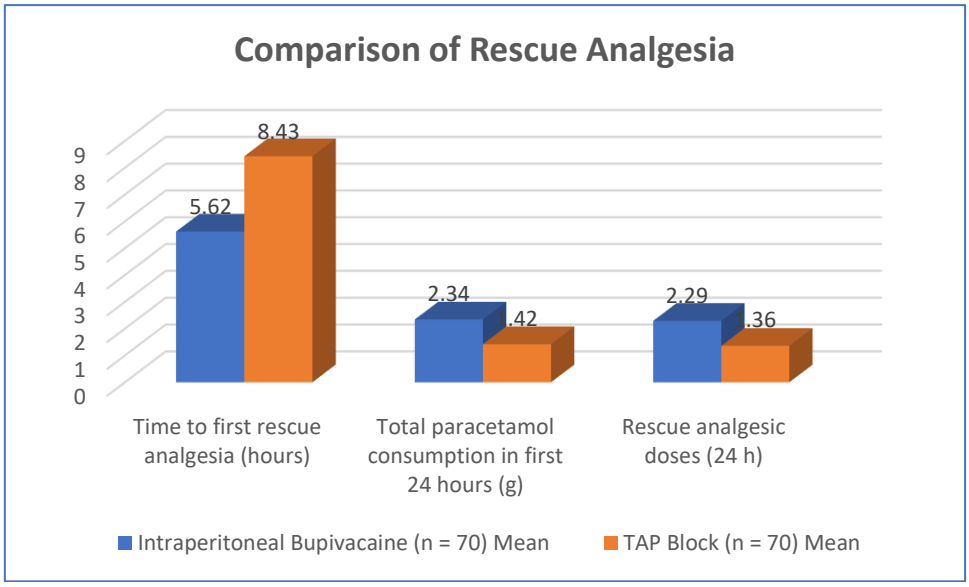

Figure 2 Comparison of Rescue Analgesia

Table 4. Comparison of Intraoperative Hemodynamic Parameters

Variable	Intraperitoneal Bupivacaine (n = 70) Mean ± SD	TAP Block (n = 70) Mean ± SD	p-value	Statistical test
Heart rate (beats/min)	81.7 ± 8.2	80.9 ± 7.9	0.562	Independent t-test
Systolic BP (mmHg)	122.4 ± 11.3	121.1 ± 10.9	0.488	Independent t-test
Diastolic BP (mmHg)	76.3 ± 8.1	75.8 ± 7.6	0.703	Independent t-test
Mean arterial pressure (mmHg)	91.7 ± 7.8	90.9 ± 7.2	0.531	Independent t-test

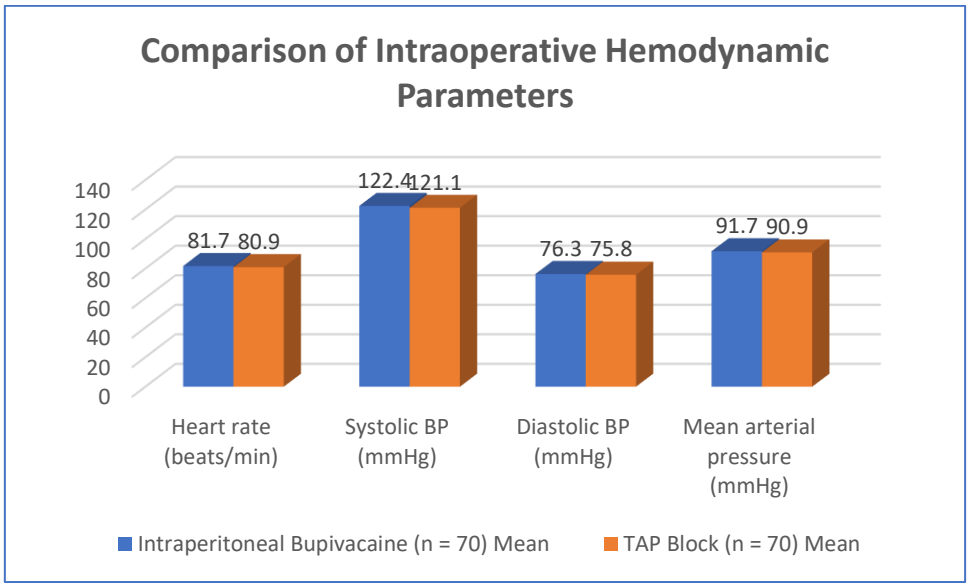

Figure 3 Comparison of Intraoperative Hemodynamic Parameters

Table 5. Comparison of Postoperative Complications

Variable	Intraperitoneal Bupivacaine (n = 70) n (%)	TAP Block (n = 70) n (%)	p-value	Statistical test
Nausea	11 (15.7)	6 (8.6)	0.196	Chi-square test
Vomiting	6 (8.6)	3 (4.3)	0.302	Fisher's Exact test
Shoulder tip pain	18 (25.7)	7 (10.0)	0.015	Chi-square test
Port-site pain	21 (30.0)	10 (14.3)	0.026	Chi-square test
Local anesthetic toxicity	0 (0.0)	0 (0.0)	—	—
Overall complications	24 (34.3)	13 (18.6)	0.035	Chi-square test

