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ORIGINAL ARTICLE

Does Prehabilitation Reduce Postoperative Length of Hospital Stay after Esophageal Cancer Surgery?

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Objectives: At our hospital, prehabilitation has been provided to patients undergoing esophageal cancer surgery since October 2019. This study explored the effects of prehabilitation based on the accumulated database of these patients. **Methods:** This retrospective cohort study included 621 patients who underwent thoracoscopic subtotal esophagectomy. Multiple linear regression analysis was performed using postoperative hospital stay as the objective variable and age, sex, body mass index (BMI), preoperative ventilatory impairment, left ventricular ejection fraction, preoperative hemoglobin A1c, clinical stage, histological type, operative time, surgical blood loss, postoperative complications, and prehabilitation as explanatory variables. We also performed a multivariate analysis in the subgroup of patients who developed postoperative complications and adjusted for possible confounding factors. Postoperative complications and postoperative hospital stay were compared between patients without (n=416) and with (n=205) prehabilitation. **Results:** Postoperative complications, age, blood loss, BMI, and ventilatory impairment influenced the overall length of hospital stay. When the analysis was restricted to patients with complications, prehabilitation was added to that list of factors as a substitute for BMI. The rate of postoperative complications was not affected by prehabilitation (P=0.1675). The number of hospital days did not change with or without prehabilitation in the overall population, but when restricted to patients with complications, the number of hospital days was significantly decreased in the prehabilitation group (P=0.0328). **Conclusions:** Prehabilitation as a perioperative approach has the potential to reduce the postoperative length of hospital stay in patients undergoing esophageal cancer surgery, and active intervention is recommended.

Key Words: esophageal cancer; length of hospital stay; prehabilitation

INTRODUCTION

Esophageal cancer has a poor prognosis and is the sixth leading cause of cancer-related deaths worldwide.[1,2] Surgical treatment for esophageal cancer involves resection with reconstruction, which is highly invasive, spanning the neck, chest, and abdomen. As a result, the incidence of complications and mortality are high.[3,4] The most common complications of esophagectomy include recurrent nerve palsy, pneumonia, and anastomotic leakage.[5,6] Several studies have shown that complications worsen the prognosis of esophageal cancer.[7,8]

In addition to disabilities caused by cancer, those with cancer suffer from physical and mental dysfunctions caused by complications associated with surgery, chemotherapy, and radiation therapy. Therefore, efforts to prevent these functional impairments should ideally be made in the rehabilitation department before starting cancer treatment. However, after patients are trained to leave their beds after surgery, rehabilitation is often provided for complications that develop on a case-by-case basis. Recently, measures to promote postoperative recovery have been adopted

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perioperatively. The well-known evidence-based enhanced recovery after surgery (ERAS), which originated in Northern Europe in 2005, has been revised and is now used in various procedure-specific protocols.[9] Prehabilitation was adopted for the first time in the fourth edition of the ERAS Guidelines for Colorectal Surgery.[10] Prehabilitation is a term coined to refer to rehabilitation prior to surgery.[11] Although prehabilitation has been overlooked as a recommendation in ERAS because of a lack of scientific evidence, it is now expected to be used in surgeries for a large number of older patients. In 2020, a protocol on post esophageal cancer resection was published and has since been used.[12]

Cancer prehabilitation, a process on the continuum of care that occurs between the time of cancer diagnosis and the beginning of acute treatment, includes physical and psychological assessments that establish a baseline functional level, identify impairments, and provide targeted interventions that improve patient health to reduce the incidence and the severity of current and future impairments.[13] Inoue et al.[14] conducted a retrospective cohort study on the prevention of postoperative pulmonary complications by providing preoperative intensive respiratory rehabilitation in patients with esophageal cancer. They found that it significantly prevented postoperative pulmonary complications.[14] Yamana et al.[15] conducted a prospective randomized controlled trial and reported the efficacy of preoperative intensive respiratory rehabilitation. Halliday et al.[16] compared the impact of preoperative rehabilitation on postoperative outcomes in esophageal cancer surgery using propensity score-matched comparisons and found a reduction in hospital length of stay as well as a lower incidence of pneumonia after esophagectomy.

