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ORIGINAL ARTICLE

Impact of enhanced recovery after surgery on outcomes of elderly patients undergoing open thoracic surgery

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Abstract

Objective An enhanced recovery after surgery (ERAS) program might be effective for postoperative recovery in elderly patients undergoing thoracic surgery. This study aimed to clarify the impact of ERAS on the post-operative recovery of elderly patients, with regard to shortening hospital stay and reducing complications after open thoracic surgery.

Methods We used a prospectively collected database and retrospectively accessed the data of patients who underwent lobectomies or segmentectomies for pulmonary malignancies from April 2013 to March 2018 and evaluated outcomes after implementation of ERAS. ERAS patients were those who completed an ERAS program. The control patients were those who underwent surgery before June 2015 and later operated patients who did not receive ERAS. Propensity score matching was performed to balance the characteristics of patients in both groups. Patients were also divided into the following three groups for evaluating the efficacy of ERAS: patients aged < 65 years, 65–74 years of age, and ≥ 75 years of age.

Results Before propensity score matching, the ERAS patients had shorter postoperative stay, shorter duration of chest tube drainage, and lower rate of postoperative complications than the patients without ERAS. The difference between readmission rates was not significant. After matching, the ERAS patients had shorter postoperative stay. The difference between readmission rates was not significant. After matching, the postoperative hospital stay was shorter in the patients aged ≥ 65 years.

Conclusions ERAS shortened the length of postoperative hospital stay in patients aged ≥ 65 years and did not increase readmission rates.

Keywords Enhanced recovery after surgery · Elderly · Thoracic surgery

Introduction

Elderly patients tend to have comorbidities and be physically impaired. Although they recognized that the treatment for non-small cell lung cancer (NSCLC) should not be denied based on chronologic age alone [1], Seely et al. showed that the treatment complication rate was higher in patients older than 71 years of age [2]. Rivera et al. found higher mortality in older patients [3]. However, differences between morbidity rates, mortality rates, and the quality of life of patients older than 70 years versus younger patients who underwent lung cancer resection were not significant [4]. Advances in perioperative management and surgical techniques could have resulted in the safety of thoracic surgery in elderly patients.

Enhanced recovery after surgery (ERAS) is an approach aimed at achieving an uneventful recovery after thoracic surgery [5–13]. It applies evidence-based methods that are focused on providing an improved postoperative recovery, which includes early ambulation; multimodal, opioid-sparing analgesia; and reduction in surgical stress. ERAS might improve the outcome of surgery, decrease costs [12], shorten the length of time to full recovery, and improve the patient's quality of life. Therefore, ERAS might be effective for improving the postoperative recovery of elderly patients undergoing thoracic surgery. However, the effects of ERAS management have not been clarified in elderly patients.

The purpose of this study was to clarify the impact of ERAS on the postoperative recovery of elderly patients,

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which includes shortening hospital stay and reducing the complication rate after open thoracic surgery.

Patients and methods

This was a retrospective study using our institution's prospectively collected patient database. Our institutional Ethics Committee approved this study and waived the need for informed consent, since patient data remained anonymous.

Study design

We used an established prospectively collected database for patients undergoing thoracic surgery. Our database included the following data: (1) patient demographics (age, gender, smoking status, body height, body weight, body mass index, tumor markers, comorbidities, and pulmonary function tests), (2) NSCLC stage, (3) surgical procedures, (4) pathological findings, (5) complications, and (6) outcomes (readmission, site of recurrence, death, and follow-up). The data were reviewed weekly by the authors.

With the aim of shortening the hospital stay, reducing postoperative complications, and promoting a multidisciplinary team approach, we established an ERAS protocol that was based on a systematic review by Nicholson et al. and was implemented for thoracic surgery starting in June 2015 [14]. The ERAS protocol consisted of a standardized patient education plan on preoperative treatment, a multimodal approach to analgesia, timing and details on postoperative oral intake, early initiation of ambulation 4 h after surgery, and standard chest tube management. Table 1 lists the features of the ERAS protocol and non-ERAS management. Before June 2015, perioperative management was based on the discretion of the physician. After June 2015, although the patients who underwent surgery in the morning were able to complete the ERAS protocol, those patients who underwent surgery in the afternoon were not able to perform early ambulation and oral intake because of the lack of patient caretakers at our institution. Those patients were not able to complete the ERAS protocol. During the study period, the types of analgesia were modified based on each patient's comorbidities.

