Delayed Discharge after Thoracic Surgery under the Guidance of ERAS Protocols

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Abstract

Background Enhanced recovery after surgery (ERAS) protocols have been applied in thoracic surgery and are beneficial to patients. However, some issues about ERAS are still pending.

Methods A total of 1,654 patients who underwent thoracic surgery under the guidance of ERAS protocols were enrolled in this study. We set the length of postoperative stay (LOPS) as our key research indicator. Patients were divided into routine discharge group and delayed discharge group based on LOPS. Causes of delayed discharge were analyzed to improve management of postoperative recovery.

Results Male, old age, underlying disease (coronary artery disease, chronic kidney disease, old cerebral infarction, chronic obstructive pulmonary disease, and arrhythmia), intensive care unit (ICU) stay, type of insurance, and lower forced expiratory volume in one second (FEV1) are the independent impact factors causing delayed discharge. Increased nonchylous drainage (INCD) and prolonged air leakage were the two leading causes for delayed discharge.

Conclusion Patients should have personalized recovery goal under the same ERAS protocols. We should accept that patients in poor general condition have a prolonged LOPS. More stringent ICU stay indications should be developed to increase postoperative patients' ERAS protocols compliance. Further research on chest tube management will make a contribution to ERAS protocols.

Keywords

- thoracic surgery
- enhanced recovery after surgery
- hospital stay
- chest tube management

Introduction

Lung cancer is currently the leading cause of deaths related to malignancies.[1,2] Technology, apparatus, and concept of surgery have been greatly developed in recent years as primary treatment for lung cancer, especially nonsmall cell lung cancer. Enhanced recovery after surgery (ERAS) has been proposed and practiced in other surgical specialties.[3,4] ERAS protocols have also been applied in patients undergoing thoracic surgery, and it has been confirmed that ERAS is beneficial to patients after thoracic surgery.[5,6]

Many elements such as the length of stay have significantly improved under the guidance of existing ERAS protocols. However, there are questions posed regarding other factors which affect the recovery of patients after thoracic surgery such as "What improvements can be made to enhance recovery?" and "Can ERAS protocols be applied consistently to all patients?" We retrospectively collected data for patients who underwent thoracic surgery at our center after applying the ERAS protocols. The length of postoperative stay (LOPS) was our key research for its immediacy, measurability and can reflect the speed of postoperative recovery. We analyzed reasons for the delay in discharge of patients to formulate effective recommendations for the management of perioperative period in patients during thoracic surgery.

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Patients and Methods

Patients who underwent thoracic surgery with ERAS protocols at our center from September 2018 to August 2019 were included in the study. The characteristics including age, sex, smoking history, alcohol consumption history, surgical approach, operation mode, LOPS, and other clinical data were retrospectively analyzed. Patients were divided into routine discharge group (RDG) and delayed discharge group (DDG) based on LOPS. This retrospective study was performed under the authorization approved by the Institutional Review Board of Peking Union Medical College Hospital, Beijing, China (No. S-K1202).

Inclusion Criteria

1. Operative mode: anatomical lobectomy, sublobectomy, combined lobectomy, and pneumonectomy.
2. Lymphadenectomy during the operation, including hilar and mediastinal lymph node dissection or sampling.
3. Surgery is the initial treatment.
4. Preoperative examination is required to exclude distant metastasis of malignancy.
5. Planned operation.
6. $\geq$18 years old.

Exclusion Criteria

1. Compound surgery such as lung resection combined with thymectomy, lung resection combined with gastric cardia surgery.
2. No lymphadenectomy during the operation.
3. Patient has received neoadjuvant treatment (chemotherapy, radiotherapy, or chemoradiotherapy) before surgery.
4. Emergency or unplanned surgery.
5. $<$18 years old.