In general, esophageal cancer is treated with a combination of chemotherapy, surgery, and radiation therapy, depending on the site and degree of progression. Surgical therapy includes endoscopic submucosal dissection and esophageal subtotal resection combined with gastric tube reconstruction, and the latter is divided into open thoracotomy and combined thoracoscopic and laparoscopic esophageal cancer radical surgery (VATS-E: video-assisted thoracoscopic surgery for esophagus). At our Esophageal Cancer Center, VATS-E, which is minimally invasive with few complications, is actively performed. Standard treatment for resectable cases is neoadjuvant chemotherapy (NAC) followed by surgery. The chemotherapy schedule consists of two or three 1-week hospitalizations within 1–2 months, followed by a few more weeks of home stay before surgery. NAC has significantly improved survival rates for esophageal cancer and esophagogastric junction cancer.[17] However, the associated toxicity can affect lung function and cause functional decline, which must be addressed in addition to the loss of mobility after surgery.[18] Therefore, we initiated prehabilitation for all patients scheduled for esophageal cancer surgery from October 2019 using the period of chemotherapy hospitalization.

At our facility, occupational therapists and speech-language pathologists, in addition to physical therapists, provide comprehensive prehabilitation that includes swallowing training and behavioral and psychological guidance. These preoperative efforts may have an impact on the postoperative hospital stay. In this study, we hypothesized that prehabilitation will reduce the length of hospital stay after esophageal cancer surgery.

MATERIALS AND METHODS

Patients and Study Design

This retrospective cohort study included 621 patients who underwent thoracoscopic subtotal esophageal resection in our esophageal surgery department from 2016 (when the database on esophageal cancer surgery began in our hospital) to the end of 2021. The following inclusion criteria were used: patients diagnosed with esophageal cancer (gastrointestinal stromal tumor and esophagogastric junction cancers were not included), whose clinical stage was not limited, who underwent the VATS-E procedure on a standby basis after being judged resectable by the attending physician, and those in whom the progress of complications could be followed until discharge from the hospital after surgery. Prehabilitation was incorporated with a request from the attending physician to the rehabilitation department and was initiated when a training prescription was issued by the physiatrist to the physical therapist, occupational therapist, and speech-language pathologist. To avoid differences in postoperative complications because of surgical technique, patients who underwent open thoracotomy, mediastinoscopy, or robot-assisted minimally invasive esophagectomy were excluded. The following NAC regimens were used: FP therapy (fluorouracil + cisplatin), n=455; DCF therapy (docetaxel + cisplatin + fluorouracil), n=93; other regimens, n=28; no regimen, n=45.

Data for the following patient characteristics were recorded for all eligible patients: age, sex, body mass index (BMI), esophageal cancer stage, histological type, presence or absence of preoperative ventilatory impairment, left ventricular ejection fraction, preoperative hemoglobin A1c (HbA1c), operative time, intraoperative blood loss, presence

Table 1. Prehabilitation programs

Program	Program details
Patient evaluation	Physical, nutritional, and psychological assessment
Exercise instruction	Walking training, cycling, and other aerobic exercises for the entire body, instruction/training of movements around the bed such as getting up, etc. Intervention from training that can be easily introduced with few individual differences in movements and methods.
Breathing exercises	Incentive spirometry, respiratory muscle stretching, abdominal breathing, huffing, self-expectorant technique.
Swallowing training	Shaker exercise, Mendelsohn maneuver, breath-hold swallowing, pushing/pulling physical exercise for swallowing.
Smoking cessation	Instruction provided 3 months prior to surgery and at least 1 month of smoking cessation.

or absence of postoperative complications, and presence or absence of prehabilitation.

