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Ultrasound image-based paravertebral nerve block combined with general anesthesia in laparoscopic radical resection of esophageal cancer

Paravertebral nerve block versus general anesthesia in the treatment of esophageal cancer: a randomized controlled trial

Tingting Yang[1] and Yuan He[2*]

Abstract

Background Thoracic epidural analgesia (TEA) is the gold standard for analgesia after thoracotomy, but it has limitations. There are few studies on the analgesic effect of ultrasound-guided paravertebral nerve block (PVB) combined with general anesthesia in esophageal cancer surgery.

Methods 52 TLE patients from November 2020 - November 2021 were randomly divided into Group G (general anesthesia, $n=26$) and Group G + P (ultrasound - guided PVB + general anesthesia, $n=26$). General data, intraoperative/postoperative indicators, VAS scores, HR, MAP, NTI, and patient satisfaction were recorded.

Results There were no significant differences in general data such as age, gender, BMI, and ASA grade between the two groups ($P>0.05$). The intraoperative dosages of propofol, remifentanil, and sufentanil in Group G + P were significantly lower than those in Group G, while the dosage of phenylephrine was higher. The extubation time, PACU stay time, and postoperative hospital stay in Group G + P were shorter, the dosage of sufentanil in PACU was less, and the incidence of agitation was lower. The VAS scores of Group G + P in the resting and coughing states at multiple time points such as waking up, leaving the PACU, and after surgery were significantly lower than those of Group G. There was no significant difference in HR between the two groups at most time points during the operation. The MAP of Group G was higher than that of Group G + P at time points t8 and t9, and there were significant differences in NTI between the two groups from t2 to t7. The satisfaction rate of patients in Group G + P (96.14%) was significantly higher than that in Group G (80.76%).

Conclusion Ultrasound - guided PVB combined with general anesthesia reduces opioid use, eases pain, lowers agitation, shortens hospital stay, and boosts satisfaction in esophageal cancer surgery patients.

Keywords Ultrasound, Paravertebral nerve block, General anesthesia, Postoperative pain, Anesthetic effect

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Introduction

Esophageal cancer is one of the common malignant tumors worldwide, posing a serious threat to human health [1–2]. With the advancement of medical technology, thoracoscopic-laparoscopic combined radical resection of esophageal cancer (TLE) has gradually become an important treatment method for esophageal cancer due to its advantages such as minimal invasiveness and rapid recovery [3]. However, surgical anesthesia and postoperative analgesia are crucial for patients' perioperative experience and rehabilitation outcomes. The selection of appropriate anesthesia methods and analgesia regimens remains a key focus of clinical research.

Thoracic epidural analgesia (TEA) has long been regarded as the gold standard for analgesia after thoracotomy. By injecting local anesthetics into the epidural space, it blocks the nerve conduction of the corresponding segments, achieving the purpose of analgesia [4]. However, TEA has many limitations. It can widely inhibit the sympathetic nerve, leading to cardiovascular adverse reactions such as hypotension and bradycardia [5]. It may also affect the intercostal respiratory muscles, impeding the recovery of patients' postoperative respiratory function and increasing the risk of pulmonary complications [6]. Moreover, the epidural puncture operation is somewhat difficult and may cause serious complications such as epidural hematoma and infection, limiting its widespread application in clinical practice [7].

In recent years, ultrasound-guided paravertebral nerve block (PVB) has received increasing attention due to its unique advantages [8–9]. PVB involves injecting local anesthetics into the paravertebral space to block the spinal nerves on that side, resulting in unilateral and segmental anesthesia and analgesia effects [10]. Compared with TEA, PVB has less interference with the body's physiological functions and relatively fewer adverse reactions [11]. Meanwhile, the application of ultrasound technology provides visual guidance for PVB, allowing clear visualization of the anatomical structure of the paravertebral space, improving the accuracy of puncture, reducing damage to surrounding tissues, and enhancing the success rate of nerve block [12].

Many studies on the application of PVB in anesthesia and analgesia cover different types of surgeries and patient groups, but there are relatively few studies on its application in esophageal cancer surgery [13–14]. Our study specifically targets patients undergoing laparoscopic radical resection of esophageal cancer. This targeted approach enables us to accurately evaluate the impact of the combined anesthesia method on this specific patient group. Esophageal cancer surgery has its own characteristics. For example, the anatomical location is complex, and there may be impacts on the respiratory and digestive systems during and after the operation [15]. By focusing on this specific patient group, we can obtain more targeted and clinically relevant results. For example, the study by Aiolfi et al. incorporated a wide range of thoracic surgeries [16]. This broad scope likely concealed the unique impacts that the anesthesia method might have on esophageal cancer patients specifically. In view of the deficiencies in previous studies, we can't help but have many questions regarding the application of PVB combined with general anesthesia in esophageal cancer surgery. Can it ensure the depth of anesthesia while reducing the use of opioid drugs and minimizing drug-related adverse reactions? Can it relieve postoperative pain more effectively, reduce patients' suffering, and improve their comfort? What impact will it have on patients' postoperative awakening quality, hospital stay, and overall rehabilitation process?

We use a high - resolution ultrasound machine equipped with advanced imaging technology. This allows us to clearly observe the paravertebral space, the spread of local anesthetics, and the relationship with surrounding tissues. This high - precision guidance reduces the risk of complications and improves the success rate of nerve block. For example, Yang et al. merely made a brief mention of the utilization of ultrasound guidance. However, they failed to elaborate on the specific equipment and techniques employed for real - time monitoring during the PVB procedure [17].

This study aims to comprehensively evaluate the effects of ultrasound-guided PVB combined with general anesthesia and general anesthesia alone on various perioperative indicators of patients by comparing their applications in esophageal cancer surgery, providing a strong basis for optimizing clinical anesthesia plans and expecting to bring better treatment experiences and prognoses for esophageal cancer patients.

Materials and methods

Study subjects

From November 2020 to November 2021, 52 patients who received TLE in Shaanxi Cancer Hospital were selected as the research object. They were randomly divided into general anesthesia group (Group G, $n = 26$) and ultrasound-guided PVB group (Group G + P, $n = 26$). The average age of the patients was (56.84 ± 5.42) years. This study was approved by the medical ethics committee of Shaanxi Provincial Cancer Hospital, and the patient and their families signed the informed consent forms. The study was carried out in accordance with WMA Declaration of Helsinki 2013 - Ethical Principles for Medical Research Involving Human Subjects.

Inclusion criteria: (1) Patients who were diagnosed as EC by pathological examination and underwent thoraco-laparoscopy combined with radical resection of EC; (2) The American Society of Anesthesiologists (ASA)

physical status classification is grade I - II; (3) Age ranges from 50 to 65 years old; (4)Patients without severe heart, liver, and kidney diseases before surgery; (5) Patients with normal coagulation function and immune system; (6) Patients with healthy skin at the puncture site required for surgery, without infection or damage.

Exclusion criteria: (1) Patients with thoracic deformity, trauma, long - term low back or back pain, or morbid obesity; (2) Patients with abnormal coagulation function or immune system; (3) Patients with infection at the puncture site; (4) Patients allergic to local anesthetics; (5) Patients with a history of drug abuse or alcohol dependence; (6) Patients with severe anxiety, depression, or mental illness; (7) Patients whose surgical methods are temporarily changed to thoracotomy during the operation; (8) Patients who are unwilling to participate and do not cooperate.

Anesthesia method

All patients were routinely put on fasting and water deprivation before the operation. After entering the operating room, the upper limb venous access was opened, electrocardiogram (ECG) monitor was connected, and vital signs such as heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), oxygen saturation (SPO_2), and bispectral index (BIS) were monitored. Radial artery puncture and catheterization were performed under local anesthesia.

