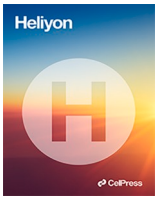
Heliyon 9 (2023) e20878

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



The effects of ultrasound-guided QLB and TAPB combined with opioid-free anesthesia (OFA) on clinical efficacy of the patients undergoing abdominal surgery

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ARTICLE INFO

Keywords:
Transversus abdominis plane block
Quadratus lumborum block
Opioid-free anesthesia
Clinical efficacy
Abdominal surgery

ABSTRACT

Background: Although opioids provide effective analgesia for abdominal surgery, they also present serious unwanted side effects. Ultrasound-guild quadratus lumborum block (QLB) and transversus abdominis plane block (TAPB) have been proven to offer long-lasting and efficient analgesia during abdominal surgery. However, the clinical efficacy of ultrasound-guided QLB and TAPB combined with opioid-free anesthesia (OFA) in abdominal surgery remains unclear.

Objective: This study aimed to investigate the impact of ultrasound-guided QLB and TAPB combined with opioid-free anesthesia (OFA) on the clinical efficacy of abdominal surgery.

Methods: A total of 122 patients scheduled for abdominal surgery at People's Hospital of Wanning between March 2021 and April 2022 were enrolled in this study. Participants were randomly divided into two groups: the experimental group (QLB/TAPB + OFA, 62 patients) and the control group (opioid anesthesia, 60 patients). The clinical efficacy of the QLB/TAPB combined with OFA technique was evaluated by analyzing patients' vital signs, postoperative consciousness recovery time, numeric rating scale (NRS) score, and immune function in both groups.

Results: We observed that systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) in experimental group were significantly higher than those in control group after induction ($p < 0.05$). Heart rate (HR) in experimental group was significantly lower than in the control group at intraoperative 1h ($p < 0.05$). Additionally, bispectral index (BIS), state entropy (SE), and response entropy (RE) levels in the experimental group were significantly higher than those in the control group ($p < 0.05$). Furthermore, extubation and awakening time were significantly shorter in the experimental group compared to the control group ($p < 0.05$). The NRS scores in the experimental group were markedly lower than those in the control group. Moreover, IL-6 and CRP levels in the experimental group were obviously lower than in the control group after postoperative 1d ($p < 0.05$). Interestingly, IL-6 ($p < 0.001$), CRP ($p < 0.001$), and PCT ($p = 0.037$) levels in female patients of the experimental group were all significantly lower than those in the control group after postoperative 1d.

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https://doi.org/10.1016/j.heliyon.2023.e20878
Received 5 March 2023; Received in revised form 3 October 2023; Accepted 9 October 2023
Available online 11 October 2023

Conclusions: Ultrasound-guided QLB and TAPB combined with OFA technique can reduce pain intensity and enhance the patients' immune function in abdominal surgery.

1. Introduction

Opioids are the most commonly used narcotic analgesics in clinical practice. Patients often require opioids for pain relief during the perioperative period, especially in abdominal surgery [1]. However, the use of opioids can lead to various side effects, including oversedation, postoperative nausea, vomiting, urinary retention, constipation, hyperalgesia, respiratory depression, and immunosuppression [2–4]. Opioids can have various effects on immune function, such as modulation of cytokines, interaction with immune cells, impacting on the neuroendocrine system, and vascular permeability. It has been reported that opioids can promoted the production of pro-inflammatory cytokines (including IL-6), and acute-phase proteins (such as C-reactive protein (CRP) and serum procalcitonin (PCT), which can subsequently impact the overall immune response [5–7]. This inflammatory response can modulate immune function and contribute to postoperative complications such as infections and delayed wound healing. Opioid-free anesthesia (OFA) is a novel multimode analgesia technology that aims to replace opioids in surgical anesthesia by combining non-opioid analgesics and/or nerve block techniques. This approach aims to reduce opioid-related adverse effects. Currently, multimodal analgesia techniques have been widely used in surgical procedures [8,9]. Ultrasound-guided transversus abdominis plane block (TAPB) and quadratus lumborum block (QLB) are effective analgesic methods used in anesthesia combined with multimodal analgesia techniques. TAPB is a nerve block technique that blocks sensory nerves by injecting local anesthetics into the plane between the transverse abdominis and the internal oblique muscles [10–12]. Although TAPB can effectively relieve somatic pain in patients undergoing minimally invasive laparoscopic surgery, it is not suitable for visceral analgesia [13,14]. QLB is another nerve block technique that blocks sensory nerves by injecting local anesthetics into an interfascial plane between the quadratus lumborum and the psoas muscles [15]. Due to its anatomical advantages, QLB can achieve both somatic and visceral analgesia, and provide extensive, long-lasting, and more effective postoperative analgesia during laparoscopic obstetric procedures [16,17]. Many studies have compared the analgesic efficacy of TAPB and QLB in abdominal surgery, but the results have been inconsistent [18–21]. Furthermore, the use of TAPB or QLB can reduce opioid consumption and improve analgesia in caesarean section and laparoscopic surgeries [22–24]. TAPB or QLB, combined with the general anesthesia (containing opioids), has been widely used in abdominal surgeries such as laparoscopic colorectal surgery [25], laparoscopic surgery [26], laparoscopic sleeve gastrectomy [27], and abdominal hysterectomy [28]. However, the roles of ultrasound-guided QLB and TAPB combined with OFA technique in the clinical efficacy of abdominal surgery are unclear.