All patients underwent postoperative rehabilitation from the day after surgery, including breathing training (deep breathing and expectoration) and assisted walking training provided by physicians and nurses in the intensive care unit. Two to 3 days later, exercise therapy was provided by a physical therapist, and patients who were independent in walking continued independent training until discharge in accordance with the critical path. Depending on the postoperative status of the patients, postoperative occupational therapy and postoperative speech therapy were provided for those who needed these therapies.

From October 2019 onward, prehabilitation by physical therapists, occupational therapists, and speech-language pathologists was provided to eligible patients from the time of admission for preoperative chemotherapy. Patients were given prehabilitation instructions during their admission for preoperative chemotherapy. The basic prehabilitation program during hospitalization consisted of one 20-min unit, and two units per day were allocated for instructional time from the rehabilitation staff. The prehabilitation program is outlined in **Table 1**. The exercise load consisted of 3–4 metabolic equivalents (METs) of aerobic exercise for 1 h/day, and the patients were instructed to perform a minimum of 23 METs/h per week in total. In cases where sufficient space was available, patients were instructed to perform squats, exercises with dumbbells, and resistance exercises with rubber tubing, but these exercises were not deemed mandatory. Although we did not set up an outpatient clinic specializing in prehabilitation for training at home, we asked the patients to record the exercises they performed as voluntary training in a record booklet. This record was checked by the therapist in charge during the instructional time when the patient was admitted to hospital.

To explore the effects of prehabilitation, eligible patients were divided into two groups for comparison. The 416 patients who underwent surgery between 2016 and September 2019 before the introduction of prehabilitation were defined as the no-prehabilitation group. The 205 patients who underwent surgery between October 2019 and December 2021 (after the introduction of prehabilitation) were defined as the prehabilitation group. This study was conducted until June 2022, when all patients were discharged from the hospital, and the outcomes were recorded.

Factors Influencing Postoperative Length of Hospital Stay

Factors affecting postoperative hospital stay were investigated retrospectively using the esophageal cancer database compiled by our hospital. Postoperative hospital stay was set as the objective variable, and factors that were considered important from a medical perspective were selected as explanatory variables in multiple regression equations. Patient attributes included age, sex, BMI as nutritional status, and preoperative patient physical status, including presence of ventilatory disturbance, left ventricular ejection fraction, and HbA1c. Ventilatory impairment was defined as a 1-s forced expiratory volume (FEV_1%) of less than 70% or a vital capacity of less than 80%. Esophageal cancer stage and histological type were examined as tumor characteristics, and operative factors such as operative time and blood loss were evaluated. The presence or absence of postoperative complications was also investigated. Postoperative complications were defined as Grade I or higher according to the Clavien–Dindo classification.

Postoperative Complication Rate

Postoperative complications of Grade I or higher on the

Table 2. Characteristics of participants

Characteristic	Total n = 621
Age, years	68 (40–96)
Sex, male/female	478/143
BMI, kg/m^2	21.09±3.11
Ventilatory impairment, yes/no	246/373
EF, %	64.68±7.11
HbA1c, %	5.84±0.67
Histological type (SCC/adeno/NEC/other)	601/8/4/8
cStage (0/1/2/3/4/other)	1/204/121/214/67/14
Operative time, min	355.26±100.33
Surgical blood loss, mL	145.11±244.98
Postoperative hospital stay, days	20.51±16.91
Postoperative complications, yes/no	349/272
Prehabilitation, yes/no	205/416

Data given as number or mean ± standard deviation. Age given as median (range).
EF, ejection fraction; cStage, clinical stage; SCC, squamous cell carcinoma; adeno, adenocarcinoma; NEC, neuroendocrine carcinoma.

Clavien–Dindo classification were investigated. Complications that occurred between the date of surgery and the date of discharge were examined, including recurrent nerve palsy, pneumonia, atelectasis, pleural effusion, pneumothorax, chyle leak, cervical lymph leak, surgical site infection, suture failure, anastomotic dilation, bleeding, thrombus, arrhythmia, heart failure, sepsis, and many others. Patients with any of the above complications were counted as having postoperative complications, and the total number of patients with postoperative complications was compared between the two groups.