In Group G + P, general anesthesia combined with ultrasound-guided PVB was used. The patient was placed in the lateral decubitus position, the knee was flexed, and the head was lowered to fully expose the ultrasound scan and puncture site, and the right T_{4-5} and T_{7-8} were used as the block puncture site. Ultrasound scanning used oblique axial cross-sectional scanning method to make the ultrasound probe and spine in oblique axial position, and the long axis of the probe performed scanning between the intercostal space to determine the puncture point. A portable SonoSite Edge II Ultrasound machine (Sonosite, USA) was used to guide plane puncture, and a 20G puncture needle entered the thoracic paravertebral space along the lateral intercostal approach. 20 mL of 0.5% ropivacaine (GYZZ H20060137, Jiangsu Hengrui Pharmaceuticals Co., Ltd.) was slowly injected, and ultrasound image can observe the spread of local anesthetics, showing pleural depression sign. As shown in Fig. 1, the arrow indicates the injection site. PP represents the parietal pleura, PVS represents the paravertebral space, and Tp represents the transverse process. A moment later, acupuncture method was adopted to test the patient's pain loss, the block plane was $T_2 \sim T_{10}$. After the completion of the block, the patient was given general anesthesia induction. Multiple doctors from the Department of Anesthesia and Surgery participated in this study. They needed to demonstrate their proficiency in performing PVB under the guidance of experienced senior anesthesiologists. Their proficiency was judged based on their ability to accurately identify the paravertebral space on ultrasound images, perform the puncture correctly, and ensure the proper spread of local anesthetics. Only after being evaluated as proficient by senior anesthesiologists were they permitted to participate in this RCT. This approach ensured the consistency of the operation quality and met the required standards.

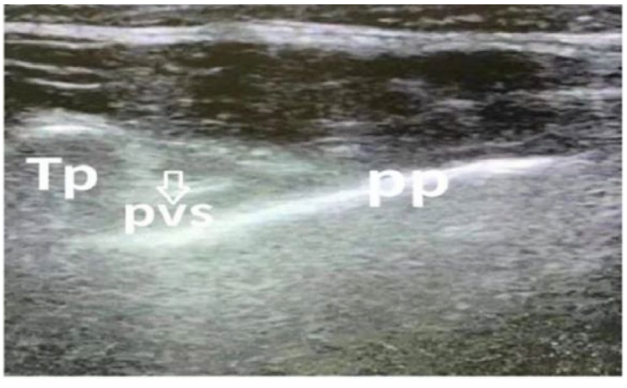

Fig. 1 Ultrasonic scanning images of paravertebral nerve block. Note: PP stands for the parietal pleura, PVS denotes the paravertebral space, and Tp refers to the transverse process

Patients in Group G directly underwent general anesthesia induction. The induction methods for the two groups of patients were the same. 0.03 mg/kg midazolam (GYZZ H10980026, Jiangsu Nhwa Pharmaceutical Co., Ltd.), 1 mg/kg propofol (GYZZ H19990282, Xi'an Libang Pharmaceutical Co., Ltd.), 0.5 μg/kg sufentanil (GYZZ H20054172, Yichang Humanwell Pharmaceutical Co., Ltd.) and 0.3 mg/kg cisatracurium (GYZZ H20090202, Zhejiang Xianju Pharmaceutical Co., Ltd.) were intravenously injected successively for double-lumen endotracheal tube intubation and fiberoptic bronchoscopic localization. During two-lung ventilation, volume of tidal (VT) was set at 7 mL/kg, respiratory rate at 15 breaths/min, inspiratory/expiratory ratio (I/E) at 1:2, and oxygen flow at 1.5 L/min. Before changing the patient's body position and performing one - lung ventilation, a fiberoptic bronchoscope was used again to confirm the position of the double - lumen tube to avoid displacement of the double - lumen tube.

Maintenance of anesthesia

During the operation, 4–6 $mg \cdot kg^{-1} \cdot h^{-1}$ propofol and 0.2–0.5 $\mu g \cdot kg^{-1} \cdot min^{-1}$ remifentanil was continuously pumped, and the pumping speed of propofol and remifentanil was adjusted according to HR, blood pressure value, and BIS value during the operation, and the intraoperative BIS value was maintained at 40–60. During the operation, sufentanil was intermittently injected at a dose

of 0.2 ~ 0.3 μg/kg as needed to maintain analgesia, and cis - atracurium was intermittently administered at a dose of 0.06 ~ 0.12 mg/kg to maintain muscle relaxation.

When HR was 50 beats/min, 0.3 ~ 0.5 mg/time atropine(Chinese Medicine Zhunzi H42021537, Huazhong pharmaceutical co., ltd) was given, 6 ~ 12 mg/time ephedrine (Chinese medicine quasi-word H42020949, Hubei Wudang Jinding Pharmaceutical Co., Ltd.) was given when SBP < 80 mmHg or DBP < 50 mmHg with HR slowing; 40 ~ 80 μg/time phenylephrine (Sinopharm Zhunzi H20056690, Chifeng Aike Pharmaceutical Technology Co., Ltd.) was injected when MAP decreased with HR increasing. 0.2 mg nicardipine (Chinese Medicine Zhunzi H22021940, Changchun Yishenkang Biopharmaceutical Co., Ltd.) was intravenously administered for MAP > 20% of baseline or BP > 160/90 mmHg; it was repeated if necessary. To keep the fluctuation range of BP < 20% of the baseline value, and HR > 50 beats/min. Hemodynamic indicators were monitored throughout the process to maintain hemodynamic stability. Intraoperative body temperature protection was carried out using heating blankets. Lung protective ventilation strategy was used during one-lung ventilation, V_T 7 mL/kg during two-lung ventilation, decreased to 5 mL/kg during one-lung ventilation, PEEP 5 cmH_2O, perioperative maintenance of $P_{ET}CO_2$35 ~ 45 mmHg, SpO_2 > 90%. At the end of one-lung ventilation, apply pressure of 35 ~ 40cmH_2O for 5 ~ 10s, and perform lung recruitment, repeating 3 times.

Postoperative analgesia

Patients in both groups were given intravenous drip of 100 mg flurbiprofen axetil (GYZZ H20041508, Beijing Tide Pharmaceutical Co., Ltd.) and 20 mg azasetron (GYZZ H20041141, Chia Tai Tianqing Pharmaceutical Group Co., Ltd.) 30 min before the end of surgery. Patients were given patient-controlled intravenous analgesia, connected to an electronic analgesic pump, and the parameters of the electronic analgesic pump were set as: load 2 mL, background dose 2 mL, single dose 3 mL, locking time 15 min; formula: 7.5 μg/kg sufentanil + 200 to 250 mg flurbiprofen axetil + normal saline diluted to 250 mL. Remifentanil was stopped 10 min before the end of surgery, and all intravenous medication was stopped after the end of skin suture. All the treatments relevant to this study were carried out by the research team members who were well - informed about the study design. They were well - trained and had in - depth knowledge of the anesthesia and pain - management procedures.

Steward recovery score, restlessness score, and visual analogue scale criteria

Steward recovery score: (1) consciousness score: no response to stimulation 0 points, response to stimulation 1 point, fully awake 2 points; (2) respiratory tract obstruction score: no conscious movement of limbs 0 points, airway patency without support 1 point, cough according to guidance 2 points; (3) limb range of motion score: no movement of limbs 0 points, no conscious movement of limbs 1 point, conscious movement of limbs 2 points. The higher the score, the better the degree of recovery, and the score above 4 can leave the operating room.