Figure 1 shows the patient enrollment algorithm used in this study. Between January 2013 and March 2018, a total of 722 consecutive patients underwent complete resection for lung cancer or pulmonary metastasis. After exclusion of patients undergoing wedge resection ($n = 163$), pneumonectomy ($n = 11$), carinal resection ($n = 1$); and patients for whom data were not available ($n = 12$), 535 patients were identified. There were 130 patients who received and 405 patients who did not receive ERAS management. Patients who were treated with neoadjuvant chemotherapy or neoadjuvant chemoradiotherapy were included. The patients who underwent complete ERAS were defined as the investigated group. The control patients were those patients who underwent surgery before June 2015 ($n = 232$) and those patients who did not obtain complete ERAS because of afternoon surgery ($n = 173$). We compared patient characteristics, durations of hospital stay, durations of chest tube drainage, complication rates, and readmission rates. Moreover, patients were divided into the following three groups: Group 1 consisted of patients aged < 65 years; group 2, patients aged 65–74 years; group 3, patients aged ≥ 75 years. We compared the patients within each age group that were further subdivided based on receiving or not receiving ERAS, according to duration

Table 1 Perioperative management

	ERAS (+)	ERAS (–)
Preoperative patient education	Standardized preoperative education by iPad	Non-standardized education
Preoperative chest rehabilitation	Performed by physiotherapist in outpatient clinic	None
Oral care	Performed by dentist	None
Intraoperative analgesia	Paravertebral block	Epidural anesthesia
Chest tube drainage	1 chest tube, 20Fr	Based on surgeons' preference
Postoperative pain control	Multimodal analgesia. Acetaminophen (1,000 mg i.v., q6h), Celecoxib (200 mg p.o., q12h), and patient-controlled analgesia infusion of fentanyl. Diclofenac suppository as rescue	Celecoxib (200 mg p.o., q12h) and patient-controlled analgesia infusion of fentanyl Diclofenac suppository as rescue
Early ambulation	4 h after surgery	None
Oral intake	Clear fluid diet 4 h after surgery and meal on POD 1	POD 1
Removal of chest tube	POD 1 if < 240 mL/12 h, nonchylous, not bloody and no air leak. No clamp test	Based on surgeons' preference
Discharge	POD 4	Based on surgeons' preference

ERAS enhanced recovery after surgery, *NSAIDS* nonsteroidal anti-inflammatory drugs, *POD* postoperative day

