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Research Article

Ultrasound-guided versus laparoscopic-assisted subcostal transversus abdominis plane block for postoperative analgesia after laparoscopic cholecystectomy: A prospective randomized trial

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ABSTRACT

Objective: To compare the analgesic efficacy of ultrasound-guided and laparoscopic-assisted subcostal transversus abdominis plane (TAP) block after laparoscopic cholecystectomy.

Methods: In this prospective, randomized, double-blind trial, 60 adults undergoing elective laparoscopic cholecystectomy received either ultrasound-guided (US-TAP, $n = 30$) or laparoscopic-assisted (L-TAP, $n = 30$) subcostal TAP block under standardized general anesthesia and multimodal analgesia. The primary outcome was pain intensity on the Numeric Rating Scale (NRS) across the first 24 postoperative hours; comparisons at individual time points were exploratory. Secondary outcomes were analgesic consumption, time to first rescue analgesia, rescue opioid requirement, postoperative nausea and vomiting (PONV), time to ambulation, length of stay, and complications.

Results: Baseline characteristics were comparable; pain scores declined over time in both groups. NRS scores were lower with US-TAP at 1 hour (2.50 ± 1.72 vs 4.03 ± 1.56 ; difference 1.53, 95% CI 0.68 to 2.38; $p = 0.001$) and 6 hours (1.83 ± 1.44 vs 2.70 ± 1.47 ; difference 0.87, 95% CI 0.12 to 1.62; $p = 0.015$), with no differences at the other six time points. No differences were found in time to first analgesic request, rescue analgesic or opioid requirements, PONV, ambulation, hospital stay, complications, or the overall 24-hour reduction in NRS.

Conclusion: Ultrasound guidance was associated with lower early postoperative pain scores, but these differences fell below commonly cited thresholds for clinically important change and were not accompanied by differences in analgesic requirements or recovery outcomes. Without a no-block control group and not being designed to test equivalence, this trial compares the two techniques rather than establishing the efficacy of either.

Trial Registration: The study was registered at ClinicalTrials.gov (ID: NCT07352189). Registration was retrospective.

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1. Introduction

Upper abdominal surgery represents a considerable proportion of surgical procedures performed world-

wide, with laparoscopic cholecystectomy being one of the most common abdominal operations. Compared with open surgery, the laparoscopic approach offers several advantages, including lower postoperative morbid-

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ity, shorter hospital stays, faster recovery, and earlier mobilization. Despite these benefits, postoperative pain remains an important clinical concern. When inadequately controlled, pain can interfere with recovery, delay mobilization and potentially contribute to the development of chronic postsurgical pain [1,2].

For this reason, effective postoperative analgesia is an essential part of perioperative management. Regional anesthesia techniques have increasingly been incorporated into multimodal analgesic strategies because they can provide effective pain relief while reducing opioid requirements and the adverse effects associated with opioid use. Among these techniques, the transversus abdominis plane (TAP) block is widely used in abdominal surgery because it is relatively simple to perform, has a favorable safety profile, and can provide meaningful opioid-sparing analgesia [3].

The TAP block is performed by injecting local anesthetic into the fascial plane between the internal oblique and transversus abdominis muscles. This targets the anterior rami of the lower thoracic and upper lumbar nerves (T6–L1), thereby providing somatic analgesia to the anterolateral abdominal wall. As a result, TAP block has become a well-established component of multimodal analgesia in a range of abdominal surgical procedures [4].

Several techniques have been developed for performing the TAP block. The conventional landmark-based, or “double-pop,” technique depends on the operator’s ability to identify the fascial planes by tactile feedback as the needle is advanced. Ultrasound guidance has largely become the preferred approach because it enables direct visualization of the abdominal wall anatomy and facilitates more precise deposition of local anesthetic. Another option is to perform the block intraoperatively under direct laparoscopic visualization. This laparoscopic-assisted approach does not require additional ultrasound equipment, adds little time to the procedure, and can be easily integrated into the surgical workflow [5].

Although previous studies have compared ultrasound-guided and laparoscopic-assisted TAP block techniques, most investigations have focused on lateral TAP block approaches, heterogeneous abdominal surgery populations, or infraumbilical procedures. Evidence specifically comparing subcostal TAP block techniques in a homogeneous population undergoing laparoscopic cholecystectomy remains limited. In addition, relatively few prospective randomized studies have evaluated these techniques using standardized perioperative protocols together with blinded assessment of postoperative outcomes.

Accordingly, the present prospective randomized trial was designed to compare ultrasound-guided and laparoscopic-assisted subcostal TAP block in patients undergoing laparoscopic cholecystectomy. The primary outcome was postoperative pain intensity across the first 24 postoperative hours. Secondary outcomes were analgesic consumption, time to first rescue analgesia, rescue opioid requirement, postoperative nausea and vomiting, time to ambulation, length of hospital stay, and adverse events.

2. Materials and Methods

2.1. Study design and ethical approval

This prospective, randomized, double-blind trial was conducted in the operating rooms of Maltepe University Faculty of Medicine Hospital in accordance with the Declaration of Helsinki and was designed and reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) recommendations. The study protocol was approved by the Maltepe University Clinical Research Ethics Committee (Decision No. 3; 1 November 2022) and subsequently authorized by the Turkish Medicines and Medical Devices Agency (TİTCK; Reference No. E-66175679-514.13.02-965164; Study No. 22-AKD-156; 26 December 2022). Both approvals were obtained before participant recruitment began in 2023. Written informed consent was obtained from all participants before enrollment. The trial was retrospectively registered at ClinicalTrials.gov (NCT07352189), with the initial registration submitted on 11 January 2026 and the record first posted on 20 January 2026, after enrollment and follow-up had been completed. Retrospective registration is acknowledged as a study limitation.