Restlessness Score (RS) scoring criteria in postanesthesia care unit (PACU): A score of 0 is given when there is basically no restlessness. A score of 1 is assigned for mild restlessness, during which the patient can follow the instructions of medical staff. A score of 2 indicates moderate restlessness, in which case the patient requires control by medical staff. A score of 3 corresponds to severe restlessness, where the patient is extremely uncooperative and engages in dangerous behaviors. Restlessness is determined to occur when the RS is greater than or equal to 2 points.

Visual Analogue Scale (VAS) score: A 10 cm line was drawn in a paper strip, 0 marked at one end for no pain and 10 at the other end for intense pain. According to the degree of self-perceived pain, the patient drew a number reflecting the degree of pain in a straight line to reflect the actual degree of pain of the patient.

Postoperative recovery

At the end of the operation, after the patients recovered spontaneous breathing, the patients were admitted to the PACU for routine monitoring, and the patients with VAS scores ≥ 4 were given intravenous 5–10 μg sufentanil. When the patients were fully awake, swallowing reflex was completely recovered, and patients were able to breathe normally, the endotracheal tube was removed and patients were returned to the ward when the Steward score was > 4.

Outcome measures

General data questionnaire: The general data of the patients were collected and statistically analyzed, including gender, age, body mass index (BMI), ASA grade, education level, preoperative complications, tumor location, tumor stage and preoperative medication status.

The dosage of postoperative anesthetic drugs and vasoactive drugs in the two groups: the dosage of anesthetic drugs propofol, remifentanil, and sufentanil was recorded; the dosage of postoperative vasoactive drugs phenylephrine, ephedrine, and nicardipine was recorded.

Intraoperative and postoperative related indicators in the two groups: intraoperative one-lung ventilation time, operation time, and extubation time in the two groups. The number of cases of postoperative PACU agitation was recorded, the incidence of agitation, the dosage of

sufentanil in PACU, the duration of PACU stay, and the time of postoperative discharge were recorded.

VAS scores at different time points in the two groups: VAS scores were recorded upon recovery, at the time of discharge from the PACU, during the resting state on the 1st, 2nd, 4th, and 6th days after surgery, and during coughing.

HR, MAP, and Narcotrend index (NTI) were recorded at baseline (t0), before induction of general anesthesia and after nerve block (t1), after induction of general anesthesia (t2), during thoracoscopic skin incision (t3), at 1 h after thoracoscopic surgery (t4), during laparoscopic skin incision (t5), at 1 h after laparoscopic surgery (t6), at the end of surgery (t7), at tracheal extubation (t8), and at PACU discharge (t9).

The degree of satisfaction of all patients with the anesthetic and analgesic effects was investigated: patients feel intraoperative pain, with low comfort: dissatisfaction; patients feeling mild pain, with postoperative comfort were satisfactory; patients feeling painless, with postoperative comfort were very satisfactory.

In our study, the individuals assessing the outcomes were blinded to the intervention arms. We took several steps to ensure this blinding. The data collectors and outcome assessors were a separate group from the anesthesiologists who administered the treatments. They had no knowledge of which patients belonged to Group G and which ones were in the Group G + P. All the data related to the outcome measures, such as the dosage of anesthetic drugs, hemodynamic parameters, VAS scores, and recovery - related indicators, were recorded in a standardized format without any indication of the treatment group. This way, when the assessors evaluated these outcomes, they could not be influenced by their knowledge of the treatment the patient had received. By implementing this blinding method, we effectively minimized the potential for assessment bias. This helped us obtain more objective and reliable results, as the assessors' judgments were not affected by preconceived notions about the different anesthesia methods. It also enhanced the internal validity of our study, making our findings more trustworthy.

Statistical analysis

Data were analyzed using SPSS 19.0 statistical software. For measurement data following a normal distribution, they were presented as ($\bar{x}\pm s$). An independent - samples t - test was employed to assess differences between the two groups. Within - group analysis made use of repeated - measures analysis of variance. Enumeration data were represented as percentages (%), and the chi - square (χ^2) test was applied. Specifically, the dosage of anesthetic drugs, vasoactive drugs, and intraoperative VAS scores conformed to a normal distribution and were thus presented as ($\bar{x}\pm s$). Categorical measurement data such as gender, presence of hypertension, and diabetes were expressed in percentage (%). However, when comparing the satisfaction levels of the two groups of patients, considering that sample size assumptions might not be fully met for the chi - square test, Fisher's exact test was adopted. This test is more appropriate when dealing with categorical data, especially in situations where the sample size is relatively small or the expected frequencies in some cells of the contingency table are low. A significance level of $P < 0.05$ was considered to denote a statistically significant difference.

In this study, the sample size was calculated based on the primary outcome of postoperative pain, measured by the VAS score. The following steps were involved in the sample size determination:

(1) Formulating the Research Hypothesis: The null hypothesis (H_0) was that there is no difference in the mean postoperative VAS scores between Group G and Group G + P. The alternative hypothesis (H_1) was that the mean postoperative VAS scores in Group G + P are significantly lower than those in Group G.
(2) Selecting Key Parameters: Based on a review of similar previous studies, we estimated the standard deviation (σ) of postoperative VAS scores to be approximately 1.5. We aimed to detect a clinically significant difference (σ) of 1.0 in the mean VAS scores between the two groups. This difference was considered clinically relevant as it represents a meaningful reduction in pain intensity that could potentially impact patient recovery and satisfaction.
(3) Determining the Significance Level and Power: We set the significance level (α) at 0.05. The power of the study ($1-\beta$) was set at 0.80, meaning we had an 80% probability of correctly rejecting the null hypothesis when the alternative hypothesis was true.
(4) Using the formula for sample size calculation in a two - sample t - test for independent groups:

$$n = \frac{2\sigma^2(z_{1-\alpha/2} + z_{1-\beta})^2}{\delta^2}$$

Where $z_{1-\alpha/2}$ is the critical value corresponding to the significance level (for $\alpha = 0.05$, $z_{1-\alpha/2} = 1.96$) and $z_{1-\beta}$ is the critical value corresponding to the power (for $1-\beta = 0.80$, $z_{1-\beta} = 0.84$). Substituting the values into the formula. Rounding up, we determined that a minimum of 36 patients per group was required. Considering potential dropouts, we decided to recruit 52 patients in total, with 26 patients in each group. This approach ensured that our study had sufficient statistical power to detect a meaningful difference between the two

anesthesia methods, enhancing the reliability and validity of our research findings.

Results

General data

In Group G, the patients' mean age was 55.39 ± 5.82 years. In terms of esophageal cancer characteristics, 12 patients had tumors located in the upper esophagus, 8 in the middle esophagus, and 6 in the lower esophagus. According to the TNM staging system, 10 patients in Group G were at stage I, 10 at stage II, and 6 at stage III. In Group G + P, the mean age was 57.76 ± 5.56 years. For tumor location, 11 patients had tumors in the upper esophagus, 9 in the middle esophagus, and 6 in the lower esophagus. In terms of tumor stage, 9 patients in Group G + P were at stage I, 10 at stage II, and 7 at stage III. Statistical analysis demonstrated that there were no significant differences between the two groups in terms of age, gender distribution, BMI, ASA grade, educational attainment, co - existing hypertension, diabetes, tumor location, or tumor stage (all $P > 0.05$). This indicates that the two groups were comparable in these aspects (Table 1).

