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# Real-world study on the application of enhanced recovery after surgery protocol in video-assisted thoracoscopic day surgery for pulmonary nodule resection

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## Abstract

**Objective** This study aims to evaluate the real-world effectiveness of applying different levels of Enhanced Recovery After Surgery (ERAS) guidelines to video-assisted thoracic day surgery (VATS). The goal is to determine the optimal degree of ERAS protocols and management requirements to improve postoperative recovery outcomes.

**Methods** It was designed as a single-centre, prospective pragmatic randomized controlled trial (PRCT), including patients who underwent VATS at the Day Surgery Center of West China Hospital, between January 2021 and November 2022. Patients were divided into Group A and Group B through convenience sampling to implement different levels of ERAS management protocols. Data collection included the baseline characteristics (gender, age, marital status, education level, BMI, PONV risk score, ASA classification), surgery-related indicators (type of surgery, pathological results, hospitalization costs, duration of surgery, intraoperative blood loss, intraoperative rehydration volume), postoperative recovery indicators (postoperative chest tube duration time, time to first postoperative ambulation and urination, postoperative complications, follow-up condition), pain-related indicators (pain threshold score, pain score at 6 h postoperatively, bedtime, and predischarge), psychological state indicators (anxiety level), Athens Insomnia Scale (AIS) scores, and social support scores. Propensity score matching (PSM) was utilized and statistical analyses were conducted using R version 4.4.1. Comparisons of categorical variables were performed using the $\chi^2$ test, while comparisons of continuous variables were conducted using ANOVA or the Kruskal-Wallis rank-sum test. A significance level of $\alpha = 0.05$ was set for statistical tests.

**Result** A total of 340 patients were included, with 187 in Group A and 153 in Group B. After propensity score matching (PSM), there were 142 patients in Group A and 105 in Group B, with no significant baseline differences. Group A had a significantly higher proportion of chest tube removals within 24 h postoperatively ($P < 0.001$) and earlier mobilization ($P < 0.001$). Despite a higher pain threshold in Group A ($P = 0.016$), their postoperative pain scores were not higher than those in Group B. Additionally, Group A had a lower incidence of postoperative complications.

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**Conclusion** The more comprehensive ERAS protocol significantly improved postoperative recovery, confirming its value in day-case VATS and supporting its clinical adoption. However, the study has limitations; future research should focus on standardizing ERAS protocols and expanding their application to a broader patient population to validate these findings further.

**Trail Registration** This study underwent review by the Ethics Committee of West China Hospital of Sichuan University under No. 2020 (1001). It has been officially registered with the China Clinical Trial Registry, TRN: ChiCTR2100051372 and registration date is Sept. 22, 2021.

**Keywords** Day surgery, ERAS, VATS, Video-assisted thoracoscopic surgery, Real world study

## Background

Day surgery is an innovative surgical management model that dates back to the 19th century. It is defined as a surgical or procedural intervention where patients are admitted and discharged within a 24-hour period in accordance with a predetermined treatment plan [1]. Benefiting from the development of the enhanced recovery after surgery (ERAS) concept, day surgery has gained widespread international recognition and has been applied in various clinical fields [2]. The ERAS concept has also facilitated the transition of certain complex surgical procedures from inpatient to day surgery management, such as video-assisted thoracoscopic surgery (VATS) for lobectomy in early-stage lung cancer and laparoscopic colorectal cancer resection [1, 3].

Particularly in China, lung cancer ranks first in both incidence and mortality rates, making timely treatment crucial for patient survival [3]. The implementation of day-case VATS offers an effective solution to the problem of timely surgical treatment [4]. VATS, as a minimally invasive surgery, involves small incisions in the chest to insert a camera, which reduces postoperative recovery time and lowers the risk of postoperative complications. These characteristics make VATS an ideal choice for day surgery [5]. Since 2019, our day surgery centre has pioneered the implementation of day-case VATS for pulmonary nodule resection in China. Prospective studies and clinical practice reports have demonstrated its feasibility and high value for widespread adoption [6, 7]. However, current recovery strategies primarily reference the enhanced recovery guidelines for lung surgery jointly proposed by the ERAS Society and the European Society for Thoracic Surgery (ESTS) in 2018, which have several limitations: Firstly, the optimal level of adherence to ERAS management guidelines to achieve maximum benefit remains an unanswered and critical question [8]. Secondly, due to a lack of robust data support, some guideline recommendations are still quite general and broadly applicable to other clinical disciplines. Finally, the guidelines themselves do not provide personalized reference suggestions specific to the VATS procedure [9, 10].

In real clinical settings, the degree of implementation and outcomes of ERAS management vary, influenced by factors such as large population bases, tight medical resource allocation, transitions to new models, and the involvement of multiple disciplines. For example, a survey in Chongqing, China, found that only 14.83% of inpatients received daily ERAS-related training activities [11]. An American study indicated that when the ERAS compliance rate exceeds 80%, the incidence of postoperative complications in gynecologic oncology significantly decreases [12]. Therefore, for VATS procedures under the day-case model, further exploration is needed to determine how to effectively implement ERAS guidelines to optimize postoperative recovery outcomes [4].

Real World Studies (RWS) utilize data from actual clinical, community, or home environments to evaluate the real impact of treatment measures on patient health [13]. RWS aims to obtain evidence that is more representative of clinical reality, thereby providing further validation and complementary insights to traditional randomized controlled trials [14, 15]. Given the current lack of a well-defined perioperative recovery process for VATS under the day-case model, our centre focuses on the consistency between the day surgery process and the ERAS concept, selectively integrating existing ERAS management guidelines into clinical practice. Through the analysis and evaluation of real-world clinical data, we aim to provide scientific evidence for the exploration of systematic perioperative recovery processes for VATS under the day-case model and the implementation of corresponding ERAS guidelines.