2.2. Participants

Adult patients aged 18–70 years with American Society of Anesthesiologists (ASA) physical status I–III scheduled for elective laparoscopic cholecystectomy were screened for eligibility. Exclusion criteria were neuropsychiatric disorders potentially affecting pain perception, regular use of antidepressant or antipsychotic medication, chronic opioid use, allergy to any study medication, contraindications to TAP block, bleeding diathesis, ASA physical status IV or higher, and refusal to participate. Following enrolment, patients were randomly assigned in a 1:1 ratio to the ultrasound-guided TAP block group (Group U) or the laparoscopic-assisted TAP block group (Group L) (Fig. 1).

2.3. Randomization and blinding

Eligible patients were allocated in a 1:1 ratio to Group U or Group L. The allocation sequence was generated by drawing lots from a prepared set of 60 slips containing 30 assignments to each group, randomly shuffled before the start of enrolment; this corresponds to restricted randomization within a single block of 60 and ensured equal group sizes. Allocation was concealed using sequentially numbered, opaque, sealed envelopes prepared before the start of enrolment by an independent person who was not otherwise involved in the study and took no part in patient recruitment, block performance, or outcome assessment. Each envelope was opened only after induction of general anesthesia, so that neither the patient nor the investigator assessing postoperative outcomes was aware of the assignment at any point before allocation. Because the two techniques were necessarily performed by different operators, the anesthetist and the surgical team could not be blinded; however, all blocks were performed under general anesthesia and needle entry sites in both groups were covered with

identical adhesive dressings before emergence, so that no external marking distinguished the groups. All post-operative assessments were performed by an independ-

ent investigator who was not present in the operating room and remained blinded to allocation throughout data collection.

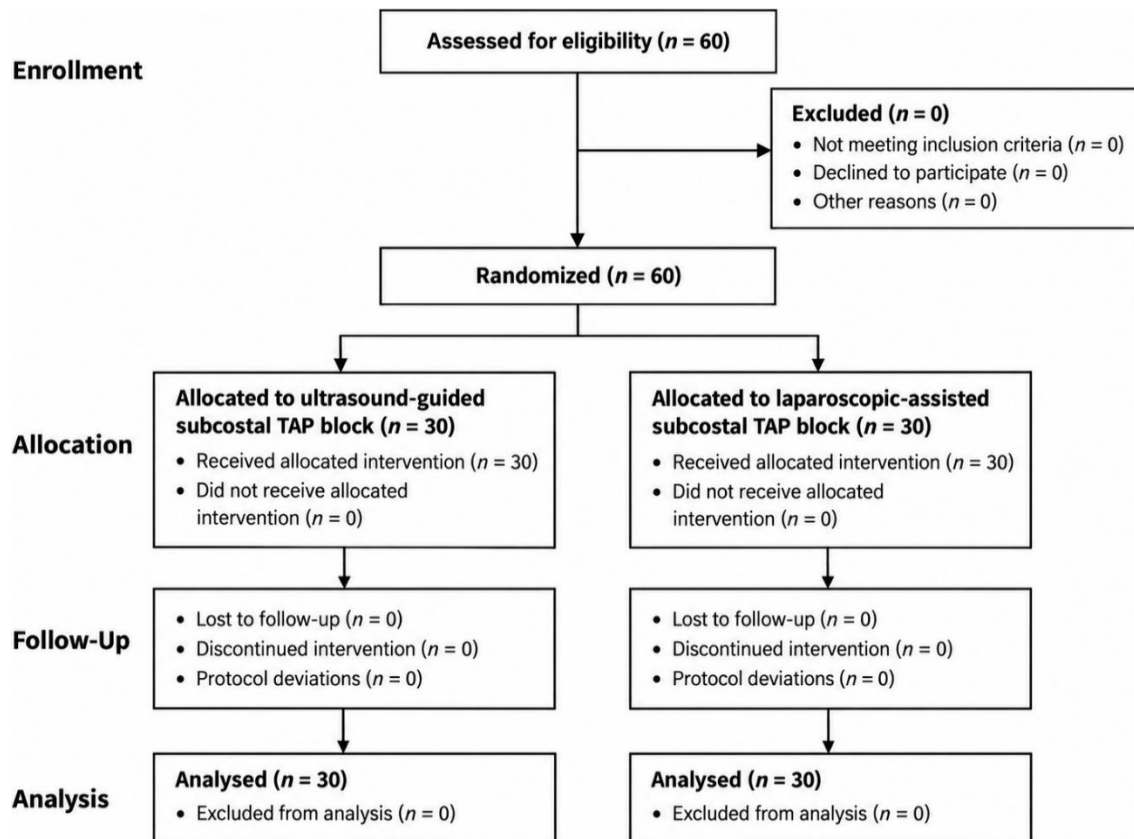


Fig. 1. CONSORT 2010 flow diagram showing patient eligibility assessment, randomization, allocation, follow-up and analysis. No patients were excluded, lost to follow-up or withdrawn, and no protocol deviations occurred.