Among the patients with a history of hypertension, 6 patients in Group G and 5 patients in Group G + P had taken the angiotensin - converting enzyme inhibitor (ACEI) lisinopril. In Group G, 2 patients took the calcium channel blocker (CCB) amlodipine, and 1 patient took a combination of an ACEI and a diuretic. In Group G + P, 2 patients took amlodipine, and 1 patient took a beta - blocker. For patients with diabetes, 3 patients in Group G and 4 patients in Group G + P used metformin to control blood sugar. In Group G, 1 patient used insulin, and 1 patient used sulfonylureas. In Group G + P, 1 patient used insulin, and 1 patient used a combination of metformin and glinides. To avoid the impact of pre - operative medications on the experiment, appropriate wash - out periods were determined based on the pharmacokinetic characteristics of the drugs, and the use of these medications was suspended during the wash - out periods. During the wash - out periods, relevant physiological indicators of the patients were closely monitored to ensure that when entering the experimental stage, the patients' physical conditions were relatively stable and the residual effects of the medications had been basically eliminated.

Table 1 Comparison of baseline characteristics between the two groups

Item	Group G ($n=26$)	Group G + P ($n=26$)	t / χ^2	*P*
Mean age ($\bar{x}$±s, years)	55.39 ± 5.82	57.76 ± 5.56	-1.49	0.352
Gender (n, %)			0.078	0.780
Male	14 (53.84)	15 (57.69)		
Female	12 (46.15)	11 (42.30)		
BMI ($\bar{x}$±s, kg/m^2)	21.39 ± 2.84	21.76 ± 5.53	-0.30	0.124
ASA grade (n, %)			0.077	0.781
Grade I	12 (46.15)	13 (50.00)		
Grade II	14 (53.84)	13 (50.00)		
Education level (n, %)			0.357	0.837
Primary school	8 (30.76)	10 (38.46)		
Middle school	12 (46.15)	11 (42.30)		
Bachelor degree or above	6 (23.07)	5 (19.23)		
Hypertension (n, %)	9 (34.61)	8 (30.76)	0.719	0.397
Diabetes (n, %)	5 (19.23)	6 (23.07)	0.115	0.734
Tumor Location (n, %)			0.102	0.950
Upper esophagus	12 (46.15)	11 (42.31)		
Middle esophagus	8 (30.77)	9 (34.62)		
Lower esophagus	6 (23.08)	6 (23.08)		
Tumor Stage (n, %)			0.130	0.937
Stage I	10 (38.46)	9 (34.62)		
Stage II	10 (38.46)	10 (38.46)		
Stage III	6 (23.08)	7 (26.92)		

Comparison of intraoperative anesthetic and vasoactive drug dosage

As illustrated in Fig. 2, which shows the comparison of intraoperative anesthetic and vasoactive drug dosages. In terms of anesthetic drugs, patients in Group G + P demonstrated a significant reduction in the intraoperative dosages of propofol, remifentanil, and sufentanil compared to those in Group G. Specifically, the propofol dosage was 1,334.3 ± 219.3 mg in Group G versus 1,283.5 ± 156.9 mg in Group G + P, the remifentanil dosage was 3,938.2 ± 524.3 μg in Group G versus 3,428.1 ± 478.5 μg in Group G + P, and the sufentanil dosage was 68.3 ± 5.4 μg in Group G versus 5.49 ± 8.2 μg in Group G + P ($P = 0.021$).

Regarding vasoactive drugs, the phenylephrine dosage in Group G + P was significantly higher than that in Group G. The dosage was 145.2 ± 76.3 mg in Group G and 247.1 ± 95.3 mg in Group G + P ($P = 0.032$). However, there were no significant differences in the dosages of ephedrine (3.7 ± 1.5 mg in Group G vs. 4.2 ± 1.8 mg in Group G + P) and nicardipine (0.1 ± 0.1 mg in Group G vs. 0.3 ± 0.2 mg in Group G + P) between the two groups ($P > 0.05$).

Comparison of intraoperative and postoperative relevant indicators

When compared with Group G, the extubation time in Group G + P was significantly shorter, with values of 27.5 ± 12.3 min versus 43.6 ± 13.5 min ($P = 0.013$). However, there were no significant differences in one - lung ventilation time and operation time between the two groups ($P > 0.05$) (Fig. 3).

In addition, compared to Group G, Group G + P showed a significant reduction in the sufentanil dosage in the PACU, with amounts of 2.1 ± 1.5 μg and 1.2 ± 0.3 μg respectively. Moreover, the duration of stay in the PACU

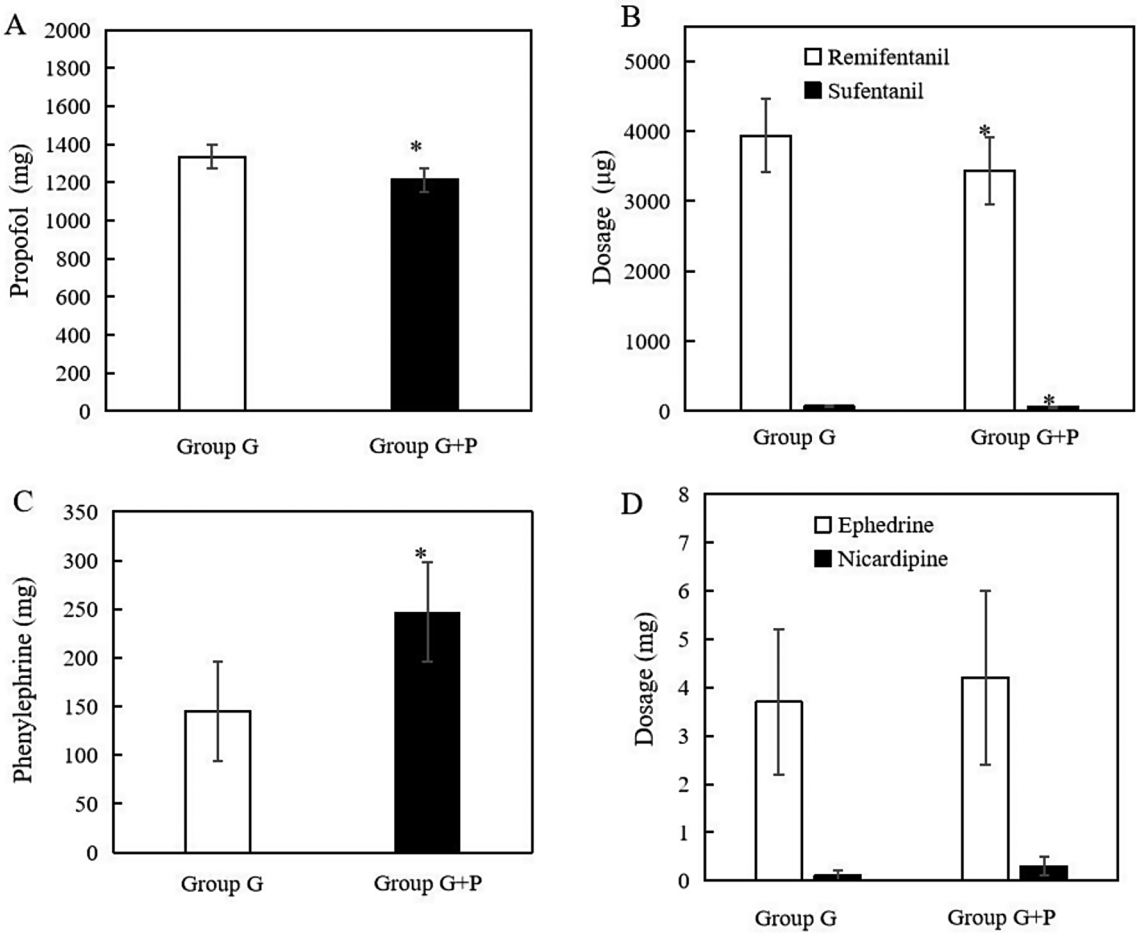

Fig. 2 Comparison of Intraoperative Anesthetic and Vasoactive Drug Dosage. Note: **A** Comparison of propofol dosage; **B** Comparison of remifentanil and sufentanil dosage; **C** Comparison of phenylephrine dosage; **D** Comparison of ephedrine and nicardipine dosage; * indicates a significant difference compared with Group G ($P < 0.05$)