## Methods

### Objective

The objective of this study is to evaluate the efficacy of varying degrees of ERAS protocol application in VATS day surgery, as well as aims to delve into the optimal ERAS methodologies and management requirements to enhance the quality and safety of recovery for patients undergoing VATS day surgery.

### Study design

The study design was a pragmatic non-randomized controlled trial(PRCT).

## Participants and recriutment

Participants in this trial underwent VATS at the Day Surgery Centre of West China Hospital of Sichuan University from January 2021 to November 2022.

To be eligible for participating in the trial, individuals had to meet the following criteria: (1) Adherence to the clinical pathway of day surgery; (2) Chest CT showed that the diameter of pulmonary nodules was ≤3 cm; (3) Age≤55 years old; (4) Anesthetic risk grade according to the American Society of Anesthesiologists (ASA) was ≤II; (5) Absence of significant impairment in cardiopulmonary function, such as COPD, asthma, or severe hypertension; (6) VATS procedure was used and informed consent was given to this study. Exclusion criteria encompassed meeting any of the following conditions: (1) Disabilities affecting understanding and communication abilities; (2) Severe impairment of vision, hearing, or communicative abilities; (3) Undergoing radiotherapy, chemotherapy, or having a history of lung surgery; (4) Conditions hindering cooperation as judged by the study physician; (5) Concurrent participation in another intervention trial.

### Sample size calculation and grouping method

$$n = \frac{\pi_t \times (1-\pi_t) \times \pi_c \times (1-\pi_c)}{(\pi_t - \pi_c - \Delta)} \times (\mu_{\alpha/2} + \mu_{\beta})^2$$

This study is a clinical trial study with a stereotyped variable as the primary efficacy outcome indicator, using an equal (1:1) superiority design scheme, setting $\alpha=0.025$ (unilateral), $\beta=0.20$ (unilateral), $\Delta=5\%$, and estimating a sample size of n. According to the design of this clinical trial study and the primary efficacy outcome indicator, 84 cases are needed in each group as calculated by public disclosure. Considering a 20% dropout rate, each group needs to recruit 105 patients, totalling at least 210 cases in both groups.

The study planned to recruit at least 210 patients undergoing VATS at the Day Surgery Center of West China Hospital, Sichuan University. Patients meeting the eligibility criteria for VATS would sign informed consent forms and, based on their willingness to participate, were divided into Group A and Group B through convenience sampling. Each group received different levels of ERAS management.

### Different ERAS management measures

#### *Preoperative rehabilitation phase provided by MDT team for group A patients*

Inclusion criteria for pre-rehabilitation patients (meeting any of the following criteria): (a) Smoking cessation for more than 2 weeks, and meeting any of the following: smoking index≥800 pack-years/smoking index≥400 pack-years and age≥45 years old; (b) Airway hyperresponsiveness; (c) Female: PEF<280 L/min/Male: PEF<320 L/min; (d) Critical lung function state; (e) Obesity: BMI>30; (f) Prolonged surgical duration; (g) Smoking cessation for less than 2 weeks. Pre-rehabilitation measures: Preoperative education and counseling, exercise training, respiratory muscle exercises, airway clearance techniques, bronchodilators, breathing strategies, nutritional guidance, psychological intervention.

#### *Management of chest tubes*

Group A utilized 18 F Foley silicone balloon catheter drainage, injecting 15 mL of saline into the balloon and pulling it back to adhere to the chest wall without applying negative pressure suction. Group B employed conventional drainage materials. Both groups employed three-chamber water seal bottles for connection.

#### *Multi-modal pain management*

Both groups received timely pain education preoperatively at 7 days, 1 day before surgery, before surgery in the operating room, and when pain occurred. Pain thresholds were assessed by puncture nurses during venipuncture. Based on the patient's medication history, intravenous injections of flurbiprofen ester 5 mg or parecoxib sodium 40 mg were administered preoperatively. Group A patients orally took hydrocodone-acetaminophen tablets (each containing hydrocodone hydrochloride 5 mg, acetaminophen 325 mg) 1 h before surgery and received regional intercostal nerve block anaesthesia before the end of anaesthesia. Group B patients postoperatively received one transdermal fentanyl patch. Pain was assessed using the numerical rating scale (NRS) for both groups. For postoperative NRS scores≥4, parecoxib sodium 40 mg was administered intravenously; observation for 1 h, and if pain is not relieved, dexmedetomidine 5 mg (intravenous injection) is added. Upon discharge, if the wound pain score is ≥3, celecoxib 200 mg is orally administered, and if pain persists after 1 h, the patient is referred to a specialist through the hospital's green channel.

#### *Postoperative nursing pathway*

Group A patients were not monitored with ECG monitor after surgery, while Group B patients were monitored with ECG monitor for 6 h after surgery.

#### *Postoperative activity management*

Postoperative patients, categorized into Group A for immediate and Group B for delayed instruction four hours after they had returned to the ward, were accompanied by family members or nurses to initiate rehabilitation activities based on their tolerance. These activities included respiratory tract clearance training, bed exercises, and ambulation. For respiratory tract clearance training, the head of the bed was elevated by 30 degrees, and patient's knees were flexed to an angle of 15 to 30 degrees, followed by diaphragmatic breathing, deep breathing, and effective coughing. Bed exercises included flexion and extension of the upper and lower limbs, combing hair, arm movements with the healthy side supporting the affected elbow, hip and knee flexion, and ankle pumping exercises. Ambulation adhered to the "get up trilogy": after getting up, the patient sat for one minute, then dangled their feet over the edge of the bed for one minute, and finally stood for one minute. In the absence of symptoms such as dizziness or nausea, patients were permitted to engage in activities away from the bed, with careful attention paid to protecting the chest tube to prevent falls. The frequency of all activities was determined by the patient's endurance.