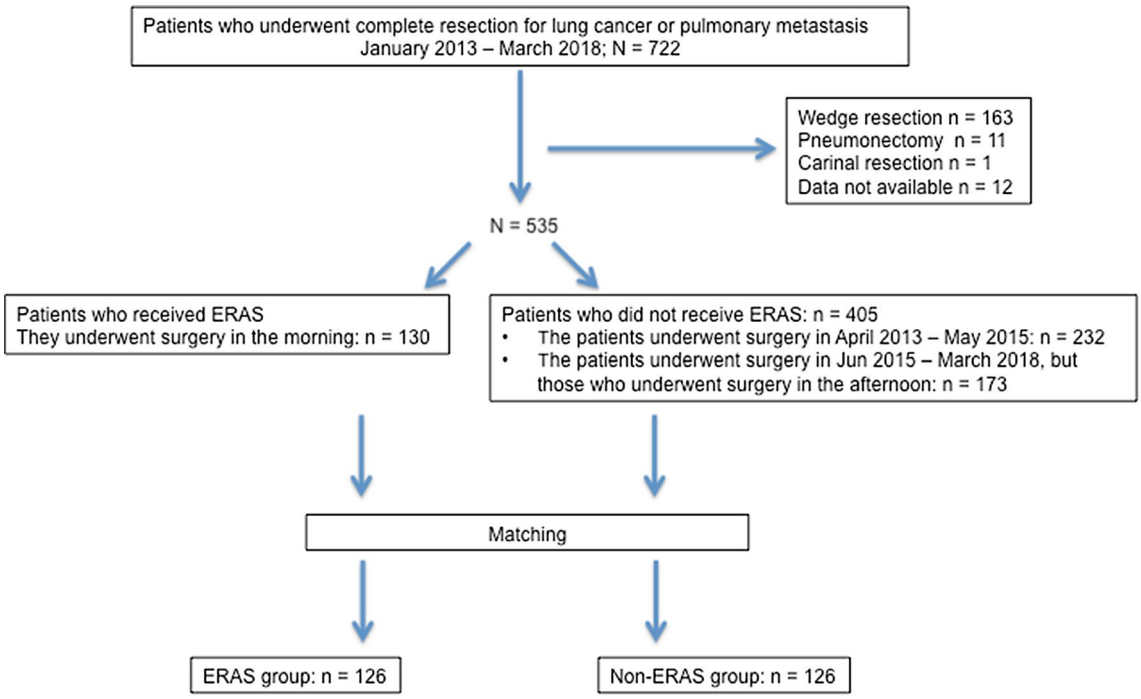

Fig. 1 Patient enrollment algorithm. *ERAS* enhanced recovery after surgery

of postoperative hospital stay, duration of chest tube drainage, postoperative complication rates, and readmission rates.

Before surgery

In the outpatient clinic, each patient underwent preoperative evaluations performed by the thoracic surgeon, physician, and anesthesiologist. Each patient received patient education on his or her disease, rehabilitation, need for early ambulation, and smoking cessation. For education on rehabilitation, a physical therapist trained the patient on how to use an incentive spirometer. Patients with comorbidities were referred for consultation to the relevant department and specialist. Each patient was hospitalized the day before surgery. The order of surgery was decided by the order of the first visiting to our department.

During surgery

Each patient, except those allergic to the agent, received drip infusion of a single dose of cefazolin (1.0 g) immediately before the skin incision and the same dose 3 h after surgery. Lobectomies and segmentectomies that were performed via an open thoracotomy were standard procedures at our institution. The posterolateral thoracotomy incision that spared the serratus anterior muscle was approximately 12 cm. The rib that was cut varied according to the patient.

A segmentectomy was performed for patients with the following characteristics: poor performance status, impaired respiratory function and/or severe comorbidities, or lesions ≤ 2 cm with a ground glass appearance. A mediastinal lymphadenectomy was performed for patients undergoing lobectomy. A hilar lymphadenectomy and lymph node sampling were performed for patients undergoing segmentectomy. A 20 Fr chest tube was positioned apically and posteriorly in each patient.

After surgery

Each patient underwent conventional chest radiography immediately after surgery and extubation in the operating room. Only patients who underwent pneumonectomy were admitted to the intensive care unit. Postoperative management followed our postoperative protocols, as shown in Table 1. To prevent postoperative nausea and vomiting, a single dose of intravenous metoclopramide (10 mg) was administered before ambulation. Chest radiography and blood chemistries were performed on postoperative days (PODs) 1 and 4. After the results of day 4 examinations were reviewed, the patient was discharged.

Chest tube drainage was on suction with a pressure of -10 cm H_2O until the morning of POD1. Chest tube drainage was discontinued on POD1, and the tube was removed if the drainage volume was <240 mL/12 h, nonchylous, not bloody, and without evidence of air leakage. The chest tube

removal protocol was almost similar to that used in the study of Cerfolio et al. [15]. The chest tube was placed on water seal if air leakage was still observed on POD1.

Postoperative complications

Complications were diagnosed as we described previously [16, 17] and were finalized after discussion with thoracic surgeons. We investigated postoperative pneumonia, empyema, prolonged air leak, pleural effusion, arrhythmia, and hypoxia. Postoperative pneumonia was characterized by purulent sputum and pulmonary infiltrative changes on postoperative radiological imaging. Empyema was defined as purulent effusion in the postoperative thoracic cavity. Prolonged air leakage was diagnosed for chest tube drainage persisting for >7 days and/or pleurodesis. Pleural effusion was defined as pleural effusion requiring chest tube drainage. Arrhythmia was defined by the need for medication. Hypoxia was defined by a decrease in oxygen saturation to $\leq 90\%$ as measured by pulse oximetry and need for home oxygen therapy.

Statistical analysis

The chi-squared test or Fisher exact test was used to evaluate the association between categorical variables and patients with or without ERAS. Analysis of variance was used to compare continuous variables in patients with or without ERAS. To control for potential differences in the characteristics of patients treated with or without ERAS, we performed propensity score matching. Propensity scores were calculated by a logistic model and included the following variables: age, gender, comorbidities (hypertension, diabetes mellitus, cardiac disease, cerebrovascular disease), smoking status, neoadjuvant treatment, pulmonary function [forced vital capacity (FVC), forced expiratory volume in 1 s [FEV1], forced expiratory volume as a percentage of forced vital capacity (FEV1%)], body mass index (BMI), operative time, and blood loss during surgery. Propensity scores generated by the model were used for caliper matching, which used a caliper distance of 0.2 without replacement and 1-to-1 control matching.