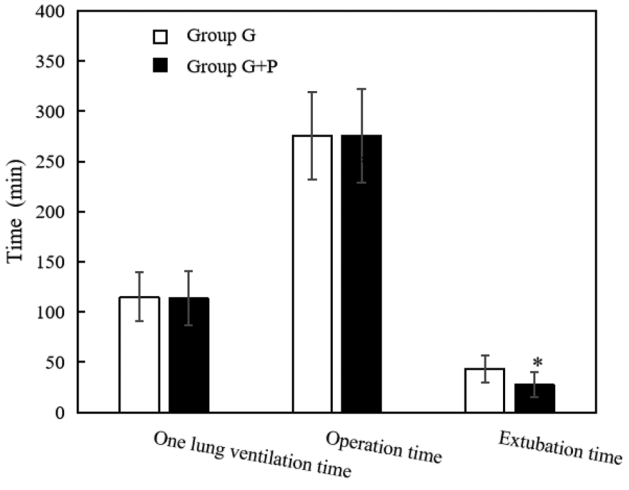

Fig. 3 Comparison of intraoperative time indicators

Table 2 Contrasting postoperative relevant indicators in two groups

Indicators	Group G ($n=26$)	Group G + P ($n=26$)	*P*
PACU sufentanil dosage (μg)	2.1 ± 1.5	1.2 ± 0.3	0.024*
PACU stay (min)	87.5 ± 24.3	68.3 ± 21.5	0.015*
Incidence of PACU agitation (%)	5(19.23)	1(3.84)	0.002*
Postoperative hospital stay (d)	14.3 ± 7.2	9.7 ± 2.6	0.027*

Note: * indicates a significant difference compared with Group G ($P < 0.05$)

(87.5 ± 24.3 min vs. 68.3 ± 21.5 min), the incidence of agitation in the PACU (19.23% vs. 3.84%), and the postoperative hospital stay (14.3 ± 7.2 days vs. 9.7 ± 2.6 days) were all significantly decreased in Group G + P (Table 2).

Comparison of VAS scores at various time points

As shown in Fig. 4, in the resting state, compared with Group G, Group G + P had significantly lower VAS scores at the time of waking up, when leaving the PACU, and on the 1st, 2nd, and 6th days after surgery. This indicates

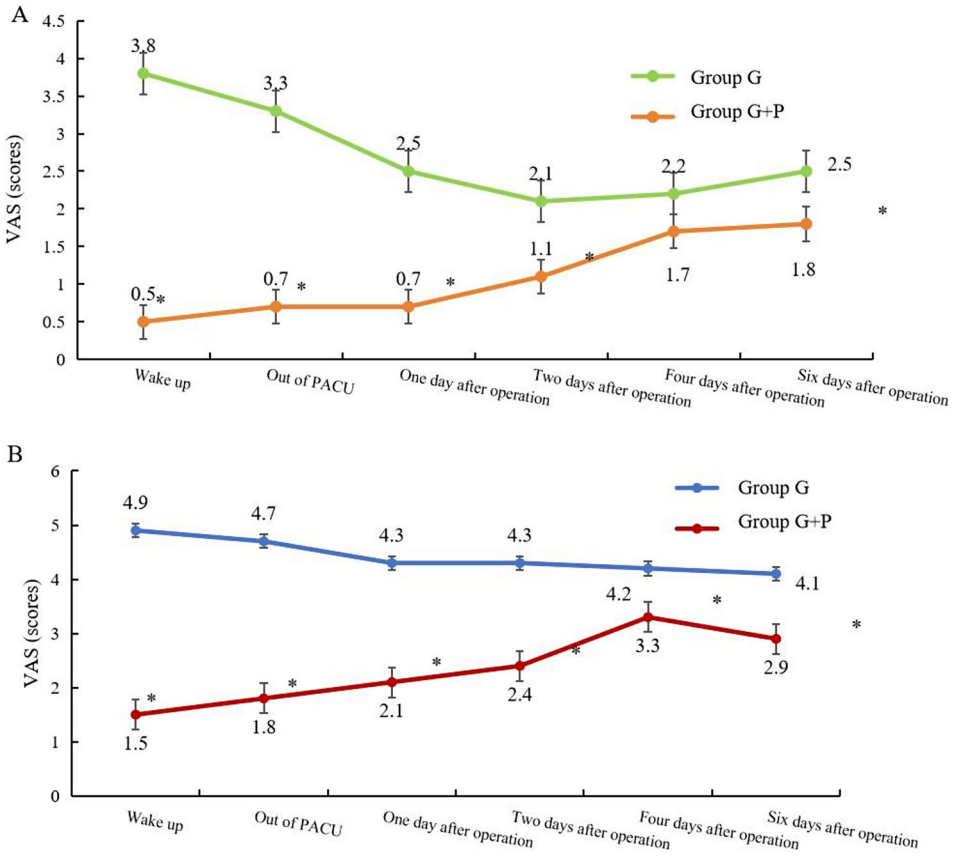

Fig. 4 Comparison of VAS scores between group G and Group G + P at resting (**A**) and coughing (**B**) states across different time points

that the analgesic effect of Group G + P has more advantages at multiple key time points in the resting state.

In the coughing state, Group G + P also had significantly lower VAS scores than Group G at the time of waking up, when leaving the PACU, and on the 1st, 2nd, and 6th days after surgery. Coughing increases the pressure on the chest and the surgical site, exacerbating the pain sensation. However, Group G + P was able to maintain lower VAS scores at the above - mentioned time points under this condition that is more likely to trigger pain, further highlighting the effectiveness and stability of the Group G + P protocol in pain control under different physiological states.

Comparison of HR, MAP, and NTI at different time points

Figure 5 shows the changes in HR, MAP, and NTI of Group G and Group G + P at different time points (t0 - t9). At most time points, the difference in HR values between Group G and Group G + P is small, and there is no significant difference ($P > 0.05$), indicating that different treatments have little effect on heart rate.

During the period from t0 to t7, the fluctuation trends of MAP are basically the same, suggesting that there is little difference in mean arterial pressure between the two groups during this period. However, at time points t8 and t9, the curve of Group G is higher than that of Group G + P, and there are significant differences in mean arterial pressure between the two groups at these two time points ($P = 0.024$).

Within the time interval from t2 to t7, there are significant differences in NTI between Group G + P and Group G, implying that the two treatment methods have different effects on the depth of electroencephalogram - related consciousness during this period.

Comparison of patient satisfaction regarding anesthetic and analgesic effects

As shown in Fig. 6, there were 5 patients who were dissatisfied in Group G, accounting for 19.23%; 10 patients were satisfied, accounting for 38.46%; and 11 patients were very satisfied, accounting for 42.3%. In Group G + P, only 1 patient was dissatisfied, accounting for 3.84%; 9 patients were satisfied, accounting for 34.61%; and 16 patients were very satisfied, accounting for 61.53%.

The satisfaction rate of Group G + P reached 96.14%, which was significantly higher than that of Group G (80.76%). With a P - value of 0.032, this difference was statistically significant. This indicates that the treatment method adopted by Group G + P was more likely to satisfy patients in terms of anesthetic and analgesic effects.

