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Comparison of the effectiveness of two different concentrations of ropivacaine for intrapleural analgesia in reducing stimulatory pain caused by chest tubes after uniportal video-assisted thoracoscopic surgery: a randomised controlled study

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Abstract

Background Pain caused by chest tube placed after uniportal video-assisted thoracoscopic surgery (UVATS) is often neglected. Ropivacaine can be used to alleviate pain related to the chest tube, but the current lowest effective concentration of ropivacaine remains unclear.

Methods To investigate the analgesic effect of administering two different concentrations of ropivacaine into the pleural cavity via pleural drainage tube bypass after UVATS. Ninety patients were randomly divided into three groups: Control group (PCIA only), Low-dose group (PCIA combined with intrathoracic infusion of 200 ml 0.25% ropivacaine), Medium-dose group (PCIA combined with intrathoracic infusion of 200 ml 0.5% ropivacaine). The analysis included Visual Analogue Scale (VAS) scores for chest tube-related pain and surgical incision pain at 6 h, 12 h, 24 h, and 48 h post-operation for each group. Compare incidence of adverse reactions (respiratory depression, hypotension, nausea/vomiting, arrhythmia, dizziness) within 48 h.

Results Compared to the control group, both 0.25% and 0.50% ropivacaine effectively reduced chest tube-related pain ($P<0.001$) and surgical incision pain ($P<0.001$) at 6 h, 12 h, 24 h, and 48 h postoperatively. However, no significant differences were observed between the two concentrations of ropivacaine in alleviating rest and cough pain related to the chest tube ($P>0.05$) or surgical incision ($P>0.05$) within 48 h postoperatively. Adverse reaction rates were similar among groups within 48 h postoperatively ($P=0.383$).

Conclusion The analgesic effect of ropivacaine infusion with concentrations of 0.25% and 0.50% administered via intrathoracic pumps for chest tube-related pain after UVATS showed no significant difference, but both were superior to the sole use of PCIA.

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Registration Chinese Clinical Trial Registry ChiCTR2200065184.
Keywords Ropivacaine, Chest tube pain, Intrapleural analgesia, Uniportal video-assisted thoracoscopic surgery

Introduction

The rapid advancement of thoracoscopic surgery has led to an increased focus on minimally invasive techniques, with uniportal thoracoscopy emerging as the leading approach. This method significantly reduces patient discomfort at incision sites compared to traditional thoracotomy [1]. However, both acute and chronic pain can persist following video-assisted thoracoscopic surgery (VATS), with reported incidence rates as high as 90% for acute pain and between 40% and 60% for chronic pain [2]. A major contributor to postoperative pain is the presence of an indwelling chest drainage tube, which has been shown to impede the process of enhanced recovery after surgery [3].

Postoperative indwelling chest tubes following uniportal video-assisted thoracoscopic surgery (UVATS) serve a dual purpose: draining pleural effusion and facilitating lung re-expansion, thereby reducing the risk of postoperative complications [4]. Traditionally, after a lobectomy, the standard practice has been to use two chest tubes: one positioned superiorly to evacuate air and the other inferiorly to remove fluid. However, the discomfort caused by the contact of chest tubes with the pleura often leads to patients being reluctant to engage in coughing and deep breathing exercises, which can negatively impact postoperative oxygenation. This reluctance may result in prolonged hospital stays, increased pain levels, and a higher risk of postoperative complications, such as atelectasis and lung infections [5].

Pain is recognized as the most prevalent direct complication associated with chest tube insertion, with an incidence rate of 4.1%, and a delayed complication incidence of 18%. Generally, smaller-caliber chest tubes (10–14 Fr) are associated with less pain compared to larger-caliber tubes (>20 Fr) [6]. While numerous studies have focused on pain reduction following chest tube removal [7–9], there is a paucity of data addressing pain management during the period of chest tube drainage. Modifying chest tube management protocols appears to be a promising strategy for alleviating pain associated with drainage tubes. One study demonstrated that the use of a 7-Fr central venous catheter instead of a conventional chest tube significantly reduced perioperative pain in patients undergoing VATS [10]. Additionally, another investigation revealed that employing bi-pigtail catheter drainage (two 8-Fr pigtail catheters) resulted in significantly lower Numeric Pain Rating Scale scores for patients three days post-surgery when compared to traditional chest tube drainage using a single 28-Fr chest tube [11].

The concept of intrapleural analgesia (IPA) was first proposed by Reiestad and Stromskag in 1986 [12]. The analgesic efficacy of IPA has long been a subject of debate. In 1987, Rosenberg et al. [13] demonstrated that a single administration of 0.50% bupivacaine in a volume of 15-20 ml, or a continuous infusion of 0.25% bupivacaine at a rate of 5–10 ml/h, could effectively manage post-thoracotomy pain. However, subsequent investigations have proposed that the administration of 40 ml of 0.25% bupivacaine or 20 ml of 0.5% bupivacaine may be inadequate for achieving sufficient analgesia [14]. The principle of IPA entails the infiltration of a local anesthetic into the tissue plane situated between the visceral and parietal pleura, subsequently diffusing into the subpleural space and accompanied by a multisegmental intercostal nerve block. Hence, IPA is also termed interpleural analgesia [15, 16]. Upon entering the pleural space, the local anesthetic initially diffuses to the intercostal spaces situated both above and below the catheter insertion point, and then spreads inwardly towards the paravertebral space. Consequently, the analgesic coverage extends across multiple dermatomes [17]. For thoracoscopic minimally invasive surgery, IPA is not an adventurous analgesic technique; on the contrary, it is even safer and easier to manage than thoracic epidural analgesia (TEA) [18]. The administration of IPA through the chest drainage tube does not result in any serious complications, and additionally improves the patient's ventilation function [19–21].

