Article

Clinical Effects of Enhanced Recovery after Surgery in Perioperative Period Patients with Video-Assisted Thoracoscopic Lobectomy

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AIM: Enhanced recovery after surgery (ERAS) guidelines provide significant benefits for patients after surgery. Care bundles combine various evidence-based treatments and care measures for managing refractory clinical diseases. Therefore, we aimed to evaluate the ERAS measures and care bundles to reduce post-operative complications associated with video-assisted thoracic surgery (VATS) lobectomy and promote patients' recovery.
METHODS: As a retrospective study, this study included 120 non-small cell lung carcinoma patients, who were divided into a control group and an observation group according to the post-operative care methods of the patients in the medical record system. Among them, sixty patients, admitted from January 2018 to January 2019, were included in the control group, and 60 patients, admitted from January 2022 to January 2023, were included in the observation group. The control group received routine care (non-ERAS group), and the observation group followed the bundles of care strategy based on ERAS guidelines (ERAS group). Data collected included baseline characteristics, clinical parameters, and post-operative parameters of patients in the ERAS and non-ERAS groups. The clinical data of all patients came from the hospital medical record system.
RESULTS: There were no significant differences in gender, age, tumor node metastasis (TNM) stages, smoking, and drinking between the ERAS and non-ERAS groups ($p > 0.05$). Similarly, no significant differences were observed in Cardiac Ejection fraction ($\geq$50%), forced expiratory volume in 1 sec % (FEV1%) forced vital capacity (FVC), Lymphocyte, Neutrophils (%), and Tumor diameter between the ERAS and non-ERAS groups ($p > 0.05$). In contrast, significant differences were found in FVC, FEV1%, diffusing capacity of the lungs for carbon monoxide single breath (DLCO SB), Albumin, C-reactive protein, Leukocyte, Monocytes, Lymphocyte (%), Hemoglobin, and Neutrophils between the ERAS and non-ERAS groups ($p < 0.05$). Furthermore, Receiver Operating Characteristic (ROC) analysis indicated that Leukocytes, DLCO, C-reactive protein (CRP), FEV1%, Monocytes, Lymphocytes (%), Neutrophils (%), and Body Mass Index (BMI) were essential predictors of ERAS. Using cutoff values of Leukocytes >12.5, FEV1% >112.9, Monocytes >16.8 (10^9/L), and Neutrophils >11.6, patients undergoing VATS lobectomy were more likely to experience a quick recover. When ERAS measures integrated bundles of care, the extubation time can reduced to less than 5.5 days, the visual analogue scale (VAS) score to less than 3.5, and the post-operative hospital stay to less than 10.5 days.
CONCLUSIONS: ERAS management measures based on bundles of care can significantly improve the prognosis of patients undergoing VATS lobectomy, reduce post-operative complications, and accelerate safe rehabilitation. Furthermore, they can greatly shorten hospital stays, lower overall healthcare costs, and alleviate social and family burdens. These significant differences may be related to factors such as Leukocytes, FEV1%, Monocytes, and Neutrophils.

Keywords: enhanced recovery after surgery; non-small cell lung carcinoma; bundles of care; VATS lobectomy

Introduction

Lung cancer is one of the most common malignancies, characterized by a high mortality rate and the second highest incidence [1]. For lung cancer patients, video-assisted thoracic surgery (VATS) lobectomy is the primary treatment approach. However, due to the invasive nature of the procedure, post-operative complications are common, resulting in prolonged hospital stays and increased financial burden on patients. Enhanced recovery after surgery (ERAS), a new nursing model emerging in the early 21st century [2], aims to optimize nursing protocols and reduce post-operative trauma and complications. Guided by evidence-based medicine, ERAS seeks to alleviate the perioperative physiological and psychological stress experienced by surgical patients. To achieve this goal, clinical measures have been optimized and modified, including the pre-operative, intraoperative, post-operative, discharge, and follow-up stages.

The effectiveness of ERAS can significantly improve the therapeutic outcomes of lung cancer surgery and reduce

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the complications after surgery, thereby enhancing safe and rapid recovery. Additionally, it can significantly shorten hospital stays, reduce overall medical costs, and decrease the burden on society and families. In recent years, this nursing model has been increasingly applied to patients with various types of cancer, yielding good clinical results. The concept of care bundles was first proposed by the American Institute for Healthcare Improvement in 2001 to help healthcare workers provide patients with the most optimal care and achieve better healthcare outcomes [3]. Care bundles combine a range of evidence-based treatments and care measures to address refractory clinical diseases. Each nursing guideline and intervention is supported by reliable scientific evidence and must be proven in clinical practice to improve patient outcomes [4].