Discharge Criteria

Because the patients in our center came from all over the country and were discharged to home, to ensure the safety of the patients, we have established a stricter discharge criteria and then we did not allow patients discharge with chest tube. The following are the criteria for discharge:

1. Patients had resumed oral feeding and mobilization.
2. Chest tube has been removed, and stable, good lung expansion on final chest X-ray with no evident pleural effusion and pneumothorax.
3. No need for intravenous medication.
4. No signs of infection such as fever or leukocytosis.
5. No need for prolonged O_2 therapy.
6. Agreement by the patient and family members to discharge.

ERAS Protocols

ERAS protocols distributed in the preoperative phase, intraoperative phase, and postoperative phase as shown in ►**Fig. 1**.

Definition of Underlying Diseases and Perioperative Management Principles

We define hypertension, insulin-dependent diabetes, coronary artery disease (CAD), chronic kidney disease (CKD), old cerebral infarction, chronic obstructive pulmonary disease (COPD), interstitial lung disease, and arrhythmia as underlying diseases. Pulmonary function test was adopted to assess the preoperative pulmonary function. We considered post-bronchodilator forced expiratory volume in one - second/forced vital capacity (FEV1/FVC) ratio $<$0.7 as the threshold that indicates airflow limitation, and the patients were diagnosed as COPD. We made corresponding perioperative treatment plan according to the suggestion of multidisciplinary consultation before operation, such as

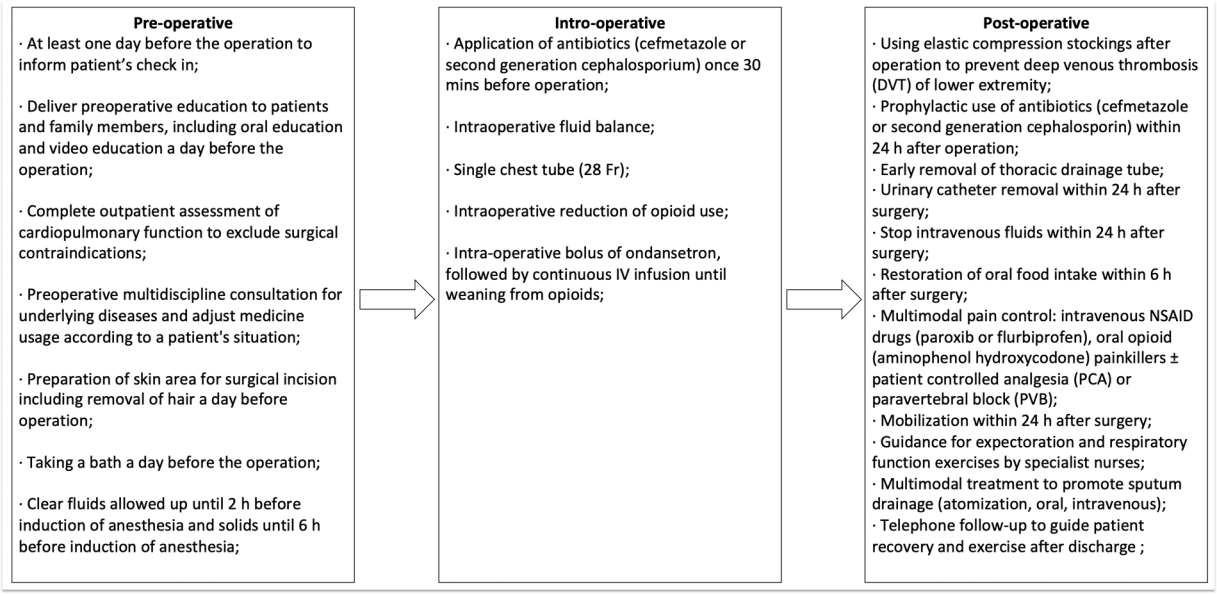

Fig. 1 ERAS protocols distributed in the pre-operative phase, intraoperative phase, and postoperative phase. ERAS, enhanced recovery after surgery.

monitoring blood pressure, adjusting antihypertensive drugs, perioperative low molecular heparin anticoagulant therapy, and applying antiarrhythmic drugs. After permitted by critical care specialist, patients with severe underlying diseases would be transferred to the intensive care unit (ICU) after surgery for 1 to 2 days for monitoring.