Data were analyzed by JMP software, version 5.0.1J (SAS Institute Inc., Cary, NC, USA). A p value <0.05 was considered to indicate statistical significance.

Results

Patient demographics

Regarding adherence to early ambulation, all patients [130 of 535 (24.3%) patients] who underwent surgery in the morning after June 2015 were able to obtain complete ERAS. Before propensity score matching, the operative time was shorter and amount of blood loss was lower in the patients with ERAS than in the patients without ERAS (Table 2). After propensity score matching, there were no differences between the two groups.

Surgical outcomes

Table 3 shows the surgical outcomes. For all study patients, the median duration of postoperative hospital stay was 5 days (range 3–83 days), and median duration of chest tube drainage was 1 day (range 1–32 days). The incidence of complications in all patients was 19.8%, and the readmission rate was 5.8%. Before propensity score matching, the patients with ERAS had shorter postoperative stays, shorter durations of chest tube drainage, and lower incidence of all types of postoperative complications than the patients without ERAS. The differences between hospital readmission rates and mortality rates were not significant. After propensity score matching, the patients with ERAS had shorter postoperative stays and durations of chest tube drainage. The differences between hospital readmission rates and mortality rates remained insignificant after propensity score matching. Among the 19 of 535 (3.6%) patients with hospital stays ≥ 14 days, only 1 patient received ERAS.

The 30- and 90-day mortality rates were 0.2% and 1.2%, respectively. None of the patients who died received ERAS. None of the deaths could be attributed to ERAS. One death due to interstitial pneumonia occurred within 30 days of surgery. From 31 to 90 days after surgery, three patients died of interstitial pneumonia, one patient died of acute respiratory distress syndrome, and one patient died of sudden death.

Complications

Propensity score matching was not performed for the low number of complications. Table 4 shows the postoperative complications according to patients with and without ERAS. Pulmonary complications developed in 7 of 130 (5.4%) patients with and 43 of 405 (10.6%) patients without ERAS. Hypoxia was the most frequent pulmonary complication in patients with ERAS, and prolonged air leakage was the most frequent complication in patients without ERAS. The incidence of cardiovascular complications was similar for both groups. With regard to other complications, although the difference was not significant, 12 of 405 (3.0%) patients without ERAS had an episode of delirium, but only 1 of 130 (0.8%) patients with ERAS had an episode ($p=0.277$).

Table 2 Patient demographics[a]

Factors	Before propensity score matching			After propensity score matching		
	ERAS (+) ($n=130$)	ERAS (–) ($n=405$)	p	ERAS (+) ($n=126$)	ERAS (–) ($n=126$)	p
Median age, years (IQR)	70 (65–77)	70 (63–77)	0.512	70 (65–76)	70 (63–77)	0.969
Gender						
Male	86 (66.2%)	231 (57.0%)	0.064	84 (66.7%)	86 (68.3%)	0.788
Female	44 (33.8%)	174 (43.0%)		42 (33.3%)	40 (31.8%)	
Diseases						
Lung cancer	122 (93.8%)	369 (91.1%)	0.800	118 (93.7%)	118 (93.7%)	1.000
Metastatic lung tumor	8 (6.2%)	36 (8.9%)		8 (6.4%)	8 (6.4%)	
Smoking						
Non-smoker	44 (34.1%)	144 (35.6%)	0.764	42 (33.3%)	38 (30.2%)	0.588
Smoker	85 (65.9%)	261 (64.4%)		84 (66.7%)	88 (69.8%)	
Pulmonary function						
FVC, L (IQR)	3.21 (2.79–3.72)	3.12 (2.55–3.72)	0.184	3.21 (2.81–3.72)	3.37 (2.80–3.86)	0.483
%FVC, % (IQR)	108.2 (97.5-117.2)	106.5 (94.8–117.0)	0.046	107.6 (97.0-116.2)	106.2 (99.7–119.0)	0.470
FEV1, L (IQR)	2.26 (1.93–2.80)	2.24 (1.82–2.73)	0.278	2.25 (1.93–2.79)	2.43 (1.95–2.84)	0.360
FEV1%, % (IQR)	74.0 (67.5–78.7)	73.9 (67.2–80.3)	0.111	74.0 (67.5–78.7)	73.8 (68.0-80.5)	0.269
Blood gas analysis						
PaO_2, mmHg (IQR)	85.0 (78.5–91.4)	83.9 (77.0-91.5)	0.137	85.0 (78.5–91.4)	85.5 (78.6–92.5)	0.912
$PaCO_2$, mmHg (IQR)	37.9 (35.3–40.3)	38.9 (36.2–40.9)	0.060	37.9 (35.3–40.3)	38.1 (35.4–40.2)	0.941
Body mass index (IQR)	22.7 (20.5–27.7)	22.5 (20.4–26.6)	0.241	22.8 (20.4–24.5)	22.6 (20.9–25.1)	0.770
Comorbidities						
Hypertension	62 (47.7%)	206 (50.9%)	0.529	58 (46.0%)	67 (53.2%)	0.257
Diabetes mellitus	21 (16.2%)	56 (13.8%)	0.515	21 (16.7%)	21 (16.7%)	1.000
Cardiac disease	16 (12.3%)	61 (15.1%)	0.429	16 (12.7%)	23 (18.3%)	0.221
Cerebrovascular disease	10 (7.7%)	26 (6.4%)	0.619	9 (7.1%)	12 (9.5%)	0.493
Procedure						
Segmentectomy	33 (25.4%)	81 (20.0%)	0.198	32 (25.4%)	26 (20.6%)	0.369
Lobectomy	97 (74.6%)	324 (80.0%)		94 (74.6%)	100 (79.4%)	
Median operative time, minutes (IQR)	142 (120–162)	154 (133–184)	<0.001	143 (120–163)	144 (123–171)	0.465
Median blood loss, g (IQR)	16 (5–34)	20 (6–51)	0.027	16 (5–35)	17 (5–32)	0.407
Neoadjuvant therapy	7 (5.4%)	16 (4.0%)	0.800	7 (5.6%)	3 (2.4%)	0.338