### Common ERAS management measures

#### *Preoperative management*

Thoracic surgeons and anesthesiologists assess patients based on day surgery admission criteria, including postoperative nausea and vomiting (PONV) risk assessment. Patients who passed the evaluation and entered into the day surgery integrated information management system. Preoperative management nurses conducted health assessments and guidance 7 days, 1 day and upon admission before surgery. Health assessment included blood glucose, blood pressure, medication history, smoking history within the past 4 weeks, and other abnormalities. Health guidance covered disease education, key points for surgical cooperation, respiratory exercise, smoking cessation within 4 weeks, perioperative dietary plans, pain education, PONV education, and postoperative activity plans.

#### *Surgical management*

The surgical and anaesthetic techniques employed were consistent across both patient groups. All procedures utilized the three-port approach, with double-lumen endotracheal intubation. Preoperative urinary catheterization was not performed. Intraoperative anaesthesia was administered using intravenous-inhalational combined anaesthesia. Unilateral ventilation of the healthy lung was maintained while the operative lung was intentionally collapsed. Resection types, wedge, segmentectomy and lobectomy, were determined based on the nodules' location, size, and characteristics. Systematic lymph node dissection was conducted in both groups with routine. Intraoperative frozen section pathological examination performed. Additionally, immunohistochemical analysis was conducted on all resected nodules [16].

#### *Dietary plan*

Preoperative dietary guidance included a light diet the day before surgery and fasting for 24 h prior. From before 6 a.m. to 2 h before surgery, clear fluids were allowed. Postoperative dietary instructions involved drinking warm water 30 min postoperatively, followed by consuming appetizers and nutritional powders at 2 and 4 h. Appetizers and nutritional powders were personalized by the nutrition department to promote early postoperative intestinal function recovery and meet the needs of different patients (ordinary patients or diabetic patients).

#### *PONV management*

Both groups of patients were assessed for PONV risk by anesthesiologists preoperatively, and total intravenous anaesthesia was administered to high-risk individuals throughout the procedure. Patients with low PONV risk were not restricted by the anaesthesia method. In the event of PONV, ondansetron 10 mg was administered, and oral intake was temporarily prohibited, along with intravenous fluid supplementation.

#### *Nebulization therapy*

Both groups received nebulized inhalation therapy two hours after surgery. The nebulized medication used was acetylcysteine (Fluimucil™) 3 ml.

#### *Fellow-up*

Professional nurses conducted postoperative follow-ups on days 2, 3, and 28 via telephone, intelligent voice systems, or internet-based platforms. The follow-up included assessments of diet, activity, wound healing, and chest tube conditions, as well as monitoring for symptoms like fever, cough with sputum, subcutaneous emphysema, and pain. Patients with a pain score of 3 or higher were instructed to take 200 mg celecoxib or ibuprofen, with their condition monitored for 60 min post-administration. In cases of special conditions or ineffective pain relief, a specialist was consulted. Patients are instructed for routine follow-up at the outpatient clinic one-month post-surgery. In the event of an emergency occurring after discharge, we will immediately activate the emergency green channel to ensure a swift response and professional medical team intervention, thereby providing timely safeguarding of the patient's life safety.

The comparison of all interventions between the two groups is shown in Fig. 1.

### Observation indicators & data collection

#### *Basic information material*

The study's medical staff retrieved patients' data from the medical management information system after enrollment. This included information such as age, gender, marital status, education level, and body mass index.

### Main observational indicators

#### *Indicators related to the occurrence of pain*

Patients' subjective complaints served as pain observation indexes, with medical staff assessing and recording throughout the process. Assessments occurred preoperatively (during venous puncture and tube placement), 6 h postoperatively, at bedtime, pre-discharge. The numerical rating scale (NRS), ranging from 0 to 10 points, was utilized, where 0 points indicate no pain, 1–3 points present mild pain, 4–6 points denote moderate pain, and 7–10 points signify severe pain [17].

#### *Indicators of postoperative rehabilitation*

Medical staff documented postoperative chest tube duration time, the first early ambulation activity time (in hours), the first postoperative urination time (in hours), and the regression before patients were discharged from the hospital. Considering the characteristics of postoperative bleeding time in VATS, the critical observation period for drainage fluid observation time, as well as the feasibility of clinical monitoring or documentation, we categorized the postoperative chest tube duration time into 0–6 h, 6–12 h, 12–24 h, and over 24 h. Indications for drain removal: The chest tube is removed at the bedside if a chest X-ray taken 4 h postoperatively shows no significant pneumothorax or pleural effusion.

#### *Surgery-related indicators*

Surgery type, pathological results, hospitalization costs, duration of surgery (in minutes), intraoperative blood loss (in millilitres), and intraoperative rehydration volume (in millilitres) were retrieved from the hospital management information system before the patients were discharged from the hospital.