Management of Chest Drainage

Patients used water seal drainage bottle after thoracic operation. Air leakage persisting for more than 5 days was described as prolonged air leakage (PAL). Patients with PAL were given two types of external suction treatment: traditional negative pressure (three-chamber drainage bottle, 10–12 cm H_2O) or electronic drainage system (Medela Healthcare, Baar, Switzerland; 6–10 cm H_2O). Chest tube would be removed if no air leakage or chylothorax, no atelectasis and an output of less than 200 mL in 24 hours.

Statistical Analysis

The SPSS version 22.0(IBM, SPSS statistics, Chicago, Illinois, United States) was used to analyze data. Chi-square test and *t*-test were used to analyze differences between groups of categorical variables. Logistic regression analysis was used to analyze differences between consecutive variables and variables with statistical significance at $p < 0.01$. A *p*-value of <0.05 ($p < 0.05$) was considered to be statistically significant in this study.

Results

Patient Characteristics

A total of 1,654 patients were included in this study. Patient selection process is presented in ►**Fig. 2**. Out of the 1,654 patients, 645 were males and 1,009 females. The average age was 59 years (18–85 years). Patients under 70 years were classified as the younger group, the left as the older group. Average postoperative hospital stay was 4.83 days (2–46 days). Patients with LOPS of $\leq$5 days were classified as the RDG and >5 days as the DDG. Our study had 326 patients in the DDG group and 1,328 patients in the RDG group. Patients with the public medical insurance are insured by the government, which covers the entire population and hospitalization expense is low. However, the proportion of hospitalization expense reimbursement is relatively low. Patients with the private insurance are covered at their own expenses, and the premium is higher than that of public insurance. Hospitalization expenses for patients covered with private insurance are high, and the proportion of reimbursement is relatively high.

Comparison between RDG and DDG

The results of the comparative analysis are shown in ►**Table 1**. We established that male ($B = 0.473$, $p = 0.005$), older age ($B = 0.828$, $p < 0.001$), private insurance ($B = 1.924$, $p < 0.001$), ICU stay ($B = 1.086$, $p = 0.001$), non-minimally invasive approach ($B = -1.194$, $p = 0.019$), CAD ($B = 0.859$, $p = 0.001$), CKD ($B = 1.944$, $p = 0.038$), old cerebral infarction ($B = 1.661$, $p = 0.01$), COPD ($B = 0.891$, $p = 0.008$), arrhythmia ($B = 2.327$, $p < 0.001$), and lower FEV1 ($B = -0.521$, $p < 0.001$) were independent impact factors of delayed discharge after including previously mentioned variables in our logistic regression analysis. Variables included in our analysis did not reveal any significant difference in the distribution of extra pain control measures ($p = 0.072$) between RDG and DDG.

Analysis of DDG

The two key causes of delayed discharge were increased nonchylous drainage (INCD) (123/326), and PAL (109/326), followed by patient's discharge intention (36/326), postoperative pulmonary complications (30/326), chylothorax (14/326), cardiocerebrovascular complications (12/326), and others (2/326) (►**Table 2**). A total of 241 patients in the DDG were covered by public insurance and 85 patients were covered by private insurance. Discharge time for patients in the DDG ranged from 6 to 46 days and average prolonged discharge time was 7 days. We defined $\leq$7 days as short-term DDG and >7 days as long-term DDG. The short-term DDG had 175 patients and long-term DDG had 151 patients. Different management interventions (conservative observation, extra suction, chemical pleurodesis, invasive maneuvers) in patients with PAL between short-term DDG and long-term DDG did not significantly differ ($p = 0.770$). In addition, distribution of management interventions (conservative observation, treatment modalities) in patients with INCD between short-term DDG and long-term DDG revealed no significant difference ($p = 0.585$). Analysis of the causes of delayed discharge indicated that PAL significantly correlated with long-term DDG ($p < 0.001$).