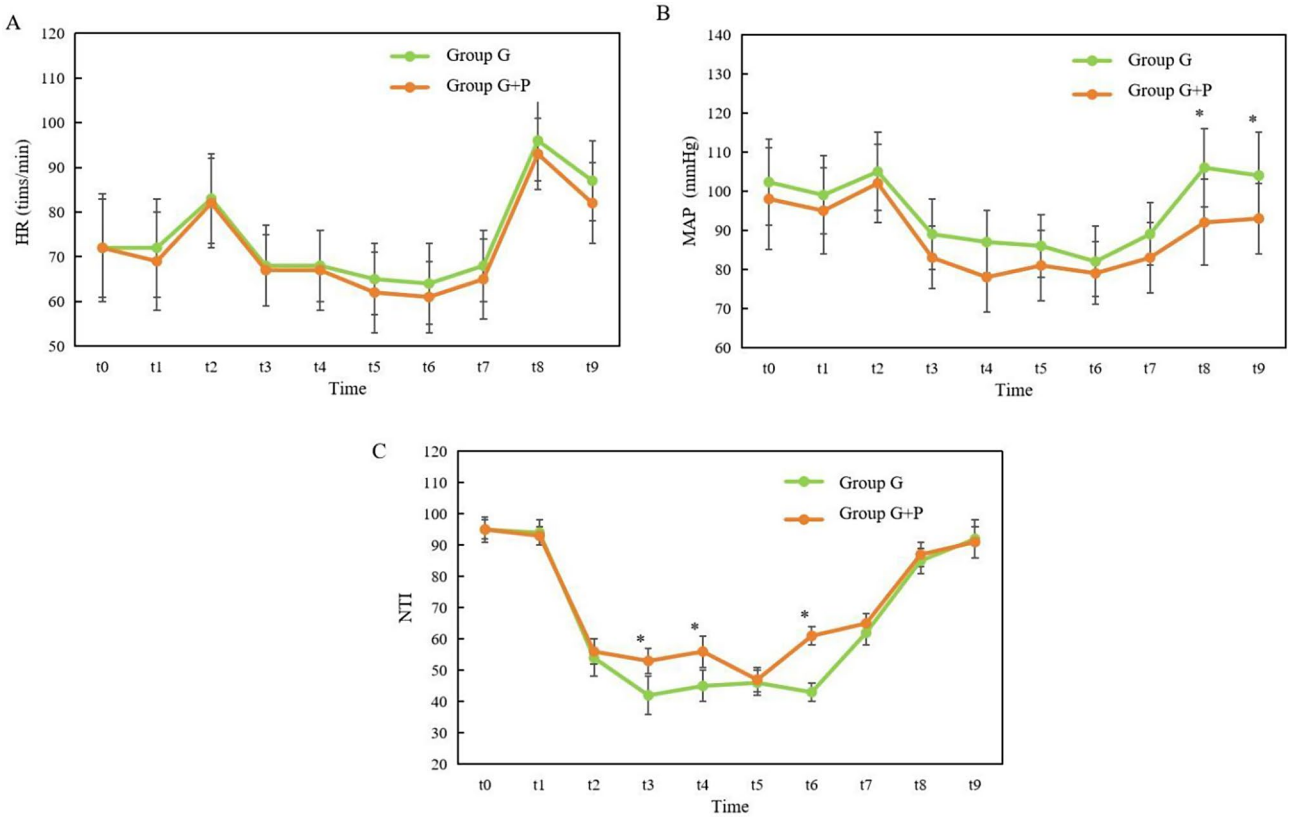

Fig. 5 Comparison of HR (**A**), MAP (**B**), and NTI (**C**) at different time points

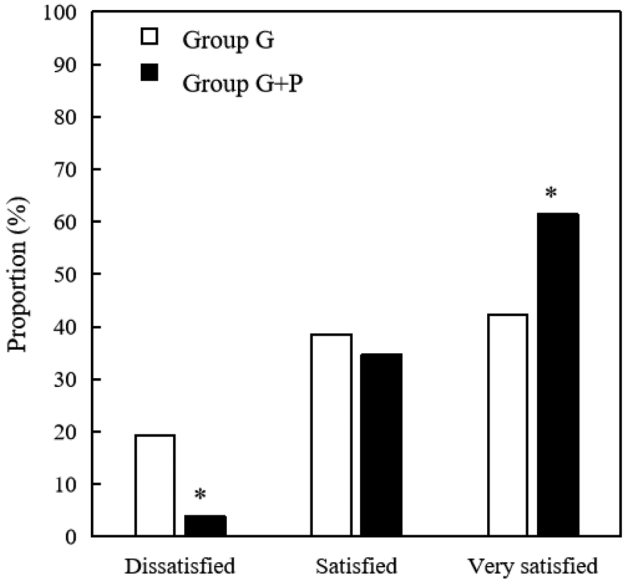

Fig. 6 Comparison of patient satisfaction regarding anesthetic and analgesic effects

Discussion

In thoracic surgery, the most commonly used analgesic approach is multimodal analgesia, which combines local analgesia with opioids. However, multimodal analgesia has a broad blocking scope. It directly inhibits the sympathetic nerves, which may lead to hypotension and bradycardia. Moreover, it might also block the intercostal respiratory muscles of patients, directly influencing the recovery of postoperative respiratory function [18]. Among various analgesic methods, PVB demonstrates excellent anesthetic and analgesic effects with relatively few side effects [19]. Research results have indicated that, compared with sole general anesthesia, general anesthesia combined with PVB can significantly improve patients' perioperative hemodynamics, reduce the dosage of opioid analgesics, lower the perioperative VAS score, and decrease the emergence agitation rate.

The postoperative 24-hour resting VAS pain score was selected as the primary outcome. Given that esophageal cancer surgery is highly invasive, postoperative pain significantly impacts patients' recovery. The 24-hour postoperative period is a crucial time when pain is intense. The VAS score in the resting state can directly reflect the patient's pain perception in the basic physiological state, and it can intuitively demonstrate the core effect of PVB combined with general anesthesia in relieving early postoperative pain compared with general anesthesia alone.

The secondary outcomes include the total amount of perioperative opioid use, postoperative extubation time, PACU stay time, incidence of postoperative agitation,

and patients' satisfaction with anesthesia and analgesia. Monitoring the total amount of perioperative opioid use can evaluate the sparing effect of different anesthesia methods on opioids and help determine the advantages of combined anesthesia. The extubation time reflects the speed of the patient's recovery of consciousness and respiratory function after anesthesia. A shorter extubation time means that the patient can be free from the stimulation of the tracheal intubation more quickly, reducing the risk of complications such as pulmonary infection. It is also an important indicator for measuring the anesthesia effect and the quality of the patient's postoperative recovery, which is helpful for comparing the impact of the two anesthesia methods on the early postoperative recovery process of patients. The PACU stay time is affected by multiple factors, such as the residual effect of anesthetic drugs, the quality of the patient's awakening, and postoperative pain control. This indicator can comprehensively reflect the impact of different anesthesia methods on the speed and quality of the patient's postoperative recovery, as well as the efficiency of post-anesthesia management. It is an important dimension for evaluating the overall effect of the anesthesia plan. Comparing the incidence of postoperative agitation between the two groups of patients can further clarify whether combined anesthesia can reduce the risk of postoperative agitation and improve the safety and comfort of patients during postoperative recovery. Patients' satisfaction comprehensively reflects their experience during the surgery and postoperative recovery process, covering aspects such as pain control, the awakening process, and comfort. It is an important clinical indicator for measuring the effects of anesthesia and analgesia.