### Indicators of postoperative complications

Indicators of postoperative complications were collected by the follow-up medical staff of the study group after the patient's surgery;

Pneumothorax: Chest X-ray suggesting > 30% pneumothorax and reintubation;

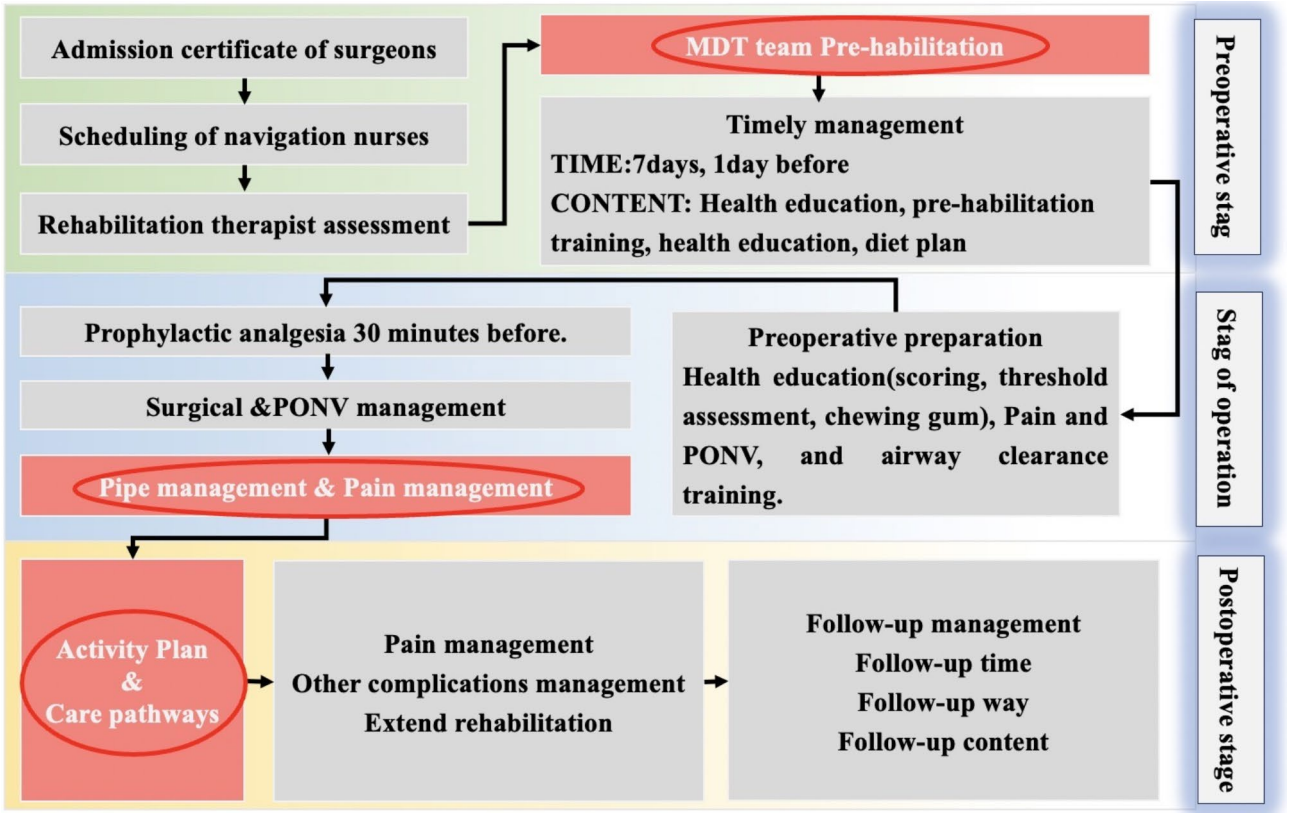


**Fig. 1** Intervention comparison between the two groups (The differences have been marked with circles)

Pleural effusion: chest radiograph suggests moderate to large amounts of fluid;

Bleeding: postoperative bloody drainage of more than 200 mL of fluid per hour and for 3 h;

Arrhythmias: including atrial fibrillation, atrial/ventricular pre-systole, paroxysmal supraventricular tachycardia, ventricular tachycardia;

Sputum retention; lung infection: clear evidence of pathogenesis, imaging suggestive of atelectasis or large lamellar shadows, fever, total white blood cell count > 10,000/mL or 15,000/mL;

Persistent lung air leaks: air leaks > 7 d and requiring clinical intervention.

#### Other indicators of postoperative adverse reactions

Other indicators of postoperative adverse effects were collected by the study group's follow-up medical staff after the patient's surgery;

Severe pain: Pain score ≥ 7;

Severe subcutaneous emphysema: the patient develops subcutaneous emphysema on the chest wall, head, face and neck ipsilateral and contralateral to the surgical incision;

Dyspnea; palpitation; dizziness;

Delirium: specialist consultation is required to confirm the diagnosis.

#### *Indicators of psychological state*

Anxiety was assessed using the Self-Rating Anxiety Scale (SAS), which includes 15 positively worded and 5 negatively worded items, rated on a 4-point scale. Patients were instructed by medical staff to complete the questionnaire upon hospital admission. Scores were based on the Chinese normative standard: <50 indicated no anxiety, 50–59 mild anxiety, 60–69 moderate anxiety, and ≥ 70 severe anxiety. The scale demonstrated high internal consistency with a Cronbach's alpha of 0.823.

#### *Sleep status indicators*

The Athens Insomnia Scale (AIS) was employed, consisting of an 8-item questionnaire, where each item was rated on a four-point scale from 0 to 3, resulting in a total score range of 0–24. A score of 4 or more indicates possible insomnia, with a Cronbach's alpha coefficient of 0.90 [18].

#### *Social support indicators*

The Social Support Rating Scale (SSRS) assesses social support through 10 items spanning three dimensions: subjective support, objective support, and utilization of support. A higher score indicates better social support. The scale exhibits an internal consistency coefficient of 0.81 and a retest reliability of 0.92 [19, 20].

#### *Indicators of postoperative nausea and vomiting*

The preoperative PONV Simple Risk Rating Scale for Adults (Apfel Scale) was utilized, considering 4 risk factors: female gender, nonsmoking status, history of motion sickness or PONV, and use of opioids [21]. Scores categorized patients as low risk (0–1 point), intermediate risk (2 points), or high risk (3–4 points).