Discussion

ERAS protocols have been proposed and gradually applied in various surgical fields along with the development of surgical techniques and rehabilitation concepts.[7] ERAS protocols combined multidisciplinary care measures cover all stages of surgery (preoperative, intraoperative, and postoperative stages).[8] The key elements of ERAS protocols are extended patient information, reduction of surgical trauma (minimally invasive surgery), active pain control, and promotion of patient autonomy.[9] Although ERAS protocols have not been applied in thoracic surgery for a long time,[4,5,9] it has been shown to accelerate recovery of patients in several aspects such as postoperative hospital stay, medical expenses, postoperative complications, and quality of life.[4]

However, it is noted that there are still a few defects about ERAS protocols in thoracic surgery. One single intervention of ERAS protocols may not necessarily have significant benefits when studied in isolation, but their combination with other protocols of ERAS is thought to have a synergistic effect.[10] A few of the current studies have focused on one aspect (e.g., pain control or chest tube management).[11] Furthermore, the core of ERAS is the quality of recovery, and not the speed of recovery. Present research tends to focus on the speed of recovery evaluated by uniform criteria.[12] Our

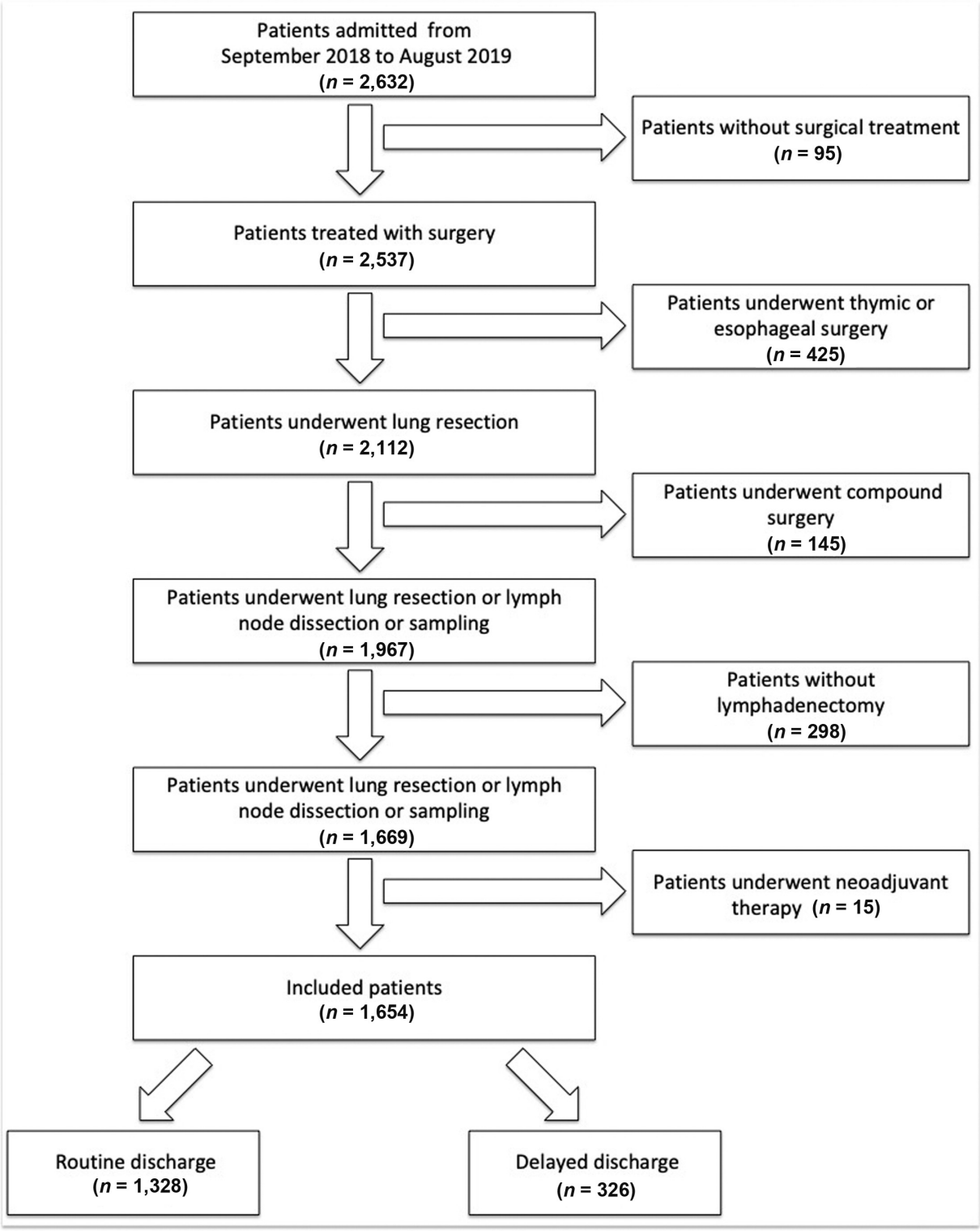

Fig. 2 Patient selection process.

study has attempted to analyze and discuss course of recovery based on our experience by reviewing postoperative recovery in patients undergoing thoracic surgery at our center as per the guidance of ERAS protocols. In this study, we only used LOPS as an indicator to evaluate and improve ERAS protocols, not as a criterion to judge ERAS success or failure.

A previous study indicated that ERAS protocols can be applied in older patients to benefit the population.[13] We established that age is still an independent impact factor for postoperative hospitalization time after application of the ERAS protocols. Patients aged >70 years had extended postoperative hospital stay. Previous studies on delayed discharge also demonstrated that age was a nonmedical

Table 1 Data on analysis of factors related to delayed discharge

Variable	RDG	DDG	χ^2/t	*p*-Values
Sex			35.283[a]	<0.001
Male	857	152		
