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CLINICAL TRIAL REPORT

Quadratus Lumborum versus Transversus Abdominis Plane Block with Oxycodone or Sufentanil for Recovery Quality After Laparoscopic Gastrointestinal Cancer Surgery: A Factorial Randomized Trial

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Purpose: Quadratus lumborum block (QLB) theoretically provides broader visceral analgesia than transversus abdominis plane block (TAPB), while oxycodone, a dual μ- and κ-opioid receptor agonist, may offer superior visceral pain control compared with sufentanil. We evaluated these two regional techniques and two opioid regimens simultaneously in a factorial design to determine their effects on recovery after laparoscopic gastrointestinal cancer surgery.

Methods: In this single-center, randomized, 2×2 factorial trial, 120 adults were randomly assigned to bilateral QLB or TAPB (0.375% ropivacaine 20 mL per side) and oxycodone or sufentanil patient-controlled analgesia. All patients received intraoperative dexmedetomidine and flurbiprofen axetil. The primary outcome was 24-h recovery quality (15-item quality of recovery scale; minimal clinically important difference 6 points). Secondary outcomes included recovery quality at 48 and 72 h, visceral and incisional pain, opioid consumption, rescue analgesia, and adverse events.

Results: For 24-h recovery quality, no significant interaction was found between block and opioid ($P = 0.283$); QLB vs TAPB (mean [SD] 102.1 [7.9] vs 102.6 [7.6]; mean difference −0.5, 95% CI −3.3 to 2.4; $P = 0.740$) and oxycodone vs sufentanil (103.7 [6.9] vs 100.9 [8.3]; mean difference 2.8, 95% CI 0.1 to 5.6; $P = 0.045$) did not reach the Bonferroni-corrected threshold ($P < 0.025$) or the 6-point difference. Oxycodone was associated with lower visceral pain scores at 1, 6, 24 and 48 h, lower incisional pain scores at 1 and 6 h, and decreased rescue analgesia use (13.3% vs 29.3%). Other outcomes were comparable.

Conclusion: Within comprehensive multimodal analgesia, neither QLB nor oxycodone demonstrated superior recovery compared with TAPB or sufentanil. Exploratory findings of lower postoperative pain and less rescue analgesia with oxycodone should be considered hypothesis-generating.

Trial Registration: Chinese Clinical Trial Registry (ChiCTR2400080766).

Keywords: laparoscopic gastrointestinal surgery, multimodal analgesia, oxycodone, quadratus lumborum block, quality of recovery, sufentanil, transversus abdominis plane block

Introduction

Colorectal and gastric cancers are among the most common malignancies worldwide,[1] and laparoscopic resection is the standard of care for resectable disease.[2–6] Despite the minimally invasive approach, patients frequently experience significant postoperative pain, particularly visceral pain, that delays ambulation, enteral feeding, and hospital discharge.[7,8] Within

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enhanced recovery after surgery (ERAS) pathways, multimodal analgesia comprising non-opioid adjuncts and regional techniques is used to minimize opioid exposure and accelerate recovery; however, the combination of truncal block and opioid regimen that best supports postoperative pain management and patient-centered recovery remains to be clarified.

Truncal blocks such as transversus abdominis plane block (TAPB) and quadratus lumborum block (QLB) are widely used for abdominal surgery. Although QLB theoretically offers broader visceral coverage through thoracolumbar fascia spread,[9–11] direct comparisons in laparoscopic gastrointestinal cancer procedures have yielded inconsistent results.[12–16] Similarly, sufentanil and oxycodone are standard options for intravenous patient-controlled analgesia (PCA), but their receptor pharmacology differs: oxycodone acts as a dual μ- and κ-opioid receptor agonist, with evidence suggesting enhanced efficacy for visceral nociception through κ-mediated spinal and peripheral mechanisms,[17–19] whereas sufentanil is a highly selective μ-opioid receptor agonist.

Regional blocks and opioid regimens target postoperative pain through partially overlapping mechanisms, and a more effective block may reduce opioid demand via PCA. Whether their combination influences recovery after laparoscopic gastrointestinal cancer surgery remains uncertain. Because these represent two independent analgesic decisions frequently made in combination during ERAS pathways, a 2×2 factorial design was chosen for simultaneous evaluation with improved efficiency. We evaluated the main effects and potential interaction of lateral QLB vs TAPB (pooled across opioid regimens) and oxycodone- vs sufentanil-based PCA (pooled across block techniques), and hypothesized that each intervention would improve 24-h recovery quality and reduce postoperative visceral pain after laparoscopic gastrointestinal cancer surgery.

Methods

Study Design

This is a randomized, 2×2 factorial trial conducted at a university teaching hospital in China. The study was approved by the Ethics Committee of the First Affiliated Hospital of Soochow University (No. 2024–039) and registered on the Chinese Clinical Trial Registry (ChiCTR2400080766; https://www.chictr.org.cn/showproj.html?proj=220080; dated 6 February 2024). This study was conducted in accordance with the Declaration of Helsinki. The first patient was enrolled on 11 March 2024. Reporting adhered to CONSORT 2010 and SPIRIT 2013 extensions for factorial trials.[20] The study followed the published protocol,[21] with one clarification: rescue analgesia comprised i.v. tramadol or dezocine for persistent pain after PCA self-titration.

Patients

Adults with American Society of Anesthesiologists (ASA) physical status I–III undergoing elective laparoscopic surgery for colorectal or gastric cancer were eligible. Key exclusion criteria included BMI ≥ 35 kg/m^2, severe organ dysfunction, or inability to complete assessments; full details are provided in the published protocol.[21] Written informed consent was obtained.

Randomization and Blinding

An independent researcher performed randomization (1:1:1:1, block size 8) using the Sealed Envelope tool, with allocation concealment in sequentially numbered opaque envelopes. Patients were randomly assigned to one of four analgesic combinations: QLB plus oxycodone PCA, QLB plus sufentanil PCA, TAPB plus oxycodone PCA, or TAPB plus sufentanil PCA. An independent nurse prepared the study medications. PCA syringes were prepared by an independent nurse not involved in clinical care or outcome assessment. Oxycodone and sufentanil solutions were prepared as colourless solutions of identical total volume (100 mL) and equal bolus volume (2 mL per activation) to maintain blinding of both patients and outcome assessors. Anesthesiologists performing regional blocks were aware of block allocation but were blinded to the opioid regimen. Two independent research nurses, masked to group allocation, served as blinded outcome assessors and were responsible for collecting QoR-15 questionnaires, recording pain scores, and documenting adverse events. They had no involvement in clinical care, rescue analgesia decisions, or PCA preparation.