Reduction in Postoperative Length of Hospital Stay

The mean length of hospital stay from the date of surgery to the date of discharge was compared between the prehabilitation and no-prehabilitation groups.

Postoperative Length of Hospital Stay in Patients with Postoperative Complications

The mean length of hospital stay from the date of surgery to the date of discharge in patients with postoperative complications, as indicated above, was compared between the prehabilitation and no-prehabilitation groups.

Statistical Analysis

Multiple regression analysis was performed for all patients using the least squares method with postoperative hospital stay as the objective variable. Partial regression coefficients were standardized to compare the influence of independent variables, and factors contributing to postoperative hospital stay were ranked. In addition, a similar multivariate analysis was performed only for patients who developed postoperative complications as a subgroup to adjust for confounding factors.

The chi-square test was used to determine whether there was a decrease in postoperative complications, and $P<0.05$ was considered statistically significant. The Wilcoxon rank-sum test was used to compare postoperative hospital stays, and $P<0.05$ was considered statistically significant. All statistical calculations were performed using JMP-pro 16 statistical analysis software.

The research protocol was approved by the Ethics Committee on Human Subjects Research at Showa University (Approval No. 22-132-A). Informed consent was obtained by the opt-out method.

RESULTS

Table 2 shows patient characteristics for all participants. Information was collected for age, sex, BMI, presence of preoperative ventilatory impairment, left ventricular ejection fraction, preoperative HbA1c, clinical stage, histological type, operative time, surgical blood loss, presence of postoperative complications, and presence of prehabilitation.

Table 3. Multiple regression analysis of all cases

Ranking[a]	Factor	Standardized partial regression coefficient	Partial regression coefficient	SE	P value	Lower 95%	Upper 95%	VIF
1	Postoperative complications	0.245	8.353	1.328	<0.0001	5.744	10.962	1.043
2	Age	0.144	0.253	0.072	0.0004	0.112	0.394	1.140
3	Surgical blood loss	0.121	0.008	0.003	0.0034	0.003	0.014	1.154
4	BMI	−0.112	−0.616	0.223	0.0059	−1.054	−0.178	1.143
5	Ventilatory impairment	0.103	3.571	1.361	0.0089	0.898	6.245	1.061
-	Sex	0.072	2.875	1.695	0.0904	−0.454	6.205	1.231
-	Prehabilitation	−0.064	−2.305	1.411	0.1029	−5.077	0.467	1.049
-	Operative time	−0.011	−0.002	0.007	0.7961	−0.016	0.012	1.214
-	cStage	0.007	0.056	0.322	0.8625	−0.577	0.688	1.019
-	Histological type	−0.005	−0.227	1.746	0.8968	−3.656	3.202	1.029
-	EF	0.003	0.007	0.092	0.9409	−0.174	0.188	1.025
-	HbA1c	0.002	0.041	0.995	0.9669	−1.913	1.996	1.094
-	Intercept	0	7.774	10.354	0.4531	−12.562	28.110	

Adjusted R^2 =0.123252.
cStage, clinical stage; EF, ejection fraction; SE, standard error; VIF, variance inflation factor.
[a] Ranking of contribution to postoperative hospital stay.

Factors Contributing to Postoperative Length of Hospital Stay

Table 3 shows the results of multiple linear regression analysis in which postoperative hospital stay was used as the objective variable and age, sex, BMI, presence of preoperative ventilatory disturbance, left ventricular ejection fraction, preoperative HbA1c, clinical stage, histological type, operative time, surgical blood loss, presence of postoperative complications, and presence of prehabilitation were added as independent variables. In addition, standardized partial regression coefficients were obtained to show the ranking influence of the independent variables. The results showed that postoperative complications had the greatest impact on postoperative length of hospital stay, followed by age, surgical blood loss, BMI, and ventilatory impairment. Other factors, including prehabilitation, were not significant and did not appear to affect postoperative hospital stay.