In this study, we aimed to determine the influence of ultrasound-guided QLB and TAPB combined with OFA technique on clinical

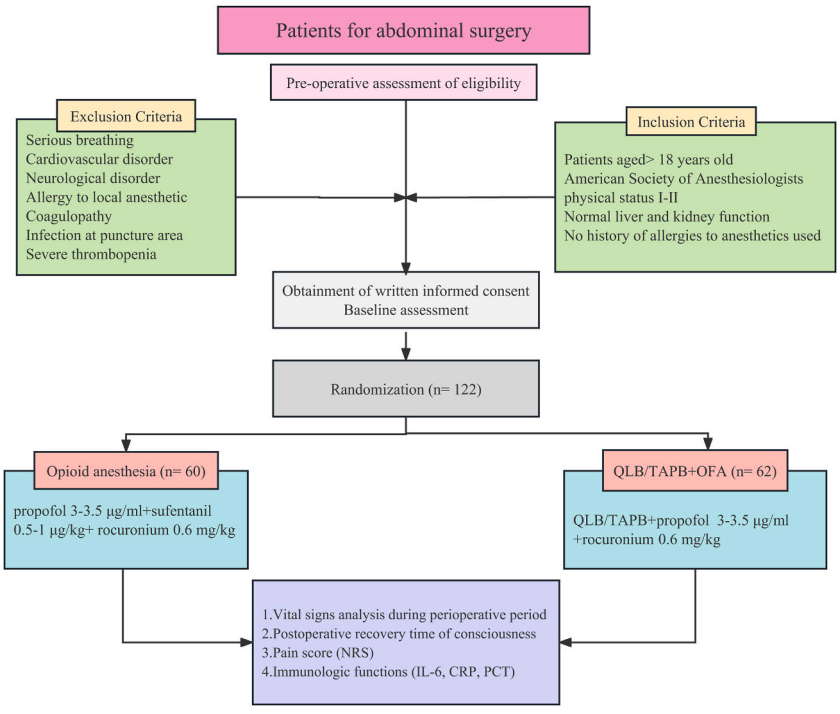

Fig. 1. Flow chart of the study. QLB, quadratus lumborum block; TAPB, transversus abdominis plane block; OFA, opioid-free anesthesia; CRP, C-reactionprotein; PCT, procalcitonin.

efficacy (including patients' vital signs, postoperative consciousness recovery time, NRS score, and immunologic functions) of the 122 patients undergoing abdominal surgery through the random number table method. We also analyzed the clinical efficacy of ultrasound-guided QLB and TAPB combined with OFA technique separately in both male and female patients. The flow diagram of the study is presented in Fig. 1.

2. Methods

2.1. Study participants

Our project was approved by the local ethics committee of People's Hospital of Wanning (No. SL-2021-002), and written informed agreement was obtained from each participant prior to the study. The trial was registered in Chinese Clinical Trial Registry (No. ChiCTR2300072842) and the National Health Security Information Platform's Medical Research Registration and Record Information System (No. MR-46-23-010,135). Before starting the study, we used G power V3.1.9.7 software to estimate the necessary sample size. With a power of 0.90, an effect size of 0.80, and an alpha error probability of 0.05, it was determined that at least 34 individuals were required in each group. In this study, we recruited a total of 122 patients who were scheduled for abdominal surgery (including appendectomy, cholecystectomy, colectomy, exploratory laparotomy, ectopic pregnancy, myomectomy, ovarian cyst surgery, holmium laser lithotripsy for kidney stones, ureteral stone lithotripsy, and percutaneous nephrolithotomy) from People's Hospital of Wanning between March 2021 and April 2022. According to the random number table method, the participants included in this study were divided into 2 groups, including QLB/TAPB + OFA group (62 patients, experimental group) and the opioid anesthesia group (60 patients, control group). The inclusion criteria were as follows: 1) patients aged> 18 years old; 2) American Society of Anesthesiologists physical status I-II; 3) normal liver and kidney function; 4) no history of allergies to anesthetics used in this study. Patients with serious breathing, cardiovascular, or neurological disorder, allergy to local anesthetic, coagulopathy, infection at puncture area, and severe thrombopenia were excluded. Additionally, contraindications of OFA, such as cardiac arrhythmias, shock, hypovolemia, circulatory insufficiency, and unstable coronary artery disease, were also excluded. The characteristics of patients, such as age, gender, height, weight, body mass index (BMI), and past medical history, were obtained from their medical records. The assessment of patient satisfaction was conducted through face-to-face questionnaires at 24 and 48 h after the surgery. Moreover, regular follow-up telephone calls were made to monitor the patients' postoperative condition. The examination and surgical methods used in this study were safe methods for clinical application, and the study methods followed the tenets of the Declaration of Helsinki for medical research.

2.2. Analgesic technique and general anesthesia

In the experiment group, ultrasound-guided bilateral TAPB and QLB techniques were performed before general anesthesia to ensure successful blockage. Before the induction of general anesthesia, 5 mg of tropisetron was administered via intravenous injection, followed by an intramuscular injection of 0.1 mg/kg penehyclidine hydrochloride. Subsequently, dexmedetomidine was slowly infused at a rate of 0.5 μg/kg/h over a period of 10 min. Under ultrasound guidance, a high-frequency linear array probe was placed for single or double-sided TAPB/QLB. The nerve block needle was inserted on each side, moving from the outside to the inside, and 1 mL of 0.9% normal saline was injected, respectively. After confirming the correct needle tip position, 20 mL of 0.20% ropivacaine was injected on each side (totaling four points), respectively. The blocking effect was assessed by needle puncture after 15 min, and general anesthesia was performed after successful blocking. All block operations were performed by an experienced anesthesiologist familiar with the application of ultrasound-guided block. Anesthesia was induced with target-controlled infusion of propofol at 3–3.5 μg/ml, followed by an intravenous injection of rocuronium at a dose of 0.6 mg/kg. After the induction of general anesthesia, a laryngeal mask was inserted, with the size determined by patients' body weight. Propofol was used to maintain general anesthesia during the operation, and rocuronium 0.3 mg/kg was intermittently administered as needed.