Anesthesia and Interventions

For all patients, general anesthesia was induced with propofol and sufentanil, maintained with sevoflurane inhalation and remifentanil infusion, and monitored with bispectral index, as described in the protocol.[21] A dedicated research nurse provided standardized preoperative education on PCA device use. Prophylactic antiemetics with dexamethasone and palonosetron were given routinely. Hypotension and bradycardia were corrected using ephedrine, phenylephrine, or atropine as clinically indicated. All patients received perioperative multimodal analgesia comprising assigned regional blocks before surgery, intraoperative dexmedetomidine infusion (0.4 μg/kg/h) and flurbiprofen axetil 50 mg, and PCA with the assigned opioids for 48 h.

Following induction, with the patient in the supine position, a consultant anesthetist skilled in ultrasound-guided regional anesthesia performed bilateral blocks. For the lateral QLB, a low-frequency probe was placed in the midaxillary line at the level of the L3–L4 transverse process to identify the quadratus lumborum muscle within the thoracolumbar fascia complex. Using an in-plane technique, a 22G needle was advanced from the lateral aspect of the probe to the lateral border of the quadratus lumborum muscle (Figure 1a), and 20 mL of 0.375% ropivacaine was injected incrementally per side after negative aspiration. Correct needle placement and local anesthetic spread were confirmed by ultrasound visualization of displacement of the retroperitoneal fat plane. For the transversus abdominis plane block, a high-frequency probe facilitated either a subcostal approach in gastric surgery (Figure 1b) or a lateral approach in colorectal surgery (Figure 1c), with the needle inserted between the internal oblique and transversus abdominis muscles to deposit 20 mL of 0.375% ropivacaine per side.

Before skin closure, patients assigned to oxycodone received i.v. oxycodone 0.2 mg/kg, whereas those assigned to sufentanil received i.v. sufentanil 0.2 μg/kg. The PCA solutions were prepared to a total volume of 100 mL, containing oxycodone at 1 mg/mL or sufentanil at 1 μg/mL. No background infusion was used; PCA was delivered as 2 mg oxycodone or 2 μg sufentanil per bolus with a 5-min lockout interval. Rescue analgesia with i.v. tramadol 50 mg or dezocine 5 mg was administered at the attending physician's discretion when the overall NRS pain score at rest (the higher of visceral or incisional pain) was ≥ 4 despite PCA use. Rescue analgesia was administered by the attending physician based on clinical assessment. The blinded outcome assessors were not involved in rescue analgesia decisions and remained unaware of group allocation throughout the trial.

Study Outcomes

The primary outcome was quality of recovery at 24 h postoperatively, assessed using the validated Chinese version of the QoR-15 scale.[22,23] The QoR-15 is a patient-reported outcome measure that captures the multidimensional experience of postoperative recovery, encompassing pain, physical comfort, physical independence, psychological support, and emotional state (range 0–150, higher scores indicate better recovery), with a minimal clinically important difference (MCID) of 6 points.[24,25] To eliminate observer bias, patients completed the questionnaire independently.

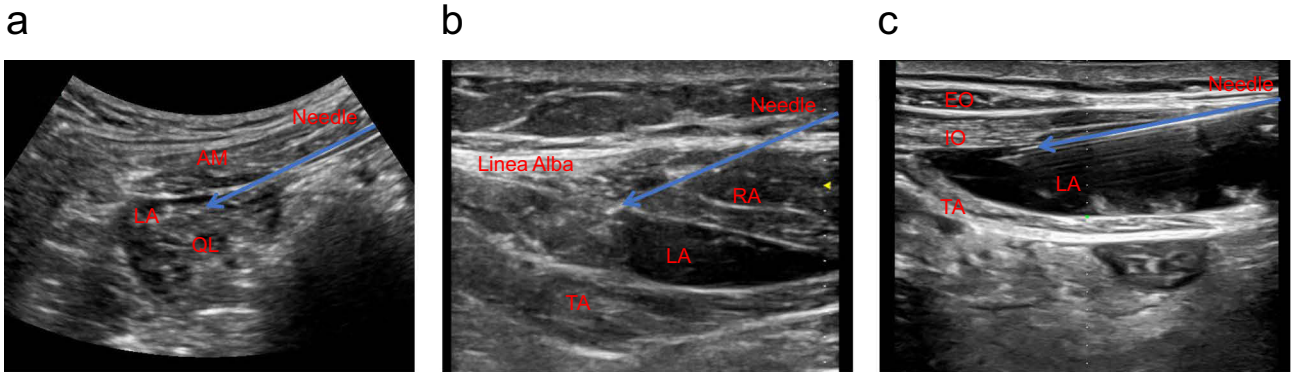


Figure 1 Ultrasound-guided quadratus lumborum block and transverse abdominis plane block. (**a**) Lateral quadratus lumborum block. (**b**) Subcostal transverse abdominis plane block. (**c**) Lateral transverse abdominis plane block. Blue arrows indicate the needle path.
Abbreviations: AM, abdominal wall muscle; EO, external oblique; IO, internal oblique; LA, local anesthetic; QL, quadratus lumborum; RA, rectus abdominis; TA, transverse abdominis.

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Secondary outcomes included QoR-15 scores at 48 and 72 h; visceral and incisional NRS pain scores at rest and during coughing at 1, 6, 24, and 48 h; PCA consumption during 0–24 and 24–48 h; rescue analgesia requirement; time to first flatus; adverse events (sedation, nausea and vomiting, rescue antiemetic use, respiratory depression, dizziness); severe complications (stroke, reoperation, anastomotic leakage, death); and length of hospital stay. Patients were instructed to independently score each pain component using the NRS. Visceral pain was defined as deep, dull, or cramping pain located within the abdominal cavity, distinct from incisional pain characterized as superficial, sharp, or burning pain at the port-site or incision location.

Sample Size Calculation

For this 2×2 factorial trial, sample size was calculated to detect main effects using pooled comparisons. Assuming a mean (standard deviation [SD]) QoR-15 score of 99 (10) at 24 h,[23] a 6-point improvement with either the preferred block or opioid, 80% power, and two-sided $\alpha = 0.025$ (Bonferroni-corrected for two primary comparisons), 110 patients were required (PASS 15.0; NCSS, USA). To allow for possible attrition, we enrolled 120 patients (60 per main comparison; 30 per factorial group).