Female	471	174		
Age			42.111[a]	<0.001
Younger group	714	119		
Older group	614	207		
Type of medical insurance			128.266[a]	<0.001
Public medical insurance	1,225	241		
Private medical insurance	73	85		
ICU stay			50.727[a]	<0.001
Yes	1,302	293		
No	26	33		
Perioperative anticoagulant			6.975[a]	0.008
Yes	27	15		
No	1,301	311		
Smoking history			19.101[a]	<0.001
Yes	256	99		
No	1072	227		
Drinking history			9.336[a]	0.002
Yes	156	59		
No	1,172	267		
Operation time			6.713[a]	0.009
≤3 h	1,266	299		
>3 h	62	67		
Intraoperative transfusion			6.092[a]	0.014
Yes	11	1,317		
No	8	318		
Surgical approach			11.080[a]	0.004
Thoracotomy	10	8		
VATS	1,309	312		
VATS to thoracotomy	9	6		
Pleural adhesion			5.515[a]	0.019
None or light	1,119	257		
Medium or heavy	209	69		
HTN			13.780[a]	<0.001
Yes	962	202		
No	366	124		
CAD			28.412[a]	<0.001
Yes	52	37		
No	1,276	289		
CKD			15.529[a]	0.001
Yes	2	6		
No	1,326	320		

(*Continued*)

Table 1 (*Continued*)

Variable	RDG	DDG	χ^2/t	*p*-Values
Old cerebral infarction			19.973[a]	<0.001
Yes	10	13		
No	1,318	313		
ILD			8.390[a]	0.016
Yes	2	4		
No	1,326	322		
COPD			18.471[a]	<0.001
Yes	31	23		
No	1,297	303		
Arrhythmia			66.840[a]	<0.001
Yes	8	25		
No	1,320	301		
FEV1	2.57 ± 0.61	2.43 ± 0.69	6.54[b]	0.001

Abbreviations: CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic kidney disease; DDG, delayed discharge group; FEV1, forced expiratory volume in one second; HTN, hypertension; ICU, intensive care unit; RDG, routine discharge group; VATS, video-assisted thoracoscopic surgery.
Note: Data are presented as the *n* or mean $\pm$ SD.
[a]χ^2-test.
[b]*t*-test.

factor contributing to prolonged postoperative hospital stay.[14] Long hospital stay after operation by the elderly can be explained from both medical and nonmedical perspectives. Clinically, older patients generally have poor health with more underlying diseases, and they take longer than younger people to recover. This consequently contributes to extended hospital stays because of taking longer to meet specified discharge standards. The nonmedical perspective, which includes logistic and social issues, explains that older patients are more psychologically dependent on hospitalization and require adequate preparation for family care after discharge. All these factors contribute to delayed discharge of elderly patients.