The safety and efficacy of intrapleural ropivacaine administration have been thoroughly investigated [22, 23]. However, there is limited information regarding the effective concentration of ropivacaine for alleviating chest tube pain after UVATS. The commonly used intrathoracic analgesic concentrations of ropivacaine in clinical anesthesia range from 0.2 to 0.75% [18, 22, 24, 25]. Previous studies have shown that a single intrapleural administration of 0.75% ropivacaine (15 ml or 20 ml) and four consecutive doses of ropivacaine (15 ml administered every four hours) are effective in reducing cough-related pain after thoracoscopic procedures [22, 26]. Furthermore, patients who underwent ultrasound-guided continuous paravertebral catheterization with a continuous infusion of 0.2% ropivacaine reported greater satisfaction with their pain management compared to those receiving single-shot intercostal blocks following VATS [27].

This study aims to evaluate the effectiveness of intermittent intrapleural infusion of varying concentrations of ropivacaine (0.25% and 0.50%) in alleviating pain and

discomfort associated with chest tubes. We hypothesized that in patients experiencing UVATS, the use of ropivacaine IPA was more effective in alleviating chest tube-related pain than the use of PCIA alone, and that the analgesic effects of 0.5% and 0.25% ropivacaine were comparable.

Methods

Registration and ethical approval

This prospective, randomized, unblinded trial was approved by the the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University (Ethics ID.2022 – 151, Chairman Dr. PingXu) on the 29th of June 2022. This study was registered in the Chinese Clinical Trial Registration Center (Registration ID: ChiCTR2200065184, https://www.chictr.org.cn/showproj.html?proj=182214) and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All study subjects provided written signed informed consent. The CONSORT guidelines for reporting randomised control trials were followed (Fig. 1).

Recruitment and patient involvement

We recruited participants who were scheduled to undergo UVATS at the First Affiliated Hospital of Chongqing Medical University from 2022/11/01 to 2023/05/31. The inclusion criteria include: (1) age ≥ 18 years; (2) Grade I-III according to the ASA; (3) no contraindications to general anesthesia; (4) BMI 18.5–24 kg/m^2. The exclusion criteria include: (1) pregnant or breastfeeding patients; (2) history of chronic pain; (3) history of alcohol or opioid dependence; (4) cardiopulmonary insufficiency or heart failure; (5) central nervous system diseases; (6) hepatorenal insufficiency; (7) allergic to amide local anesthetics or opioid medications; (8) intraoperative conversion to open-heart surgery; (9) abnormal sensation of thoracic skin or the presence of infections and ulcers at the incision site of thoracic surgery; (10) participation in other clinical trials at the same time; 11. inability to score the VAS Scale; 12. the patients suffered serious complications or accidents before the end of the trial; 13. the patients requested to withdraw from the clinical trial; 14. a postoperative indwelling closed chest drain was not required; 15. postoperative transfer to the ICU was required. In this study, we recruited 93 patients, yet three were excluded from the final analysis due to not meeting the inclusion criteria.

Trial procedures

Ninety subjects were evenly divided into three groups ($n = 30$). All three groups of patients received ultrasound-guided thoracic paravertebral block (TPVB) on the surgical side before surgery, the dosage administered is 40 ml of 0.25% ropivacaine. Ropivacaine injection (10 ml:100 mg, Aspen, batch no.NBPS) was preservative-free, free of additives and chemical stabilizers.

Control group (Group N): routine use of PCIA after surgery;

0.25% Group (Group L): Routine use of PCIA after surgery combined with intrathoracic infusion of 0.25% ropivacaine (total volume 200 ml);

0.5% Group (Group M): Routine use of PCIA after surgery combined with intrathoracic infusion of 0.5% ropivacaine (total volume 200 ml).

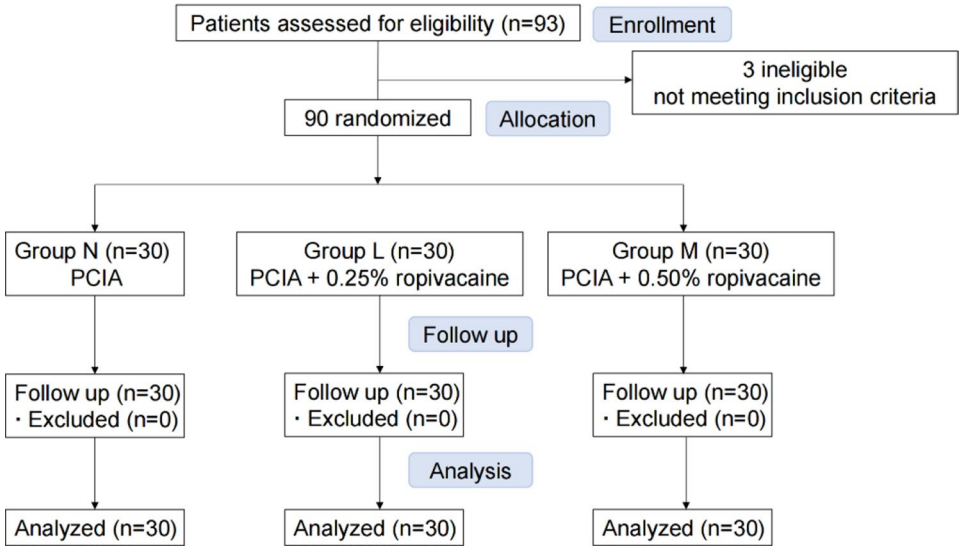

Fig. 1 CONSORT flowdiagram of the study design

The randomization sequence was independently created by team member YG-H using EXCEL's random number generator. YG-H was not involved in data collection or patient care. The codes were sealed in sequentially numbered opaque envelopes and were only opened by GM-W before analyzing the results. The data collection was conducted by WJ-T, who remained blinded to the group assignments.