In the control group, before the induction of general anesthesia, 5 mg of tropisetron was administered via intravenous injection, followed by an intramuscular injection of 0.1 mg/kg penehyclidine hydrochloride. Subsequently, dexmedetomidine was slowly infused at a rate of 0.5 μg/kg/h over a period of 10 min. Anesthesia was induced with 3–3.5 μg/ml propofol, 0.5–1 μg/kg sufentanil, and 0.6 mg/kg rocuronium. After the induction of general anesthesia, a laryngeal mask was inserted, with the size determined by patients' body weight. Intraoperatively, sufentanil, and propofol was used to maintain general anesthesia. During the entire surgery, 0.3 mg/kg rocuronium was intermittently administered as needed.

For patients in both groups, the dosages of anesthetic used during surgery were determined by patients' body weight. The ventilation tidal volume was set at 5–8 ml/kg, and positive end-expiratory pressure (PEEP) was 5–6 mmHg. Besides, the respiratory rate was maintained at 12–15 times/min, $PetCO_2$ at 35–45 mmHg, and bispectral index (BIS) at 40–60 during the surgery. Anesthesia was discontinued during skin suturing, and 50 mg flurbiprofen axetil was intravenously injected. This was followed by patient-controlled intravenous analgesia (PCIA) consisting of 50 mg esketamine, 250 mg flurbiprofen, and 5 mg tropisetron, diluted in 100 ml of 0.9% normal saline, at a rate of 2 ml/h, with an additional bolus dose of 0.5 ml every 15 min.

2.3. Observation indicators

The vital signs of patients, including systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), bispectral index (BIS), state entropy (SE), response entropy (RE), and oxygen saturation (SPO_2), were monitored and recorded at different time points, including before anesthesia, after anesthesia, skin incision, intraoperative 1h, and extubation. This

study also recorded anesthesia time, and the dosages of anesthetic used in the surgery. In addition, the postoperative recovery time of consciousness including extubation and awakening time was recorded, respectively. The Numeric Rating Scale (NRS score) for pain was compared between the two groups at various time points: pre-surgery, and then 1 h, 12 h, 24 h, and 48 h post-surgery. The NRS score was: 0 no pain, 1–3 mild pain, 4–6 moderate pain, 7–10 severe pain [29]. The levels of IL-6, C-reactionprotein (CRP) and procalcitonin (PCT) from venous blood samples of all patients were measured before and 24 h after surgery. Additionally, we carried out a comparison of the differences in the observed indicators between the experimental and control groups, with stratification by sex.

2.4. Statistical analysis

Data analysis was analyzed by SPSS 22.0 statistical software. Continuous data were analyzed for normality using the Kolmogorov-Smirnov test, and normally distributed parameters were analyzed using the analysis of variance (ANOVA) method. Normally distributed data were expressed as mean ± standard deviation (SD). Differences in continuous variables between the two groups were compared by using Student's *t*-test, and categorical variable such as gender was tested using Pearson's X^2 test. Comparisons between multiple groups were conducted using one-way ANOVA analysis. A $p < 0.05$ indicated statistical significance.

3. Results

3.1. Patient demographic and surgical characteristics

In this study, we selected 122 patients (62 patients in the experimental group and 60 patients in the control group) undergoing abdominal surgery. Table 1 listed the basic characteristics of the study participants. The mean age was 51.5 ± 16.79 years in the experimental group and 54.2 ± 13.33 years in the control group. No significant differences were observed in age, gender, height, weight, and BMI between the study groups (all $p > 0.05$). Besides, the time of anesthesia and the consumption of anesthetic (including propofol, rocuronium bromide, and dexmedetomidine) during the surgery showed no statistical differences between the two groups (all $p > 0.05$). Additionally, the satisfaction of patients in the experimental group was superior to that of the control group at 24 h after the operation ($p < 0.001$). Patient satisfaction was higher in the experimental group than in the control group at 48 h after surgery, although this difference was not statistically significant ($p = 0.691$).

3.2. Comparison of patients' vital signs during perioperative period

We compared the vital signs of the study participants during the entire surgery, and the results were shown in Fig. 2 and Table 2. All patient's vital signs showed no significant differences before anesthesia between the groups. The experimental group's SBP ($p = 0.003$), DBP ($p = 0.021$), and MAP ($p = 0.006$) were significantly higher than those of in the control group at after anesthesia. For HR, it was found that the experimental group was significantly lower than the control group at intraoperative 1h ($p = 0.017$). In addition, the level of BIS ($p = 0.009$), SE ($p = 0.021$), and RE ($p = 0.001$) in the experimental group were significantly higher compared to the control group at the time of extubation.

Table 1
The basic characteristics of study participants.

Variables	Control (n = 60)	Experiment (n = 62)	x^2/t	*p*
Gender (n, %)			1.656	0.198[a]
Male	36 (60.0 %)	30 (48.4 %)		
Female	24 (40.0 %)	32 (51.6 %)		
Age (years) (mean ± SD)	54.2 ± 13.33	51.5 ± 16.79	0.982	0.328[b]
Height (cm) (mean ± SD)	162.9 ± 7.91	160.95 ± 7.83	1.367	0.174[b]
Weight (kg) (mean ± SD)	60.78 ± 12.23	60.58 ± 11.58	0.090	0.928[b]
BMI (kg/m^2) (mean ± SD)	22.81 ± 3.87	23.27 ± 3.62	−0.685	0.495[b]
Anesthetic time (min) (mean ± SD)	112.45 ± 72.83	135.23 ± 84.98	−1.587	0.115[b]
Details of anesthetic				
Propofol consumption (mg) (mean ± SD)	675 ± 377.46	797.34 ± 472.76	−1.576	0.118[b]
Rocuronium bromide consumption (mg) (mean ± SD)	67.42 ± 26.48	73.44 ± 33.58	−1.097	0.275[b]
Dexmedetomidine consumption (ug) (mean ± SD)	32.55 ± 11.04	37.42 ± 18.21	−1.792	0.076[b]
Past medical history			0.961	0.327[a]
No	40 (66.7 %)	36 (58.1 %)		
Yes	20 (33.3 %)	26 (41.9 %)		
24h postoperative satisfaction				
Satisfaction	32 (53.3 %)	56 (90.3 %)	20.754	**< 0.001**[a]
Dissatisfaction	28 (46.7 %)	6 (9.7 %)		
48h postoperative satisfaction				
Satisfaction	55 (91.7 %)	58 (93.5 %)	0.158	0.691[a]
Dissatisfaction	5 (8.3 %)	4 (6.5 %)		

[a] Pearson's X^2 test is used.
[b] Student's *t*-test is used.