2.4. Perioperative anesthetic management

Baseline demographic and clinical characteristics, including age, sex, weight, height, body mass index, ASA physical status, smoking status, comorbid conditions and previous abdominal surgery, were recorded. Standard intraoperative monitoring included electrocardiography, non-invasive blood pressure monitoring, pulse oximetry and neuromuscular monitoring using train-of-four stimulation. After three minutes of preoxygenation with 100% oxygen, anesthesia was induced with intravenous propofol (2–3 mg/kg), fentanyl (1–2 µg/kg) and rocuronium (0.6 mg/kg), and orotracheal intubation was performed after adequate neuromuscular blockade. Mechanical ventilation was adjusted to maintain tidal volumes of 6–8 mL/kg and end-tidal carbon dioxide between 30 and 35 mmHg. Anesthesia was maintained with sevoflurane ~2% in 50% O₂/air (flow 2 L/min) and remifentanyl (0.05 µg/kg/min). Thirty minutes before completion of surgery, all patients received intravenous paracetamol (1 g) and tenoxicam (20 mg) as part of a multimodal analgesic regimen.

2.5. Subcostal TAP block procedures

All blocks were performed bilaterally after completion of surgery and before emergence from anesthesia, with patients supine under general anesthesia. In both

groups the target was the subcostal segment of the transversus abdominis plane, and an identical local anesthetic solution and volume were administered. All ultrasound-guided blocks were performed by the same anesthetist and all laparoscopic-assisted blocks by the same surgical team, both experienced in their respective techniques before the start of the study.

2.6. Ultrasound-guided subcostal TAP block (Group U)

After sterile skin preparation and draping, a high-frequency linear transducer (8–12 MHz) (LOGIQ e, GE Medical Systems, Jiangsu, China) enclosed in a sterile sheath was positioned obliquely along and parallel to the costal margin, with its medial end adjacent to the xiphoid process. The rectus abdominis muscle was identified medially, and the internal oblique and transversus abdominis muscles laterally. A 22-G, 80-mm short-bevel block needle (Stimuplex D plus 0.71 × 80 mm; B. Braun, Melsungen, Germany) was advanced in plane along the subcostal line toward the fascial plane separating the rectus abdominis and internal oblique muscles from the transversus abdominis muscle. Needle-tip position was confirmed by hydrodissection with 0.5–1 mL of the local anesthetic solution to confirm the correct needle tip position. Subsequently, the remaining volume of the solution was administered, ensuring a total injection volume of 20 mL per side.

The identical sequence was repeated on the contralateral side, and needle entry sites were covered with adhesive dressings. This oblique subcostal approach targets the T6–T9 dermatomes relevant to upper abdominal incisions [6].

2.7. Laparoscopic-assisted subcostal TAP block (Group L)

In Group L the block was performed by the operating surgeon under direct laparoscopic vision before trocar removal, targeting the same subcostal plane. The needle was introduced immediately below the costal margin close to the midline, superficial to the rectus abdominis,

and directed along the subcostal line. Correct deposition was confirmed by two criteria applied together: the tactile perception of two distinct fascial “pops” corresponding to passage through the anterior and posterior layers of the rectus sheath, and direct laparoscopic visualisation of a smooth extraperitoneal bulge of the abdominal wall developing as the local anesthetic was injected, without intraperitoneal spill of the injectate. The needle tip is deliberately not advanced into the peritoneal cavity and is therefore not visualised laparoscopically; the developing bulge is the endpoint that confirms correct extraperitoneal deposition. Twenty millilitres were administered on each side, and the procedure was repeated bilaterally (Fig. 2).