Hence, this study is based on the ERAS measures and integrates care bundles with intensive nursing care approaches to further reduce post-operative complications associated with VATS lobectomy and promote patient's recovery.

Materials and Methods

Study Subjects

As a retrospective study, this study included 120 lung cancer patients undergoing VATS lobectomy in the department of Thoracic Surgery, the Affiliated Cancer Hospital of Zhengzhou University & Henan Cancer Hospital. They were divided into a control group and an observation group according to the post-operative care methods of the patients in the medical record system. The control group included of 60 lung cancer patients admitted from January 2018 to January 2019, while the observation group comprised 60 patients admitted from January 2022 to January 2023. The clinical data of all patients came from the Affiliated Cancer Hospital of Zhengzhou University & Henan Cancer Hospital medical record system.

The inclusion criteria were as follows: ①patients diagnosed with non-small cell lung cancer, ②aged between 18 years and 75 years, ③with clear consciousness and normal mental status, ④and voluntary participation in this study. Moreover, exclusion criteria included: ①patients with severe endocrine or metabolic system diseases; ②and a history of pre-operative lung surgery or radiotherapy. The Affiliated Cancer Hospital of Zhengzhou University & Henan Cancer Hospital implemented ERAS management measures based on care bundles in 2020.

The study was approved by the Medical Ethics Committee of the Affiliated Cancer Hospital of Zhengzhou University & Henan Cancer Hospital (2022-KY-0163), and all patients provided informed consent. We ensured that all the procedures and protocols adhered to the Declaration of Helsinki statement, as revised in 2013.

Patients Treatment and Care

The control group received routine care. The nurse responsible for the patient provided preoperative health education to ensure that the patient could understand the post-operative operation process and precautions. The patient underwent an enema the night before surgery, fasting for 12 hours, and avoided drinking water for 6 hours before the procedure. Vital signs were closely monitored during and after the surgery. Post-operative thoracic drainage care was performed, and patients were administered a small amount of fluid food on the morning of the first day after the operation. Additionally, the patients were instructed to perform rehabilitation exercises.

The observation group followed the care bundle strategy based on ERAS guidelines. We established a dedicated care bundles nursing team, which included the director of thoracic surgery, a head nurse, a physician, two senior nurses, and two master-level nursing students. The director of the Thoracic Surgery Department primarily coordinated with the Department of Anesthesiology. The head nurse in the Department of Thoracic Surgery was responsible for advancing the cluster care intervention plan based on ERAS procedures. The physician provided training on post-operative precautions for patients. The two senior nurses and two nursing students were responsible for implementing specific cluster care measures.

Preoperative Measures

Members of the care bundles team communicated with patients and their families about the surgical procedures and precautions for VATS lobectomy, the timing of care steps, thorough preoperative evaluation, nutritional support, and the significance of moderate to high-intensity aerobic exercise and strength training. The nursing staff instructed patients on effective coughing methods and respiratory function training. The surgeon reduced the fasting period to 6 hours before surgery and abstinence from drinking water to 2 hours before surgery.

Intraoperative Measures

The anesthesiologist closely monitored the patient's vital signs, adjusted the operating room temperature, and regulated the infusion volume and temperature. The infusion was heated to the patient's body temperature, and the volume was less than 1500 mL. Based on the patient's condition, nurses and physicians adjusted the dose of anesthesia and the use of analgesics for effective pain management. Operating room nurses assisted in positioning the patient laterally to avoid skin pressure injuries. The chest drain was reinforced after surgery, the drainage fluid depth was recorded, and the drain was checked every 30 minutes.

Post-operative Measures

Upon returning to the ward, the patient was positioned semi-sitting with the upper body elevated by 30° and turned over once every 2 hours. Lower limb compression therapy was performed once a day. Patients were instructed to perform moderate lower limb exercises and encouraged to

Table 1. Comparison of pre-operative measures between the ERAS and non-ERAS groups.