Preoperative preparations

During the preoperative evaluation, the researchers fully educated the patients and their families about the detailed use and advantages and disadvantages of the pulse self-control analgesic pump (Apon®, Jiangsu, China). The patients were instructed to press the analgesic device when they perceived their conscious VAS score > 3 for patient-controlled analgesia. The VAS scores were recorded at rest and while coughing at 6 h, 12 h, 24 h, and 48 h postoperatively.

Anesthesia protocol

All subjects were fasting for 8 h and water deprivation for 2 h before surgery. Prior to the surgery, ultrasound-guided paravertebral nerve block (0.25% ropivacaine, 40 ml) was performed on the surgical side. Anesthesia induction was performed with intravenous propofol (2 mg/kg), sufentanil (0.5ug/kg), vecuronium bromide (0.1 mg/kg), and midazolam (0.05 mg/kg). For maintenance of anesthesia, propofol (4 mg/kg·h pumped), sevoflurane (1%~2% inhalation), remifentanil (10ug/kg·h pumped), sufentanil (10ug/h), and intermittent administration of vecuronium bromide and sufentanil were used to maintain a bispectral index (BIS) of 40–60. For two-lung ventilation, the maintenance tidal volume at 8 ml/kg, respiratory rate at 12 breaths/min, and inspiratory/expiratory ratio at 1:2. During the surgery, the patient's heart rate, arterial blood pressure, and arterial blood CO_2 partial pressure are continuously monitored. During mechanical ventilation, parameters such as tidal volume, respiratory rate, and PEEP are dynamically adjusted based on blood gas analysis and $PETCO_2$. For single-lung ventilation, tidal volume is set at 8–10 ml/kg with a respiratory rate of 15 breaths per minute. PaO_2 is maintained above 70 mmHg, and $PaCO_2$ is kept at 37–40 mmHg, while peak inspiratory pressure is limited to 30 cmH_2O. If PaO_2 drops or hypoxemia occurs, PEEP is applied to the ventilated lung, with the PEEP value not surpassing 5 cmH_2O. Two-lung ventilation is preferred whenever possible. The dosage of anesthesia medication is adjusted according to the BIS value. Vasoactive drugs and fluid replacement are used based on the patient's circulatory condition. A double-lumend endotracheal tube or bronchial blocker is inserted according to the surgical side of the patient.

After the end of surgery, all patients were routinely placed on intravenous self-control analgesic pumps for intravenous self-control administration of analgesia (sufentanil 50 μg, flurbiprofen ester 100 mg, saline 69 ml), with a background infusion volume of 2 ml/h, a lockout time of 20 min, and a single dose of 2 ml of bolus, with a maximum dose of 20 ml per hour. Two closed chest tubes of different diameters are routinely placed in the pleural cavity. The 24-Fr (Cat No.#4242, QINGZE, Jiangsu, China) chest tube is placed at the incision, while the 10-Fr (Cat No.#YB-A-I-3.3/235, YUBANG, Jiangsu, China) chest tube is placed in the second intercostal space below the incision. The anesthesiologist immediately connects the prepared ropivacaine pulse pump to the side channel of the 10-Fr chest tube and administers the first dose of medication into the pleural cavity (Fig. 2). A patient-controlled analgesia pump intermittently injected 0.25% or 0.50% of ropivacaine into the pleural cavity. The initial loading dose was 15 ml, the background infusion rate was 1.0 ml/h (to avoid catheter blockage), the lockout time was 4 h, a single bolus of 15 ml was administered, and the maximum dosage was 250 mg (total volume 200 ml). The medication in the patient-controlled analgesia pump should be infused within 48 h after surgery.

Patients were asked to report rest and cough pain on a standardized VAS after completion of administration for 6 h, 12 h, 24 h, and 48 h. The rest VAS score ≤ 3 was considered effective analgesia, otherwise it was deemed ineffective. For patients identified as ineffective, tramadol injection (2 ml:100 mg) will be administered intramuscularly for analgesic remediation.

Outcome measures

The primary outcome was the effective analgesia for drainage discomfort, defined as the rest and cough VAS scores for chest tube pain within 48 h after ropivacaine administration. Cough VAS was defined as VAS when coughing. Scores ranged from 0 to 10, with 0 denoting no pain; 1–3 denoting mild pain; 4–6 denoting moderate pain; and 7–10 denoting intractable pain. Secondary outcomes in this study included incision pain (defined as the rest and cough VAS scores); incidence of hypotension (defined as a decrease in blood pressure of more than 20% from baseline, or an absolute value of < 90mmHg); nausea and vomiting; bradycardia (defined as a heart rate of < 60 bpm); and respiratory depression (defined as an oxygen saturation of < 90).