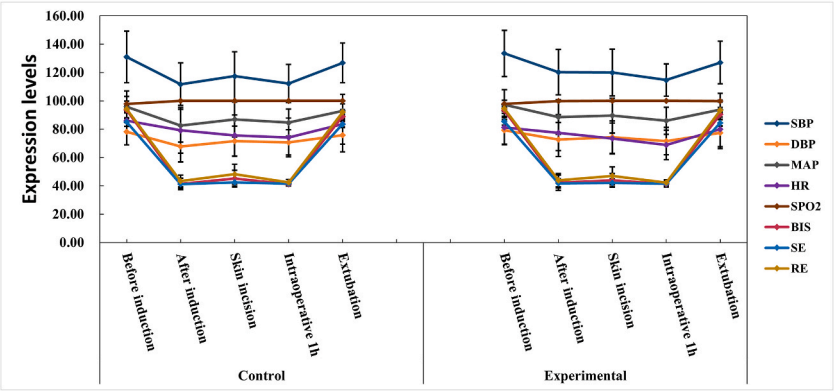

Fig. 2. The patients' vital signs during perioperative period.

Table 2
Comparison of the vital signs between the experimental and control group.

Variables		Control group	Experimental group	*t*	p^a	p^b	p^c
SBP (mmHg)	Before anesthesia	130.97 ± 18.22	133.5 ± 16.31	−0.81	0.420	<0.001	<0.001
	After anesthesia	111.77 ± 15.1	120.23 ± 16	−3.001	**0.003**		
	Skin incision	117.42 ± 17.29	119.97 ± 16.43	−0.836	0.405		
	Intraoperative 1h	112.25 ± 13.44	114.69 ± 11.38	−1.085	0.280		
	Extubation	126.83 ± 13.96	127.02 ± 15.01	−0.07	0.945		
DBP (mmHg)	Before anesthesia	78.1 ± 9.29	79.26 ± 9.81	−0.669	0.505	<0.001	<0.001
	After anesthesia	67.82 ± 11	72.71 ± 12	−2.346	**0.021**		
	Skin incision	71.52 ± 10.67	74.37 ± 11.5	−1.42	0.158		
	Intraoperative 1h	70.68 ± 8.88	71.66 ± 9.67	−0.581	0.562		
	Extubation	75.82 ± 11.91	77.39 ± 11.15	−0.752	0.453		
MAP (mmHg)	Before anesthesia	95.77 ± 11.12	97.32 ± 10.53	−0.794	0.429	<0.001	<0.001
	After anesthesia	82.5 ± 11.54	88.56 ± 12.26	−2.811	**0.006**		
	Skin incision	86.83 ± 12.29	89.58 ± 12.35	−1.231	0.221		
	Intraoperative 1h	84.63 ± 9.54	85.94 ± 9.53	−0.754	0.452		
	Extubation	92.85 ± 11.77	93.87 ± 11.48	−0.485	0.629		
HR (bpm)	Before anesthesia	86.02 ± 17.14	81.23 ± 12.22	1.773	0.079	<0.001	<0.001
	After anesthesia	79.15 ± 16.17	77.5 ± 12.72	0.628	0.531		
	Skin incision	75.53 ± 14.46	73.35 ± 10.93	0.941	0.349		
	Intraoperative 1h	74.22 ± 13.66	68.9 ± 10.37	2.424	**0.017**		
	Extubation	83.65 ± 14.23	80 ± 12.35	1.515	0.132		
SPO2 (%)	Before anesthesia	97.88 ± 1.9	97.84 ± 2.51	0.111	0.912	<0.001	<0.001
	After anesthesia	99.97 ± 0.18	99.85 ± 0.47	1.732	0.087		
	Skin incision	99.98 ± 0.13	99.95 ± 0.38	0.612	0.542		
	Intraoperative 1h	100 ± 0	100 ± 0	/	/		
	Extubation	100 ± 0	99.85 ± 0.67	1.696	0.095		
BIS	Before anesthesia	93.4 ± 1.94	93.35 ± 2.27	0.118	0.906	<0.001	<0.001
	After anesthesia	41.4 ± 3.95	42.21 ± 5.41	−0.946	0.346		
	Skin incision	45.12 ± 5.96	43.85 ± 4.89	1.281	0.203		
	Intraoperative 1h	41.2 ± 1.25	41.26 ± 2.01	−0.193	0.848		
	Extubation	89 ± 2.48	90.39 ± 3.25	−2.642	**0.009**		
SE	Before anesthesia	85 ± 2.97	85.5 ± 2.63	−0.985	0.327	<0.001	<0.001
	After anesthesia	41.12 ± 2.74	41.77 ± 3.29	−1.198	0.233		
	Skin incision	42.43 ± 2.51	42.13 ± 2.97	0.61	0.543		
	Intraoperative 1h	41.47 ± 1.35	41.5 ± 1.8	−0.116	0.908		
	Extubation	83.52 ± 1.96	84.44 ± 2.35	−2.34	**0.021**		
RE	Before anesthesia	94.23 ± 2.12	94.55 ± 2.14	−0.817	0.416	<0.001	<0.001
	After anesthesia	43.38 ± 4.15	43.89 ± 4.68	−0.628	0.531		
	Skin incision	48.18 ± 7.05	47.05 ± 6.43	0.929	0.355		
	Intraoperative 1h	42.48 ± 1.96	42.26 ± 2.06	0.618	0.538		
	Extubation	92.03 ± 1.83	93.24 ± 1.99	−3.488	**0.001**		

SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, HR: heart rate, BIS: bispectral index, SE: state entropy, RE: response entropy.
The p^a value was calculated by Student's *t*-test between control and experimental group.
The *pb* value was calculated by one-way ANOVA analysis among control group.
The *pc* value was calculated by one-way ANOVA analysis among experimental group.
Bold values are statistically significant ($p < 0.05$).