Statistical Analysis

Distributional assumptions were evaluated using the Shapiro–Wilk test. Continuous variables were summarized as mean (SD) or median (IQR), and categorical variables as counts (%). Factorial analysis used two-way analysis of variance to test the interaction between block type and opioid regimen for 24-h QoR-15 scores. We selected the 2×2 factorial design to evaluate two concurrent analgesic decisions efficiently within the same surgical population. Because both regional blocks and opioid PCA target postoperative pain, it is plausible that they partly substitute for each other (eg, a more effective block may reduce PCA demand). The PCA system also allows self-titration, meaning that differences in block efficacy may manifest as differences in bolus frequency rather than pain scores alone. The factorial framework explicitly tests for such interdependence via the interaction term. The pooled comparisons (QLB vs TAPB across opioid regimens and oxycodone vs sufentanil across block techniques) were prespecified to estimate the average main effect of each intervention. This approach does not assume that the effects of the block and opioid were necessarily independent or additive; rather, absent a statistically significant interaction, pooled main-effect comparisons provide unbiased estimates of each intervention's average effect under the factorial framework.

For main-effect comparisons, we used unpaired *t* test or Mann–Whitney *U*-test for continuous variables and χ^2 test or Fisher's exact test for categorical variables, reporting mean/median differences (MD) or relative risk (RR) with 95% confidence intervals (CI). Exploratory four-group comparisons used one-way ANOVA, Kruskal–Wallis (with Dunn's post-hoc), or χ^2 tests as indicated. All analyses followed a modified intention-to-treat principle (including all randomized patients with available data). Based on complete outcome capture in our pilot study,[23] we anticipated minimal missing data and performed complete-case analysis. The primary outcome was tested at $P = 0.025$ (Bonferroni-corrected for two main comparisons), and all secondary outcomes were exploratory. Analyses were conducted in SPSS 25.0 (IBM, Chicago, IL) and GraphPad Prism 9.0 (GraphPad Software, Boston, MA).

Results

Study Flow

Between March 2024 and November 2025, we screened 203 adults undergoing laparoscopic gastrointestinal cancer surgery. Of these, 83 were excluded and 120 were randomly assigned to one of four analgesic regimens (Figure 2). Two patients in the sufentanil-assigned groups (one receiving QLB and one TAPB) underwent laparoscopic exploration without resection and were excluded from analysis, leaving 118 patients for analysis: 30 in the QLB-oxycodone group, 29 in the QLB-sufentanil group, 30 in the TAPB-oxycodone group, and 29 in the TAPB-sufentanil group. Data on 72-h quality of recovery were missing for two patients in the QLB-sufentanil group because of early hospital discharge; all other data were complete.

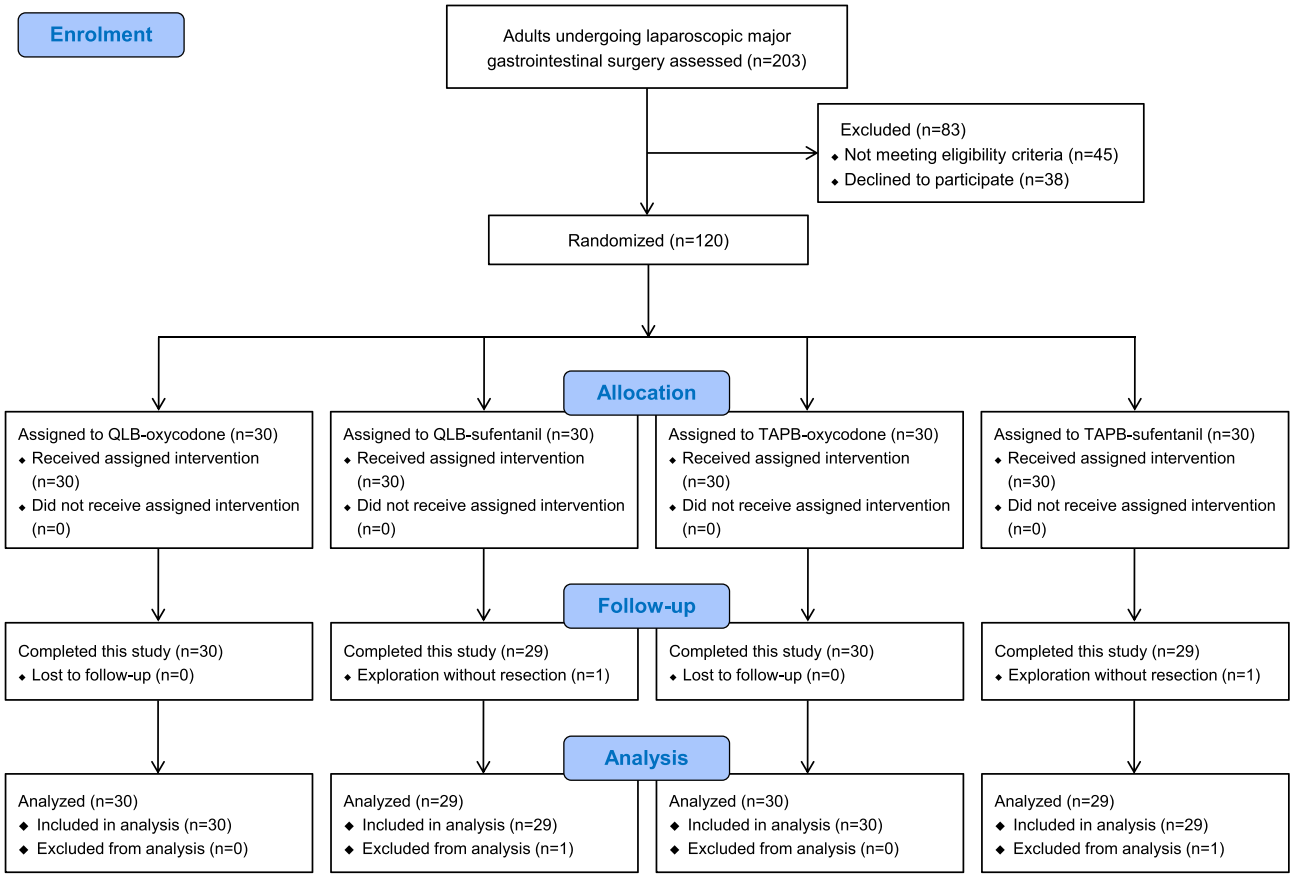


Figure 2 Trial flow diagram. Two patients (one in QLB-sufentanil and one in TAPB-sufentanil) underwent laparoscopic exploration without tumor resection and were excluded from analysis after randomization (ie, intraoperatively, before postoperative outcome assessment).
Abbreviations: QLB, quadratus lumborum block; TAPB, transversus abdominis plane block.