Measures	ERAS group	non-ERAS group
Pre-operative measures		
Nutrition assessment	+	−
Pre-operative health education	+	−
Training of cardiopulmonary function	+	−
Prophylactic antithrombotic treatment	+	+
All-purpose food	+	−
Bowel preparation	−	+
Prophylactic use of antibiotics	+	+
ERAS video education	+	−
Intraoperative measures		
Maintain anesthesia	+	+
Ventilation with low tidal volume	+	+
Thoracic paravertebral nerve block	+	−
Ropivacaine infiltration of surgical incisions	+	−
Indwelling thoracic cavity drainage tube	If needed	Necessary
Body temperature condition monitoring	+	+
Fluid management	+	+
Post-operative measures		
Early removal catheter (post-operative 1st day)	+	−
Early activity	+	−
Early extirpation of thoracic cavity tube	+	−
6 h early feeding	+	−
Rewarming	+	+
Preventing nausea and emesis	+	+
Respiratory management	+	+
Active analgesia management	+	+
Preventing constipation	+	−
Wound management	+	−
Prophylactic antithrombotic treatment	+	+
Post-operative health education	+	−
Post-operative follow-up	+	−

ERAS, enhanced recovery after surgery.

perform bedside activities on the first day and to get out of bed on the second day. Patients were allowed to drink a small amount of water 6 hours post-operation; if there was no discomfort, they could consume fluids or semi-fluid food. They were also encouraged to consume eggs, fruits, and vegetables from day 1 to 3 post-operation, but advised to abstain from egg yolks, dairy products, and meat. By day 4 after surgery, patients were encouraged to begin eating normally.

A self-controlled analgesic pump combined with medication-based analgesia was used. The pain levels of the patients were evaluated using the visual analogue scale (VAS) score [5], and the dose of medication was adjusted accordingly as per the physician's instructions. The thoracic tube was removed on the third day, and patients were encouraged to increase the frequency and intensity of their activities. Responsible nurses instructed patients to perform pulmonary function exercises. For patients experiencing evident chest tightness, excessive phlegm, and difficulty in coughing, cough-relieving and expectorant drugs, along with mechanical vibration expectoration, were used to reduce symptoms. The specific measures for both experimental groups are shown in Table 1.

Statistical Analysis

Statistical analysis was performed using SPSS 25.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed as mean ± standard deviation (SD). The statistical analysis compared measurement parameter values between two independent groups using a student's *t*-test, and the Pearson's chi-squared test for the count parameter values. For normally distributed variables, the student *t*-test was applied, while the Mann-Whitney test was used for the remaining data, which were non-parametric. Parameters with statistically significant differences were analyzed using logistic regression. Receiver Operating Characteris-

Table 2. Comparison of baseline characteristics between the ERAS and non-ERAS groups.

Clinicopathological variables		ERAS (n = 60)	non-ERAS (n = 60)	*X² or t*	*p*
Gender	Male	27	28	0.034	0.855
	Female	33	32		
Age (years)	Mean ± SD	55.2 ± 12.3	51.7 ± 12.0	1.623	0.107
TNM stages	I	36	30	1.276	0.528
	II	8	11		
	III	16	19		
	IV	0	0		
Smoking	Yes	29	32	0.300	0.584
	No	31	28		
Drinking	Yes	38	33	0.862	0.353
	No	22	27		
BMI (kg/m^2)	Mean ± SD	25.6 ± 2.9	26.9 ± 3.8	–2.218	0.029

SD, standard deviation; TNM, tumor node metastasis; BMI, Body Mass Index. Chi-square test and Student *t*-test were used as statistical tests.

tic (ROC) curve analysis was performed to determine cut-off values between complication occurrence and laboratory values. A *p*-value < 0.05 was considered statistically significant.

Results

Baseline Characteristics of the Study Participants

The male-to-female ratios in the ERAS and non-ERAS groups were about 1:1. The tumor node metastasis (TNM) stage I was predominantly observed among the patients, with no patients in stage IV. Both experimental groups included patients with a history of smoking and drinking. There were no significant differences between the ERAS and non-ERAS groups regarding gender, age, TNM stages, smoking habits, and alcohol consumption ($p > 0.05$). However, a statistically substantial difference in Body Mass Index (BMI) was observed between the two groups, with the non-ERAS group exhibiting a higher BMI than the ERAS group ($p < 0.05$). A comparison of baseline characteristics between the two experimental groups is shown in Table 2.