Table 6. Comparison of Patient Satisfaction

Satisfaction Grade	Intraperitoneal Bupivacaine (n = 70) n (%)	TAP Block (n = 70) n (%)	p-value	Statistical test
Excellent	16 (22.9)	34 (48.6)		
Good	32 (45.7)	28 (40.0)		
Fair	17 (24.3)	7 (10.0)		
Poor	5 (7.1)	1 (1.4)	0.006	Chi-square test

DISCUSSION

The present prospective randomized controlled trial compared the efficacy of ultrasound-guided transversus abdominis plane (TAP) block with intraperitoneal instillation of bupivacaine for postoperative analgesia following laparoscopic cholecystectomy. The findings demonstrated that TAP block provided superior postoperative pain relief, prolonged analgesia, reduced analgesic consumption, fewer pain-related complications, and higher patient satisfaction while maintaining comparable intraoperative hemodynamic stability.Baseline demographic and clinical characteristics were comparable between the two groups, confirming successful randomization. There were no significant differences in age, BMI, ASA physical status, gender distribution, or duration of surgery (all $p>0.05$). These findings are consistent with the randomized trial by Davey et al.[14], which also reported comparable baseline characteristics between TAP block and intraperitoneal local anesthetic groups, allowing valid comparison of postoperative outcomes.Postoperative pain control was significantly better with TAP block. Mean NRS scores at 30 minutes, 2 hours, 6 hours, and 12 hours were significantly lower in the TAP block group than in the intraperitoneal bupivacaine group (all $p<0.001$). These results are in agreement with Davey et al.[14], who demonstrated significantly lower postoperative VAS scores at both 6 and 24 hours following laparoscopic-assisted TAP block. Similarly, Balcı et al.[15] reported that modified thoracoabdominal nerve block (M-TAPA) produced significantly lower postoperative pain scores than intraperitoneal bupivacaine during the first 24 postoperative hours, supporting the superiority of fascial plane blocks for postoperative analgesia.The duration of analgesia was significantly longer with TAP block. Patients required their first rescue analgesic much later (8.43 ± 1.82 vs. 5.62 ± 1.46 hours; $p<0.001$), consumed less paracetamol during the first 24 hours (1.42 ± 0.56 vs. 2.34 ± 0.69 g; $p<0.001$), and required fewer rescue analgesic doses (1.36 ± 0.54 vs. 2.29 ± 0.67; $p<0.001$). Although Davey et al.[14] also observed superior pain control with TAP block, they did not demonstrate a significant reduction in opioid consumption, possibly because of differences in rescue analgesic protocols and multimodal analgesic regimens.

Intraoperative heart rate, systolic and diastolic blood pressure, and mean arterial pressure remained comparable between the two groups (all $p>0.05$), indicating that both techniques were hemodynamically safe. Similar findings have been reported in previous randomized studies evaluating TAP block during laparoscopic cholecystectomy, where improved analgesia was achieved without clinically significant cardiovascular instability.The TAP block group also experienced fewer postoperative complications, with significantly lower rates of shoulder tip pain (10.0% vs. 25.7%; $p=0.015$), port-site pain (14.3% vs. 30.0%; $p=0.026$), and overall pain-related complications (18.6% vs. 34.3%; $p=0.035$). Although postoperative nausea and vomiting occurred less frequently following TAP block, the difference was not statistically significant. No patient developed local anesthetic systemic toxicity, confirming the safety of both techniques.Patient satisfaction was significantly higher in the TAP block group ($p=0.006$), with nearly half of the patients rating their analgesia as excellent. Similar observations were reported by Balcı et al.[15], who found greater postoperative comfort and satisfaction among patients receiving fascial plane blocks.The present findings are further supported by the systematic review and meta-analysis by Boddy et al.[16], which concluded that although intraperitoneal local anesthetic provides modest early postoperative pain relief compared with placebo, its analgesic effect is limited. In contrast, TAP block directly anesthetizes the thoracolumbar nerves supplying the anterior abdominal wall, resulting in superior postoperative analgesia. Overall, the present study supports the incorporation of ultrasound-guided TAP block into multimodal analgesic protocols for laparoscopic cholecystectomy because of its superior analgesic efficacy, reduced analgesic requirement, favorable safety profile, and improved patient satisfaction.

CONCLUSION

Ultrasound-guided transversus abdominis plane (TAP) block provided superior postoperative analgesia compared with intraperitoneal instillation of bupivacaine following laparoscopic cholecystectomy. TAP block significantly reduced postoperative pain scores, prolonged the duration of analgesia, decreased rescue analgesic requirements and postoperative analgesic consumption, and improved patient satisfaction while maintaining comparable intraoperative hemodynamic stability. It was also associated with fewer postoperative pain-related complications. Therefore, ultrasound-guided TAP block can be considered an effective and safe component of multimodal analgesia for patients undergoing laparoscopic cholecystectomy.

Limitations

The present study was conducted at a single center with a relatively small sample size, which may limit the generalizability of the findings. Postoperative outcomes were assessed only during the first 24 hours, and long-term pain outcomes or the development of chronic postoperative pain were not evaluated. In addition, functional recovery parameters such as time to ambulation, length of hospital stay, and cost-effectiveness were not assessed.

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