Table 4 shows the results of the multiple regression analysis, restricting the subjects to those with complications. The results showed that age had the strongest influence on postoperative hospital stay, followed by ventilatory impairment, surgical blood loss, and prehabilitation. Prehabilitation was shown to reduce hospital stay predominantly in patients with comorbidities.

The backgrounds of the 416 patients in the no-prehabilitation group and 205 patients in the prehabilitation group are shown in **Table 5**. Although men predominated in both groups, approximately three times over women, there were no significant differences in the male-to-female ratio, age, BMI, and ventilatory impairment between the two groups. Despite the broad study windows and different treatment periods in the two groups, the postoperative rehabilitation was identical, although changes in NAC were introduced during the study.

Postoperative Complication Rate

The overall rate of postoperative complications was 56.2% (349 of 621 patients). The rate of postoperative complications was 53.8% in the no-prehabilitation group and 61.0% in the prehabilitation group. Prehabilitation interventions did not reduce the incidence of complications. The chi-square test showed no significant difference in the incidence of postoperative complications (P=0.0922). Postoperative complication rates were not affected by prehabilitation. **Table 6** shows a breakdown of postoperative complications. Postoperative complications of Grade I or higher on the Clavien–Dindo classification are shown, and those unrelated to the surgical procedure were also counted. Prehabilitation did not significantly reduce the incidence of postoperative complications.

Reduction in Postoperative Length of Hospital Stay

The number of days from the date of surgery to discharge in the no-prehabilitation group was 20.98±17.95 days (range

Table 4. Multiple regression analysis of complicated cases

Ranking[a]	Factor	Standardized partial regression coefficient	Partial regression coefficient	SE	P value	Lower 95%	Upper 95%	VIF
1	Age	0.179	0.378	0.119	0.0017	0.143	0.613	1.173
2	Ventilatory impairment	0.137	5.705	2.262	0.0122	1.255	10.156	1.080
3	Surgical blood loss	0.130	0.009	0.004	0.0188	0.001	0.016	1.114
4	Prehabilitation	−0.110	−4.714	2.305	0.0416	−9.248	−0.180	1.067
	BMI	−0.098	−0.631	0.371	0.0899	−1.361	0.099	1.221
	Sex	0.072	3.501	2.801	0.2122	−2.009	9.011	1.232
	HbA1c	−0.044	−1.232	1.526	0.4198	−4.234	1.769	1.083
	Histological type	−0.041	−2.672	3.434	0.4370	−9.427	4.083	1.027
	cStage	0.041	0.735	0.970	0.4493	−1.173	2.642756	1.063
	Operative time	0.018	0.003	0.011	0.7487	−0.018	0.024688	1.154
	EF	−0.001	−0.002	0.151	0.9871	−0.300	0.295548	1.045
	Intercept	0	14.562	16.695	0.3837	−18.282	47.40526	

Adjusted R^2 =0.086707
cStage, clinical stage; EF, ejection fraction; SE, standard error; VIF, variance inflation factor.
[a] Ranking of contribution to postoperative hospital stay.

Table 5. Background comparison between prehabilitation and no-prehabilitation groups

	No-prehabilitation group[a]	Prehabilitation group[b]	P value
Number of operations	416	205	
Male/female	326/90	152/53	0.5787
Age, years	68 (40–96)	70 (44–92)	0.0622
BMI, kg/m^2	21.18±3.07	20.94±3.19	0.3748
Ventilatory impairment	160	86	0.3893
Rate of postoperative complications, %	53.8	61.0	0.0922

Data given as number, median (range), or mean ± standard deviation.
[a] From January 2016 to September 2019.
[b] From October 2019 to December 2021.