Baseline and Perioperative Characteristics

Demographic and clinical characteristics were balanced across the four groups, as presented in Table 1. The mean (SD) age was 64.5 (11) years, and 68.3% were male; most patients had ASA physical status II or III. Perioperative parameters were comparable (Table 2), with median surgical duration ranging from 170 to 198 minutes. As per protocol, patients allocated to oxycodone received intraoperative oxycodone (median 12–14 mg) and lower-dose sufentanil (median 12–14 μg), whereas those allocated to sufentanil received higher-dose intraoperative sufentanil (median 24–25 μg) and no intraoperative oxycodone.

Primary Outcome

The estimated block-by-opioid interaction for the 24-h QoR-15 score was not statistically significant (P = 0.283), although the trial was not powered to exclude a clinically relevant interaction. The prespecified pooled comparisons were then used to estimate the average main effect of each intervention across the levels of the other factor. For QLB vs TAPB (pooled across opioid regimens), mean (SD) 24-h QoR-15 scores were 102.1 (7.9) vs 102.6 (7.6), with an MD of −0.5 (95% CI −3.3 to 2.4; $P = 0.740$; Figure 3a). For oxycodone vs sufentanil PCA (pooled across block techniques), mean (SD) scores were 103.7 (6.9) vs 100.9 (8.3), with an MD of 2.8 (95% CI 0.1 to 5.6; $P = 0.045$; Figure 3b). Neither comparison achieved the prespecified significance threshold ($P < 0.025$) or the MCID of 6 points.

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Table 1 Baseline Characteristics

	QLB-oxycodone (n = 30)	QLB-sufentanil (n = 30)	TAPB-oxycodone (n = 30)	TAPB-sufentanil (n = 30)
Age, y	66.3 (10.5)	65.3 (11.2)	63.7 (11.7)	62.8 (10.9)
Sex				
Female	7 (23.3%)	9 (30%)	10 (33.3%)	12 (40%)
Male	23 (76.7%)	21 (70%)	20 (66.7%)	18 (60%)
Weight, kg	64.8 (9.7)	62.1 (10)	59.3 (8.8)	62.3 (11.2)
Height, cm	165.6 (7.3)	165.9 (7.7)	165 (7.8)	163.5 (8.1)
BMI, kg/m^2	23.6 (2.9)	22.5 (3.1)	21.7 (2.9)	23.2 (3.2)
Current smoker	11 (36.7%)	11 (36.7%)	9 (30%)	7 (23.3%)
Employment status				
Employed	11 (36.7%)	7 (23.3%)	9 (30%)	13 (43.3%)
Unemployed	6 (20%)	7 (23.3%)	9 (30%)	8 (26.7%)
Retirement	13 (43.3%)	16 (53.3%)	12 (40%)	9 (30%)
ASA physical status				
I	3 (10%)	1 (3.3%)	1 (3.3%)	4 (13.3%)
II	21 (70%)	27 (90%)	26 (86.7%)	24 (80%)
III	6 (20%)	2 (6.7%)	3 (10%)	2 (6.7%)
Comorbidity				
Hypertension	16 (53.3%)	16 (53.3%)	9 (30%)	10 (33.3%)
Diabetes	5 (16.7%)	4 (13.3%)	5 (16.7%)	4 (13.3%)
Pulmonary disease	1 (3.3%)	0	2 (6.6%)	2 (6.6%)
Cardiac disease	4 (13.3%)	4 (13.3%)	5 (16.7%)	3 (10%)
Anaemia	10 (33.3%)	8 (26.7%)	9 (30%)	14 (46.7%)
Preoperative medication				
ACEI/ARB	8 (26.7%)	10 (33.3%)	4 (13.3%)	5 (16.7%)
β blocker	5 (16.7%)	3 (10%)	1 (3.3%)	0
CCB	13 (43.3%)	6 (20%)	6 (20%)	5 (16.7%)
Antidiabetics	4 (13.3%)	4 (13.3%)	3 (10%)	4 (13.3%)
Antiplatelets	2 (6.6%)	5 (16.7%)	2 (6.6%)	2 (6.6%)
Haemoglobin, g/L	127.3 (27)	128 (21.6)	123.3 (23.1)	119.2 (26.8)
Albumin, g/L	38.7 (4.7)	39.2 (3.7)	38.7 (3.2)	38 (4.1)
Serum K^+, mmol/L	3.89 (0.28)	3.92 (0.37)	3.98 (0.26)	3.91 (0.4)
Serum creatinine, μmol/L	70.6 (19.3)	68.9 (15)	64.6 (17.2)	69.4 (27)

Notes: Data are mean (SD) or n (%).
Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CCB, calcium channel blocker; BMI, body mass index; QLB, quadratus lumborum block; TAPB, transverse abdominis plane block.

Secondary and Exploratory Outcomes

Quality of recovery at 48 and 72 h was similar across all comparisons (Table 3). Oxycodone was associated with lower visceral pain scores (both at rest and on coughing at 1, 6, 24, and 48 h), lower incisional pain scores (both at rest and on coughing at 1 and 6 h), and decreased rescue analgesia use (13.3% vs 29.3%, RR = 0.45, 95% CI 0.21 to 0.94). PCA consumption during 0–24 and 24–48 h was comparable across block comparisons. For the opioid comparison, oxycodone was associated with lower PCA consumption during 0–24 h (25 [24–30] versus 28 [24–37] mL; $P = 0.049$), but not during 24–48 h (24 [24–30] versus 24.5 [24–40] mL; $P = 0.197$).