### Statistical analysis

Statistical analysis was conducted using R version 4.4.1 (The R Foundation for Statistical Computing, 2024). Propensity score matching (PSM) was used to match patients between the two groups, including variables such as sex, age, marital status, educational level, BMI, PONV risk, and ASA classification. Logistic regression analysis was performed to obtain propensity scores, with a calliper value set at 0.03, and patients were randomly matched into groups at a 2:1 ratio based on the closest propensity scores. Categorical variables were expressed as proportions, while continuous variables were represented as mean ± standard deviation (SD) or median and interquartile range. The comparison of categorical variables among multiple groups was conducted using the $\chi^2$ test, and continuous variables were compared using analysis of variance (ANOVA) or the Kruskal-Wallis rank-sum test, depending on the normality of the distribution. A significance level of $\alpha = 0.05$ was set for statistical tests.

### Ethical review and trial registration

Patient informed consent: Prior to enrollment, patients participating in the study were provided with comprehensive information about this clinical trial. This included details on the trial procedure, treatment protocol and scale, the number and duration of follow-up visits, methods of reporting adverse events and adverse reactions, and confidentiality agreements for patient information. Participation in this study was entirely voluntary, and patients willingly agreed to take part by signing a written informed consent form before enrollment. The study underwent review by the Ethics Committee of West China Hospital of Sichuan University under No. 2020 (1001). It adheres to the principles outlined in the Declaration of Helsinki and has been officially registered with the China Clinical Trial Registry(TRN: ChiCTR2100051372, Registration Date: Sept. 22, 2021).

## Results

Between January 2021 and November 2022, 355 individuals were treated with VATS at our centre, with a total of 15 patients (4%) lost to follow-up or dislocated. Thus, 340 patients were included in the study: 187 in group A and 153 in group B, and subsequent propensity score matching analysis was performed. The flowchart is shown in Fig. 2.

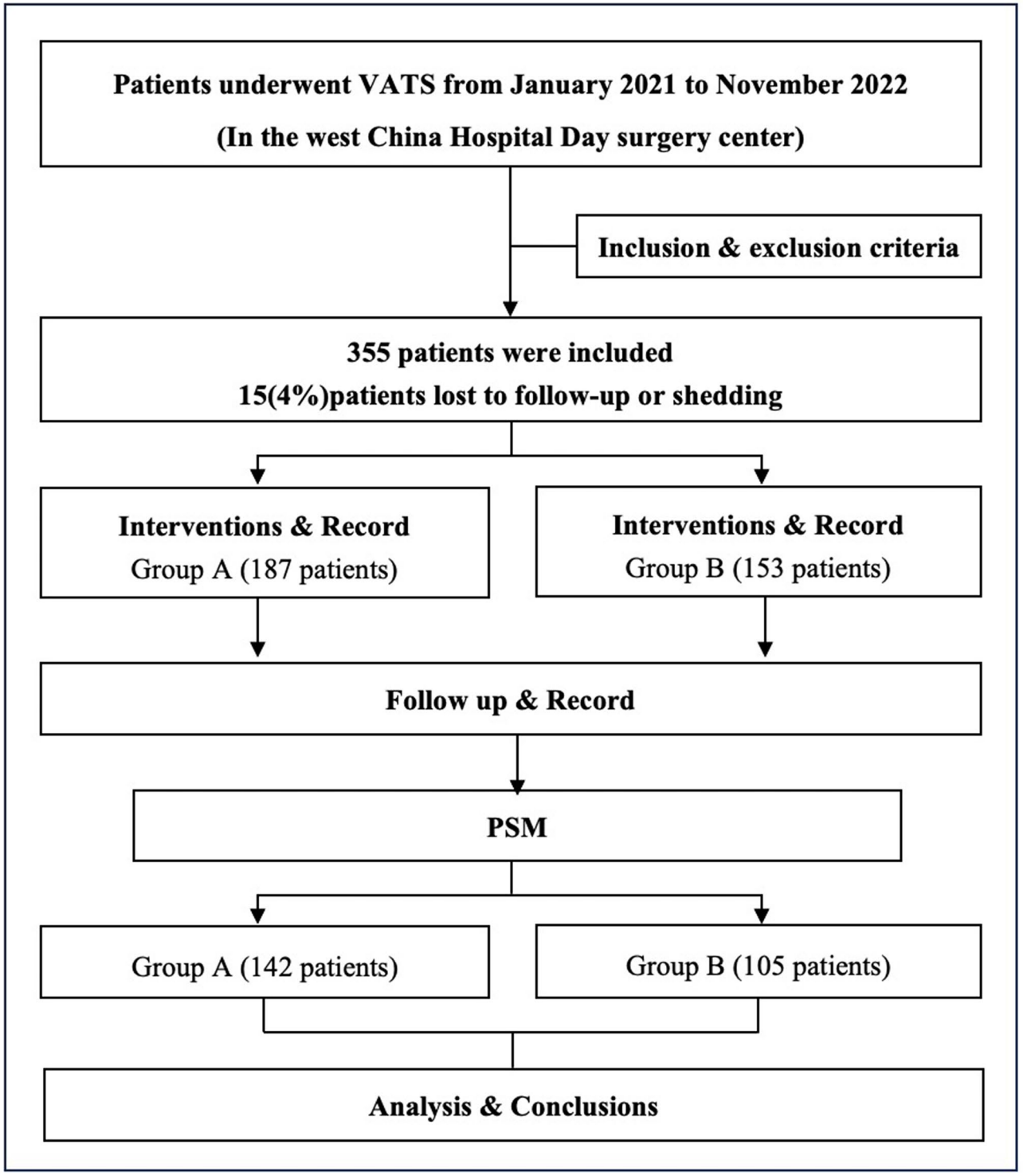


**Fig. 2** Study flow chart

#### PSM matching and baseline results

A total of 340 patients undergoing VATS were included in the study, with 187 patients in Group A and 153 patients in Group B. Prior to PSM matching, there was a statistically significant difference in educational level between the two groups ($P<0.05$). After matching, 142 patients were included in Group A, and 105 patients were included in Group B, with no statistically significant differences observed across various indicators ($P>0.05$), indicating baseline consistency (see Table 1).