Comparison of Clinical Parameters between the Two Experimental Groups

As shown in Table 3, we conducted Normality Tests for all parameters. The quantile-quantile (Q-Q) Plot demonstrated that clinical parameters conform to the normality of continuous variables except Lymphocyte (%) and Lymphocyte. There were no significant differences in Cardiac Ejection fraction ($\geq$50%), forced expiratory volume in 1 sec (FEV1)/forced vital capacity (FVC) (%), Lymphocyte (10^9/L), Neutrophils (%), and Tumor diameter between the ERAS and non-ERAS groups ($p >$0.05). However, significant differences were observed in FVC%, FEV1%, diffusing capacity of the lungs for carbon monoxide single breath (DLCO SB), Albumin, C-reactive protein, Leukocyte, Monocytes, Lymphocyte (%), Hemoglobin, and Neutrophils (10^9/L) between the ERAS and non-ERAS groups ($p < 0.05$). We conducted a logistic regression analysis on the parameters with statistically significant differences and found that the *p*-values for parameters such as FVC%, FEV1%, albumin, leukocyte, monocyte, hemoglobin, and neutrophil could be used to evaluate the significance of the predicted outcomes ($p < 0.05$, Table 4).

ROC Curve Analysis between the Two Experimental Groups

ROC analysis indicated that Leukocytes, forced expiratory volume in 1 sec % (FEV1%), Monocytes, and Neutrophils are crucial predictive factors for reducing complications and promoting rapid recovery after VATS lobectomy in patients undergoing ERAS measures and integrated care bundles (Fig. 1).

Patients are more likely to experience rapid recovery when they meet the following criteria: Leukocytes >12.5, FEV1% >112.9, Monocytes >16.8, and Neutrophils >11.6 (Table 5).

Comparison of the Post-Operative Parameters between the Two Experimental Groups

We performed Normality Tests for all parameters listed in Table 6. The Q-Q Plot indicated that all parameters conformed to the normality of continuous variables. Regarding post-operative parameters, there were significant differences in Catheter extraction time, Lymphocyte recovery time after surgery, first post-operative defecation time, post-operative hospitalization time, extirpation of thoracic cavity tube time, pulmonary atelectasis recovery time, psychological recovery time, and compliance and satisfaction scores between ERAS and non-ERAS groups ($p < 0.05$, Table 6). These significant differences in post-operative parameters between ERAS and non-ERAS groups may be closely linked to the factors identified by the ROC curve.

Table 3. Comparison of clinical parameters between ERAS and non-ERAS groups.

Clinical parameter	ERAS (n = 60)	non-ERAS (n = 60)	*t or Z*	*p*-value
	Mean ± SD/Median [P25, P75]	Mean ± SD/Median [P25, P75]		
Cardiac Ejection fraction (≥50%)	64.2 ± 2.8	64.8 ± 3.1	–1.213	0.228
FVC%	99.9 ± 11.7	95.3 ± 10.2	2.289	0.024
FEV1%	100.3 ± 12.4	95.6 ± 12.0	–2.353	0.020
FEV1% FVC	99.2 ± 9.8	95.5 ± 9.0	1.308	0.194
DLCO SB (mmol/min/kPa)	87.3 ± 10.5	82.8 ± 11.6	–2.491	0.014
Albumin (g/L)	37.9 ± 3.8	36.1 ± 3.7	2.665	0.009
C-reactive protein (mg/L)	96.4 ± 21.4	104.5 ± 22.9	–1.998	0.048
Leukocyte (10^9/L)	12.4 ± 3.5	20.0 ± 5.9	–8.684	<0.001
Monocyte (10^9/L)	0.69 ± 0.15	0.76 ± 0.14	–2.354	0.020
Lymphocyte (%)	10.3 [7.0, 20.3]	13.7 [8.5, 23.2]	–2.131	0.033
Lymphocyte (10^9/L)	2.9 [1.3, 5.3]	3.3 [1.7, 4.7]	–0.021	0.983
Hemoglobin (g/L)	116.1 ± 18.6	104.7 ± 17.0	3.489	0.001
Neutrophil (10^9/L)	10.3 ± 3.1	12.5 ± 3.5	–3.700	<0.001
Neutrophil (%)	78.5 ± 7.5	76.7 ± 6.9	1.365	0.175
Tumor diameter (cm)	3.1 ± 1.5	3.4 ± 1.4	–1.009	0.315

FVC, forced vital capacity (Measured value/estimated value); FEV1%, forced expiratory volume in 1 sec % (Measured value/estimated value); DLCO SB, diffusing capacity of the lungs for carbon monoxide single breath; Student *t*-test and the Mann-Whitney test were used as statistical tests.