Ultrasound guidance offers a distinct advantage for PVB by providing a clear and effective surgical field. When combined with general anesthesia, it can effectively mitigate the stress response and remarkably alleviate early postoperative pain and agitation in patients [13]. The findings of this study revealed that, in both the resting and coughing states, compared with patients in Group G, those in Group G + P had significantly lower VAS scores upon waking up, when leaving the PACU, and on the 1st, 2nd, and 6th days after the operation. The primary mechanisms underlying this are as follows: Firstly, PVB exerts a preventive analgesic effect. It blocks the hyperalgesia induced by noxious stimuli, preventing nerve impulses generated by surgical trauma and other noxious factors from reaching the central nervous system, thereby effectively alleviating postoperative acute pain. Secondly, PVB can reduce the dosage of opioids, which helps inhibit the development of pain hypersensitivity. The use of analgesic drugs, especially opioids, to counteract surgical pain and noxious stimuli may trigger postoperative pain sensitivity. High - dose opioid use can exacerbate this hyperalgesia. In contrast, PVB itself provides reliable analgesia and can reduce the requirement for perioperative opioid analgesics. Consequently, Group G + P can minimize the occurrence of agitation during the early postoperative pain period by reducing high - dose opioid - induced hyperalgesia, which is consistent with the findings of Kalagara et al. [20] Although ultrasound - guided paravertebral nerve block cannot ensure the continuous effect of ropivacaine, after the initial administration, a small amount of the drug may still remain around the nerves. This can continuously exert a certain degree of nerve conduction block, thus alleviating pain. General anesthetics have a metabolic process in the body. By the 6th postoperative day, they may still maintain a certain concentration in the body, which has an inhibitory effect on the central nervous system and indirectly reduces the patient's perception of pain. By the 6th postoperative day, the body's self - repair mechanism is activated. Local inflammation is reduced, and tissue repair decreases noxious stimuli, thereby relieving pain. The G + P group uses a combined anesthesia method. Patients have a better experience during the operation, have more confidence in the surgical outcome psychologically, and are in a relatively positive mental state. To a certain extent, this can reduce the subjective perception of pain.

During thoracoabdominal surgery for esophageal cancer, the disappearance of negative thoracic pressure and the implementation of positive pressure ventilation can reduce patients' blood return volume. Additionally, surgical manipulations may compress the great vessels of the heart, resulting in a decrease in cardiac output and subsequent blood pressure reduction, often accompanied by tachycardia. Therefore, intravenous bolus injection of phenylephrine is frequently employed during surgery to maintain hemodynamic stability [21]. The results of this study showed that the dosage of phenylephrine in Group G + P was significantly higher than that in Group G, which is consistent with the findings of Babu et al. [22] There are two main reasons for this: First, although there is no significant age difference between the two groups, there is a notably higher proportion of elderly patients over 65 years old in Group G + P. The compensatory function of the circulatory system in elderly patients is relatively weak and is more significantly affected by surgical procedures. Second, Group G + P uses general anesthesia combined with PVB. Intravenous local anesthetics gradually spread along the paravertebral space, and a single injection point can anesthetize multiple segments. Chest surgery can cause circulatory system changes, and hypotension is more easily detected in Group G + P compared to Group G. Additionally, due to the more comprehensive analgesic effect provided by the G + P group, under the same depth of anesthesia, the stimuli causing pain

are smaller, resulting in relatively lower blood pressure. As a result, a larger dosage of phenylephrine is required in Group G + P to increase blood pressure and slow the heart rate. If the great vessels of the heart are compressed during surgery, serious adverse events such as cardiovascular and cerebrovascular accidents, malignant arrhythmias, and cardiac arrest may occur. However, by closely monitoring hemodynamic changes in real - time during the procedure and adjusting treatment according to the patient's condition, no adverse consequences occurred.

To avoid delayed recovery or postoperative cognitive dysfunction caused by excessive anesthesia depth, BIS values were maintained between 40 and 60. Patients' hemodynamic changes were closely monitored, and optimized treatment measures were implemented. These measures included adopting lung - protective ventilation strategies, maintaining a stable body temperature, and using multimodal analgesia. These steps ensured a more stable anesthetic process, minimized the trauma and stress responses caused by surgery or anesthesia, and facilitated patients' early recovery. Ultrasound - guided general anesthesia combined with PVB for thoraco - laparoscopic EC surgery is a safer option. It can significantly shorten the operation time and reduce the incidence of adverse events. Under general anesthesia, the paravertebral space can be clearly identified, enabling precise guidance of the puncture point to the target area [23]. This reduces damage to surrounding tissues and improves the success rate of nerve block. Furthermore, ultrasound images allow for clear visualization of the needle insertion direction, facilitating the operation, ensuring consistent anesthetic infiltration, and providing a more accurate drug dosage for the procedure [24]. The results indicated that the extubation time in Group G + P (27.5 ± 12.3 min) was significantly shorter than that in Group G (43.6 ± 13.5 min). The reduction in extubation time might be attributed to the lower consumption of intraoperative opioids. Compared with Group G, patients in Group G + P had a significantly shorter PACU stay (87.5 ± 24.3 min vs. 68.3 ± 21.5 min) and postoperative hospital stay (14.3 ± 7.2 d vs. 9.7 ± 2.6 d), which is consistent with the findings of Ajkay et al. [25] The SBP, MAP, and HR in Group G + P were more stable at different time points during surgery compared with Group G. There may be several reasons why the NTI values of Group G + P were higher than those of Group G at time points t3, t4, and t6. Group G + P received general anesthesia combined with ultrasound-guided paravertebral nerve block. The local anesthetic used in paravertebral nerve block synergized with the general anesthetic, resulting in changes and adjustments in the demand for and dosage of anesthetic drugs at these time points, which led to an increase in the NTI value. This indicates that the overall anesthesia and analgesia regimen could maintain a more stable state at these moments. Group G only received general anesthesia, which was relatively insufficient to cope with the surgical stimulation. In contrast, in Group G + P, the paravertebral nerve block blocked local noxious stimuli, leading to different manifestations of the body's stress response, which was reflected as a higher NTI value. The satisfaction rate of Group G + P (96.14%) was significantly higher than that of Group G (80.76%). These results suggest that ultrasound - guided general anesthesia combined with PVB in laparoscopic EC surgery can achieve better anesthetic and analgesic effects than general anesthesia alone. It can reduce the dosage of opioid analgesics, extend the analgesic duration, shorten the patient's recovery time, maintain stable patient vital signs, and enhance patients' satisfaction with the anesthetic and analgesic effects. Akıncı et al. [26] reported that in partial nephrectomy, the application of ultrasound - guided general anesthesia combined with PVB led to more stable intraoperative vital signs, less intraoperative sufentanil use, and a more significant postoperative analgesic effect compared with patients undergoing complete nephrectomy with only general anesthesia. This further confirms the advantages of ultrasound - guided general anesthesia combined with PVB in unilateral organ surgery.

However, this study has several limitations. The clinical trial duration and location were restricted, resulting in a final inclusion of only 52 patients. The overall sample size was relatively small, and it was a single - center study, which inevitably introduced some bias. Thus, the final results may lack broad representativeness. Conducting large - sample, multicenter clinical studies can comprehensively and deeply explore the impact of ultrasound - guided general anesthesia combined with PVB on postoperative pain management and recovery in patients undergoing laparoscopic surgery.

Conclusion

This study investigated the application of ultrasound-guided PVB combined with general anesthesia in laparoscopic radical resection of esophageal cancer. The results revealed that compared with general anesthesia alone, this combined anesthesia approach significantly decreased the usage of perioperative opioid analgesics, effectively alleviated postoperative pain, and notably reduced the incidence of emergence agitation. It also led to a substantial shortening of the extubation time, PACU stay, and postoperative hospital stay, facilitating faster patient recovery. In terms of patient satisfaction, the combined anesthesia group achieved a significantly higher satisfaction rate, indicating better anesthetic and analgesic effects. Although the study had some limitations such as a small sample size and being a single-center study, the findings still demonstrated the advantages

of ultrasound-guided PVB combined with general anesthesia in esophageal cancer surgery. This combined anesthesia method is a valuable option for clinical practice, which can improve the quality of anesthesia and analgesia, and contribute to the overall well-being and recovery of patients. Future research with larger sample sizes and multi-center studies is needed to further validate and expand on these findings.