**Table 1** Patients' baseline characteristics

| Observation indicators | Pre-PSM | | | Post-PSM | | |
|---|---|---|---|---|---|---|
| | Group A (*n* = 187) | Group B (*n* = 153) | *P*-value | Group A (*n* = 142) | Group B (*n* = 105) | *P*-value |
| **Gender** | | | | | | |
| Male | 40 (21.39%) | 40 (26.14%) | 0.304 | 33 (23.2%) | 25 (23.8%) | 1.000 |
| Female | 147 (78.61%) | 113 (73.86%) | | 109 (76.8%) | 80 (76.2%) | |
| **Age** | 42.50 (9.85) | 42.10 (10.31) | 0.143 | 41.35 (9.818) | 42.78 (9.610) | 0.255 |
| **Marital status** | | | | | | |
| Unmarried | 11 (5.88%) | 15 (9.80%) | 0.388 | 10 (7.0%) | 11 (10.5%) | 0.597 |
| Married | 174 (93.05%) | 136 (88.89%) | | 130 (91.5%) | 92 (87.6%) | |
| Divorced or widowed | 2 (1.07%) | 2 (1.31%) | | 2 (1.4%) | 2 (1.9%) | |
| **Education** | | | | | | |
| Junior high school | 13 (6.95%) | 31 (20.26%) | < 0.01 | 10 (7.0%) | 9 (8.6%) | 0.834 |
| Senior high school | 47 (25.13%) | 52 (33.99%) | | 42 (29.6%) | 33 (31.4%) | |
| Undergraduate and above | 127 (67.91%) | 70 (45.75%) | | 90 (63.4%) | 63 (60.0%) | |
| **BMI** | 21.66 [20.05, 23.90] | 21.81 [20.50, 23.81] | 0.627 | 22.42 [20.04, 24.41] | 22.21 [20.42, 23.73] | 0.570 |
| **PONV risk** | | | | | | |
| Non-high risk | 74 (39.57%) | 60 (39.22%) | 0.947 | 48 (33.8%) | 42 (40.0%) | 0.386 |
| High risk | 113 (60.43%) | 93 (60.78%) | | 94 (66.2%) | 63 (60.0%) | |
| **ASA** | | | | | | |
| 1 | 1 (0.53%) | 3 (1.96%) | 0.675 | 1 (0.7%) | 1 (1.0%) | 0.954 |
| 2 | 185 (98.93%) | 148 (96.73%) | | 140 (98.6%) | 103 (98.1%) | |
| 3 | 1 (0.53%) | 2 (1.31%) | | 1 (0.7%) | 1 (1.0%) | |

### Comparison of intraoperative and postoperative recovery indicators

As presented in Table 2, the comparison between Group A and Group B showed no statistically significant differences ($P>0.05$) in terms of surgical duration, intraoperative blood loss, intraoperative rehydration volume, pathological results, hospitalization costs, time of first urination, anxiety standard scores, anxiety grading levels, Athens sleep scores, social support scores, and follow up condition (include revisit and readmission rates). The result verified the proportion of extubation within 24 h postoperatively was higher in Group A compared to Group B patients ($P<0.01$). Group A patients also had earlier time to first ambulation after surgery ($P<0.01$).

### Comparison of pain-related indicators

The analysis did not show a significant difference in terms of the pain scores at postoperative 6 h, bedtime and pre-discharge, in spite of the pain thresholds of group A being significantly higher, with all observed differences statistically significant ($P=0.016$) (See Table 3).

### Comparison of postoperative complications

Postoperative complications occurred in a total of 4 patients in group A and 10 patients in group B. The complication rate was lower in group A than in group B ($P<0.05$), and the difference was statistically significant (Table 4).

## Discussion

This study aims to evaluate the effectiveness of different levels of ERAS management strategies in patients undergoing VATS day surgery. Compared to Group B, Group A implemented a bunch of systematic more comprehensive ERAS protocol, including preoperative prehabilitation, utilizing small-diameter drainage tubes, multimodal pain management, the absence of postoperative ECG monitoring, and the encouragement of early mobilization. The results demonstrated significant improvements in postoperative drainage duration, complication rates, and early mobilization in Group A. Although patients in Group A exhibited a higher pain threshold, their pain scores at various critical postoperative stages were not higher than those of Group B. A critical discussion of these interventions and study outcomes will follow.

Prehabilitation, as a comprehensive preoperative intervention, has been shown to enhance the physical and mental well-being of patients with pulmonary diseases, thereby facilitating better postoperative recovery [22]. The results indicates that patients in Group A, who received prehabilitation, experienced a significantly earlier time to first ambulation postoperatively, with an average advancement of 0.55 h, and showed marked improvements in postoperative activity. This finding is consistent with the conclusions drawn by Liu et al. in a randomized controlled trial, where a two-week multimodal prehabilitation program significantly improved patients' postoperative six-minute walk testresults, with