Among the 25 patients who received rescue analgesia, tramadol 50 mg was used in 24 patients (96%) and dezocine 5 mg in 1 patient (4%) who was in the TAPB-sufentanil group. Postoperative opioid exposure during 0–48 h, comprising PCA consumption and rescue analgesia, was calculated as morphine milligram equivalents (MME; sufentanil 1 μg = 1 mg MME, oxycodone 1 mg = 1 mg MME, tramadol 50 mg = 5 mg MME, dezocine 5 mg = 5 mg MME). For the block comparison (pooled across opioid regimens), median (IQR) postoperative MME was 52 (48–70) mg in the QLB group and 50 (48–

Table 2 Perioperative Data

	QLB-oxycodone (n = 30)	QLB-sufentanil (n = 30)	TAPB-oxycodone (n = 30)	TAPB-sufentanil (n = 30)	*P* value
Mean arterial pressure, mmHg					
Baseline	97 (11)	100 (12)	95 (12)	95 (12)	0.399
After induction	80 (15)	82 (10)	75 (10)	75 (15)	0.156
Skin incision	95 (16)	98 (17)	97 (18)	98 (13)	0.816
Skin closure	88 (11)	91 (10)	85 (8)	89 (11)	0.196
Heart rate, beats/min					
Baseline	73 (10)	73 (9)	73 (12)	71 (12)	0.845
After induction	67 (14)	67 (11)	68 (13)	67 (13)	0.995
Skin incision	62 (14)	60 (12)	65 (13)	60 (9)	0.351
Skin closure	61 (9)	60 (8)	62 (9)	61 (7)	0.928
Anesthetics and analgesics					
Propofol, mg	110 (100–122)	120 (100–130)	100 (100–120)	120 (100–140)	0.350
Dexmedetomidine, μg	80 (63–100)	80 (63–93)	80 (68–88)	80 (62–100)	0.991
Sufentanil, μg	14 (12–15)	25 (23–30)	12 (11–14)	24 (22–30)	<0.001
Oxycodone, mg	14 (12–15)	0	12 (11–14)	0	<0.001
Remifentanil, μg	1000 (637–1000)	1000 (756–1300)	900 (750–1050)	950 (700–1250)	0.495
Sevoflurane, MAC	0.6 (0.6–0.7)	0.7 (0.6–0.7)	0.6 (0.6–0.7)	0.65 (0.6–0.7)	0.903
Hemodynamic events and medications					
Hypotension	17 (56.7%)	16 (53.3%)	16 (53.3%)	19 (63.3%)	0.846
Bradycardia	8 (26.7%)	4 (13.3%)	6 (20%)	3 (10%)	0.333
Ephedrine	16 (53.3%)	12 (40%)	14 (46.7%)	21 (70%)	0.113
Phenylephrine	4 (13.3%)	4 (13.3%)	7 (23.3%)	6 (20%)	0.669
Atropine	2 (6.7%)	2 (6.7%)	3 (10%)	0	0.410
Type of surgery					
Gastric	9 (30%)	12 (40%)	17 (56.7%)	12 (40%)	0.210
Colorectal	21 (70%)	18 (60%)	13 (43.3%)	18 (60%)	
Surgical time, min	170 (152–214)	189 (149–236)	185 (143–213)	198 (157–226)	0.783
Anesthetic time, min	210 (184–261)	220 (173–275)	222 (184–247)	234 (189–271)	0.806
Length of PACU stay, min	44 (30–77)	50 (28–67)	51 (30–75)	40 (23–63)	0.466

Notes: Data are mean (SD), median (IQR), or n (%).
Abbreviations: MAC, minimum alveolar concentration; PACU, post-anesthesia care unit. QLB, quadratus lumborum block; TAPB, transverse abdominis plane block.

70) mg in the TAPB group ($P = 0.554$). For the opioid comparison (pooled across block techniques), median (IQR) postoperative MME was 50 (48–62) mg in the oxycodone group and 53 (48–81) mg in the sufentanil group ($P = 0.066$).

The proportions of patients with clinically relevant pain (NRS ≥ 4) are shown in Table 4. For the regional block comparison, the proportions of patients with NRS ≥ 4 did not differ significantly between QLB and TAPB at any time point or pain domain (all $P > 0.05$). For the opioid comparison, oxycodone was associated with significantly lower proportions of patients with clinically relevant visceral pain during coughing at 1 h (0% vs 8.6%, $P = 0.026$), 6 h (5% vs 32.8%, $P < 0.001$), 24 h (26.7% vs 58.6%, $P < 0.001$), and 48 h (30% vs 51.7%, $P = 0.016$). Oxycodone also reduced the proportion of patients with clinically relevant incisional pain during coughing at 6 h (8.3% vs 22.4%, $P = 0.033$). In exploratory four-group comparisons (Table 5), QLB-oxycodone produced lower visceral pain scores than either TAPB-sufentanil or QLB-sufentanil combinations. No local anesthetic toxicity occurred.

Discussion

This randomized factorial clinical trial demonstrates that, when integrated into multimodal analgesia, both QLB and TAPB produced comparable patient-centered recovery after laparoscopic gastrointestinal cancer surgery. Oxycodone-and sufentanil-based PCA also produced comparable global recovery at the prespecified significance threshold and did not reach the QoR-15

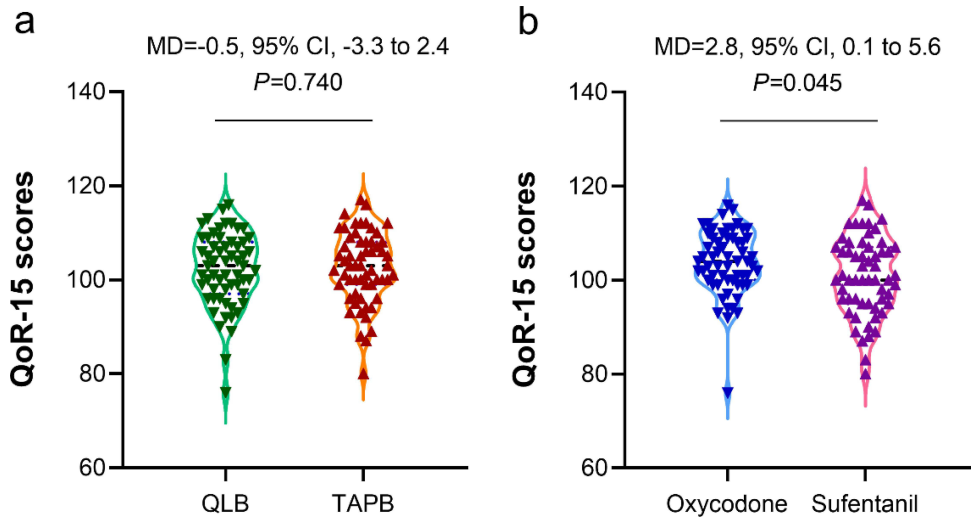


Figure 3 Quality of recovery at 24 h postoperatively. (**a**) QLB vs TAPB. (**b**) Oxycodone vs sufentanil. In (**b**), $P = 0.045$ did not reach the prespecified Bonferroni-corrected significance threshold of $P < 0.025$.
Abbreviations: CI, confidence interval; MD, mean difference; QLB, quadratus lumborum block; QoR-15, Quality of Recovery-15; TAPB, transversus abdominis plane block.