In addition to the age, there are clinical factors associated with delayed discharge. In our logistic regression analysis, male, ICU stay, and underlying diseases (CAD, CKD, old cerebral infarction, COPD, and arrhythmia) were all associated with delayed discharge. Factors of ICU stay and underlying disease can be attributed to the sex-related factors. In the present study, 90.99 and 88.37% patients with a history of smoking and drinking were men, and this corresponds with the actual situation in China. Smoking and drinking habits exacerbate the condition of patients with underlying diseases such as CAD, old cerebral infarction, arrhythmia, and so on. This ultimately makes postoperative treatment of such patients differ from other patients (transfer to ICU for monitoring, perioperative anticoagulant treatment, complex postoperative medication, and so on). Rogers and others also established that postoperative transfer to ICU was an independent factor affecting delayed discharge.[14] Research has proven that early mobilization,[13] early removal of chest drainage and urinary catheter, and resumption of early oral feeding can promote postoperative recovery,[15] Postoperative ICU stay decreased compliance with previously mentioned protocols, resulting in delayed discharge.

Surgical approach is a significant aspect of the ERAS protocols. Previous studies on ERAS have revealed that incidence of atrial fibrillation, cardiopulmonary complications, use of pain medication, and hospitalization costs significantly decreased in patients undergoing thoracotomy.[4,5] But ERAS protocols were not beneficial to patients treated with minimally invasive surgical approach, like video-assisted thoracoscopic surgery (VATS).[5] In our study, nonminimally invasive approach, like thoracotomy, was an independent impact factor of delayed discharge. Notably, most patients in this study underwent minimally invasive surgery. According to the current view, minimally invasive surgery is one feature of ERAS protocols,[16] and most patients with minimal invasive approach have been applied ERAS protocols such as early mobilization and removal of chest tubes in their treatment routines.[4,5]

Pulmonary function has always been one of the important indicators of preoperative evaluation of lung dissection. After lobectomy, the maximum reduction of FEV1 was 22% of the preoperative values,[17] so worse pulmonary function may not only lead to increased postoperative pulmonary complications, but also lead to higher perioperative mortality. In this study, the analysis found that patients are likely to have delay discharge with a low FEV1. Now, studies have confirmed that preoperative aerobic exercise cannot only improve FEV1 and FVC,[18] but also reduce postoperative chest tube duration and incidence of prolonged air leak.[19] The above findings and the results of this study reflect the important effect of pulmonary function on the short-term

Table 2 Distribution of postoperative complications

Postoperative complications	No.
INCD	123
PAL	109
Pulmonary complications	
Pulmonary infection	10
Subcutaneous emphysema	6
Hydrothorax	4
Poor lung recruitment	3
Pulmonary embolism	2
Hypoxia	2
Air leakage during chest tube remove	1
Torsion of right middle lobe	1
Hemoptysis	1
Chylothorax	14
Cardiovascular and neurological complications	
Acute myocardial infarction	3
Atrial fibrillation	3
Deep vein thrombosis in the lower extremities	2
Recurrent laryngeal nerve injury	1
Intracranial aneurysm rupture	1
Internal jugular vein thrombosis	1
Arteriovenous fistula thrombosis (dialysis patients)	1
Others	
Intraocular pressure increase	1
Wilkie's disease	1

Abbreviations: INCD, nonchylous drainage; PAL, prolonged air leakage.

prognosis of thoracic surgery patients. Along with the wide application of sublobectomy in clinic, the requirement of preoperative lung function is gradually decreasing, but it can be found that this parameter (especially FEV1) is still an important factor affecting the short-term prognosis of patients. We recommend the addition of prehabilitation to preoperative ERAS protocols, for improving the short-term prognosis and accelerating the recovery of patients. We are also preparing to bring preoperative aerobic exercise into our future ERAS protocols.