Table 6. Breakdown of complications (Grade I or higher of Clavien–Dindo classification)

	Complication							
	Pneumonia	Recurrent nerve palsy	Incomplete suture	Dysphagia	Atelectasis	Pleural fluid	Pneumo-thorax	Other
Prehabilitation, %	10.24	16.1	5.85	5.37	16.59	14.14	5.85	16.1
No prehabilitation, %	9.13	13.22	5.53	8.89	11.3	14.66	1.92	27.16
P value	0.6575	0.3338	0.8689	0.1216	0.0658	0.0929	0.0091	0.0022

9–224 days, median 15.5 days). This result was not significantly different from 19.55±14.57 days (range 9–111 days, median 15 days) for the prehabilitation group (P=0.1675) (**Fig. 1A**).

Postoperative Length of Hospital Stay in Patients with Postoperative Complications

For patients that developed complications after surgery, the length of hospital stay was 25.82±22.68 days (range 9–224 days, median 18 days) in the no-prehabilitation group and 21.90±15.33 days (range 10–87 days, median 16 days) in the prehabilitation group. Prehabilitation significantly reduced

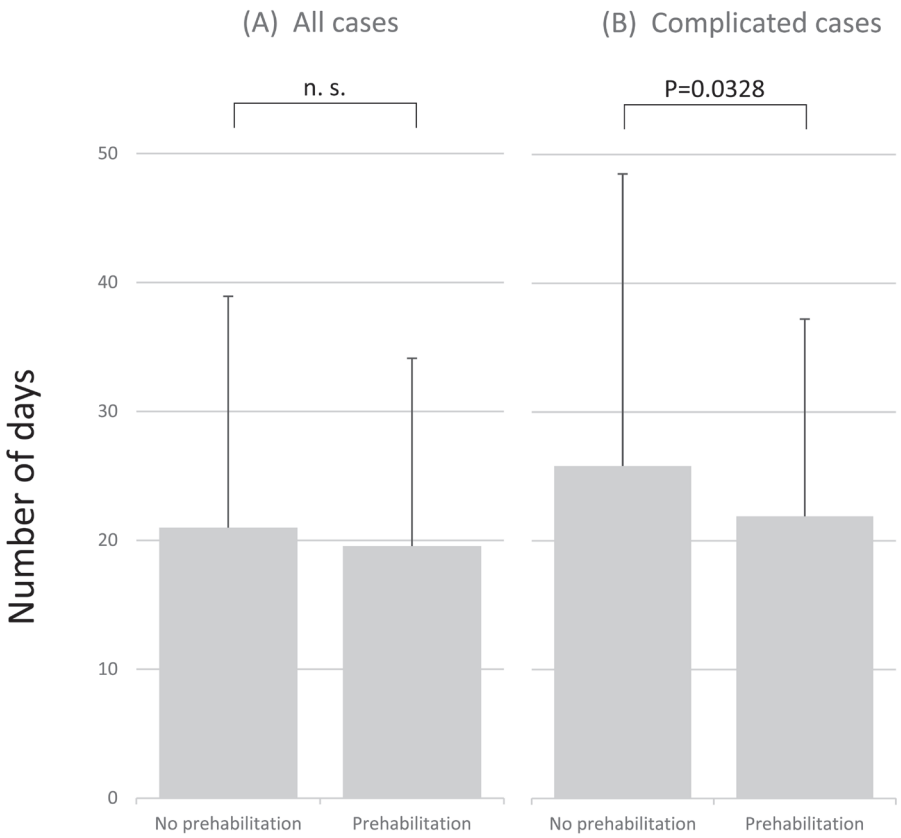

Fig. 1. Comparison of postoperative hospital stay between patients receiving prehabilitation and those not receiving prehabilitation. (A) All cases; (B) cases with complications.

the postoperative length of hospital stay in patients that developed postoperative complications (P=0.0328) (**Fig. 1B**).

DISCUSSION

After major surgery, complications can increase the length of hospital stay by two to four times, and the direct impacts are enormous, including increased rehospitalization.[11,19] Prehabilitation was devised as a countermeasure to prevent postoperative complications, achieve early independence in physical activity, and shorten the length of hospital stay by enhancing mental and physical functions to raise the level of daily functioning in advance. It is expected to be highly effective for patients with esophageal cancer.