ERAS enhanced recovery after surgery, *IQR* interquartile range, *FVC* forced vital capacity, *FEV1* forced expiratory volume in 1 s, *FEV1%* forced expiratory volume as a percentage of forced vital capacity

[a]Chi-squared test or Fisher exact test was used for categorical data, and analysis of variance was used for continuous data

Analysis by age groups

The outcomes of ERAS were evaluated according to age groups. Before propensity score matching, the median duration of postoperative hospital stay was shorter in the patients with ERAS aged 65–74 years and ≥ 75 years than in the patients in those age groups without ERAS. Fewer postoperative complications occurred in patients with ERAS aged < 65 years than in that age group without ERAS. The median duration of chest tube drainage was shorter in patients with ERAS aged 65–74 years than in that age group without ERAS. The differences in readmission rates within 30 days after surgery were not significant between any patient age group with/without ERAS (Table 5). After propensity score matching, although the readmission rates within 30 days were not significant for any patient age group with/without ERAS (Table 5), the median postoperative hospital stay was shorter in patients with ERAS aged 65–74 years and ≥ 75 years than in patients in those age groups without ERAS.

Discussion

This study showed that patients with ERAS had decreased duration of postoperative stay and duration of chest tube drainage, and the difference between readmission rates was not significant. The clinical impact of ERAS was found to

Table 3 Surgical outcomes according to with/without ERAS[a]

All ages: outcomes	Before propensity score matching			After propensity score matching		
	ERAS (+) ($n=130$)	ERAS (–) ($n=405$)	p	ERAS (+) ($n=126$)	ERAS (–) ($n=126$)	p
Median postoperative stay, days (range)	4 (4–18)	5 (3–83)	< 0.001	4 (4–18)	5 (3–25)	< 0.001
Median duration of chest tube drainage, days (range)	1 (1–9)	2 (1–32)	0.006	1 (1–9)	1 (1–18)	0.029
Postoperative complications	17 (13.1%)	89 (22.0%)	0.022	16 (12.7%)	24 (19.1%)	0.167
Readmission within 30 days after surgery	4 (3.1%)	27 (6.7%)	0.104	3 (2.4%)	6 (4.8%)	0.304
Mortality, within 30 days	0 (0)	1 (0.2%)[b]	0.549	0 (0)	0 (0)	0.999
Mortality, within 90 days	0 (0)	5 (1.2%)[c]	0.454	0 (0)	1 (0.8%) [b]	0.999

ERAS enhanced recovery after surgery

[a]Chi-squared or Fisher exact test was used for categorical data, and analysis of variance was used for continuous data

[b]One patient died of interstitial pneumonia

[c]Three patients died of interstitial pneumonia, One patient died of sudden death, one patient died of acute respiratory distress syndrome

