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Impact of a Fast-Track Esophagectomy Protocol on Esophageal Cancer Patient Outcomes and Hospital Charges

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Abstract

Objective—To evaluate the effects of a fast-track esophagectomy protocol (FTEP) on esophageal cancer patients' safety, length of hospital stay (LOS) and hospital charges.

Background—FTEP involved transferring patients to the telemetry unit instead of the surgical intensive care unit (SICU) after esophagectomy.

Methods—We retrospectively reviewed 708 consecutive patients who underwent esophagectomy for primary esophageal cancer during the 4 years before (group A; 322 patients) or 4 years after (group B; 386 patients) the institution of an FTEP. Postoperative morbidity and mortality, LOS, and hospital charges were reviewed.

Results—Compared with group A, group B had significantly shorter median LOS (12 days vs 8 days; $P < 0.001$); lower mean numbers of SICU days (4.5 days vs 1.2 days; $P < 0.001$) and telemetry days (12.7 days vs 9.7 days; $P < 0.001$); and lower rates of atrial arrhythmia (27% vs 19%; $P = 0.013$) and pulmonary complications (27% vs 20%; $P = 0.016$). Multivariable analysis revealed FTEP to be associated with shorter LOS ($P < 0.001$) even after adjustment for predictors like tumor histology and location. FTEP was also associated with a lower rate of pulmonary complications (odds ratio = 0.655; 95% confidence interval = 0.456, 0.942; $P = 0.022$). In addition, the median hospital charges associated with primary admission and readmission within 90 days for group B ($65,649) were lower than that for group A ($79,117; $P < 0.001$).

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Conclusion—These findings suggest that an FTEP reduces patients' LOS, perioperative morbidity and hospital charges.

Introduction

Surgical resection is the mainstay treatment for localized esophageal carcinoma in the absence of medical contraindications.[1] However, surgery poses a high risk of complications, which requires that patients be admitted to the intensive care unit (ICU) immediately after surgery. This prolongs their hospital stay and increases costs to both the patients and hospital.

A fast-track surgery protocol first introduced by Kehlet and Wilmore[2] represents an advance in postoperative surgical care. In this approach, surgery patients are transferred from the post-anesthesia care unit directly to a monitored (telemetry) unit, eliminating the need for an ICU stay.[3] In the telemetry unit, multidisciplinary care is provided by a focused group of surgeons, midlevel providers, and trained surgical nurses. In addition, family members are permitted to be with the patients, and the patients are allowed to ambulate within a few hours after surgery. All of these advantages help reduce the physiological and psychological stress associated with surgery, thereby enhancing patients' postoperative recovery and reducing their length of hospital stay (LOS).[2, 4]

Fast-track surgery protocols can be cost-effective because they require fewer postoperative ICU admissions, less monitoring, and less nursing care per patient course than traditional surgery protocols do while eliciting the same or better patient outcomes.[5, 6] Although numerous studies have investigated such protocols for other procedures, notably colorectal surgery,[7] relatively fewer studies have investigated the use of a fast-track surgery protocol for esophagectomy.[6, 8-18] Also, only a few fast-track esophagectomy protocol (FTEP) studies conducted in United States have evaluated the impact on hospital charges. An assessment of the safety of the protocol will serve as a performance measure that will help clinicians and policy makers change practice and improve the care of esophageal cancer patients. Therefore, we investigated the effect of a FTEP on patient safety, postoperative recovery, LOS and hospital charges.