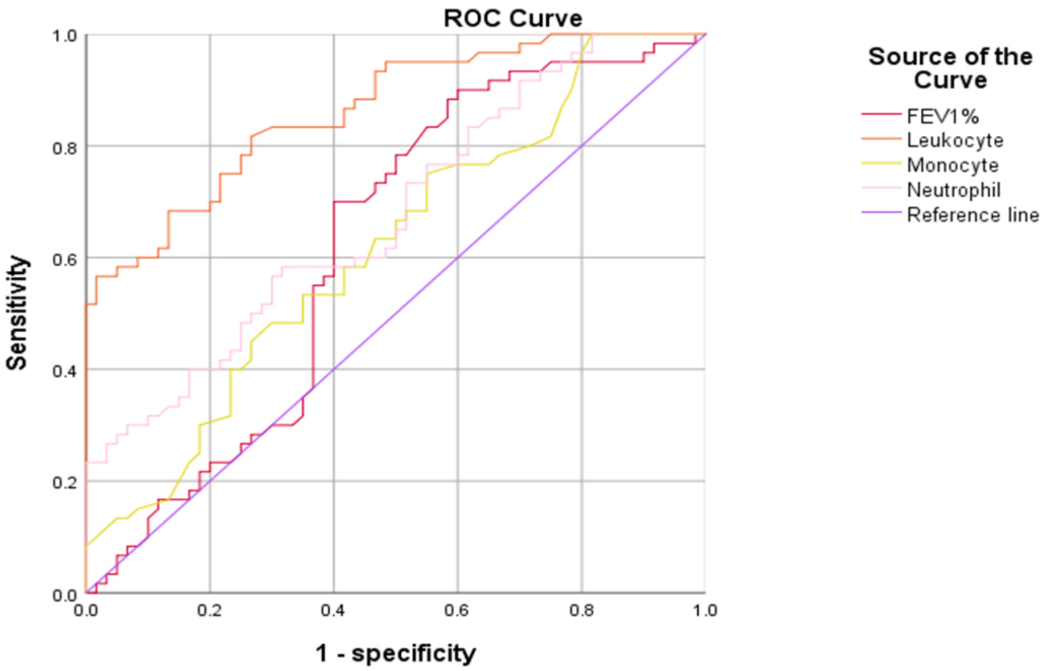

Fig. 1. ROC curve of clinical parameters between ERAS and non-ERAS groups. ROC, Receiver Operating Characteristic; FEV1%, forced expiratory volume in 1 sec %.

Logistic Regression Analysis on the Post-Operative Parameters

Logistic regression analysis on the post-operative parameters indicated that the *p*-values for parameters such as catheter extraction, VAS score, and post-operative hospitalization time could be used to evaluate the significance of the predicted outcomes ($p < 0.05$, Table 7). Furthermore, ROC curve analysis revealed that ERAS measures and integrated care bundles significantly impact catheter extraction time, VAS score, and post-operative hospitalization parameters (Fig. 2). When ERAS measures integrated bundles of care were performed, catheter extraction time was de-

Table 4. Logistic regression analysis results of ERAS and non-ERAS associated risk factors.

Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% CI for Exp(B)
FVC%	–0.115	0.039	8.752	1	0.003	0.892	0.827–0.962
FEV1%	0.088	0.041	4.608	1	0.032	1.092	1.008–1.183
DLCO SB	0.073	0.045	2.639	1	0.104	1.076	0.985–1.175
Albumin	–0.443	0.133	11.040	1	0.001	0.642	0.495–0.834
CRP	0.019	0.018	1.038	1	0.308	1.019	0.983–1.056
Leukocyte	0.485	0.109	19.932	1	0.000	1.624	1.313–2.010
Monocyte	2.940	1.287	5.219	1	0.022	18.923	1.519–235.816
Lymphocyte (%)	0.074	0.049	2.274	1	0.132	1.076	0.978–1.185
Hemoglobin	–0.046	0.021	4.791	1	0.029	0.955	0.917–0.995
Neutrophil	0.339	0.142	5.650	1	0.017	1.403	1.061–1.855
BMI	0.059	0.124	0.225	1	0.635	1.061	0.832–1.353

CRP, C-reactive protein.

Table 5. Cutoff values for rapid rehabilitation of patients receiving ERAS measures determined by the ROC curve.

Parameters	AUC (95% CI)	Sensitivity	1-Specificity	Cutoff value	*p*-value
Leukocytes	0.863 (0.800–0.926)	0.883	0.450	12.5	0.000
FEV1%	0.621 (0.517–0.724)	0.300	0.250	112.9	0.032
Monocytes	0.617 (0.517–0.717)	0.683	0.133	16.8	0.015
Neutrophils	0.677 (0.582–0.771)	0.583	0.317	11.6	0.017

AUC, Area Under Curve; ROC, Receiver Operating Characteristic; FEV1%, forced expiratory volume in 1 sec % (Measured value/estimated value).