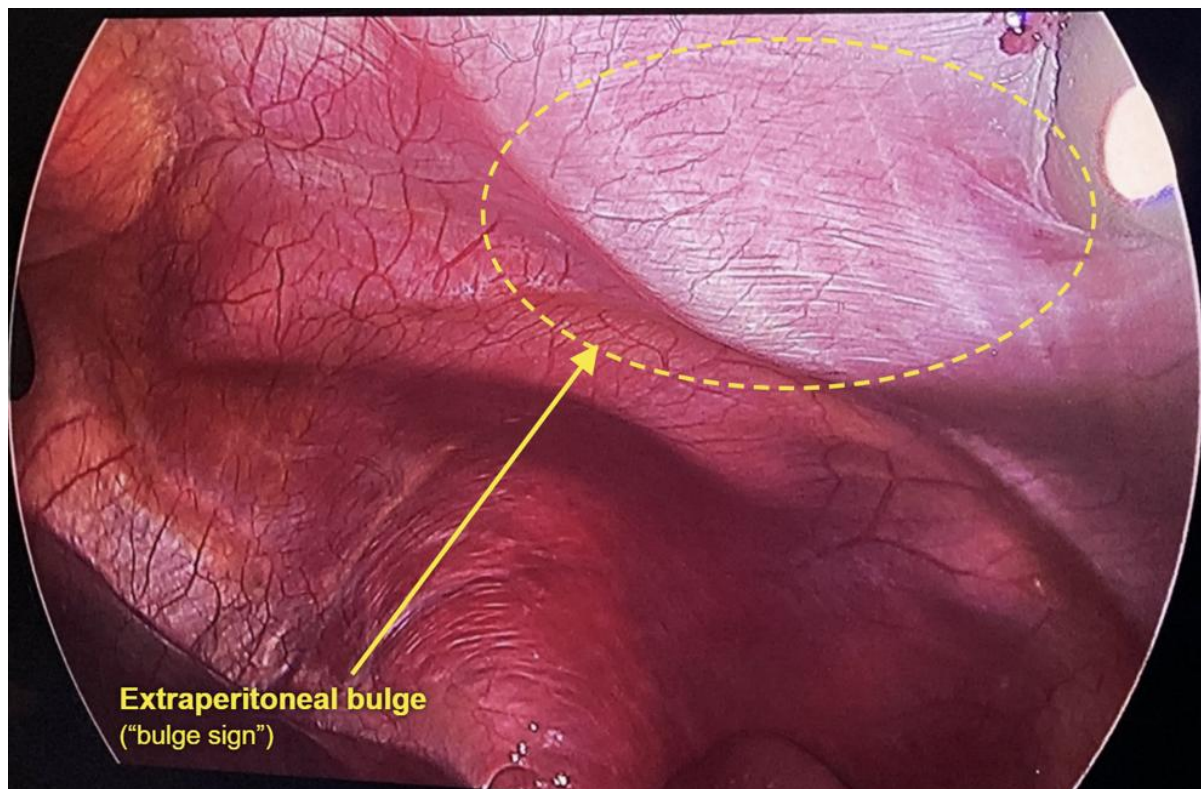


Fig. 2. Representative intraoperative laparoscopic view during laparoscopic-assisted subcostal transversus abdominis plane block. The dashed ellipse indicates the extraperitoneal bulge (“bulge sign”) that develops as local anesthetic is deposited in the subcostal transversus abdominis plane.

2.8. Local anesthetic solution

In both groups, the block was performed using 40 mL of a solution containing 30 mL of 0.25% bupivacaine and 10 mL of 1% lidocaine, divided equally as 20 mL per side, as specified in the approved study protocol. The final concentrations were 0.1875% bupivacaine and 0.25% lidocaine, corresponding to total doses of 75 mg and 100 mg, respectively. Given the potential for systemic absorption following abdominal wall blocks [7,8] and the additive toxicity of concurrently administered local anesthetics [9], the combined dose fraction was calculated using reference maximum doses of 2 mg/kg for bupivacaine and 4.5 mg/kg for lidocaine. At the cohort's mean body weight of 78.47 kg, the combined dose fraction was approximately 76.1%. However, this calculation based on mean body weight does not establish that the reference threshold was met for every individual participant.

2.9. Postoperative analgesia and outcome assessment

After block administration, neuromuscular blockade was reversed with intravenous atropine (0.02 mg/kg) and neostigmine (0.04 mg/kg), and patients were extubated after adequate spontaneous ventilation and recovery of neuromuscular function. Postoperative analgesia was standardized: intravenous paracetamol 1 g was administered every 8 hours during the first 24 postoperative hours. Pain intensity was assessed using an 11-point Numeric Rating Scale (NRS), where 0 represented no pain and 10 the worst imaginable pain, at 20 minutes, 40 minutes, 1, 3, 6, 12, 18 and 24 hours postoperatively by the blinded investigator. Patients with an NRS score of 4 or above received intramuscular diclofenac sodium 75 mg as rescue analgesia; if pain remained at 4 or above after 30 minutes, intravenous tramadol 1 mg/kg was administered.

All NRS assessments were performed with the patient at rest. Pain on movement or during coughing was not assessed.

Postoperative nausea and vomiting was recorded as a single composite outcome (presence of nausea, vomiting, or both) during the first 24 postoperative hours. No antiemetic prophylaxis was administered to either group; antiemetic treatment was given on demand.

2.10. Outcome measures

The primary outcome was postoperative pain intensity, assessed by serial NRS measurements across the first 24 postoperative hours. No single time point was prespecified as the primary endpoint. Secondary outcomes were paracetamol consumption, time to first rescue analgesia, requirement for rescue analgesia and for rescue opioid, postoperative nausea and vomiting, time to first ambulation, time to first flatus, length of hospital stay, and adverse events including pruritus, pneumothorax and local anesthetic systemic toxicity.

2.11. Sample size calculation

An a priori power analysis was performed using G*Power (version 3.1.9.2; Heinrich-Heine University, Düsseldorf, Germany) for the primary outcome of postoperative pain intensity. A between-group difference of approximately 1 NRS point was regarded as the smallest difference of clinical interest, and a large effect size (Cohen's $d = 0.80$) was used in the calculation on that basis. The standard deviation assumed at the planning stage was not recorded in the study documentation. With a two-sided alpha of 0.05 and 80% power, the minimum required sample size was 26 patients per group; 30 patients were recruited into each group to allow for losses to follow-up or protocol deviations.

With the standard deviations subsequently observed in this cohort (1.07 to 2.01), an effect size of $d = 0.80$ corresponds to detectable between-group differences of approximately 0.86 to 1.61 NRS points, depending on the assessment time point, that is, below the median minimum clinically important difference of approximately 1.7 points reported for acute pain [10]. This is a translation of the prespecified effect size into clinical units using the observed variability, and not a post hoc power calculation based on the observed effect.