INCD is a chief contributor of delayed discharge, although it largely leads to short-term delayed discharge. During our clinical practice, for reasons of Asian stature and safety after discharge, the drainage tube was only removed when output was $\leq$200 mL per 24 hours, which may have affected removal of the chest tube. Previous studies have demonstrated that the rate of re-intubation (drainage tube) was higher when chest tube was removed $<$200 mL/24 h.[20] Therefore, a few researchers do not consider the effect of drainage output as an effective indicator of tube removal.[21] There have been increasing studies on indications of drainage output and chest tube removal.[13] Present studies indicate that there are great differences in the output volume for drainage removal, ranging between 200 and 450 mL for every 24 hours.[20] Several factors such as stature, sex, and race influence output of the chest tube and an output of 5 mL/kg as recommended by Gonfiotti et al would be reasonable and executable.[22]

PAL is the second leading cause of delayed discharge. The incidence of PAL after thoracic surgery is 6 to 18%, and it is believed that PAL can cause empyema, pneumonia, delayed discharge, increased hospitalization costs, and reoperation.[23] PAL is not only one of the principal causes of delayed discharge according to our study, but also a leading cause of long-term extended discharge. Interventions such as conservative observation, extra suction, chemical pleurodesis, and invasive maneuvers (re-intubation or re-operation) do not differ significantly in reducing air leakage time. When PAL occurs, the terminal of treatment is reducing duration of the chest tube and/or expediting discharge. Thoracic surgeons have two different opinions about extra suction: (1) suction applied to the chest tube can increase gas overflow from the lung parenchyma and prolong air leakage time; (2) extra suction can reduce the chest cavity, promote pleural adhesion, and reduce air leakage. Research findings on extra suction for PAL have been controversial. Three different conclusions on improvement,[24] deterioration,[25] and indifference[26] have been drawn. We have applied electronic drainage system, which can accurately determine air leakage, intuitively measure air leakage speed, and improve patient mobilization in PAL patients. Present study suggests that electronic drainage system has advantages in promoting lung recruitment, reducing tubulization time, and hospital stay.[27]

This study has some limitations. First, like most ERAS studies on thoracic surgery, this is also a retrospective study. Therefore, has inclusion bias. Second, this study only focused on objective indicators during hospitalization, but did not analyze patient-reported outcomes and the patients' condition after discharge. Moreover, this study is a single-centered study because there is currently no uniform standard for ERAS protocols, and there are still differences between this study and other studies on ERAS. We cannot predict whether differences in other studies like analgesic regimen and chest tube management will affect the results of our study.

This study analyzed the primary causes of delayed discharge through retrospective analysis of a consecutive cohort. Male, old age, underlying disease, ICU stay, nonminimally invasive approach, and type of insurance are the independent impact factors causing delayed discharge. In patients experiencing delayed discharge, INCD and PAL were the two leading causes.

Our recommendations for improving ERAS protocols based on the results of our study are: (1) we ought to accept that certain patients (elderly patients, patients with one or more underlying diseases including CAD, CKD, old cerebral infarction, COPD or arrhythmia) need longer postoperative hospital stay for recovery. Consequently, we recommend setting of ERAS recovery goals based on the specific status of different types of patients to replace the invariable

criteria; (2) The indication of postoperative ICU stay should be stricter to avoid the occurrence of ICU stay to the greatest extent, which can improve the compliance of ERAS protocols to promote the postoperative recovery of patients. c. At present, the application of minimally invasive surgical approaches has increased because it is one of the guidelines of the ERAS protocols. Therefore, postoperative hospitalization time for patients has been reduced although INCD and PAL still remain the key reasons for delayed discharge. Further studies on the management of chest tube, including indication of chest tube removal and PAL treatment should be conducted to accelerate the recovery process by reducing time of the chest tube duration.

Conflict of Interest
None declared.

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