Table 3
Comparison of the vital signs between the two groups under sex-based stratification.

Variables		Control group	Experimental group	*t*	*p*
Male					
SBP (mmHg)	Before anesthesia	132.5 ± 18.56	135.7 ± 14.45	−0.769	0.445
	After anesthesia	114.14 ± 16.01	122.9 ± 16.44	−2.237	**0.025**
	Skin incision	121.58 ± 17.55	122.47 ± 18.14	−0.201	0.842
	Intraoperative 1h	112.72 ± 13.62	115.1 ± 11.86	−0.748	0.457
	Extubation	126.61 ± 13.5	128.43 ± 13.51	−0.677	0.499
DBP (mmHg)	Before anesthesia	80.19 ± 9.22	80.5 ± 8.37	−0.140	0.889
	After anesthesia	68.78 ± 11.84	75 ± 10.72	−2.469	**0.014**
	Skin incision	74.28 ± 11.57	76.63 ± 12.14	−0.805	0.424
	Intraoperative 1h	70.89 ± 9.31	71.43 ± 11.4	−0.214	0.832
	Extubation	76.94 ± 12.6	79.87 ± 10.06	−1.026	0.309
MAP (mmHg)	Before anesthesia	97.64 ± 11.2	98.83 ± 9.05	−0.470	0.640
	After anesthesia	83.92 ± 12.38	90.97 ± 11.12	−2.546	**0.011**
	Skin incision	90.08 ± 12.88	91.93 ± 13.1	−0.576	0.566
	Intraoperative 1h	84.89 ± 9.78	85.93 ± 11.22	−0.404	0.688
	Extubation	93.53 ± 12.14	95.97 ± 10.13	−0.875	0.385
HR (bpm)	Before anesthesia	87.06 ± 16.54	80.8 ± 12.57	−1.205	0.228
	After anesthesia	79.69 ± 15.91	77.3 ± 12.74	−0.742	0.458
	Skin incision	74.28 ± 13.88	73.6 ± 12.03	−0.019	0.985
	Intraoperative 1h	73.81 ± 11.98	67.73 ± 11.32	−2.133	**0.033**
	Extubation	82.44 ± 13.36	80.27 ± 13.35	−0.574	0.566
SPO2 (%)	Before anesthesia	97.64 ± 1.87	97.07 ± 2.89	−0.689	0.491
	After anesthesia	99.97 ± 0.17	99.83 ± 0.53	−1.246	0.213
	Skin incision	100 ± 0.00	99.9 ± 0.55	−1.095	0.273
	Intraoperative 1h	100 ± 0.00	100 ± 0.00	/	/
	Extubation	100 ± 0.00	99.8 ± 0.81	−1.561	0.119
BIS	Before anesthesia	93.25 ± 2.01	93.3 ± 2.39	−0.208	0.835
	After anesthesia	41.75 ± 3.60	42.33 ± 4.88	−0.220	0.826
	Skin incision	45.11 ± 5.37	45.17 ± 6.07	−0.006	0.995
	Intraoperative 1h	41.14 ± 1.31	41.4 ± 2.44	−0.917	0.359
	Extubation	89.11 ± 2.47	90.4 ± 2.31	−2.236	**0.025**
SE	Before anesthesia	85.31 ± 2.9	85.6 ± 2.69	−0.669	0.504
	After anesthesia	41.42 ± 2.58	42.1 ± 3.13	−0.972	0.335
	Skin incision	42.36 ± 2.59	42.73 ± 3.19	−0.346	0.730
	Intraoperative 1h	41.67 ± 1.41	41.57 ± 2.08	−0.853	0.393
	Extubation	83.67 ± 1.69	84.7 ± 2.31	−1.862	0.063
RE	Before anesthesia	94.36 ± 2.06	94.8 ± 1.63	−0.947	0.347
	After anesthesia	43.97 ± 4.03	44.6 ± 4.42	−0.603	0.549
	Skin incision	49 ± 7.11	48.17 ± 7.44	−0.542	0.588
	Intraoperative 1h	42.81 ± 2.05	42.37 ± 2.41	−1.196	0.232
	Extubation	92.08 ± 1.79	93.17 ± 2.02	−2.486	**0.013**
Female					
SBP (mmHg)	Before anesthesia	128.67 ± 17.83	131.44 ± 17.86	−0.575	0.568
	After anesthesia	108.21 ± 13.13	117.72 ± 15.41	−2.431	**0.018**
	Skin incision	111.17 ± 15.17	117.63 ± 14.54	−1.948	0.051
	Intraoperative 1h	111.54 ± 13.42	114.31 ± 11.08	−0.846	0.401
	Extubation	127.17 ± 14.91	125.69 ± 16.39	0.347	0.730
DBP (mmHg)	Before anesthesia	74.96 ± 8.65	78.09 ± 11.00	−1.154	0.254
	After anesthesia	66.38 ± 9.65	70.56 ± 12.89	−1.169	0.242
	Skin incision	67.38 ± 7.65	72.25 ± 10.63	−1.650	0.099
	Intraoperative 1h	70.38 ± 8.38	71.88 ± 7.89	−0.686	0.496
	Extubation	74.13 ± 10.84	75.06 ± 11.76	−0.305	0.761
MAP (mmHg)	Before anesthesia	92.96 ± 10.63	95.91 ± 11.72	−0.969	0.337
	After anesthesia	80.38 ± 10.04	86.31 ± 13.00	−1.858	0.069
	Skin incision	81.96 ± 9.69	87.38 ± 11.37	−1.877	0.066
	Intraoperative 1h	84.25 ± 9.38	85.94 ± 7.80	−1.161	0.246
	Extubation	91.83 ± 11.38	91.91 ± 12.45	−0.022	0.982
HR (bpm)	Before anesthesia	84.46 ± 18.24	81.63 ± 12.07	−0.108	0.914
	After anesthesia	78.33 ± 16.85	77.69 ± 12.9	−0.257	0.797
	Skin incision	77.42 ± 15.4	73.13 ± 9.97	−0.829	0.407
	Intraoperative 1h	74.83 ± 16.11	70.00 ± 9.46	−0.920	0.357
	Extubation	85.46 ± 15.55	79.75 ± 11.54	−1.011	0.312
SPO2 (%)	Before anesthesia	98.25 ± 1.92	98.56 ± 1.87	−0.758	0.449
	After anesthesia	99.96 ± 0.20	99.88 ± 0.42	−0.760	0.447
	Skin incision	99.96 ± 0.20	100 ± 0.00	−1.155	0.248
	Intraoperative 1h	100 ± 0.00	100 ± 0.00	/	/
	Extubation	100 ± 0.00	99.91 ± 0.53	−0.866	0.386
BIS	Before anesthesia	93.63 ± 1.86	93.41 ± 2.18	0.395	0.695