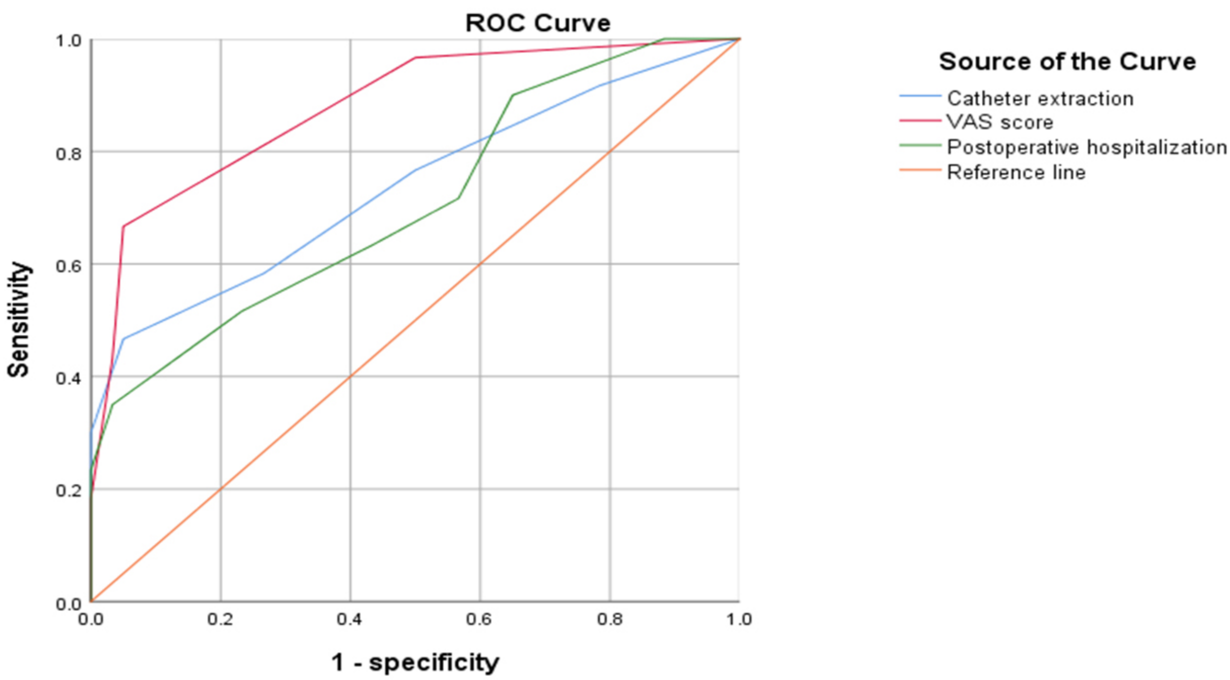

Fig. 2. ROC curve of post-operative parameters between the ERAS and non-ERAS groups.

creased to less than 5.5 days, the VAS score was less than 3.5, and post-operative hospitalization time was less than 10.5 days (Table 8).

Discussion

ERAS aims to minimize the physiological and psychological stress response during the perioperative period. For this purpose, we optimized a series of clinical techniques and measures across five phases: pre-operation, intra-

Table 6. Comparison of post-operative parameters between ERAS and non-ERAS groups.

Post-operative parameters	ERAS (n = 60)	Non-ERAS (n = 60)	*t*-value	*p*-value
	Mean ± SD	Mean ± SD		
Catheter extraction (days)	3.6 ± 1.2	5.1 ± 1.8	–5.329	<0.001
VAS score	2.6 ± 0.7	4.3 ± 1.2	–9.462	0.024
Lymphocyte recovery time after surgery (days)	5.2 ± 1.5	6.3 ± 1.4	–4.049	0.000
First post-operative defecation (hours)	9.1 ± 1.8	10.1 ± 1.4	–3.632	<0.001
Post-operative hospitalization (days)	7.8 ± 1.8	9.4 ± 2.2	–4.354	<0.001
Extirpation of thoracic cavity tube (days)	3.4 ± 0.9	4.0 ± 1.3	–2.968	0.004
Psychological recovery (days)	4.1 ± 1.8	4.9 ± 2.2	−2.11	0.027
Pulmonary atelectasis recovery (days)	2.1 ± 1.2	3.4 ± 1.4	−5.111	0.007
Compliance and satisfaction (0–5)	4.5 ± 0.7	3.4 ± 1.0	6.748	0.000

SD, standard deviation; VAS, visual analogue scale; Student *t*-test was used as a statistical test.