Sample size estimation

The sample size for this study was determined based on the outcomes of a preliminary experiment. In this experiment, thirty qualified patients were randomly and equally assigned to three groups. At the end of UVATS, each receiving intrathoracic analgesia with ropivacaine at

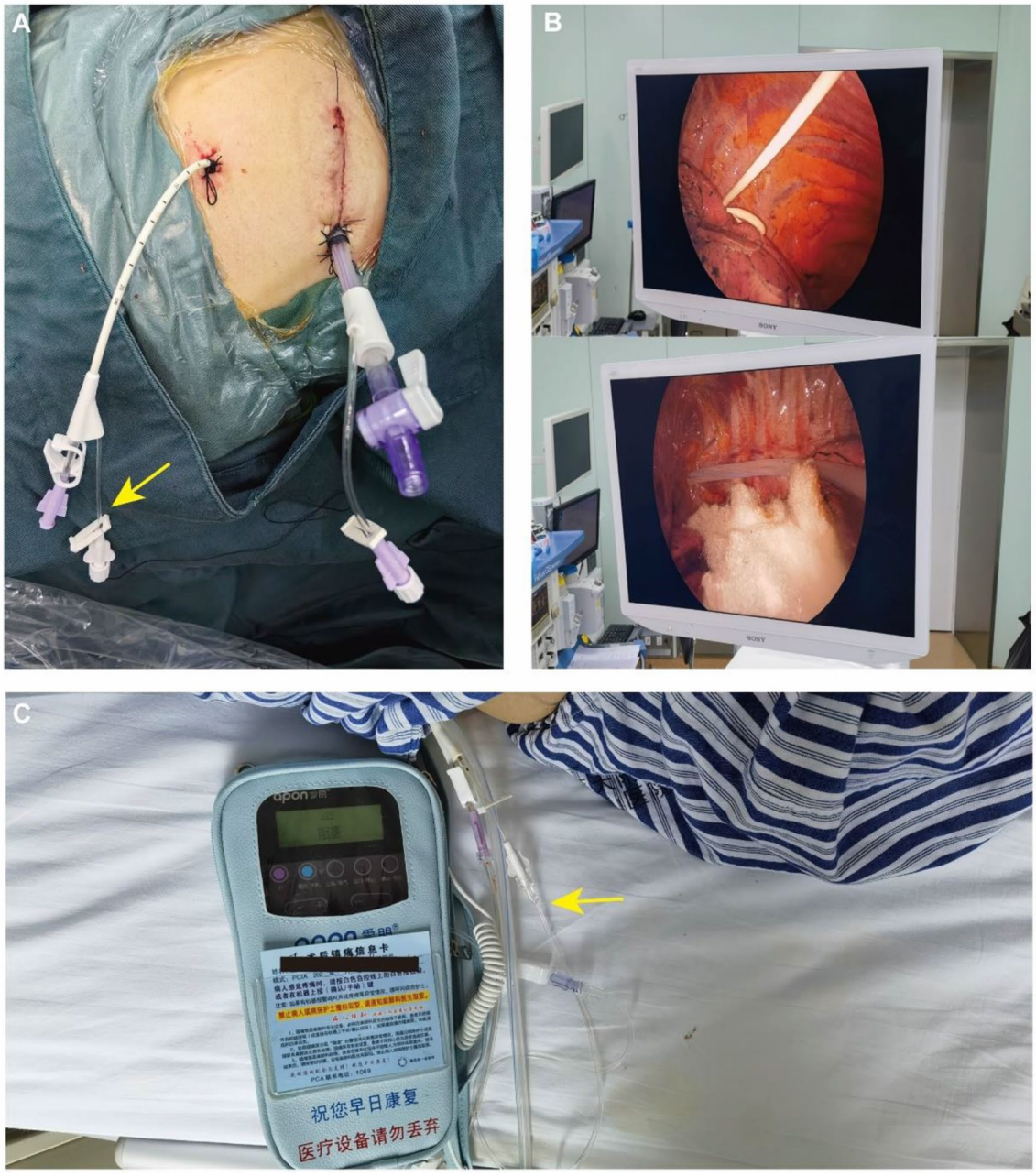

Fig. 2 Drainage strategies after uniportal video-assisted thoracic lung surgery. (**A**) One 24-Fr×20 cm catheter was placed at the incision site, and another 10-Fr×20 cm catheter was placed in the second intercostal space below the incision. (**B**) Thoracoscopic view of two drainage tubes placed. (**C**) The ropivacaine infusion pump is connected to the side tube of the 10-Fr chest tube (indicated by the yellow arrow)

concentrations of 0.125%, 0.25%, and 0.5%, respectively. The cough VAS scores for drainage tube pain at 6 h were analyzed [28], and the results were as follows: 3.8 ± 1.03 (group N), 2.5 ± 0.84 (group L), 1.9 ± 0.57 (group M) (Supplemental File 1). For a one-way ANOVA comparing three groups, calculate the sample size needed in each group to obtain a power of 0.90, and a significance level of 0.05 is employed. Sample size calculation was performed using PASS software (NCSS, LLC), which determined that a total of 81 patients needed to be recruited. Considering a 10% dropout rate, a minimum of 30 patients were required in each group.