(*continued on next page*)

Table 3 (*continued*)

Variables		Control group	Experimental group	*t*	*p*
	After anesthesia	40.88 ± 4.46	42.09 ± 5.93	−0.358	0.720
	Skin incision	45.13 ± 6.88	42.63 ± 3.03	−0.846	0.398
	Intraoperative 1h	41.29 ± 1.16	41.13 ± 1.52	−0.425	0.671
	Extubation	88.83 ± 2.55	90.38 ± 3.97	−1.605	0.109
SE	Before anesthesia	84.54 ± 3.08	85.41 ± 2.63	−1.165	0.244
	After anesthesia	40.67 ± 2.96	41.47 ± 3.45	−0.913	0.365
	Skin incision	42.54 ± 2.43	41.56 ± 2.68	−1.343	0.179
	Intraoperative 1h	41.17 ± 1.20	41.44 ± 1.52	−0.650	0.516
	Extubation	83.29 ± 2.33	84.19 ± 2.40	−1.134	0.257
RE	Before anesthesia	94.04 ± 2.24	94.31 ± 2.53	−0.950	0.342
	After anesthesia	42.5 ± 4.25	43.22 ± 4.89	−0.324	0.746
	Skin incision	46.96 ± 6.93	46.00 ± 5.22	0.000	1.000
	Intraoperative 1h	42.00 ± 1.74	42.16 ± 1.71	−0.371	0.711
	Extubation	91.96 ± 1.92	93.31 ± 1.99	−2.329	**0.020**

SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, HR: heart rate, BIS: bispectral index, SE: state entropy, RE: response entropy.
The *p* value was calculated by Student's *t*-test between control and experimental group.
Bold values are statistically significant ($p < 0.05$).

The results of sex-based stratified analysis were shown in Table 3. In male patients, we discovered that the SBP ($p = 0.025$), DBP ($p = 0.014$), and MAP ($p = 0.011$) in the experimental group were significantly higher compared to the control group after anesthesia. The HR values of the experimental group were significantly higher than those of the control group at intraoperative 1h ($p = 0.033$). Additionally, both the BIS ($p = 0.025$) and RE ($p = 0.013$) in the experimental group were significantly higher than those in the control group at the time of extubation. In female patients, the RE in the experimental group demonstrated elevated levels compared to those in the control group at the time of extubation ($p = 0.020$).3.3 Comparison of postoperative recovery time of consciousness.

We analyzed the postoperative recovery time of consciousness between the study groups (Table 4). We observed that the time of extubation ($p = 0.001$) and awakening ($p = 0.003$) in the experimental group was significantly shorter than in the control group. The stratified results by sex revealed that both the extubation time and awakening time of patients in the experimental group were significantly shorter than those in the control group (all $p < 0.05$). Notably, the awakening time for female patients in the experimental group was reduced by 9 min compared to the control group ($p = 0.008$).

3.3. Comparison of NRS score at 1, 12, 24, and 48 h post-surgery

As shown in Table 5, the pain intensity in both groups diminished over time; however, the pain levels experienced by patients in the experimental group were markedly lower than those of the control group (all $p < 0.05$). Additionally, similar findings were observed in both male and female patients.

3.4. Comparison of immunologic functions in patients

We further evaluated the impact of different anesthesia techniques on immunologic functions in patients. As was presented in Fig. 3 and Table 6, there were no significant difference in IL-6 and CRP concentrations between the two groups at preoperative. However, after postoperative 1d, the levels of IL-6 ($p = 0.001$) and CRP ($p = 0.002$) in experimental group were obviously lower than in control group.

Table 4
The comparison of postoperative recovery time of consciousness between the experimental and control group.

	Group	Extubation time (min)	Awakening time (min)
Total	Control	14.17 ± 9.34	31.77 ± 10.40
	Experiment	9.15 ± 6.36	25.4 ± 12.56
	t	3.481	3.042
	p	**0.001**	**0.003**
Male	Control	13.25 ± 9.87	29.83 ± 10.59
	Experiment	9.33 ± 7.27	24.27 ± 13.15
	t	−2.155	−2.686
	p	**0.031**	**0.007**
Female	Control	15.54 ± 8.49	34.67 ± 9.6
	Experiment	8.97 ± 5.48	26.47 ± 12.1
	t	−3.080	2.733
	p	**0.002**	**0.008**

The *p* value was calculated by Student's *t*-test.
Bold values are statistically significant ($p < 0.05$).