2.12. Statistical analysis

Statistical analyses were performed using NCSS software (Number Cruncher Statistical System, version 2007; Kaysville, UT, USA). Normality was assessed using the Shapiro–Wilk test together with histograms and Q–Q plots. Normally distributed continuous variables are presented as mean $\pm$ standard deviation and non-normally distributed variables as median (range). Categorical variables are summarized as frequencies and percentages. Between-group comparisons used the independent-samples t test or the Mann–Whitney U test as appropriate, and the Pearson chi-square test, Fisher's exact test or the Fisher–Freeman–Halton test for categorical variables.

The primary analysis was the comparison of the postoperative pain trajectory over the first 24 hours. Within-group changes over time were assessed using the Friedman test, with Bonferroni–Dunn post hoc tests for pairwise comparisons. The change in NRS score from the first to the final postoperative assessment was compared between groups using the Mann–Whitney U test. Between-group comparisons of NRS scores at each postoperative time point were also performed using the Mann–Whitney U test; because no single primary time point was prespecified, these comparisons were considered exploratory and were not adjusted for multiple testing. To provide an estimate of the magnitude and precision of the between-group differences, mean differences with 95% confidence intervals were additionally calculated from the group means, standard deviations, and sample sizes using the t distribution; these estimates were considered descriptive and are reported alongside the rank-based hypothesis tests. All statistical tests were two-tailed, and a p value below 0.05 was considered statistically significant.

An additional longitudinal analysis of postoperative NRS scores was performed using generalized estimating equations (GEE), with treatment group, assessment time, and their interaction included as predictors. Assessment time was treated as a categorical variable, and an exchangeable working correlation structure was used to account for repeated measurements within participants. A Gaussian model with robust standard errors was fitted. The group-by-time interaction was evaluated using a joint Wald test. The overall between-group difference was estimated using a separate GEE model without the interaction term. This analysis was conducted after the initial statistical analysis and is reported as exploratory.

3. Results

Between January and June 2023, 60 patients undergoing elective laparoscopic cholecystectomy were enrolled and randomly assigned to laparoscopic-assisted (L-TAP, $n = 30$) or ultrasound-guided (US-TAP, $n = 30$) subcostal TAP block. All 60 patients received the allocated intervention, completed the 24-hour follow-up and were included in the analysis; there were no exclusions, losses to follow-up or protocol deviations (Fig. 1).

Baseline demographic and clinical characteristics are presented in Table 1. The mean age of the study population was 48.45 ± 14.96 years and 40 patients (66.7%) were female. The mean body mass index was 28.72 ± 5.94 kg/m², most participants were ASA physical status II (61.7%), and approximately half had at least one comorbid condition. No statistically significant differences were observed between groups with respect to demographic characteristics, anthropometric measurements, ASA classification, smoking status, comorbidities or previous abdominal surgery (all $p > 0.05$). Previous abdominal surgery was present in 24 patients (40.0%) and was similarly distributed between the groups (11 [36.7%] vs 13 [43.3%], $p = 0.598$). In every case the previous procedure was an appendectomy; no patient had undergone previous upper abdominal surgery, and no patient therefore had a previous incision within the subcostal region in which the block was performed.

Table 1. Baseline demographic and clinical characteristics.

Variable	Overall (<i>n</i> = 60)	L-TAP (<i>n</i> = 30)	US-TAP (<i>n</i> = 30)	<i>p</i>
Age (years)	48.45 ± 14.96	48.03 ± 16.25	48.87 ± 13.81	0.831
Female, <i>n</i> (%)	40 (66.7)	21 (70.0)	19 (63.3)	0.584
Weight (kg)	78.47 ± 16.82	75.13 ± 15.06	81.80 ± 18.04	0.126
Height (cm)	165.40 ± 9.25	165.23 ± 9.88	165.57 ± 8.74	0.890
BMI (kg/m ²)	28.72 ± 5.94	27.48 ± 4.56	29.97 ± 6.90	0.106
ASA I, <i>n</i> (%)	20 (33.3)	11 (36.7)	9 (30.0)	0.833
ASA II, <i>n</i> (%)	37 (61.7)	18 (60.0)	19 (63.3)	—
ASA III, <i>n</i> (%)	3 (5.0)	1 (3.3)	2 (6.7)	—
Any comorbidity, <i>n</i> (%)	31 (51.7)	16 (53.3)	15 (50.0)	0.796
Hypertension, <i>n</i> (%)	15 (25.0)	10 (33.3)	5 (16.7)	0.104
Diabetes mellitus, <i>n</i> (%)	11 (18.3)	7 (23.3)	4 (13.3)	0.320
Current smoker, <i>n</i> (%)	14 (23.3)	9 (30.0)	5 (16.7)	0.511
Previous abdominal surgery, <i>n</i> (%)	24 (40.0)	11 (36.7)	13 (43.3)	0.598

Data are mean ± standard deviation or *n* (%). ASA, American Society of Anesthesiologists; BMI, body mass index.

Perioperative and postoperative recovery outcomes are summarized in Table 2. All patients underwent elective laparoscopic cholecystectomy. Mean operative duration was comparable between the L-TAP and US-TAP groups (104.83 ± 30.10 vs 109.00 ± 36.09 minutes, *p* = 0.629), and no significant between-group differences were observed in time to first ambulation, time to first flatus or length of hospital stay. No postoperative complications occurred in either group.