Statistical analysis

Normally distributed data are expressed as the mean ± SD. Date with a skewed distribution were expressed as the median (interquartile interval, Q1~Q3). Discrete data are expressed as numbers and percentages. For continuous data that met the assumptions of normality and homogeneity of variance, one-way ANOVA with LSD post-hoc

Table 1 Comparison of general data among the three groups

	Group N($n=30$)	Group L($n=30$)	Group M($n=30$)	*P*-value
Age (year)	55.9 ± 9.8	56.8 ± 10.3	55.8 ± 9.4	0.857
Sex (male/famale)	13/17	12/18	15/15	0.730
BMI (kg/m^2)	23.2 ± 2.4	23.3 ± 2.9	23.7 ± 2.9	0.817
Operation time (min)	97.0 ± 43.2	134.7 ± 91.2	92.2 ± 48.5	0.277
Type of disease				0.600
Lung cancer	30	29	29	
Pulmonary nodule	0	1	1	
ASA (II/III)	23/7	21/9	18/12	0.378

Data were presented as the mean ± SD. Group L: 0.25% ropivacaine, group M: 0.50% ropivacaine

tests were used for multiple comparison corrections. For continuous data with skewed distribution, Kruskal-Wallis Test and Bonferrion correction were applied for multiple comparison corrections. Counting data were compared by the χ^2 test. A two-tailed *P*-value < 0.05 was considered statistically significant. All data were analyzed using SPSS software version 26.0 (SPSS, Inc., USA).

Results

Comparison of demographic information

This study included a total of 90 valid samples, with 30 cases in each group. All patients received the first intrapleural administration of ropivacaine pulse pump immediately after surgery (Fig. 2). There were no statistically significant differences among the three groups in terms of age ($p=0.857$), sex ($p=0.730$), BMI ($p=0.817$), operation time ($p=0.277$), disease type ($p=0.600$), ASA classification ($p=378$), and other aspects, as shown in Table 1.

Comparison of postoperative chest tube pain scores by time period

To evaluate the efficacy of two concentrations of ropivacaine on chest drainage tube pain, the rest and cough VAS scores were recorded at 6, 12, 24, and 48 h postoperatively. For the rest VAS scores, no significant disparities in drainage tube pain intensity were observed among the three patient cohorts at the 6-hour ($p=0.062$), 24-hour ($p=0.234$), and 48-hour ($p=0.687$) post-operative marks. Notably, at the 12-hour mark, Group M exhibited a significantly lower pain level compared to both Group N ($p=0.028$) and Group L ($p=0.011$). To elaborate, the mean VAS score for Group M at this juncture was 0.83, contrasting with 2.17 for Group N and 1.80 for Group L. Regarding the cough VAS scores, at the 6-hours postoperative timepoint, both Group M ($p<0.001$) and Group L ($p=0.009$) reported significantly reduced drainage tube pain levels compared to Group N. However, no statistically significant difference was found between Group M and Group L in terms of pain alleviation ($p=0.570$). At the 12-hour, 24-hour, and 48-hour marks, both Group M ($p<0.001$) and Group L ($p<0.001$) continued to experience significantly lower drainage tube pain levels compared to Group N. Nonetheless, the analgesic efficacy between Group M and Group L remained comparable at these timepoints, with no significant variations observed ($p=0.263$ at 12 h, $p=0.775$ at 24 h, and $p=0.425$ at 48 h) (Table 2; Fig. 3).

Table 2 Comparison of rest and cough VAS scores of postoperative drainage tube pain among the three groups

Evaluation status	Group	6 h	12 h	24 h	48 h
Rest VAS	N	1 (1,1)	1.5 (0,4)	1 (0,1)	1 (0,1)
	L	1 (1,1)	1.5 (1,2.75)$^{\#}$	1 (0,1)	1 (0,1)
	M	1 (0.25,1)	1 (0,1)*	0 (0,1)	0 (0,1)
	P-value	0.062	0.011	0.234	0.687
Cough VAS	N	4 (3,5)	4 (3,4.75)	3 (2,4)	2 (1.25,2.75)
	L	3 (2,4)**	3 (2,3)***	2 (1,2)**	1 (0.25,2)**
	M	2 (2,3)***	2 (2,3) ***	2 (1,2) ***	1 (1,1) ***
	P-value	<0.001	<0.001	<0.001	<0.001

Data are presented as median (Q1, Q3). *,**,***represents $P<0.05$, 0.01, 0.001 in the comparison between this group and group N; $^{\#}$ represents $P<0.05$ in the comparison between this group and group M. ($n=30$)

Group L: 0.25% ropivacaine, group M: 0.50% ropivacaine

Comparison of postoperative incision pain levels among the three groups of patients

The analgesic effect of two concentrations of ropivacaine on postoperative surgical incisions was also evaluated, and rest and cough VAS scores were recorded at 6, 12, 24 and 48 h after surgery, respectively. Regarding the rest VAS, at the 12-hour postoperative mark, Group M exhibited significantly lower surgical incision pain scores compared to Group N ($p<0.001$), the mean VAS score for Group M was 0.87, while the mean VAS score for Group N was 2.17. However, no statistically significant difference was observed between Group M and Group L ($p=0.055$), nor was there a significant disparity between Group L and Group N ($p=0.729$). At the 6-hour, 24-hour, and 48-hour postoperative time points, the differences in surgical incision pain levels among the three groups were not statistically significant ($p=0.840$ at 6 h, $p=0.621$ at 24 h, and $p=0.950$ at 48 h). Regarding the cough VAS, at all postoperative time points evaluated, Group M demonstrated significantly lower surgical incision pain compared to Group N ($p<0.001$ for all time points). Compared to Group N, Group L showed a significant reduction in pain levels as well ($p=0.024$ at 6 h, $p=0.009$ at 12 h, $p=0.006$ at 24 h, and $p=0.014$ at 48 h). Notably, there were no statistically significant differences in pain levels between Group M and Group L across all time points ($p=0.438$ at 6 h, $p=1.00$ at 12 h, $p=1.00$ at 24 h, and $p=0.667$ at 48 h) (Table 3; Fig. 4).