Patients and Methods

Study Population

This retrospective study included 708 consecutive patients with histologically confirmed adenocarcinoma or squamous cell carcinoma of the esophagus who underwent esophagectomy in the Department of Thoracic and Cardiovascular Surgery at The University of Texas MD Anderson Cancer Center (MDACC) between March 2004 and March 2012. For patients undergoing esophagectomy from March 17, 2008, a multi-disciplinary decision between hospital administration, nursing support and thoracic surgeons was taken to institute a fast track protocol. Thus, for this study, the patients were divided into 2 groups: Group A consisted of the 322 patients who underwent esophagectomy during 4 years before the institution of the FTEP on March 17, 2008, and group B consisted of the 386 patients who underwent the procedure during 4 years after the institution of the protocol. Group A included patients who were usually transferred to the SICU after esophagectomy, whereas group B primarily included patients who were transferred to a telemetry unit immediately after surgery regardless of whether they were admitted to the ICU during their hospital stay. Only a few patients in group B who required intubation or close monitoring were transferred to the SICU. The study was approved by MDACC Institutional Review Board. Informed consent wasn't obtained from the patients as this was a retrospective data review that involved no diagnostic or therapeutic intervention, as well as no direct patient contact.

Patient Data Retrieval

Patient demographics, tumor characteristics, and short-term postoperative outcomes were obtained from the Esophageal Departmental Database. Patients' postoperative LOS (the total number of days in the hospital after surgery until discharge), immediate postoperative ventilator days (the number of days with mechanical ventilator assistance immediately after surgery), total ventilator days (the total number of days with ventilator assistance between surgery and discharge), total ICU days (the total number of days in the SICU between surgery and discharge), and telemetry days (the number of days in the telemetry unit between surgery and discharge) were also recorded, as were postoperative complications including aspiration, acute respiratory distress syndrome (ARDS), pneumonia, discharge on home oxygen, reintubation, atelectasis, atrial arrhythmia, discharge on a jejunostomy tube (J-tube), barium swallow, ICU readmission, anastomotic leak, hospital readmission within 90 days, reoperation, and 30- and 90-day mortality. Information about the patients' technical hospital charges was collected from MDACC's enterprise information warehouse.

Statistical Analysis

Pearson chi-square and Fisher exact tests were used to analyze differences between groups for significance for categorical variable. A non-parametric Mann Whitney U test was used to analyze differences between groups for significance for continuous variables. Univariable linear regression was used to assess the association between various prognostic predictors and outcomes such as LOS and technical hospital charges. Univariable logistic regression was used to assess the association between various prognostic predictors and pulmonary complications. Factors in univariable analysis with a *P*-value < 0.25 were entered into a multivariable regression model. The final model for the data set was obtained using Wald's stepwise selection with a *P*-value of 0.10 as the entry and removal probability. All statistical analyses were performed using the Statistical Package for Social Sciences software version 17 (SPSS, Chicago, IL). *P*-values less than 0.05 were considered statistically significant.

Results

Patient Characteristics

The characteristics of the 322 patients in group A and the 386 patients in group B are summarized in Table 1. The two groups were similar in terms of gender and age as well as history of chronic obstructive pulmonary disease, coronary artery disease, and diabetes. Although tumor histology, location, grade, and pathological stage did not differ between the 2 groups, the mean tumor size of group A (1.9 cm) was significantly smaller than that of group B (2.5 cm; $P = 0.025$) (Table 2). There was also difference in the distribution of clinical staging of tumor between the 2 groups. Compared with group B, group A had lower proportions of patients with stage II cancer (39% vs 32%) and stage III cancer (46% vs 42%) and higher proportions of patients with stage I cancer (12% vs 19%) and stage IV cancer (3% vs 6%; $P < 0.008$) (Table 3). The types of preoperative treatment the 2 groups received also differed, with a greater proportion of patients in group B (85%) than in group A (73%) receiving chemotherapy plus radiation therapy ($P < 0.001$). The type of surgery also differed between the 2 groups; minimally invasive esophagectomy (MIE) was performed more frequently in group B (22%) than in group A (12%; $P < 0.001$) (Table 4).