Table 7. Logistic regression analysis of ERAS and non-ERAS post-operative associated risk factors.

Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% CI for Exp(B)
Catheter extraction	0.720	0.286	6.348	1	0.012	2.0536	1.173–3.594
VAS score	1.614	0.550	8.610	1	0.003	5.024	1.709–14.769
Lymphocyte recovery time after surgery	0.356	0.293	1.472	1	0.225	1.427	0.803–2.535
First post-operative defecation	0.278	0.327	0.724	1	0.395	1.321	0.696–2.506
Post-operative hospitalization	0.544	0.232	5.482	1	0.019	1.723	1.093–2.718
Extirpation of thoracic cavity tube	–0.110	0.343	0.103	1	0.748	0.896	0.457–1.754
Psychological recovery	0.182	0.223	0.666	1	0.415	1.200	0.774–1.859
Pulmonary atelectasis recovery	0.461	0.320	2.075	1	0.150	1.586	0.847–2.970
Compliance and satisfaction	–2.497	0.706	12.518	1	0.000	0.082	0.021–0.328

operation, post-operation, discharge, and follow-up. Implementing ERAS programs in lung cancer surgery can effectively reduce the risk of post-operative complications, shorten hospital stays, and minimize the cost without compromising patient safety. ERAS programs were associated with shorter hospital stays and did not result in increased complications or readmission rates [2]. In our study, compared to the non-ERAS group, patients in the ERAS group exhibited better outcomes in terms of catheter extraction, VAS score, lymphocyte recovery time after surgery, first post-operative defecation, extirpation of thoracic cavity tube, and overall length of hospital stay. Additionally, patients in the ERAS group indicated significantly better psychological recovery, pulmonary atelectasis recovery, compliance, and satisfaction, with these differences being statistically significant. Surgical treatment for lung cancer can cause significant trauma, with post-operative pain and complications resulting in poor patient compliance and slow recovery. Lung cancer patients not only experience physical pain during the perioperative period but also frequently encounter psychological issues such as fear and anxiety. These challenges can significantly impact their physical and mental health, and their recovery process. This study focuses on the physical and psychological recovery of lung cancer patients after surgery.

Health education combined with feedback methods can improve adherence to post-operative exercises, shorten recovery time, improve psychological status, and increase patients' satisfaction, aligning with expedited patient recovery [6]. Hence, we established a thoracic surgery health education team comprising two attending physicians, three nurses, and a rehabilitation doctor. The ERAS video education is provided through video introductions, covering multidisciplinary health education for surgical patients. Implementing an ERAS pathway after VATS lobectomy was associated with a decreased length of stay, with no increase in complications or readmission rates. Wei and Wang [7] research suggested that implementing the ERAS protocol into operating room nursing is feasible and warrants clinical promotion and application. The ERAS protocol can enhance the recovery of patients undergoing single-port thoracoscopic lung cancer surgery [7]. Xing *et al.*'s [8] findings revealed that video education effectively addresses patients' concerns, reduces the incidence of emergency agitation, and reduces total hospitalization costs and length of stay. Furthermore, video education has improved the satisfaction of patients and their families.

Pulmonary function testing is a routine pre-operative examination for thoracic surgery at the Affiliated Cancer Hospital of Zhengzhou University & Henan Cancer Hospital. It not only predicts the risk of complications and long-term quality of life in perioperative patients but also provides objective evidence for surgical decision-making [9]. FEV1 and DLCO are widely recognized indicators for predicting post-operative complications after thoracotomy [10]. These two indicators are significant in predicting the risk of post-

Table 8. Cutoff values for post-operative parameters between the ERAS and non-ERAS groups determined through the ROC curve.

Parameters	AUC (95% CI)	Sensitivity (%)	1-Specificity (%)	Cutoff value	*p*-value
Catheter extraction	0.737 (0.647–0.826)	0.467	0.050	5.5	0.000
VAS score	0.879 (0.818–0.939)	0.667	0.050	3.5	0.000
Post-operative hospitalization	0.707 (0.616–0.799)	0.350	0.033	10.5	0.000

operative complications following minimally invasive lung surgery. Our results demonstrated significant differences in FEV1 and DLCO between patients in the ERAS and non-ERAS groups, with the ERAS group indicating better parameters. Pulmonary atelectasis and lung infection are the main post-operative pulmonary complications. Pulmonary atelectasis, one of the most common complications following VATS lobectomy, can occur in patients of any age [11]. Pulmonary atelectasis interferes with gas exchange, leading to hypoxemia and other respiratory disorders such as acute lung injury and pneumonia. A previous study has reported a significantly lower incidence of pulmonary atelectasis in the ERAS group [12]. Our results align with these studies, significantly reducing post-operative lung atelectasis and other pulmonary complications in the ERAS group. Encouraging patients to get out of bed early and training them to cough effectively can reduce the incidence of post-operative lung atelectasis and pulmonary infections.