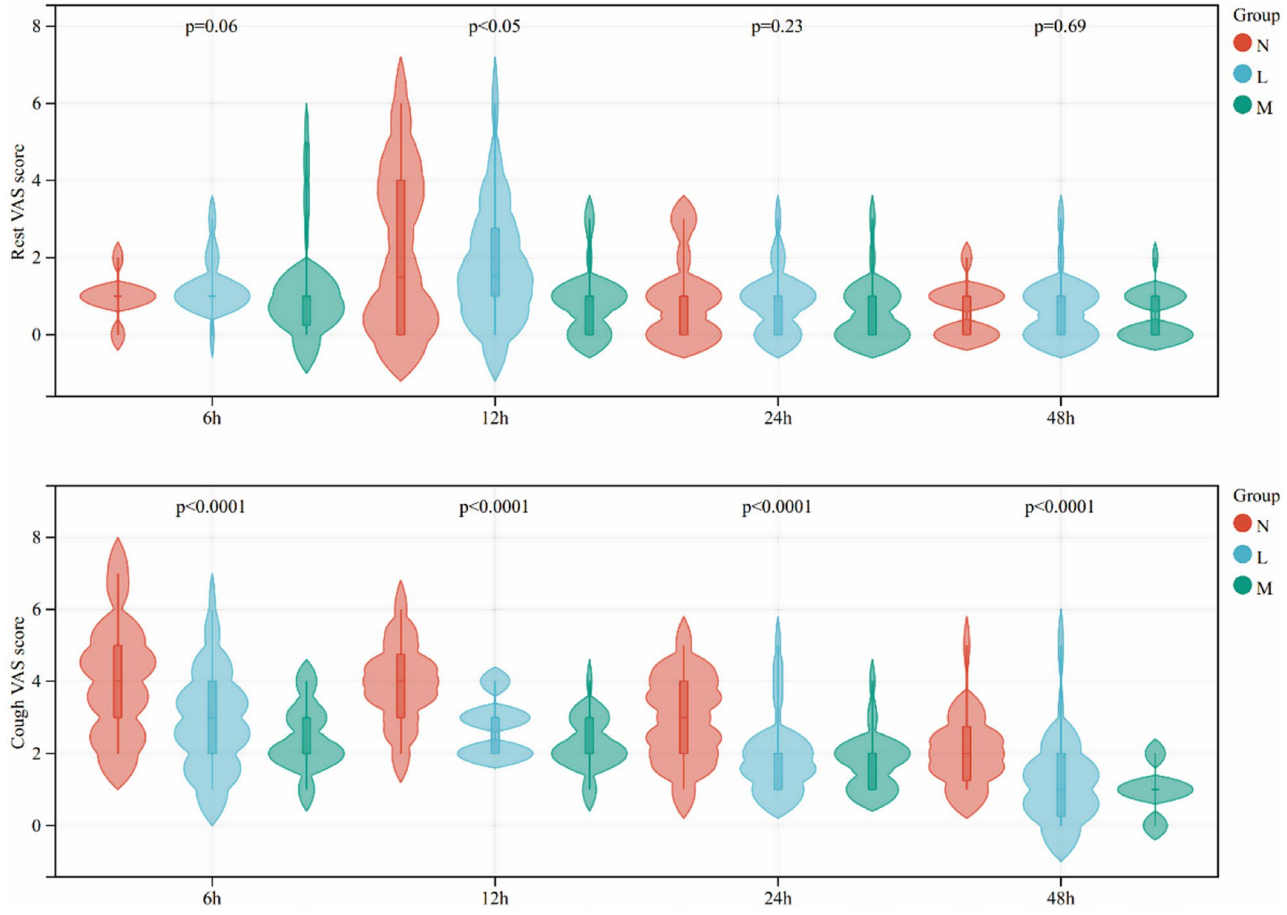

Fig. 3 Postoperative rest and dynamic visual analog scale (VAS) scores of drainage tube pain at different time points were compared among the three groups

Table 3 Comparison of rest and cough VAS scores of postoperative incision pain among the three groups

Evaluation status	Group	6 h	12 h	24 h	48 h
Rest VAS	N	1 (1,1)	2 (1,3)	1 (1,1.75)	1 (1,1)
	L	1 (1,1.75)	1 (1,2)	1 (1,1.75)	1 (0,1)
	M	1 (1,1)	1 (0,1)**	1 (1,1)	1 (1,1)
	P-value	0.840	0.002	0.621	0.950
Cough VAS	N	4 (4,5)	4 (3,4)	3 (2,3.75)	2 (1,2)
	L	3 (3,4)*	2.5 (2,4)**	2 (2,3)**	1 (1,2)*
	M	3 (2,3.75)***	2 (2,3)**	2 (2,2)***	1 (0,1.75)***
	P-value	<0.001	<0.001	<0.001	<0.001

Data are presented as median (Q1, Q3). *,**,***represents *P*<0.05, 0.01, 0.001 in the comparison between this group and group N. (*n* = 30)

Group L: 0.25% ropivacaine, group M: 0.50% ropivacaine

Secondary outcome of analgesia during 48 h after surgery

Within 48 h after surgery, there were no significant differences in the incidence of adverse reactions such as respiratory depression, hypotension, nausea and vomiting, bradycardia, dizziness, and hypoxemia among the three groups, as shown in Table 4.