Table 4 Complications according with/without ERAS[a]

All ages: Complications[b]	ERAS (+) ($n=130$)	ERAS (–) ($n=405$)	p
Postoperative complications	17 (13.1%)	89 (22.0%)	0.022
Pulmonary complications	7 (5.4%)	43 (10.6%)	0.060
Hypoxia	5	12	
Pneumonia	2	8	
Prolonged air leak	1	21	
Empyema	1	3	
Atelectasis	0	2	
Pleural effusion	0	1	
Sputum retention	0	2	
ARDS	0	1	
Cardiovascular complications	8 (6.2%)	23 (5.7%)	0.924
Arrhythmia	5	17	
Pulmonary vein thrombosis	2	4	
Hypertension	1	1	
Cardiac failure	0	1	
Cerebrovascular complications	0 (0)	2 (0.5%)	0.999
Cerebral infarction	0	2	
Other complications			
Delirium	1	12	
Wound infection	1	5	
Postoperative bleeding	1	2	
Renal failure	0	2	
Hoarseness	0	4	
Chylothorax	0	1	

ERAS enhanced recovery after surgery, *ARDS* acute respiratory distress syndrome

[a]Chi-squared or Fisher exact test was used for categorical data

[b]Some patients had more than one complication

vary according to the ages of patients. While ERAS did not significantly impact patients aged < 65 years, it decreased the duration of postoperative stay in patients aged > 65 years. The results suggest that ERAS did not benefit the younger age group. The reason why ERAS did not show benefit for the surgical outcomes of patients aged < 65 years might be

Table 5 Surgical outcome according to with/without ERAS by age[a]

	Before propensity score matching			After propensity score matching		
Aged < 65 years: Outcomes	ERAS (+) ($n=31$)	ERAS (–) ($n=126$)	p	ERAS (+) ($n=31$)	ERAS (–) ($n=36$)	p
Median postoperative stay, days (range)	4 (4–11)	5 (3–83)	0.214	4 (4–11)	4 (4–18)	0.527
Median duration of chest tube drainage, days (range)	1 (1–9)	2 (1–14)	0.815	1 (1–3)	1 (1–9)	0.545
Postoperative complications	1 (3.2%)	22 (17.5%)	0.048	1 (3.2%)	2 (8.3%)	0.618
Readmission within 30 days after surgery	3 (2.4%)	1 (3.2%)	0.795	1 (3.2)	0 (0)	0.463
Aged 65–74 years: Outcomes	ERAS (+) ($n=58$)	ERAS (–) ($n=143$)	p	ERAS (+) ($n=57$	ERAS (–) ($n=48$)	p
Median postoperative stay, days (range)	4 (4–9)	5 (3–34)	0.001	4 (4–9)	4 (4–20)	0.002
Median duration of chest tube drainage, days (range)	1 (1–7)	2 (1–32)	0.034	1 (1–7)	1 (1–18)	0.098
Postoperative complications	8 (13.8%)	26 (18.2%)	0.445	8 (14.0%)	7 (14.6%)	0.936
Readmission within 30 days after surgery	1 (1.7%)	8 (5.6%)	0.452	1 (1.8%)	2 (4.2%)	0.591
Aged ≥ 75 years: Outcomes	ERAS (+) ($n=41$)	ERAS (–) ($n=136$)	p	ERAS (+) ($n=38$)	ERAS (-) ($n=42$)	p
Median postoperative stay, days (range)	4 (4–18)	6 (3–54)	0.004	4 (4–18)	5 (3–25)	0.003
Median duration of chest tube drainage, days (range)	1 (1–7)	2 (1–20)	0.054	1 (1–7)	2 (1–15)	0.052
Postoperative complications	8 (19.5%)	41 (30.2%)	0.171	7 (18.4%)	14 (33.3%)	0.127
Readmission within 30 days after surgery	2 (4.9%)	15 (11.0%)	0.367	1 (2.6%)	4 (9.5%)	0.362

ERAS enhanced recovery after surgery

[a]Chi-squared or Fisher exact test was used for categorical data, and analysis of variance was used for continuous data

associated with their good physical condition. Brunelli et al. revealed that the ERAS program did not benefit patients undergoing video-assisted thoracoscopic lobectomies [18]. In addition, another study reported that patients undergoing minimally invasive surgery who received ERAS did not gain the same benefits of reductions in morbidity and hospital stay that patients undergoing an open approach received [13]. Although the thoracoscopic approach might decrease the benefits of ERAS, our results indicated that ERAS was associated with reduced duration of hospital stay in patients who underwent open thoracotomy.