Short-Term Postoperative Outcomes

The 2 groups' short-term postoperative outcomes are summarized in Table 5. The median LOS of group A (12 days) was significantly longer than that of group B (8 days; $P < 0.001$) (see also Figure 1). The mean numbers of total ICU days and telemetry days of group A (4.5 and 12.7, respectively) were also significantly higher than those of group B (1.2 and 9.7, respectively; $P < 0.001$ for both). In addition, group A had higher mean numbers of postoperative ventilator days (1.3) and total ventilator days (2.5) than did group B (0.3 and 0.8, respectively; $P < 0.001$ for both). The direct ICU admission rate of group A (71%) was significantly higher than that of group B (7%; $P < 0.001$). In terms of postoperative complications, the incidences of aspiration, pneumonia, discharge on home oxygen, atelectasis requiring bronchoscopy, anastomotic leak, ICU readmission, and reoperation did not differ significantly between the 2 groups. However, compared with group A, group B had significantly lower incidences of ARDS (6% vs 0.5%; $P < 0.001$), reintubation (9% vs 4%; $P = 0.005$), atrial arrhythmia requiring treatment (27% vs 19%; $P = 0.015$) and overall pulmonary complications (27% vs 20%, with aspiration, ARDS, pneumonia, discharge on home oxygen, and atelectasis grouped together; $P = 0.022$). The 2 groups' rates of 30-day mortality (3% in group A vs 2% in group B; $P = 0.386$), 90-day mortality (5% vs 4%; $P = 0.377$), and 90-day readmission (12% vs 15%; $P = 0.134$) did not differ significantly. The reasons for readmission within 90 days are summarized in Table 7. Pulmonary complication (38%), gastrointestinal symptoms (16%) like nausea, vomiting and diarrhea, and dysphagia (11%) were the major reasons for readmission. The 2 groups' rates of direct admission to the ICU, total LOS, total ICU days, total ventilator days, and immediate postoperative ventilator days for each year of the study period are summarized in Table 8 and Figure 2. Multivariable analysis revealed that the institution of the FTEP was associated with shorter LOS ($\beta = -6.415$; 95% confidence interval (CI) = 8.294, -4.536; $P < 0.001$) even after adjustment for factors such as tumor location and histology (Table 9). Multivariable analysis also revealed that the institution of the FTEP was associated with fewer pulmonary complications (odds ratio = 0.655; 95% CI = 0.456, 0942; $P = 0.022$) even after adjustment for other independent predictors such as gender, chronic obstructive pulmonary disease, and type of esophagectomy (Table 10).

Technical Hospital Charges

The median technical hospital charge associated with primary admission after surgery for group B ($63,406) was significantly lower than that for group A ($76,685; $P < 0.001$) (Table 6). Multivariable analysis revealed that the institution of the FTEP decreased hospital charges ($\beta = -41714.3$; 95% CI = -63706.3, -19722.3; $P < 0.001$) even after adjustment for predictors such as tumor histology and location (Table 11). Also, there was no significant difference in median hospital charges associated with readmission within 90 days between the two groups ($13,336 in group A vs $22,373 in group B, $P = 0.275$). However, when we compared combined technical hospital charges associated with both primary admission after surgery and readmissions within 90 days of discharge, group B ($65,649) still had significantly lower charges than those for group A ($79,117; $P < 0.001$)(Table 6).

Discussion

In our study, we demonstrated that a fast-track setup significantly reduced LOS and technical hospital charges as well as the incidence of pulmonary complications without affecting rates of hospital readmission and 30- and 90-day mortality. Taken together, our findings show that the institution of the FTEP was safe and reduced hospital charges.