Discussion

UVATS has emerged as a prominent minimally invasive surgical technique for lung procedures. Its increasing prevalence in lung surgeries can be attributed to several advantages, including minimal tissue trauma, expedited postoperative recovery, and a lower incidence of complications [29]. In contrast to traditional three-port thoracotomy, single-port thoracoscopy is characterized by a single incision, typically utilizing a thick silicone tube for routine drainage within the thoracic cavity. However, this method does not effectively alleviate postoperative pain or promote faster healing of the incision [30, 31]. The presence of the chest tube within the incision site complicates the secure suturing of the chest wall musculature. After the tube is removed, a cavity that is difficult to heal remains within the chest wall muscle, and fluid accumulation in this space further hinders the healing process [32]. Additionally, the insertion of the chest tube into the thoracic cavity may lead to complications such

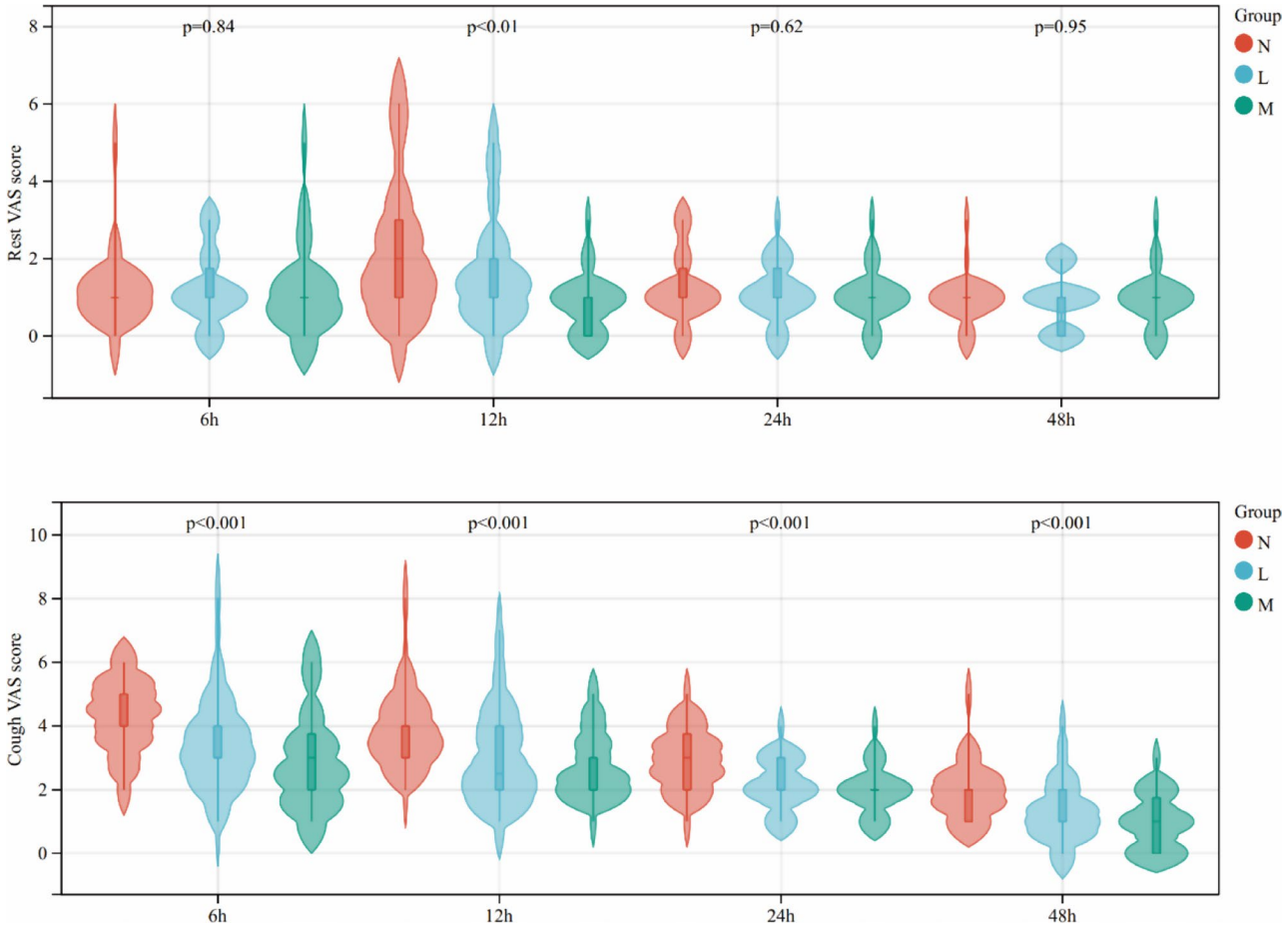

Fig. 4 The rest and dynamic visual analog scale (VAS) scores of postoperative incision pain at different time points were compared among the three groups

Table 4 Comparison of adverse reactions during 48 h after surgery among the three groups

Variable	Respiratory depression	Hypotension	Nausea and vomiting	Bradycardia	Dizziness	hypoxemia	Total adverse reaction rate (%)
Group N ($n=30$)	0	0	2	0	2	0	4 (13.3%)
Group L ($n=30$)	1	1	0	0	1	0	3 (10.0%)
Group M ($n=30$)	0	0	0	0	1	0	1 (3.3%)
χ^2	2.022	2.022	4.091	-	0.523	-	1.921
P-value	0.364	0.364	0.129	-	0.770	-	0.383

Data are presented as (n, (%)). Group L: 0.25% ropivacaine, group M: 0.50% ropivacaine

as intercostal nerve compression, pleural irritation, and diaphragmatic discomfort. Notably, the inner diameter of the chest tube has been identified as a significant independent risk factor influencing the severity of postoperative pain [5, 33].