MCID. Exploratory analyses associated oxycodone with modestly lower visceral pain scores and less rescue analgesia, but these findings do not establish a visceral-selective mechanism or support a treatment recommendation.

The absence of a clinically important difference between the two regional blocks should be interpreted in the context of the comprehensive multimodal analgesic regimen used in this trial. Although QLB can provide visceral analgesia,[9–11] dexmedetomidine, flurbiprofen, and patient-controlled opioids may have reduced the incremental contribution of a more proximal block. Recent multicenter data similarly showed that anterior QLB did not reduce opioid consumption compared with placebo when added to multimodal analgesia.[15] The 95% CI for QLB vs TAPB on the 24-h QoR-15 score (−3.3 to 2.4 points) excluded the prespecified 6-point improvement, making a clinically important advantage of QLB over TAPB unlikely under the regimen studied. However, as this trial did not include a no-block or sham-block group, it cannot determine whether either block improved recovery compared with no regional block. Because we used lateral QLB, evidence concerning injectate spread from posterior or anterior approaches should not be assumed to apply directly. An especially useful clinical implication is that, within this multimodal context, the choice between QLB and TAPB may reasonably be guided by operator expertise and resource availability rather than by expected recovery differences.

The comparable global recovery and exploratory pain findings require cautious interpretation. The QoR-15 assesses multiple dimensions of recovery, including physical independence, emotional state, psychological support, comfort, and pain; therefore, a small improvement in one domain may not translate into a detectable difference in the total score. Oxycodone has μ-opioid activity and has been proposed to exert κ-mediated effects relevant to visceral nociception,[17–19] but this trial did not assess receptor activity or other mechanisms. Moreover, oxycodone was associated with lower incisional as well as visceral pain scores at 1 and 6 h, making a specifically visceral-selective or κ-mediated explanation less certain. Differences in analgesic potency, duration of action, or loading-dose pharmacokinetics may have contributed to the observed pain differences. Consequently, these findings do not establish a visceral-selective or κ-mediated mechanism and should be considered hypothesis-generating.

The factorial design allowed two concurrent analgesic decisions to be evaluated efficiently within one trial, but the regional block and PCA opioid may not have acted independently. Both interventions contribute to postoperative analgesia, and patient self-titration could allow a more effective block to reduce PCA consumption without improving global recovery quality, given that the QoR-15 captures multiple dimensions beyond pain alone. Moreover, the comprehensive analgesic regimen in all groups may have created an analgesic floor that reduced the observable incremental benefit of study interventions. These considerations raise the possibility of overlapping, substitutive, or otherwise non-additive effects between the study interventions. Because the trial was powered for main effects, the pooled estimates should be interpreted as average effects within the multimodal regimen studied, rather than as evidence that the two factors acted independently or additively.

Table 3 Secondary Outcomes[a]

	Regional Block				Analgesic Regimen			
	QLB (n = 59)	**TAPB (n = 59)**	**Effect Size (95% CI)**	***P* value**	**Oxycodone (n = 60)**	**Sufentanil (n = 58)**	**Effect Size (95% CI)**	***P* value**
QoR-15 score at 48 h	109.5 (7.8)	110.2 (7.3)	−0.6 (−3.4, 2.1)	0.653	110.2 (6.9)	109.4 (8.2)	0.8 (−1.9, 3.6)	0.565
QoR-15 score at 72 h	116.2 (7.0) (n = 57)	117.3 (6.7)	−1.1 (−3.6, 1.4)	0.375	117.1 (6.3)	116.4 (7.4) (n = 56)	0.7 (−1.8, 3.2)	0.571
Visceral pain scores								
1 h at rest	0 (0–0)	0 (0–0)	0 (0, 0)	0.772	0 (0–0)	0 (0–1)	0 (0, 0)	0.002
6 h at rest	1 (0–1)	1 (1–2)	0 (−1, 0)	0.149	1 (0–1)	1 (1–2)	−1 (−1, 0)	<0.001
24 h at rest	2 (1–2)	2 (1–2)	0 (−1, 0)	0.043	1 (1–2)	2 (1–3)	−1 (−1, 0)	<0.001
48 h at rest	2 (1–2)	2 (1–2)	0 (0, 0)	0.338	2 (1–2)	2 (2–2)	0 (−1, 0)	0.022
1 h on coughing	1 (1–1)	1 (1–2)	0 (−1, 0)	0.142	1 (0–1)	1 (1–2)	0 (−1, 0)	0.004
6 h on coughing	2 (2–3)	3 (2–3)	0 (−1, 0)	0.056	2 (2–3)	3 (2–4)	−1 (−1, −1)	<0.001
24 h on coughing	3 (2–4)	3 (3–4)	0 (−1, 0)	0.103	3 (2–4)	4 (3–5)	−1 (−1, 0)	<0.001
48 h on coughing	3 (2–4)	3 (3–4)	0 (−1, 0)	0.386	3 (2–4)	4 (3–4)	−1 (−1, 0)	0.009
Incisional pain scores								
1 h at rest	0 (0–1)	0 (0–0)	0 (0, 0)	0.560	0 (0–0)	0 (0–1)	0 (0, 0)	0.032
6 h at rest	1 (1–2)	1 (1–1)	0 (0, 0)	0.305	1 (0–1)	1 (1–2)	0 (−1, 0)	0.010
24 h at rest	2 (1–2)	2 (1–2)	0 (0, 1)	0.202	2 (1–2)	2 (1–2)	0 (0, 0)	0.286
48 h at rest	2 (1–2)	2 (1–2)	0 (0, 0)	0.362	2 (1–2)	2 (1–2)	0 (0, 0)	0.768
1 h on coughing	1 (1–2)	1 (0–2)	0 (0, 1)	0.308	1 (0–1)	1 (1–2)	0 (−1, 0)	0.007
6 h on coughing	3 (2–3)	2 (2–3)	0 (0, 1)	0.128	2 (2–3)	3 (2–3)	0 (−1, 0)	0.007
24 h on coughing	3 (3–4)	3 (2–4)	0 (0, 1)	0.303	3 (2–4)	3 (3–4)	0 (−1, 0)	0.215
48 h on coughing	3 (3–4)	3 (2–4)	0 (0, 1)	0.154	3 (2.25–4)	3 (3–4)	0 (0, 0)	0.539
PCA consumption, mL								
0–24 h	28 (24–30)	26 (24–34)	0 (0, 4)	0.242	25 (24–30)	28 (24–37)	−2 (−4, 0)	0.049
24–48 h	24 (24–34)	24 (24–30)	0 (0 to 2)	0.599	24 (24–30)	24.5 (24–40)	0 (−6 to 0)	0.197
Rescue analgesia	15 (25.4%)	10 (16.9%)	1.50 (0.75, 3.05)	0.260	8 (13.3%)	17 (29.3%)	0.45 (0.21, 0.94)	0.034
Time to first flatus, h	67 (48–84.5) (n = 58)	60 (42–80)	4 (−6, 14)	0.394	62.5 (48–79)	64 (41–86) (n = 57)	2 (−6, 14)	0.597
Sedation	1 (1.7%)	1 (1.7%)	1.00 (0.11, 9.45)	>0.999	2 (3.3%)	0	–	0.496
Nausea and vomiting	6 (10.2%)	6 (10.2%)	1.00 (0.36, 2.80)	>0.999	6 (10%)	6 (10.3%)	0.97 (0.35, 2.70)	0.951
Antiemetic use	1 (1.7%)	0	–	>0.999	1 (1.7%)	0	–	>0.999
Respiratory depression	0	0	–	–	0	0	–	–
Dizziness	8 (13.6%)	7 (11.9%)	1.14 (0.46, 2.87)	0.782	8 (13.3%)	7 (12.1%)	1.11 (0.44, 2.77)	0.837
Severe complications	2 (3.4%)	1 (1.7%)	2.00 (0.27, 15.1)	>0.999	1 (1.7%)	2 (3.4%)	0.48 (0.06, 3.61)	0.615
Length of hospital stay, d	9 (8–11)	9 (7–12)	0 (−1, 1)	0.692	9 (7.25–11.75)	9 (7.75–10)	0 (−1, 1)	0.603