Postoperative analgesic consumption is presented in Table 3. Mean intravenous paracetamol consumption during the first 24 postoperative hours did not differ between groups (3.67 ± 0.71 vs 3.73 ± 0.69 g, *p* = 0.553; median 4 g, range 1–4 g in both groups). This total includes the 1 g administered intraoperatively; the range reflects variation in the number of scheduled postoperative doses received before discharge. Time to first analgesic request was comparable (2.93 ± 2.29 vs 3.23 ± 2.24 hours, *p* = 0.403). Additional analgesia was required by 24 patients (80.0%) in the L-TAP group and 19 (63.3%) in the US-TAP group (*p* = 0.152), and rescue opioid was required by 7 (23.3%) and 6 (20.0%) patients respectively (*p* = 0.754). Postoperative nausea and vomiting occurred in 23 patients (76.7%) and 21 patients (70.0%) respectively (*p* = 0.559).

Within-group analysis demonstrated a significant reduction in postoperative pain over time in both groups (Friedman test, both *p* < 0.001), as shown in Table 5. The mean reduction in NRS from the first to the final postoperative assessment was 2.90 ± 1.54 points in the L-TAP group and 3.17 ± 1.82 points in the US-TAP group, and the magnitude of reduction did not differ between groups (*p* = 0.830).

The additional exploratory longitudinal analysis demonstrated a statistically significant group-by-time interaction in postoperative NRS scores (Wald $\chi^2(7)$ = 22.56, *p* = 0.002), indicating different postoperative pain trajectories between the groups. However, the overall between-group difference was not statistically significant (mean difference: 0.44, 95% CI –0.09 to 0.97; *p* = 0.10).

No block-related complications occurred in either group. One patient in the US-TAP group developed an urticarial rash intraoperatively, before performance of the block. The reaction was confined to the skin, with no haemodynamic or respiratory involvement, and resolved after intravenous corticosteroid administration without sequelae; it was therefore not attributable to the block technique. No patient in either group developed pruritus, pneumothorax, signs of local anesthetic systemic toxicity, or any postoperative complication.

Table 2. Operative and postoperative recovery outcomes.

Variable	L-TAP (<i>n</i> = 30)	US-TAP (<i>n</i> = 30)	<i>p</i>
Operative duration (min)	104.83 ± 30.10	109.00 ± 36.09	0.629
Time to ambulation (h), mean ± SD	5.23 ± 2.14	5.03 ± 1.07	0.658
Time to ambulation (h), median (range)	5 (2–12)	5 (3–8)	—
Time to first flatus (h)	9.37 ± 2.08	8.90 ± 1.77	0.352
Hospital stay (days)	1.20 ± 0.41	1.13 ± 0.35	0.488
Postoperative complications, <i>n</i> (%)	0 (0)	0 (0)	—

Table 3. Analgesic consumption and adverse events.

Variable	L-TAP (<i>n</i> = 30)	US-TAP (<i>n</i> = 30)	<i>p</i>
IV paracetamol (g), mean ± SD	3.67 ± 0.71	3.73 ± 0.69	0.553
IV paracetamol (g), median (range)	4 (1–4)	4 (1–4)	—
Time to first analgesic (h), mean ± SD	2.93 ± 2.29	3.23 ± 2.24	0.403
Time to first analgesic (h), median (range)	1.5 (1–6)	2.5 (1–6)	—
Additional analgesia required, <i>n</i> (%)	24 (80.0)	19 (63.3)	0.152
Rescue opioid required, <i>n</i> (%)	7 (23.3)	6 (20.0)	0.754
Postoperative nausea/vomiting, <i>n</i> (%)	23 (76.7)	21 (70.0)	0.559
Urticarial rash (intraoperative), <i>n</i> (%)	0 (0)	1 (3.3)	—
Pruritus, <i>n</i> (%)	0 (0)	0 (0)	—
Pneumothorax, <i>n</i> (%)	0 (0)	0 (0)	—
Local anaesthetic systemic toxicity, <i>n</i> (%)	0 (0)	0 (0)	—

Paracetamol consumption includes the 1 g administered intraoperatively; the range reflects variation in the number of scheduled postoperative doses received before discharge. The urticarial rash developed before the block was performed and was not attributable to the block technique.

Table 4. Postoperative pain scores (Numeric Rating Scale).

Time	L-TAP mean ± SD	L-TAP median (range)	US-TAP mean ± SD	US-TAP median (range)	Difference (95% CI)	<i>p</i>
20 min	3.50 ± 1.43	3 (0–7)	3.50 ± 2.01	3 (0–9)	0.00 (–0.90 to 0.90)	0.474
40 min	3.50 ± 1.07	4 (1–5)	3.37 ± 1.90	3 (0–8)	0.13 (–0.67 to 0.93)	0.233
1 h	4.03 ± 1.56	4 (1–7)	2.50 ± 1.72	2.5 (0–6)	1.53 (0.68 to 2.38)	0.001
3 h	3.00 ± 1.49	3 (0–6)	2.47 ± 1.68	2 (0–6)	0.53 (–0.29 to 1.35)	0.151
6 h	2.70 ± 1.47	3 (0–6)	1.83 ± 1.44	2 (0–6)	0.87 (0.12 to 1.62)	0.015
12 h	1.93 ± 1.23	2 (0–4)	1.57 ± 1.55	1 (0–6)	0.36 (–0.36 to 1.08)	0.165
18 h	1.30 ± 1.26	1 (0–6)	1.47 ± 1.55	1 (0–6)	–0.17 (–0.90 to 0.56)	0.871
24 h	0.60 ± 0.77	0 (0–3)	0.33 ± 0.66	0 (0–2)	0.27 (–0.10 to 0.64)	0.092

Between-group hypothesis testing by Mann–Whitney *U* test. Differences are between-group differences in means (L-TAP minus US-TAP) with 95% confidence intervals derived from the *t* distribution and reported as descriptive effect estimates; positive values indicate higher pain scores in the L-TAP group. Time-point comparisons were exploratory and were not adjusted for multiplicity.