**Table 2** Intraoperative and postoperative rehabilitation indicators

| Observation indicators | Group A (*n* = 142) | Group B (*n* = 105) | *P*-value |
|---|---|---|---|
| **Surgery type** | | | |
| Lobectomy | 36 (25.35%) | 13 (12.38%) | < 0.001 |
| Segmentectomy | 95 (66.90%) | 19 (18.10%) | |
| Wedge | 11 (7.75%) | 73 (69.52%) | |
| **Duration of surgery(min)** | 60 (50, 74.5) | 55(43, 74) | 0.895 |
| **Intraoperative blood loss(ml)** | 20 (10, 20) | 10 (10, 20) | 0.132 |
| **Intraoperative Rehydration volume (ml)** | 300 (200,400) | 200(100, 900) | 0.963 |
| **Postoperative chest tube duration time (h)** | | | |
| 0–6 | 5 (3.5%) | 1 (1.0%) | < 0.001 |
| 6–12 | 39 (27.5%) | 11 (10.5%) | |
| 12–24 | 30 (21.1%) | 7 (6.7%) | |
| > 24 | 68 (47.9%) | 86 (81.9%) | |
| **Pathological results** | | | |
| Benign | 34 (23.9%) | 23 (21.9%) | 0823 |
| Malignant | 108 (76.1%) | 82 (78.1%) | |
| **Hospitalization costs** | 31865.43(6268.46) | 32705.30(6021.41) | 0.291 |
| **First ambulation activity time(h)** | 4.43(0.85) | 4.98(1.21) | < 0.001 |
| **First postoperative urination time(h)** | 5.95(1.12) | 6.19(1.04) | 0.091 |
| **Anxiety level** | | | |
| 0 | 129(90.85%) | 95(90.48%) | 0.580 |
| 1 | 10(7.04%) | 11(9.52%) | |
| 2 | 3(2.11%) | 0(0.00%) | |
| **Athens Sleep Score** | 37(31,44) | 36(30, 43) | 0.770 |
| **Social support score** | 3(0, 6) | 3(0, 6) | 0.502 |
| **Follow-up** | | | |
| Nomal | 137 (96.5%) | 96 (91.4%) | 0.160 |
| Revisit | 4 (2.8%) | 5 (4.8%) | |
| Readmission | 1 (0.7%) | 4 (3.8%) | |

**Table 3** Pain-related indicators

| Observation indicators | Group A (*n* = 142) | Group B (*n* = 105) | *P*-value |
|---|---|---|---|
| Pain Thresholds | 2.11(0.95) | 1.84(0.79) | 0.016 |
| Postoperative 6 h Pain score | 0.92(0.27) | 0.95(0.21) | 0.348 |
| Bedtime pain score | 0.85(0.38) | 0.86(0.35) | 0.915 |
| Pre-discharge pain score | 0.82(0.40) | 0.74(0.44) | 0.132 |

**Table 4** Postoperative complications

| Observation indicators | Group A (*n* = 142) | Group B (*n* = 105) | *P* value |
|---|---|---|---|
| Fever | 2 | 0 | / |
| Pneumothorax | 1 | 1 | / |
| Pleural effusion | 0 | 0 | / |
| Chylothorax | 0 | 1 | / |
| Bleeding | 1 | 1 | / |
| Pain | 0 | 4 | / |
| PONV | 0 | 1 | / |
| Pneumonia | 0 | 2 | / |
| Total | 4 | 10 | 0.048 |

an average increase of 60.9 m, further confirming the effectiveness of prehabilitation in promoting postoperative activity in VATS patients [23]. Similarly, the study by Salhi et al. demonstrated that routine resistance training during prehabilitation could significantly enhance patients' functional mobility [24]. Stigt et al. further noted that preoperative prehabilitation increased the six-minute walking distance by 35 m in VATS patients [25]. The research by Benzo et al. also emphasized that prehabilitation not only improved respiratory function and quality of life but also helped patients perform daily activities more independently [26]. Moreover, the application of preoperative rehabilitation models has been proven to improve the functional and psychological state of patients undergoing VATS for lung cancer, reduce complications, and enhance patient care satisfaction [27]. In this study, the incidence of postoperative complications in Group A, which received prehabilitation, was lower than in Group B, aligning with the aforementioned research findings. Although a systematic review by M.J.J. Voorn et al. pointed out that the quality of evidence regarding prophylactic rehabilitation programs is low, the overall trend suggests that prehabilitation can reduce postoperative pulmonary complications and shorten hospital stays for VATS patients [28]. Given the diversity of prehabilitation programs, patient variability, differences in surgical types, and postoperative care, the effectiveness of prehabilitation may vary, necessitating a critical integration of research findings into clinical practice. While existing evidence and the results of this study support the benefits of prehabilitation, future research should adopt more standardized and uniform prehabilitation protocols and be conducted on a broader patient population to further validate its effectiveness and explore its applicability in different clinical settings.

In this study, patients in Group A were managed with 18 F Foley for chest tubes, while those in Group B were treated with traditional large-bore drainage tubes. The proportion of patients in Group A who had their tubes removed within 24 h postoperatively was significantly higher than in Group B, and the complication rate was

lower, thereby confirming the safety and feasibility of the small-bore 18 F Foley tubes. The primary purpose of retaining a chest tube after VATS is to maintain negative intrathoracic pressure, effectively draining fluids or gases from the pleural cavity. Traditional large-bore drainage tubes not only impair wound healing but also exacerbate wound pain, further hindering early postoperative mobilization [29]. With the promotion of the ERAS concept and advancements in surgical techniques, healthcare providers are increasingly prioritizing rapid recovery and quality of life for patients postoperatively, making the improvement of chest tubes a focus of research [1]. The efficacy and feasibility of using small-bore chest tubes in VATS have been confirmed by several studies. A comprehensive review by Anderson D found that, compared to large-bore chest tubes, small-bore tubes were associated with a lower incidence of complications, shorter drainage time, and reduced hospital stay [30]. The findings of this study further validate Anderson D's conclusions. Additionally, Lai et al. reported that patients in the 18 F Foley catheter group experienced shorter tube placement time, reduced hospital stay, lower continuous pain scores, and fewer cases of poor wound healing [31]. A meta-analysis by Deng et al. also indicated that compared to traditional 28–32 F drainage tubes, small-bore tubes could shorten drainage time and promote wound healing, although they may have slightly less effective air drainage [32]. The study by Ma et al. is consistent with these findings, showing that patients with small-bore tubes had a higher rate of early ambulation, higher primary wound healing rates, and earlier tube removal times [33, 34]. The trend toward using small-bore chest tubes postoperatively is likely to become mainstream.