The systematic review concluded that evidence on the role of ERAS in lung resection was not conclusive [14, 19, 20]. Therefore, we used propensity score matching of a study cohort to assess the impact of ERAS on the outcomes of lung resection.

The incidence of postoperative complications after lung resections has been reported to be approximately 30% [2, 21]. The risk factors of postoperative complications include advanced age, comorbidities, performance status, and respiratory function. Operative time, especially, was significantly associated with postoperative complications [17]. Our study found an incidence of 19.8% for postoperative complications, which is lower than found by other studies. We speculate that the difference was related to the exclusion of pneumonectomy cases. However, the 30.2% incidence of postoperative complications in patients aged ≥ 75 years who did not receive ERAS was similar to the rates in other studies [2, 21]. While we did not find a relationship between ERAS and postoperative complications, given the reduction of body performance, ERAS might play an important role in uneventful recovery after thoracic surgery. Compared with the patients without ERAS, patients with ERAS had a shorter duration of chest tube drainage. As prolonged air leakage is the major reason for longer hospital stays, we meticulously repaired air leakage with free fat or fibrin glue [22] and applied standardized chest tube management [23].

We think that evaluations from patients receiving ERAS are important. Unfortunately, we did not perform a patient survey after discharge, and patient feedback is important for improving clinical management. A survey of patient satisfaction that consisted of patients who received fast-track surgery found that 91% were extremely happy or satisfied at the 2-week follow-up [5].

Regarding readmission rates, Cerfolio et al. reported a 2-week readmission rate of 1.8% [5]. Our study found a readmission rate of 5.8%, which could have been affected by the protocol governing hospital admission at our institution.

There are several limitations to this study. First, because we considered that complete ERAS accurately reflected the efficacy of ERAS, the patients who did not obtain complete ERAS were included in the patient group not receiving ERAS. The control group might not be appropriate. While the patients who underwent morning surgery after June 2015

were able to obtain complete ERAS, the patients who underwent afternoon surgery were not able to obtain early ambulation and oral intake because of lack of sufficient support staff. Rogers et al. showed that a higher ERAS compliance rate was significantly associated with decreased postoperative complications and shortened hospital stay [24]. Because of our inappropriate control, our study could not accurately determine the efficacy of ERAS. Second, this was a retrospective single-center study. Although we used propensity score matching to adjust the differences between patients with and without ERAS, some patient features could not be completely adjusted. For example, we could not accurately capture the intraoperative difficulties and management of anesthesia. Most of the patients with ERAS received a paravertebral block, which might have affected the positive results. Third, ERAS protocols vary [14]. Therefore, we do not know if our findings could be used worldwide. Fourth, in this study, we did not evaluate the patients' nutritional status. Patients with malnutrition, frailty, or sarcopenia need enhanced management. We think that the next study should include evaluating ERAS for patients with malnutrition, frailty, or sarcopenia. Finally, the overall physical condition of elderly patients is variable because of comorbidities. A standardized ERAS protocol might not be compatible with personalized treatments.

Conclusion

Although there are some shortcomings regarding the efficacy of ERAS, we found that ERAS was safe and decreased the duration of postoperative hospital stay without increasing the readmission rate in elderly patients stratified by propensity score matching.

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Compliance with ethical standards

Conflict of interest Satoshi Shiono: None declared. Makoto Endo: None declared. Katsuyuki Suzuki: None declared. Kazuki Hayasaka: None declared.