Table 5. Longitudinal pain analysis.

Variable	L-TAP (<i>n</i> = 30)	US-TAP (<i>n</i> = 30)	<i>p</i>
Baseline NRS (20 min)	3.50 ± 1.43	3.50 ± 2.01	0.474
Final NRS (24 h)	0.60 ± 0.77	0.33 ± 0.66	0.092
Change in NRS (final minus first), mean ± SD	–2.90 ± 1.54	–3.17 ± 1.82	0.830
Change in NRS (final minus first), median (range)	–3 (–7 to 1)	–3 (–8 to 0)	—
Within-group change over time	Friedman <i>p</i> < 0.001	Friedman <i>p</i> < 0.001	—

NRS, Numeric Rating Scale. Within-group change over time assessed by Friedman test; between-group comparisons by Mann–Whitney *U* test.

4. Discussion

In this randomized trial comparing ultrasound-guided and laparoscopic-assisted subcostal TAP block after laparoscopic cholecystectomy, patients in the ultrasound-guided group reported lower NRS scores at the

first and sixth postoperative hours. Across the remaining six assessment points, no significant between-group differences were detected. However, the additional exploratory longitudinal analysis demonstrated a significant group-by-time interaction over the first 24 hours (*p* = 0.002), indicating different postoperative pain trajectory

ries, although the overall between-group difference in NRS scores was not statistically significant ($p = 0.10$). No significant differences were detected in time to first analgesic request, rescue analgesic or opioid requirements, postoperative nausea and vomiting, time to ambulation, length of hospital stay, or complication rates.

Real-time sonographic guidance allows the operator to identify the fascial plane, to follow the needle tip during advancement and to observe the distribution of the injectate, so that deposition can be adjusted before the full volume is delivered [11]. Laparoscopic-assisted placement instead relies on tactile fascial endpoints combined with the intra-abdominal appearance of the abdominal wall, which confirms that injection is extra-peritoneal but does not display the fascial plane itself [12,13]. More consistently positioned injectate could plausibly produce a more reliable sensory block during the hours when local anesthetic concentrations at the target nerves are highest, which would be compatible with an early separation between groups that had resolved by the twelfth hour. Ultrasound-guided TAP block was first described in this surgical population by El-Dawlatly et al. and has since become the reference approach against which alternative delivery techniques are compared [14].

The magnitude of the observed differences deserves emphasis. At 1 hour the between-group difference was 1.53 NRS points (95% CI 0.68 to 2.38) and at 6 hours 0.87 points (95% CI 0.12 to 1.62). A systematic review of empirical studies of the minimum clinically important difference in acute pain reported a median absolute difference of approximately 1.7 points on an 11-point scale [10]. Both point estimates in the present study fall below that threshold, and at 6 hours the entire confidence interval lies below it; the lower confidence limits are compatible with differences of no practical relevance to patients. Considered together with the absence of any detectable difference in analgesic consumption or recovery endpoints, the early statistical separation should not be interpreted as evidence of a clinically important analgesic advantage.

Previous comparisons of the two guidance modalities have produced mixed results. Elamin et al., in a double-blind randomized trial in which a laparoscopically delivered TAP block was compared with wound infiltration, reported significantly lower pain scores at 1, 3 and 6 hours both at rest and on coughing, although postoperative analgesic requirements did not differ [15]. Ravichandran et al. compared the two guidance modalities directly in 60 patients undergoing laparoscopic cholecystectomy and found comparable pain relief and opioid consumption, with the laparoscopic block faster to administer [16]. Diyaolu et al. similarly found comparable recovery-room pain scores and opioid consumption in 50 children undergoing laparoscopic procedures (1.2 ± 1.3 vs 1.6 ± 1.6 , $p = 0.24$), again with a shorter block performance time in the laparoscopic arm (2.1 vs 7.9 minutes) [17], and the meta-analysis of Hamid et al. found no difference in analgesic efficacy across the first 24 hours [18]. In a non-randomized three-arm comparison that also included a no-block control, Reyna-Sepulveda et al. found lower pain scores and less postoperative analgesic requirement with both blocks than with

intravenous analgesia alone, without a significant difference between the two guidance techniques [19]. The present results fall within this range: a small early advantage for ultrasound guidance, not sustained over time and not accompanied by differences in any patient-centred endpoint.

Recent evidence syntheses point in the same direction. Wang et al. found that TAP block reduces early postoperative pain after laparoscopic cholecystectomy but confers limited additional benefit over alternative local techniques such as port-site infiltration [20], while Park et al. reported lower opioid consumption and pain scores with subcostal TAP block compared with wound infiltration, with comparable rates of nausea and vomiting [21]. A systematic review comparing ultrasound-guided with laparoscopic-assisted placement specifically reported lower pain scores with ultrasound guidance at 6 hours, but no differences at later time points, in opioid consumption, or in postoperative nausea and vomiting [22]. The present trial contributes data from a single procedure managed under a standardized perioperative protocol and is consistent with the view that the principal difference between the modalities lies in early pain scores rather than in recovery outcomes.