This study also compared multimodal pain management strategies, particularly the non-opioid analgesic approach used in Group A with the fentanyl transdermal patch employed in Group B. The results indicate that although the pain management threshold in Group A was significantly higher than in Group B, the pain scores at three critical postoperative time points, 6 h post-surgery, bedtime, and pre-discharge, were not higher in Group A than in Group B. This outcome supports the effectiveness of the non-opioid multimodal pain management approach in Group A for postoperative pain control. Opioids have traditionally been the standard choice for managing postoperative pain in cancer patients [35]. However, due to the side effects, potential for addiction, and healthcare costs, the use of non-opioid analgesics has gained increasing attention [36]. Consistent with current ERAS guidelines, Group A used oxycodone-acetaminophen tablets in combination with regional intercostal nerve block anesthesia, which provided an effective non-opioid pain management regimen. In a randomized controlled trial, An et al. demonstrated that opioid-free pain management in VATS patients achieved an equally effective intraoperative pain threshold index compared to opioid management, with the opioid-free group exhibiting significantly deeper sedation and higher blood glucose levels [37]. Piccioni et al. emphasized that effective pain management is crucial for accelerating recovery and recommended a multimodal analgesia strategy following VATS, incorporating both systemic and local-regional analgesia to minimize opioid use [38]. Multimodal analgesia is a core component of ERAS management; however, there is currently no consensus on the optimal multimodal analgesia protocol for VATS day surgery procedures [39]. The findings of this study contribute to filling this gap, advocating for the perioperative use of various analgesic drugs or methods with different mechanisms, tailored to the individual patient and surgical trauma. This combined approach aims to reduce opioid use and minimize the occurrence of analgesia-related adverse effects [40].

Furthermore, based on previous experience, patients often resist early mobilization due to the constraints imposed by postoperative ECG monitoring equipment. They frequently complain about the noise from the machines and the discomfort caused by the wires, which negatively impacts their postoperative comfort. This study optimized the postoperative care protocol for Group A by introducing a measure that eliminated the need for ECG monitoring after surgery. The results further confirmed the safety and effectiveness of this innovative approach, and to date, no similar management has been reported in the literature.

This study has certain limitations. First, due to the unique nature of day surgery, the selection criteria for VATS patients are indeed more stringent, which leads to the patients being relatively young; the applicability of our findings is limited to the context of this study, VATS day surgery, and may not be generalizable to all VATS patients. Additionally, due to the specific inclusion criteria for day surgery patients, who typically meet discharge standards within 24 h postoperatively, there were challenges in data collection and resource allocation during the post-discharge follow-up. The duration of chest tube placement could only be recorded and analyzed in a gradient manner, which somewhat weakened the empirical robustness of the data. In future studies, we plan to further optimize the collection and management of post-discharge data. Lastly, although there was a statistically significant difference in the types of surgeries between the two groups—with a higher proportion of lobectomies in Group A—lobectomy, due to its greater surgical trauma and postoperative recovery challenges, often presents more management difficulties. However, the clinical outcomes in Group A were superior to those in Group B following the implementation of a series of

ERAS measures. This suggests that ERAS management strategies remain highly effective and valuable for clinical application even in more complex surgical scenarios.

## Conclusion

This study evaluated the effectiveness of varying levels of ERAS management strategies in patients undergoing day surgery for pulmonary nodules. The results demonstrated that a more comprehensive implementation of ERAS significantly promoted postoperative recovery in patients undergoing VATS day surgery. The ERAS concept, centered on patient care and grounded in evidence-based medicine, aims to reduce patient risk, alleviate pain, and expedite recovery through a series of optimized perioperative measures. It has become a key choice in the development of modern surgical medicine [41]. To address the optimal application of ERAS protocols, resolve heterogeneity issues [42], and address the "knowledge-doing" gap [43], future research needs to explore more standardized ERAS protocols and expand the patient population to validate their applicability and effectiveness in various clinical settings.

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**Author contributions**
Han Zhang: Project implementation, Data analysis, writing, and revising the original draft. Wei Chen: Project implementation, Data curation and Tables 1, 2, 3 and 4 prepared. Jiao Wang: Implementation of ERAS measures, Supervision. Guowei Che: Implementation of ERAS measures, Supervision. Mingjun Huang: Project revision, writing, supervision.

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**Data availability**
The datasets generated and/or analysed during the current study are not publicly available due to the hospital system and it could potentially lead to the identification of specific sites based on their characteristics. However, data are available from the corresponding author on reasonable request.

## Declarations

**Human ethics approval and consent to participate**
Patient informed consent: Before enrollment, patients participating in the study were provided comprehensive information about this clinical trial. This included details on the trial procedure, treatment protocol and scale, the number and duration of follow-up visits, methods of reporting adverse events and adverse reactions, and confidentiality agreements for patient information. Researchers were included in this study only if they fully and voluntarily agreed to participate in this study and signed a written informed consent form. All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Ethics Committee of West China Hospital of Sichuan University (Committee Name: The West China Hospital Ethical Committee, ID: 2020 – 1001). This study meets the requirements of the Declaration of Helsinki and has been registered with the China Clinical Trial Registry(TRN: ChiCTR2100051372, Registration Date: Sept. 22, 2021).

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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