Author contributions
Tingting Yang completed the primary writing and proofreading of the manuscript. Yuan He made project administration partial revisions, as well as collected the data. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was approved by the medical ethics committee of Shaanxi Provincial Cancer Hospital. The study was carried out in accordance with 'WMA Declaration of Helsinki 2013 - Ethical Principles for Medical Research Involving Human Subjects'.

Consent for publication
Written informed consent for the publication has been obtained from patients.

Competing interests
The authors declare no competing interests.

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References

1. Plat VD, Kasteleijn A, Greve JWM, et al. Esophageal cancer after bariatric surgery: increasing prevalence and treatment strategies. Obes Surg. 2021;31(11):4954–62.
2. Sardaro A, Ferrari C, Carbonara R, et al. Synergism between immunotherapy and radiotherapy in esophageal cancer: an overview of current knowledge and future perspectives. Cancer Biother Radiopharm. 2021;36(2):123–32.
3. Fukushima T, Watanabe N, Okita Y, Yokota S, Kurita D, Ishiyama K, Daiko H. Preoperative physical activity is associated with prognosis in patients with esophageal cancer undergoing thoracoscopic–laparoscopic esophagectomy after neoadjuvant chemotherapy. Gen Thorac Cardiovasc Surg. 2024;72(2):134–43.
4. Macrosson D, Beebeejaun A, Odor PM. A systematic review and meta-analysis of thoracic epidural analgesia versus other analgesic techniques in patients post-oesophagectomy. Perioperative Med. 2024;13(1):80.
5. Tran DQ, Booysen K, Botha HJ. Primary failure of thoracic epidural analgesia: revisited. Reg Anesth Pain Med. 2024;49(4):298–303.
6. Kumar K, Horner F, Aly M, Nair GS, Lin C. Why do thoracic epidurals fail? A literature review on thoracic epidural failure and catheter confirmation. World J Crit Care Med. 2024;13(3):94157.
7. Wei TJ, Hsu HA, Hsiung PY, Chen PJ, Lee CT, Wu CY. Preoperative thoracic epidural analgesia with and without erector spinae plane block for thoracotomy: A retrospective study. Journal of the Formosan Medical Association. Advance online publication; 2025. https://doi.org/10.1016/j.jfma.2025.02.021
8. Zheng C, Wang J, Xie S. Ultrasound-Guided thoracic paravertebral nerve block on postoperative pain, quality of life, and recovery in patients with Non-Small-Cell lung cancer. Biomed Res Int. 2021;2021:6692815.
9. Zhen SQ, Jin M, Chen YX, et al. Ultrasound-guided paravertebral nerve block anesthesia on the stress response and hemodynamics among lung cancer patients. World J Clin Cases. 2022;10(7):2174–83.
10. Lei D, Sha Y, He L. Is ultrasound-guided thoracic paravertebral nerve block better than intercostal nerve block for video-assisted thoracic surgery under spontaneous-ventilating anesthesia? Revista Da Associação médica. Brasileira. 2021;66(5):568.
11. Kahramanlar AA, Aksoy M, Ince I, et al. The comparison of postoperative analgesic efficacy of Ultrasound-Guided paravertebral block and Mid-Point transverse process pleura block in mastectomy surgeries: A randomized study. J Invest Surg. 2022;35(9):1694–9.
12. Swathi KB, Kamal M, Kumar M, et al. Comparison of analgesic efficacy of the conventional approach and mid-transverse process to pleura approach of the paravertebral block in video-assisted thoracoscopy surgeries: A randomised controlled trial. Indian J Anaesth. 2021;65(7):512–8.
13. Shen L, Ye Z, Wang F, Sun GF, Ji C. Comparative analysis of the analgesic effects of intercostal nerve block, ultrasound-guided paravertebral nerve block, and epidural block following single-port thoracoscopic lung surgery. J Cardiothorac Surg. 2024;19(1):406.
14. Boehler S, Huber M, Wuethrich PY, Beilstein CM, Arigoni SM, Furrer MA, et al. Continuous epidural versus non-epidural pain management after minimally invasive esophagectomy: a real-life, high-case-load center experience. J Clin Med. 2024;13(24):7669.
15. Ramjit S, Davey MG, Loo C, Moran B, Ryan EJ, Arumugasamy M, et al. Evaluating analgesia strategies in patients who have undergone oesophagectomy—a systematic review and network meta-analysis of randomised clinical trials. Dis Esophagus. 2024;37(5):doad074.
16. Aiolfi A, Bona D, Shabat G, Resta M, Bonavina L. Is paravertebral block the new standard of care for postoperative analgesia after thoracoscopic surgery? J Thorac Disease. 2024;16(4):2677.
17. Yang J, He Y, Lin J, Yu S, Chang Y, Zuo Y. The effects of regional anesthesia combined with awake delayed extubation in patients undergoing esophageal cancer surgery: a single-blind randomized controlled trial. Research Square. Prepeint (version 1); 2024. https://doi.org/10.21203/rs.3.rs-3850116/v1
18. Carron M, Tamburini E, Linassi F, Pettenuzzo T, Boscolo A, Navalesi P. Efficacy of nonopioid analgesics and adjuvants in multimodal analgesia for reducing postoperative opioid consumption and complications in obesity: a systematic review and network meta-analysis. Br J Anaesth. 2024;133(6):1234–49. https://doi.org/10.1016/j.bja.2024.08.009
19. Deng C, Liang T, Guo H, Song W, Ye X, Li Z, Yan D. The potential value of paraspinal nerve block (PVB) in percutaneous nephrolithotomy (PCNL) compared with general anesthesia and epidural anesthesia. Alternative Therapies in Health and Medicine; 2024. pp. AT9069–9069.
20. Kalagara H, Gans A, Gatewood L, Nimma S. The role of inpatient/acute pain services for perioperative pain management. Perioperative pain management: A clinical guide. Springer Nature Switzerland; 2024. pp. 135–47.
21. Park HS, Choi WJ. Use of vasopressors to manage spinal anesthesia-induced hypotension during Cesarean delivery. Anesth Pain Med. 2024;19(2):85–93.
22. Babu S, Kumar M, Gadhinglajkar SV, Gregory DM, Aggarwal N, Sukesan S. Thoracotomy patients under general anesthesia: a comparison on intra-operative anesthetic and analgesic requirements, when combined with either epidural analgesia or continuous unilateral paravertebral analgesia. Ann Card Anaesth. 2024;27(1):10–6.
23. Portela DA. Ultrasound-guided thoracic paravertebral block. In: Small animal regional anesthesia and analgesia. 2024. pp. 127–135.
24. Yi R, Li Z, Yang X, Huang T, Liu H, Zhang J. The utilization of ultrasound-guided regional nerve blocks in anesthetic management for fracture surgery. J Pain Res. 2025;18:353–66.
25. Ajkay N, Bhutiani N, Clark LL, Holland M, McMasters KM, Egger ME. Effect of erector spinae plane block and thoracic epidural anesthesia on hospital length of stay and postoperative opioid use after mastectomy. Surgery. 2025;179:108897.
26. Akıncı G, Hatipoğlu Z, Güleç E, et al. Effects of Ultrasound-Guided thoracic paravertebral block on postoperative pain in children undergoing percutaneous nephrolithotomy. Turkish J Anaesthesiol Reanimation. 2019;47(4):295–300.

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