Table 5
Comparison of NRS scores at 1h, 12h, 24h and 48h post-surgery.

	Group	Before the surgery	1h after the surgery	12h after the surgery	24 after the surgery	48h after the surgery	p^a
Total	Control	2.2 ± 0.95	3.97 ± 1.01	3.22 ± 0.85	3.27 ± 1.21	2.35 ± 0.86	**< 0.001**
	Experiment	2.4 ± 0.82	3.23 ± 0.98	2.85 ± 0.94	2.48 ± 0.76	2.02 ± 0.86	**< 0.001**
	t	−1.166	−4.211	−2.061	−4.323	−2.219	
	p^b	0.243	**< 0.001**	**0.039**	**< 0.001**	**0.026**	
Male	Control	2.39 ± 0.96	3.86 ± 1.05	3.19 ± 0.75	3.22 ± 1.22	2.25 ± 0.84	**< 0.001**
	Experiment	2.5 ± 0.94	3.30 ± 0.99	2.87 ± 0.73	2.67 ± 0.71	2.07 ± 0.78	**< 0.001**
	t	−0.434	−2.550	−1.894	−2.634	−1.060	
	p^b	0.665	**0.011**	0.058	**0.008**	0.289	
Female	Control	1.92 ± 0.88	4.13 ± 0.95	3.25 ± 0.99	3.33 ± 1.2	2.50 ± 0.88	**< 0.001**
	Experiment	2.31 ± 0.69	3.16 ± 0.99	2.84 ± 1.11	2.31 ± 0.78	1.97 ± 0.93	**< 0.001**
	t	−1.914	−3.454	−1.208	−3.312	−2.119	
	p^b	0.056	**0.001**	0.227	**0.001**	**0.034**	

NRS: numeric rating scale.
The p^a value was calculated by one-way ANOVA analysis among control or experimental group.
The p^b value was calculated by Student's *t*-test between control and experimental group.
Bold values are statistically significant ($p < 0.05$).

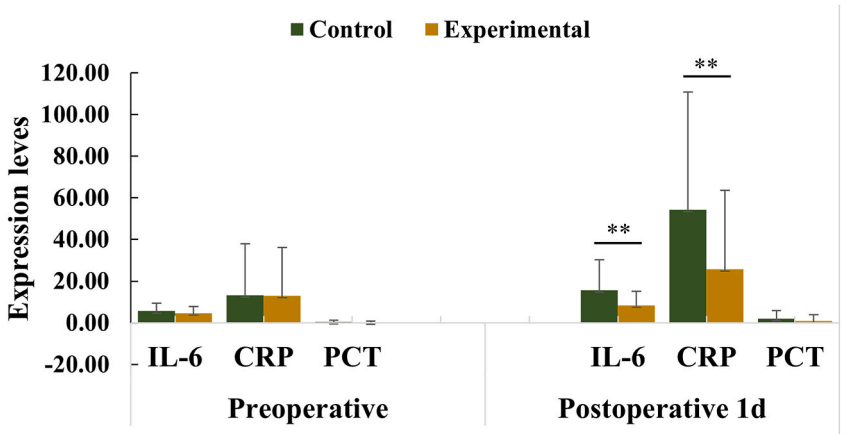

Fig. 3. The expression levels of IL-6, CRP, and PCT at preoperative and postoperative 1d. CRP, C-reactionprotein; PCT, procalcitonin. * indicates $p < 0.05$. ** indicates $p < 0.01$. *** indicates $p < 0.001$.

Table 6
The comparison of immunologic functions between the experimental and control group.

	Group	IL-6 (pg/ml)		CRP (mg/dl)		PCT (ng/ml)	
		Preoperative	Postoperative 1d	Preoperative	Postoperative 1d	Preoperative	Postoperative 1d
Total	Control	5.65 ± 3.79	15.54 ± 14.59	13.16 ± 24.86	54.23 ± 56.58	0.43 ± 0.82	2.06 ± 3.86
	Experiment	4.73 ± 3.22	8.4 ± 6.77	12.94 ± 23.13	25.8 ± 37.75	0.22 ± 0.53	0.99 ± 2.92
	t	1.441	3.449	0.050	3.253	1.611	1.722
	p	0.152	**0.001**	0.960	**0.002**	0.110	0.088
Male	Control	5.39 ± 3.53	12.45 ± 11.62	13.42 ± 24.09	47.91 ± 55.3	0.48 ± 0.89	1.91 ± 3.73
	Experiment	4.85 ± 3.12	9.53 ± 8.77	15.8 ± 22.51	36.53 ± 42.61	0.32 ± 0.7	0.45 ± 0.64
	t	−0.805	−1.217	−1.128	−0.277	−1.001	−2.281
	p	0.421	0.224	0.260	0.782	0.317	**0.023**
Female	Control	6.03 ± 4.21	20.18 ± 17.42	12.77 ± 26.49	63.71 ± 58.32	0.35 ± 0.71	2.27 ± 4.12
	Experiment	4.62 ± 3.36	7.34 ± 3.98	10.26 ± 23.74	15.74 ± 29.83	0.14 ± 0.3	1.5 ± 3.99
	t	−1.192	−4.015	−0.099	−4.115	−0.134	−2.091
	p	0.233	**< 0.001**	0.921	**< 0.001**	0.894	**0.037**

CRP: C-reactive protein, PCT: serum procalcitonin.
The *p* value was calculated by Student's *t*-test.
Bold values are statistically significant ($p < 0.05$).