Increased compliance with an ERAS pathway is associated with improved clinical outcomes after resection for primary lung cancer. Among the several elements, early mobilization appears to be more impactful [13]. ERAS protocols can reduce post-operative complications and shorten hospital stays. Although some high-risk patients may not be eligible for early discharge, ERAS can still reduce the incidence of post-operative pulmonary complications and provide benefits. Shen and Che [14] found that avoiding thoracic drainage and urinary catheterization after surgery seems to be safe and beneficial for patients. Avoiding thoracic drainage and catheter placement after surgery is safe and beneficial for patients.

Furthermore, Ding *et al*. [15] discovered that early mobilization within 24 hours following thoracoscopic surgery for lung cancer patients enhances intestinal function recovery, expedites thoracic tube removal, reduces hospital stay duration, alleviates pain, lowers complication rates, and facilitates rapid patient recovery. Perioperative management should be guided by evidence-based medicine to optimize patient outcomes. Not leaving tubes after thoracic surgery reflects the ERAS concept and effectively improves patient satisfaction and comfort during the perioperative period [14]. These measures highlight areas for further improvement. Ni *et al*. [16] reported that ultrasound-guided thoracic paravertebral block resulted in a reduced incidence of post-operative analgesia and hypotension. Additionally, using single intercostal nerve blocks, COX-2 selective inhibitors, and early chest tube removal may improve ERAS outcomes [16]. Therefore, our future research will focus on optimizing drug dosage for ultrasound-guided thoracic paravertebral block and investigating strategies to avoid and reduce post-operative complications.

The use of ERAS after lung surgery can substantially improve patient prognosis. Implementing the ERAS program has significantly improved clinical outcomes and reduced costs, making it an important example of value-based care in surgery [2]. Implementing ERAS has reduced the average hospital stay to 1.45 days (95% CI, 1.42–1.48), reducing €1060 per patient in hospital costs [17]. Using ERAS in VATS lobectomy could potentially improve patient outcomes. Despite the limited specific surgical factors, thoracic surgeons should actively collaborate and participate in perioperative management [6, 15]. A crucial aspect of ERAS is the high level of participation. Often, surgeons apply only a part of the ERAS program, wrongly believing that they are using the entire protocol, and tend to interpret their results optimistically. To address this problem, the Italian VATS Group is developing a project called "ERAS and Fast Track for Lobectomy at VATS", which aims to combine all aspects of ERAS into a comprehensive and practical thoracic surgical program, adapted to the current healthcare environment.

In terms of post-operative pulmonary rehabilitation, numerous studies have shown that effective pulmonary rehabilitation exercises can improve cardiopulmonary function and quality of life to some extent after surgery [18,19]. ERAS-based respiratory function exercise can improve respiratory function, promote post-operative functional recovery, enhance the quality of life, and reduce pulmonary complications in elderly lung cancer patients, underscoring its clinical significance for broader implementation [20]. Our research team is following 120 patients for long-term post-operative pulmonary rehabilitation using a telemedicine platform. Patients in the ERAS group were followed up and managed using a wearable device featuring remote monitoring capabilities and a rehabilitation management system. Conversely, patients in the non-ERAS group were followed up and managed using common methods, including phone calls, text messages, and WeChat.

Conclusions

With the implementation of ERAS protocols, which involve bundles of care, can significantly enhance the prognosis of patients undergoing VATS lobectomy. These protocols shorten the duration of post-operative hospitalization, reduce the incidence of complications, and decrease the psychological recovery time. The significant differences in clinical parameters may be associated with factors such as leukocytes, FEV1 percentage, monocytes, and neutrophils. Assessing these factors can help mitigate the risk of postoperative complications. Furthermore, using ERAS protocols can alleviate the burden on society and families.

Availability of Data and Materials

The data analyzed was available on the request for the corresponding author.

Author Contributions

JL designed the research study. GL, WW and JL performed the research. WX made substantial contributions to conception, design, data analysis and interpretation of this research. YX analyzed the data and drafted the manuscript. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Medical Ethics Committee of the Affiliated Cancer Hospital of Zhengzhou University & Henan Cancer Hospital (2022-KY-0163). All patients provided informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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