Notes: Data are mean (SD), median (IQR), or n (%). Effect size is presented as median/mean difference or relative risk with 95% confidence interval. Severe complications included stroke, reoperation, anastomotic leakage, and death.
[a]Secondary outcomes are exploratory. No multiple comparison corrections were applied.
Abbreviations: QoR, quality of recovery; PCA, patient-controlled analgesia; QLB, quadratus lumborum block; TAPB, transverse abdominis plane block.

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Table 4 Proportion of Patients with Clinically Relevant Pain (Numerical Rating Scale Pain Scores ≥ 4)

	Regional Block				Analgesic Regimen			
	QLB (n = 59)	TAPB (n = 59)	Relative Risk (95% CI)	*P* value	Oxycodone (n = 60)	Sufentanil (n = 58)	Relative Risk (95% CI)	*P* value
Visceral pain								
1 h at rest	0	0	–	>0.999	0	0	–	>0.999
6 h at rest	0	2 (3.4%)	–	0.496	0	2 (3.4%)	–	0.240
24 h at rest	1 (1.7%)	2 (3.4%)	0.50 (0.05, 5.37)	>0.999	0	3 (5.2%)	–	0.116
48 h at rest	0	1 (1.7%)	–	>0.999	0	1 (1.7%)	–	0.492
1 h on coughing	3 (5.1%)	2 (3.4%)	1.50 (0.26, 8.65)	>0.999	0	5 (8.6%)	–	0.026
6 h on coughing	8 (13.6%)	14 (23.7%)	0.57 (0.26, 1.26)	0.156	3 (5%)	19 (32.8%)	0.15 (0.05, 0.49)	<0.001
24 h on coughing	22 (37.3%)	28 (47.5%)	0.79 (0.51, 1.20)	0.264	16 (26.7%)	34 (58.6%)	0.46 (0.28, 0.73)	<0.001
48 h on coughing	22 (37.3%)	26 (44.1%)	0.85 (0.55, 1.31)	0.454	18 (30%)	30 (51.7%)	0.58 (0.37, 0.92)	0.016
Incisional pain								
1 h at rest	0	0	–	>0.999	0	0	–	>0.999
6 h at rest	0	1 (1.7%)	–	>0.999	0	1 (1.7%)	–	0.492
24 h at rest	2 (3.4%)	1 (1.7%)	2.00 (0.19, 21.46)	>0.999	1 (1.7%)	2 (3.4%)	0.48 (0.04, 5.19)	0.615
48 h at rest	0	0	–	>0.999	0	0	–	>0.999
1 h on coughing	2 (3.4%)	2 (3.4%)	1.00 (0.15, 6.87)	>0.999	0	4 (6.9%)	–	0.055
6 h on coughing	10 (16.9%)	8 (13.6%)	1.25 (0.53, 2.95)	0.609	5 (8.3%)	13 (22.4%)	0.37 (0.14, 0.98)	0.033
24 h on coughing	23 (39%)	20 (33.9%)	1.15 (0.71, 1.86)	0.566	19 (31.7%)	24 (41.4%)	0.77 (0.47, 1.24)	0.273
48 h on coughing	27 (45.8%)	19 (32.2%)	1.42 (0.90, 2.26)	0.131	23 (38.3%)	23 (39.7%)	0.97 (0.62, 1.52)	0.883

Notes: Data are n (%).
Abbreviations: QLB, quadratus lumborum block; TAPB, transverse abdominis plane block.