When stratified by sex, it was found that there were no significant differences in the IL-6, CRP, and PCT for both male and female patients before surgery. In male patients, the PCT levels of the experimental group were significantly lower than those of the control group after postoperative 1d ($p = 0.023$). In female patients, the IL-6 ($p < 0.001$), CRP ($p < 0.001$), and PCT ($p = 0.037$) levels of the experimental group were all significantly lower than those of the control group after postoperative 1d.

4. Discussion

In this study, we investigated the clinical efficacy of ultrasound-guild QLB and TAPB combined with the OFA technique in patients following abdominal surgery. We observed that ultrasound-guided QLB and TAPB combined with the OFA technique can improve postoperative consciousness recovery time, reduce pain intensity, and enhance patients' immune function in abdominal surgery. To the best of our knowledge, this is the first study to combine these two block techniques with the OFA technique in abdominal surgery, which may provide theoretical evidence for replacing the opioid anesthesia in surgical operations.

Maintaining intraoperative hemodynamic stability is an important aspect of anesthesia management. Opioids not only provide analgesia but also maintain hemodynamic stability by inhibiting sympathetic nerves during anesthesia [30]. It has been indicated that TAPB or QLB can provide sympathetic nerve block in OFA to ensure perioperative hemodynamic stability [31,32]. Besides, Tsuchiya et al. indicated that TAP combined with general anesthesia could promote the stability of intraoperative hemodynamics in patients undergoing abdominal surgery [33]. In our study, we observed that the value of MAP decreased in both groups after induction, but the change in the experimental group was significantly lower than that in the control group. This is due to the use of the TAPB and QLB technique in the experimental group, which has an impact on sympathetic nerves, and the OFA technique can maintain hemodynamic stability. Furthermore, we found that patients in both groups were maintained in the state of anesthesia during the operation (BIS: 40–45). However, BIS in the experimental group was significantly higher than that in the control group in extubation, indicating that the anesthesia in the experimental group was more optimal or better controlled.

Opioids are widely used for anesthesia induction, intraoperative and postoperative analgesia, but the incidence of respiratory depression caused by opioids in postoperative patients is gradually increasing. Lee et al. reported that opioid-induced postoperative respiratory depression significantly increased the duration of hospital stay, hospital costs, rehospitalization rates, and in-hospital mortality [34]. Additionally, Cuba et al. found that the incidence of postoperative respiratory depression was 1.52%, and each case showed different risk factors associated with opioid-induced respiratory depression [35]. In our study, we explored the impacts of OFA technique on postoperative recovery time of consciousness for patients. Our study showed that extubation and awakening time in experimental group was significantly shorter than in control group, which suggests that OFA technique can improve postoperative consciousness recovery time.

Surgical trauma can trigger a series of reactions, including nociception and immune response, and the use of anesthetics aims to minimize these effects and maintain the homeostasis of the internal environment. As a potent analgesic, opioids exert certain effects on the immune system while providing analgesia [36]. It has been suggested that opioids may increase the risk of infection in cancer patients [37]. For example, a retrospective study showed that patients anesthetized with morphine were more likely to develop infections than those anesthetized with oxycodone [38]. Opioids can also accelerate the growth and proliferation of cancer cells by affecting host immunity [39]. Moreover, opioids impact the immune response mainly because the body releases cytokines such as IL-2, IL-4, and IL-6 in response to the stimulation of opioid receptors [40]. Therefore, avoiding the use of opioids is essential for the patient's prognosis during surgery. The concept of OFA is to replace opioids with other drugs that have similar analgesic effects but do not affect the immune system. TAPB can block almost all splanchnic nerves passing through the abdomen, which are responsible for postoperative pain [41,42]. This technique can reduce both the use of opioids and the incidence of complications induced by opioids. In our study, we performed TAPB and QLB combined with OFA to avoid the use of opioids. The influence of this technique on the immune response of the patients was evaluated in this study. We observed that the levels of IL-6 and CRP in the experimental group were obviously lower than those in the control group after postoperative 1d, indicating that this technique decreased the inflammatory response, which may be related to the increased of the patients' immune function.

Additionally, we analyzed the clinical efficacy of opioid-free anesthesia separately in males and females. It is noteworthy that the awakening time for female patients in the experimental group was shortened by 9 min compared to the control group. More importantly, the analysis of the inflammatory response revealed that in male patients, only the level of PCT on postoperative 1d was significantly lower in the experimental group compared to the control group. In contrast, for female patients, the levels of IL-6, CRP, and PCT were all significantly lower in the experimental group on postoperative 1d compared to the control group. This highlights the importance of considering gender differences in clinical research.Our study had several limitations. First, as for patient satisfaction, this study did not investigate patient satisfaction, which is a limitation of our research. In future studies, this will be included as one of the measures of surgical success. Second, the study did not determine differences in postoperative complications such as postoperative nausea, vomiting, urinary retention, and constipation between the two groups due to limited information obtained from patients' medical records.

5. Conclusion

In summary, our study revealed that TAPB and QLB combined with OFA technique not only maintained intraoperative hemodynamic stability but also improved postoperative consciousness recovery time and reduced pain intensity. Furthermore, this technique was associated with a decrease in the inflammatory response, which may contribute to enhancing the patients' immune function.

Ethics approval and consent to participate

All procedures performed in this study involving human participants were in accordance with the ethical standards of People's Hospital of Wanning (No. SL-2021-002) and the Declaration of Helsinki's. Informed consent was obtained from all participants in this study.

Consent for publication

Not applicable.

Data availability statement

Data will be made available on request.

Funding

Our study was supported by Hainan Provincial Natural Science Foundation of China (No. 821MS165).

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Jingwei Dai: Conceptualization, Project administration, Writing – original draft. **Shiwen Lin:** Data curation, Methodology, Software. **Xiaoguang Cui:** Data curation, Methodology, Software. **Zhixin Xu:** Formal analysis. **Riyue Zheng:** Formal analysis. **Duozhi Wu:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors thank all participants and volunteers in this study.

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