The purpose of this study was to determine whether comprehensive prehabilitation with physical, occupational, and speech therapy reduces the length of hospital stay after esophageal cancer surgery. Postoperative complications, age, blood loss, BMI, and ventilatory impairment influenced the overall length of hospital stay in our database of 621 postoperative patients with esophageal cancer who underwent the VATS-E procedure. When the analysis was restricted to patients with complications, prehabilitation was added to that list of factors as a substitute for BMI. Our findings showed that the number of hospital days did not change with or without prehabilitation in the overall population, but when restricted to patients with complications, the number of hospital days was decreased significantly in the prehabilitation group.

The effectiveness of prehabilitation for esophageal cancer surgery patients has been widely reported.[14–16] Although prehabilitation has been well received at our hospital since its inception in 2019, its effectiveness has not been demonstrated numerically until now. Therefore, it will be highly encouraging for therapists in the field to be able to quantify this effectiveness using our patient database.

Tukanova et al.[20] conducted a meta-analysis to evaluate the effects of preoperative rehabilitation and perioperative or postoperative physical therapy in patients undergoing esophagectomy or gastrectomy. The results showed that in

the preoperative and postoperative physical therapy groups, the incidence of pneumonia and the length of hospital stay were reduced, whereas in the prehabilitation group, the incidences of pneumonia and complications were reduced, but not the length of hospital stay. As a comorbidity, respiratory complications had the greatest impact on the length of hospital stay in patients with esophageal cancer.[21] A reduction in the incidence of respiratory complications should be expected to shorten the length of hospital stay, but this has not been achieved.

In our study, the complication rate, including that of pneumonia, was not reduced by prehabilitation, but the length of hospital stay was reduced in patients with complications. The difference between our results and those of Tukanova et al.[20] may be attributed to the fact that our study defined postoperative complications as Grade I or higher according to the Clavien–Dindo classification, whereas Tukanova et al. defined complications as Grade II or higher, requiring at least antimicrobial agents and other drug therapy. If Grade II or higher complications are recorded, the onset of respiratory complications such as pneumonia can be captured, but radiographic changes and hoarseness at a level that does not require drug therapy would be lost as complications. These minor changes, if left untreated, can develop into pneumonia. Even in such cases, rehabilitation was conducted without the use of antimicrobial agents, and progression to Grade II should have been prevented. In other words, we considered that if we picked up only complications of Grade II or above, it would be difficult to reflect the effect of prehabilitation in the results. Therefore, we used complications of Grade I or above as the detection criteria. In postoperative esophageal cancer patients, factors related to the surgical procedure, such as recurrent nerve palsy and anastomotic stenosis, also contribute to postoperative pneumonia. Prehabilitation, including swallowing training, for these patients may be effective in shortening the length of hospital stay. Based on data from 379 esophagectomy patients, Atkins et al.[22] identified pneumonia, anastomotic leak, dysphagia, and Charlson Comorbidity Index of 3 or higher as factors related to increased mortality. However, only pneumonia was independently associated with mortality, suggesting that measures to address other factors may prevent pneumonia and reduce mortality. Evaluation of recurrent nerve palsy could also prevent pneumonia, which explains the importance of measures to prevent minor complications. Atkins et al.[22] also reported the effectiveness of preoperative identification and preoperative teaching of patients prone to aspiration together with a program of aggressive chest physiotherapy and exercise. We speculated that our comprehensive prehabilitation could have prevented health deterioration in patients with minor complications, thereby reducing the length of hospital stay. However, without data to confirm this hypothesis, it remains a matter of speculation.

The present multivariate analysis was conducted as a factorial analysis to examine the degree of influence of explanatory variables with postoperative hospital stay as the objective variable. Therefore, confounding factors to explain postoperative hospital stay were selected from a medical perspective. However, our study may have had insufficient information on the physical function and nutritional status of patients.