In the face of escalating healthcare costs, reducing patients' length of postoperative stay and number of postoperative complications is key to using medical resources optimally. Despite major advancements in the perioperative management of esophageal cancer patients, esophagectomy remains significantly associated with high incidences of mortality and morbidity. [19] Over the last decade, fast-track protocols have been used successfully for several surgical specialties[4, 7, 20-22] as well as for esophagectomy. In 1998, Brodner et al. conducted a retrospective cohort study that showed that a multimodal approach can be used to enhance recovery after esophagectomy.[23] In 2003, Chandrashekhar et al., who suggested that patients could be safely transferred to and managed on a high-dependency unit following immediate extubation after 2-stage esophagectomy, were the first to mention an FTEP.[24] In 2004, Cerfolio et al. were the first to publish a study of a fast-track protocol for esophagectomy.[10] Later retrospective cohort studies showed that FTEP was associated with reduced LOS.[6, 11, 14, 17] A recent single-institution, randomized clinical trial also showed that an enhanced recovery protocol for esophagectomy resulted in a small but significant reduction in LOS.[12]

Detailed descriptions of the clinical care pathways of the traditional esophagectomy protocol and the FTEP used at our institution are given in Table 3. As part of the FTEP, patients were immediately extubated after surgery, transferred to the post-anesthesia care unit only for a few hours, and then transferred to the telemetry unit. However, 7% of patients on FTEP still went to ICU because these were high risk salvage esophageal resection patients who had other co-morbidities that required ventilator support immediately after surgery. In the telemetry unit, the patients' vital signs, chest tube output, and urine output were monitored hourly, and the patients were allowed to ambulate within 4 hours of their arrival to the floor. Early ambulation reduces postoperative stress and fatigue and facilitates recovery.[25, 26] The reduced LOS could be attributed to close monitoring and keeping patients ambulatory in the telemetry unit.

Perioperative fluid therapy plays an important role in the care of patients after esophagectomy. Patients on a FTEP are typically recommended to receive a balanced rather than restrictive regimen of preoperative fluid therapy as well as epidural analgesia for postoperative pain management.[13] In our study, there was not much difference in perioperative fluid therapy and postoperative pain management between patients on the traditional esophagectomy protocol and those on the FTEP. For perioperative fluid therapy, patients on the traditional esophagectomy protocol as well as those on the FTEP received 5% dextrose in half the amount of normal saline (0.45% w/v of sodium chloride) at a rate of 125 ml/hour on the day of surgery and postoperative day (POD) 1 and POD 2. After POD 2, the volume of fluid administered was reduced gradually, from 125 ml/hour on POD 3 to 75 ml/hour on POD 4, 50 ml/hour on POD 5, 21 ml/hour on POD 6, and finally to saline lock on POD 7. For their postoperative pain, patients received epidural analgesia with 5 mcg/ml hydromorphone administered with 0.075% bupivacaine at a rate of 10 ml/hour continuously, with patient boluses of 3 ml administered every 10 minutes and clinician boluses of 5 ml administered every 3 hours as needed. This pain management regimen was continued for a maximum of 7 days or stopped early if the patient's chest tubes were removed before that time. The proportion of patients who were discharged on J-tube feeding without barium swallow in the FTEP group (65%) was significantly larger than that in the traditional protocol group (31%; $P < 0.001$). For patients on the FTEP, a barium swallow was performed between 10-15 days after discharge on an outpatient basis and the J-tube was removed 4-6 weeks after discharge, whenever the patient could take in most of the calories by mouth. Although J-tube feeding has been found to be a safe and effective method of providing postoperative nutritional support,[27, 28] it has not been part of the FTEPs other studies have investigated.[6, 8, 9, 11-18] Thus, additional studies to investigate the use of J-tube feeding in this setting are warranted. Also, no additional outpatient care was required for fast track patients over the standard pathway. We had a standard follow-up for all esophagectomy patients. First follow-up was done at 6 weeks after discharge, next 3 follow-ups were done every 6 months and later a yearly follow-up was done.