Table 5 Exploratory Analyses of Outcomes Across Four Groups

	QLB-oxycodone (n = 30)	QLB-sufentanil (n = 29)	TAPB-oxycodone (n = 30)	TAPB-sufentanil (n = 29)	*P* value
QoR-15 score at 24 h	102.7 (7.8)	101.4 (8.1)	104.7 (6.0)	100.3 (8.5)	0.155
QoR-15 score at 48 h	109.2 (7.1)	109.9 (8.5)	111.3 (6.6)	109.0 (8.0)	0.652
QoR-15 score at 72 h	116.1 (7.2)	116.3 (6.9) (n = 27)	118.1 (5.2)	116.5 (7.9)	0.658
Visceral pain scores					
1 h at rest	0 (0–0)	0 (0–1)	0 (0–0)	0 (0–1)	0.022
6 h at rest	1 (0–1)[a]	1 (1–2)	1 (0–1)[b]	2 (1–2)	0.002
24 h at rest	1 (1–2)[c]	2 (1–2)	2 (1–2)	2 (2–3)	0.001
48 h at rest	2 (1–2)	2 (1–2)	2 (1–2)	2 (2–2.5)	0.051
1 h on coughing	1 (0–1)[d]	1 (1–2)	1 (0–2)	1 (1–2)	0.017
6 h on coughing	2 (1–2)[e, f]	3 (2–3.5)	2 (2–3)[g]	3 (2–4.5)	<0.001
24 h on coughing	2.5 (2–3)[h, i]	4 (3–4)	3 (2.75–4)	4 (3–5)	<0.001
48 h on coughing	3 (2–4)	3 (3–4)	3 (2–4)	4 (3–4)	0.056
Incisional pain scores					
1 h at rest	0 (0–0)	0 (0–1)	0 (0–0)	0 (0–1)	0.156
6 h at rest	1 (0–2)	1 (1–2)	1 (0.75–1)	1 (0.5–2)	0.053
24 h at rest	2 (1–2)	2 (1–2.5)	1 (1–2)	2 (1–2)	0.239
48 h at rest	2 (1–2)	2 (1–2)	2 (1–2)	2 (1–2)	0.675
1 h on coughing	1 (0.75–1.25)	1 (1–2)	1 (0–1)	1 (1–2)	0.028
6 h on coughing	2 (2–3)	3 (2–3)	2 (2–2)[j]	2 (2–3.5)	0.022
24 h on coughing	3 (2–4)	3 (3–5)	3 (2.75–3.25)	3 (2–4)	0.455
48 h on coughing	3 (2–4)	3 (3–4)	3 (2.75–4)	3 (2–4)	0.481

(*Continued*)

Table 5 (Continued).

	QLB-oxycodone (n = 30)	QLB-sufentanil (n = 29)	TAPB-oxycodone (n = 30)	TAPB-sufentanil (n = 29)	*P* value
PCA consumption, mL					
0–24 h	26 (24–30)	28 (26–36)	24 (24–30)	26 (24–37)	0.135
24–48 h	24 (24–33)	26 (24–40)	24 (24–28)	24 (24–40)	0.584
Rescue analgesia	6 (20%)	9 (31%)	2 (6.7%)	8 (27.6%)	0.102
Time to first flatus, h	67 (48.8–84.5)	66 (42–86)	61 (42.8–72.5)	60 (40–86.5)	0.752
Sedation	1 (3.3%)	0	1 (3.3%)	0	0.579
Nausea and vomiting	4 (13.3%)	2 (6.9%)	2 (6.7%)	4 (13.8%)	0.685
Antiemetic use	1 (3.3%)	0	0	0	0.398
Respiratory depression	0	0	0	0	–
Dizziness	6 (20%)	2 (6.9%)	2 (6.7%)	5 (17.2%)	0.279
Severe complications	1 (3.3%)	1 (3.5%)	0	1 (3.5%)	0.789
Length of hospital stay, d	9 (8–11.25)	9 (7–10)	9 (7–12)	10 (8–11.5)	0.475

Notes: Data are mean (SD), median (IQR), or n (%). [a] vs TAPB-sufentanil: $P = 0.002$. [b] vs TAPB-sufentanil: $P = 0.020$. [c] vs TAPB-sufentanil: $P < 0.001$. [d] vs TAPB-sufentanil: $P = 0.014$. [e] vs QLB-sufentanil: $P = 0.004$. [f] vs TAPB-sufentanil: $P < 0.001$. [g] vs TAPB-sufentanil: $P = 0.008$. [h] vs QLB-sufentanil: $P = 0.016$. [i] vs TAPB-sufentanil: $P < 0.001$. [j] vs QLB-sufentanil: $P = 0.017$. Severe complications included stroke, reoperation, anastomotic leakage, and death.
Abbreviations: QoR, quality of recovery; PCA, patient-controlled analgesia; QLB, quadratus lumborum block; TAPB, transverse abdominis plane block.

This study has some limitations. First, the single-center design limits generalizability to other healthcare settings. Second, the trial was powered to detect main effects, not moderate interactions; the non-significant interaction test should therefore be interpreted cautiously as supportive rather than definitive. Third, although PCA syringes were identical in appearance and outcome assessors were masked, partial blinding (anesthesiologists aware of regional block allocation) may introduce performance bias, and no formal assessment of blinding integrity was performed. Fourth, all regional blocks were performed after anesthesia induction; although ultrasound findings confirmed correct needle placement and local anesthetic spread, sensory blockade and block success rate were not assessed, precluding confirmation of block efficacy. Fifth, rescue analgesia was not standardized; the choice between tramadol and dezocine was at the attending physician's discretion. Dezocine possesses κ-opioid and partial μ-opioid activity, which could theoretically confound the interpretation of opioid-specific effects. However, dezocine was used in only 1 of 25 rescue episodes (4%), so its potential impact on the overall comparison is negligible. Postoperative morphine-equivalent opioid exposure was comparable between groups. Sixth, pain scores were analyzed at each time point using independent tests; a longitudinal mixed-effects analysis was not prespecified. Finally, we assessed early recovery but not chronic postsurgical pain or persistent postoperative opioid use,[26] and the findings may not apply to open, emergency, or higher-risk surgery.

In conclusion, within comprehensive multimodal analgesia, neither QLB nor oxycodone demonstrated superior recovery compared with TAPB or sufentanil. Oxycodone was associated with lower visceral pain scores and reduced rescue analgesia; however, these findings are exploratory and should be considered hypothesis-generating rather than definitive evidence for selective use in visceral-dominant pain.

Data Sharing Statement

The data supporting the results reported in the manuscript can be assessed with approval from the corresponding author on reasonable request.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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