Patients with esophageal cancer are at high risk of sarcopenia, a state of reduced skeletal muscle mass caused by malnutrition and impaired transit, as well as inflammation and hypermetabolism caused by the cancer itself. If esophageal cancer surgery is performed in a state of preoperative malnutrition, postoperative complications are likely, and long-term prognosis may also be affected.[23–25] The muscle mass that makes up the body is important for surgery. Highly invasive procedures increase energy metabolism even at rest, leading to catabolism of muscle proteins throughout the body, thus resulting in decreased muscle mass, decreased albumin, and impaired immunocompetence. The increased risk of death because of sarcopenia is 3.2, 1.6, 1.9, or 2.7 times higher than the risks posed by liver cancer, pancreatic cancer, colorectal cancer, or liver metastases of colorectal cancer, respectively.[26] Several studies have reported that sarcopenia is a predictor of postoperative complications in esophageal cancer.[27–30] There are also reports suggesting that loss of skeletal muscle during preoperative chemotherapy is a risk factor for postoperative infectious complications and may be a significant predictor of survival. Such findings can be used to consider the advantages of starting prehabilitation intervention during preoperative chemotherapy, as performed in this study.[31,32]

It is possible that the improvement in sarcopenia because of prehabilitation contributed to the decreased length of hospital stay in patients with postoperative complications in this study, but we were unable to obtain sufficient data to prove this. Measurement of patient muscle mass would therefore be important. Because surgical treatment for esophageal cancer involves resection with reconstruction and is highly invasive, especially in the thoracic region, patients with ventilation problems are inevitably more susceptible to postoperative complications. Therefore, it is recommended that ventilatory disturbance in patients be identified and managed at

the preoperative stage.[33,34] A simple evaluation method is spirometry, but changes in patient condition may be difficult to achieve despite training.

In a study of 111 patients undergoing esophageal cancer surgery, the 6-min walk test was reported to be a predictor of postoperative complications as well as FEV_1% in a multivariate analysis.[35] Patients with ventilatory dysfunction should be instructed in exercise therapy based on the exercise stress test (in conjunction with smoking cessation for smokers) to increase exercise tolerance and improve the efficiency of maximal oxygen uptake. The shuttle walk test and 6-min walk test may be useful to assess exercise tolerance and the effects of prehabilitation with exercise stress tests. These tests were not used in this study but should be considered in future studies.

There are limitations of the study that should be considered. This study attempted to explore the ability of prehabilitation to reduce postoperative length of hospital stay. Postoperative hospital stay itself may be influenced by the bed utilization rate at the time and may reflect issues of convenience rather than the physical function of individual patients. Considering the long period covered in this study, the evolution of standards of care during that time may have influenced the results. Given that ERAS was introduced after prehabilitation became available, potential changes in enteral nutrition and pain management may have influenced the results. It is undeniable that the evolution of NAC has also had an impact. Because patients were grouped before and after the introduction of prehabilitation, the standard of care between the two groups was not the same based on the historical background. In addition, because patients self-reported prehabilitation during the at-home period, it was difficult to conclude whether they were able to continue their training reliably. The adjusted R^2 in the multiple regression equation in this study is very small, which means that the objective variable is not fully explained by the set of explanatory variables. This means that there could be other important associated factors. Although this study considered a large number of patients over a long study period, the comparison between groups may have been compromised by a mix of different treatments other than prehabilitation, and, because the analysis was based on an existing database, adjustments were difficult. Furthermore, the coronavirus disease pandemic that began in 2020 is expected to have had some influence on the results of this study.

CONCLUSION

Prehabilitation was originally designed to prevent postoperative complications and shorten the hospital stay. However, according to the results of this study, the occurrence of complications was not prevented. Instead, prehabilitation was effective in reducing the length of hospital stay in the event of complications. As a result, prehabilitation as a perioperative approach has the potential to reduce the length of hospital stay in patients undergoing surgery for esophageal cancer, and active intervention is recommended.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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