References

1. Pallis AG, Scarci M. Are we treating enough elderly patients with early stage non-small cell lung cancer? Lung Cancer. 2011;74:149–54.
2. Seely AJE, Ivanovic J, Threader J, Al-Hussaini A, Al-Shehab D, Ramsay T, et al. Systematic classification of morbidity and mortality after thoracic surgery. Ann Thorac Surg. 2010;90:936–42.
3. Rivera C, Falcoz PE, Bernard A, Thomas PA, Dahan M. Surgical management and outcomes of elderly patients with early stage non-small cell lung caner: a nested case-control study. Chest. 2011;140:874–80.
4. Chambers A, Routledge T, Pilling J, Scarci M. In elderly patients with lung cancer is resection justified in terms of morbidity, mortality and residual quality of life? Interact Cardiovasc Thorac Surg. 2010;10:1015–21.
5. Cerfolio RJ, Pickens A, Bass C, Katholi C. Fast-tracking pulmonary resections. J Thorac Cardiovasc Surg. 2001;122:318–24.
6. Kehlet H. Fast-track colorectal surgery. Lancet. 2008;371:791–3.
7. Kehlet H, Wilmore DW. Evidence-based surgical care and evolution of fast-track surgery. Ann Surg. 2008;248:189–98.
8. Das-Neves-Pereira JC, Bagan P, Coimbra-Israel AP, Grimaillof-Junior A, Cesar-Lopez G, Milanez-de- Campos JR, et al. Fast-track rehabilitation for lung cancer lobectomy: a five-year experience. Eur J Cardiothorac Surg. 2009;36:383–92.
9. Muehling BM, Halter GL, Schelzig H, Meierhenrich R, Steffen P, Sunder-Plassmann L, et al. Reduction of postoperative pulmonary complications after lung surgery using a fast track clinical pathway. Eur J Cardiothorac Surg. 2008;34:174–80.
10. Sokouti M, Aghdam BA, Golzari SEJ, Moghadaszadeh M. A comparative study of postoperative pulmonary complications using fast track regimen and conservative analgesic treatment: a randomized clinical trial. Tnaffos. 2011;10:12–9.
11. Madani A, Fiore JF, Wang Y, Bejjani J, Sivakumaran L, Mata J, et al. An enhanced recovery pathway reduces duration of stay and complications after open pulmonary lobectomy. Surgery. 2015;158:899–910.
12. Paci P, Madani A, Lee L, Mata J, Mulder DS, Spicer J, et al. Economic impact of an enhanced recovery pathway for lung resection. Ann Thorac Surg. 2017;104:950–7.
13. Van Haren RM, Mehran BJ, Mena GE, Correa AM, Antonoff MB, Baker CM, et al. Enhanced recovery decreases pulmonary and cardiac complications after thoracotomy for lung cancer. Ann Thorac Surg. 2018;106:272–9.
14. Nicholson A, Lowe MC, Parker J, Lewis SR, Alderson P, Smith AF. Systematic review and meta-analysis of enhanced recovery programmes in surgical patients. BJS. 2014;101:172–88.
15. Cerfolio RJ, Bryant AS. Results of a prospective algorithm to remove chest tubes after pulmonary resection with high output. J Thorac Cardiovasc Surg. 2008;135:269–73.
16. Shiono S, Yoshida J, Nishimura M, Hagiwara M, Hishida T, Nitadori J, et al. Risk factors of postoperative respiratory infections in lung cancer surgery. J Thorac Oncol. 2007;2:34–8.
17. Shiono S, Abiko M, Sato T. Postoperative complications in elderly patients after lung cancer surgery. Interact Cardiovasc Thorac Surg. 2013;16:819–23.
18. Brunelli A, Thomas C, Dinesh P, Lumb A. Enhanced recovery pathway versus standard care in patients undergoing video-assisted thoracoscopic lobectomy. J Thorac Cardiovasc Surg. 2017;154:2084–90.
19. Fiore JF, Bejjani J, Conrad K, Niculiseanu P, Landry T, Lee L, et al. Systematic review of the influence of enhanced recovery pathways in elective lung resection. J Thorac Cardiovasc Surg. 2016;151:708–15.
20. Brown LM. "Moving right along" after lung resection, but the data suggest "'not so fast". J Thorac Cardiovasc Surg. 2016;151:715–6.
21. Salati M, Refai M, Pompili C, Xiumè F, Sabbatini A, Brunelli A. Major morbidity after lung resection: a comparison between the European Society of Thoracic Surgeons Database system and the Thoracic Morbidity and Mortality system. J Thorac Dis. 2013;5:217–22.

22. Shintani Y, Inoue M, Funaki S, Kawamura T, Minami M, Okumura M. Clinical usefulness of free subcutaneous fat pad for reduction of intraoperative air leakage during thoracoscopic pulmonary resection in lung cancer cases. Surg Endosc. 2015;29:2910–3.
23. Sakamoto T, Nishio W, Okada M, Harada H, Uchino K, Tsubota N. Management of air leak after pulmonary resection. Jpn J Thorac Cardiocasc Surg. 2004;52:292–5.
24. Rogers LJ, Bleetman D, Messenger DE, Joshi NA, Wood L, Rasburn NJ, et al. The impact of enhanced recovery after surgery (ERAS) protocol compliance on morbidity from resection for primary lung cancer. J Thorac Cardiovasc Surg. 2018;155:1843–52.