The clinical presentations of local anesthetic systemic toxicity (LAST) encompass prodromal symptoms such as oral paresthesia, metallic taste, disorientation, dizziness, and somnolence, succeeded by central nervous system manifestations like epileptic seizures. The most severe consequence can lead to cardiac arrest, with toxic symptoms potentially emerging as early as 6 h post-administration of the local anesthetic [34, 35]. The maximum recommended single dose of ropivacaine is 3 mg/kg, with a total dose not exceeding 200 mg [36]. To determine whether ropivacaine can effectively alleviate postoperative pain associated with drains while ensuring adequate analgesia, it is imperative to investigate the minimum concentration of ropivacaine that can provide sufficient analgesic effects while minimizing the volume of local

anesthetic used and the associated side effects. A notable finding from this study is the equivalence in chest tube pain analgesic potency demonstrated by 0.5% and 0.25% concentrations of ropivacaine. This result may be due to the fact that the analgesic effect primarily depends on the dosage of the local anesthetic, rather than its concentration, as its mechanism of action requires the diffusion and infiltration of terminal nerves in the pleural cavity. Furthermore, administering TPVB to all patients before surgery helps reduce central sensitization and pain intensity, thereby potentially minimizing any differences in analgesic efficacy among the varying concentrations of ropivacaine used.

The findings of this study also indicate that the incorporation of ropivacaine in conjunction with PCIA yields superior relief from surgical incision pain compared to PCIA alone. However, there was little difference in the analgesic effect of the two concentrations of ropivacaine on surgical incision pain at 6, 12, 24, and 48 h after surgery. Notably, at 12 h postoperatively, patients receiving 0.5% ropivacaine exhibited significantly lower rest VAS scores for chest tube pain compared to both the 0.25% ropivacaine group and the PCIA control group. Additionally, the rest VAS scores for surgical incision pain in the 0.5% ropivacaine group also being significantly lower than those in the PCIA control group. These findings are consistent with a prior study by Jian et al. [28], which reported that 0.50% ropivacaine provided superior analgesic effects compared to 0.33% ropivacaine in patients undergoing thoracoscopic lung wedge resection, particularly within the first 12 h post-surgery. Concerning the reasons for the analgesic difference observed at the 12-hour postoperative mark, we speculate that it may be associated with the plasma metabolic rate and the accumulating dose of ropivacaine.

Preliminary experiment results showed that 0.125% ropivacaine failed to achieve effective drainage tube analgesia, while only 0.25% and 0.5% ropivacaine demonstrated relatively better analgesic effects. Consequently, only 0.25% and 0.5% concentrations of ropivacaine were selected for our formal experiments. We hypothesize that the unsatisfactory analgesic effect of 0.125% ropivacaine may be related to the mode of administration. IPA involves the deposition of the local anesthetic within the pleural cavity, a process that necessitates adequate time and space for diffusion and infiltration to reach the nerve endings of the chest wall and intercostal nerves. Moreover, the accumulation of blood and exudative fluids within the pleural cavity can further dilute the local anesthetic. Concurrently, a proportion of the local anesthetic is lost through the chest drainage tube [15, 17, 37]. Collectively, these factors contribute to the suboptimal blocking effect of 0.125% ropivacaine. In this study, we utilized the auxiliary tube of the multi-channel thoracic drainage system for drug administration without the need for additional tubing. Ropivacaine was delivered through the auxiliary tube using patient-controlled analgesia in the postoperative period. This approach not only reduced patient discomfort but also lowered the risk of infection. Our findings further indicated that there were no statistically significant differences in adverse effects between the experimental and control groups, suggesting that both concentrations of ropivacaine can be safely employed for IPA. Due to the susceptibility of patients to postoperative infectious complications in the lungs, we consider it unethical to instill physiological saline into the pleural cavity of patients for two consecutive days following UVATS, as this practice offers no clinical benefits to the patients and may even pose clinical risks [13, 38]. Therefore, this study was unblinded.

This study has several limitations. The investigation did not evaluate the median effective analgesic concentration of ropivacaine; instead, it concentrated solely on the analgesic effects of two lower concentrations. As a result, the precise minimum effective concentration requires further investigation.

Conclusion

In summary, both 0.25% ($p < 0.001$) and 0.50% ($p < 0.001$) concentrations of ropivacaine are effective in alleviating chest tube pain within 48 h after UVATS during continuous IPA treatment. There is no significant difference in adverse drug reactions among the three groups ($p = 0.383$). Considering the lower dosage and comparable efficacy, 0.25% ropivacaine may be deemed a superior choice.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-02992-5.

Supplementary Material 1

Supplementary Material 2

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Author contributions

Yonggang Hao conceived and design the study, Wenjing Tang wrote the main manuscript text, Gangming Wu analyzed the data and prepared all tables and figures, Haixia Wang performed the anesthesia. All authors reviewed the manuscript.

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

Declarations

Ethics approval and consent to participate
This work was approved by the the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University (Ethics ID.2022-151, Chairman Dr. PingXu). And was registered in the Chinese Clinical Trial Registration Center and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All study subjects provided written signed informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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