Time to first analgesic request did not differ between groups despite lower early pain scores with ultrasound guidance. Pain intensity in both groups generally remained below the NRS threshold of 4 that triggered rescue analgesia, so a modest downward shift in scores would not necessarily translate into fewer rescue doses; Saliminia et al. similarly showed that the effect of TAP block on this interval is most apparent when the comparison is with no block at all [23]. Postoperative nausea and vomiting occurred in 70–77% of patients, higher than is commonly reported after laparoscopic cholecystectomy. No antiemetic prophylaxis was administered in either group and the cohort carried several established risk factors — female predominance, a high proportion of non-smokers, laparoscopic surgery, volatile anesthesia and perioperative opioid exposure — that together predict a high baseline risk. The absence of prophylaxis is the most probable explanation for the observed incidence and represents a departure from current guideline-based practice.

The present study was not designed to compare resource utilization, equipment requirements, cost or training burden and none of these variables was measured. Procedural time, however, has been measured in three of the comparative studies cited above and each found laparoscopic-assisted placement to be quicker: block performance took 2.1 versus 7.9 minutes in the paediatric trial of Diyaolu et al. [17], the laparoscopic block was significantly faster to administer in the trial of Ravichandran et al. [16], and Reyna-Sepulveda et al. reported a shorter total operative time with the laparoscopic technique (74 versus 92 minutes) in a non-randomized comparison [19]. In the present randomized trial, total operative duration did not differ between groups (109.0 versus 104.8 minutes, $p = 0.629$), which suggests that time saved in performing the block does not necessarily translate into a shorter operation. Laparoscopic-assisted placement uses equipment already present in the operative field and can be performed by

the operating surgeon, which may be relevant where ultrasound machines or regional anesthesia expertise are limited; this consideration is offered as clinical context rather than as a finding of this trial.

This study has several strengths: a randomized design with allocation concealment, a single homogeneous surgical procedure, standardized anesthetic and analgesic management, blinded outcome assessment, and a subcostal approach matched to the dermatomes relevant to upper abdominal surgery [6]. Several limitations should be acknowledged. The study was conducted at a single center with a modest sample. The sample size calculation was based on a clinically defined target difference of approximately 1 NRS point; power to detect smaller differences and differences in the secondary outcomes was limited. Because the primary outcome was pain intensity across the first 24 postoperative hours rather than at any single prespecified time point, comparisons at individual time points were considered complementary analyses. Crucially, the trial included no no-block control group and was not designed as an equivalence or non-inferiority study, so the absence of detectable differences cannot be interpreted as demonstrated equivalence, and the absolute efficacy of either technique cannot be established from these data. Block success was not verified objectively, either by sensory dermatome testing or by imaging. Pain was assessed only at rest; dynamic pain on movement or coughing, which may differ substantially after laparoscopic abdominal surgery, was not evaluated. Patient-controlled analgesia was not used and cumulative rescue opioid dose was recorded as a requirement rather than in milligrams, so analgesic consumption was captured less precisely. The earliest assessments were performed shortly after emergence and may have been influenced by residual anesthetic effects. A mixture of two local anesthetics was used rather than a single agent, which may limit comparability with other studies. Finally, the trial was registered retrospectively, after completion of enrolment and follow-up.

5. Conclusions

In patients undergoing laparoscopic cholecystectomy within a standardized multimodal analgesic regimen, ultrasound-guided subcostal TAP block was associated with lower pain scores at the first and sixth postoperative hours than laparoscopic-assisted placement. These differences were smaller than commonly cited thresholds for clinically important change, were not sustained beyond the sixth hour, and were not accompanied by differences in rescue analgesic or opioid requirements, postoperative nausea and vomiting, time to ambulation, length of stay, or complication rates. Because no no-block control group was included and the trial was not designed to test equivalence, these findings support a comparison between the two guidance modalities rather than a conclusion about the absolute efficacy of either. Adequately powered trials with a prespecified primary time point and a longitudinal analysis are needed to determine whether the early difference observed here has any clinical consequence.

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Conflict of Interest

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Data Availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

AI Assistance

An AI assistant (Claude, Anthropic) was used specifically for refining figure-caption wording and light language polishing. The model did not generate or interpret clinical data, and no identifiable patient information was provided. All study design, analyses and clinical interpretation were produced and critically verified by the authors, who take full responsibility for the content.

Ethics Approval and Consent to Participate

This study was approved by the Maltepe University Clinical Research Ethics Committee (Decision No. 3, November 1, 2022) and authorized by the Turkish Medicines and Medical Devices Agency (TİTCK; Study Code 22-AKD-156, Reference No. E-66175679-514.13.02-965164, December 26, 2022). All procedures were conducted in accordance with the Declaration of Helsinki and relevant regulations. Written informed consent was obtained from all participants prior to enrollment.

Author Contributions

Berfin Gizem Özelsel: data curation, formal analysis, investigation, methodology, resources, validation, visualization, writing – original draft.

Talat Ercan Şerifsoy: conceptualization, methodology, supervision, data curation, investigation, writing – review and editing.

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