Patients' baseline characteristics such as age and comorbidities including diabetes, chronic obstructive pulmonary disease, and coronary artery disease are significant predictors of morbidity and mortality after esophagectomy.[29, 30] In our study, groups A and B had similar proportions of patients with these predictors. In terms of perioperative treatment, the proportion of patients who received neoadjuvant chemoradiotherapy in group B (85%) was higher than that in group A (73%). One meta-analysis showed that, compared with surgery alone, neoadjuvant chemoradiotherapy plus surgery is associated with a higher risk of mortality.[31, 32] With regards to tumor characteristics, the patients in group B had larger, more clinically advanced tumors than the patients in group A did. Although these characteristics put patients in group B at a higher risk of poor outcomes, these patients had better outcomes than the patients in group A did even after adjustment for these predictors in the multivariable analysis.

One recent trend in localized esophageal carcinoma surgery is MIE, which utilizes a combined thoracoscopic and laparoscopic approach or a hybrid approach.[33] Systematic reviews comparing MIE with conventional methods of open surgery (i.e., transthoracic and transhiatal esophagectomy) found MIE to be safe and associated with better postoperative outcomes.[34-39] In the present study, MIE was not part of the FTEP. Given that MIE is a recent development, the proportion of patients who underwent MIE in group B was unsurprisingly higher than that in group A. Multivariable analysis revealed MIE to be associated with pulmonary complications but not LOS.

The anastomotic leak rate (14% in group A vs 13% in group B, *P*=0.581) seems high because leaks were calculated including clinically non-significant leaks which required no intervention (Table 5). Anastomotic leak was classified as: grade 1, small contained leak in barium or CT requiring no intervention or basic treatment, such as giving antibiotic, or observation; grade 2, small contained leak requiring minimum intervention, such as stent or drainage placement; grade 3, leak requiring a repeat operation; and grade 4, conduit loss requiring conduit resection (Table 5). For patients who had an anastomotic leak, the mean LOS increased by 2 days but there was no difference in 30 days perioperative mortality [2.1% in leak group vs 2.9% in no leak group, *P* =1.000].

Our study, which included patients treated on a traditional esophagectomy protocol during a 4-year period immediately before the institution of a FTEP as well as patients treated on a FTEP during its first 4 years of implementation, enabled us to thoroughly assess postoperative outcomes in a large group of patients over a long period. Owing to the introduction of a FTEP in March 2008, we reduced the proportion of patients who were immediately transferred to the SICU after esophagectomy from 71% in March 2004 to just 7% in March 2012 (Table 5.) Ours is one of the first studies conducted in the United States to assess the impact of a FTEP on hospital charges. In our study, there was about 17% reduction in the median technical charges and 31% reduction in the mean technical charges after institution of a FTEP. The reduction in hospital charges can be contributed to decreased SICU days, LOS and post-operative complication rate in group B patients. This suggested that a FTEP reduced hospital charges without compromising the safety of the patients.

Our study had a few potential limitations. Although we assessed important outcomes such as patient safety and LOS, we did not assess patients' satisfaction with the new protocol because this information had not been collected for all esophagectomy patients at their time of discharge and follow-up visits. Patients' satisfaction is an important indicator of quality of care to help evaluate efficacy of a new protocol. For FTEP, patient satisfaction may be driven by various factors including pain management, ability to swallow, early ambulation, fewer postoperative complications, and enhanced recovery. However, we had collected data on difficulty in swallowing noted during the patient's post-operative follow-up visits and found it to be similar across both Group A(11%) and Group B(9%, *P*=0.151). In the future, survey studies should be conducted to assess patients' satisfaction and approval of the fast-track protocol. Another potential limitation of our study is that in the cost-effectiveness analysis, we performed only univariable and multivariable analyses to compare the overall technical charges in group A with those in group B. A detailed analysis of the cost-effectiveness of a FTEP using a more systematic approach is beyond the scope of this paper and will be published separately. More prospective randomized studies are needed to support the use of a fast-track protocol for esophageal cancer patients and provide evidence of the protocol's cost-effectiveness.

Conclusion

The results of this study confirm existing data regarding the safety of FTEPs. We found that various components of a FTEP, including the avoidance of direct ICU admission after surgery, initiation of mobilization shortly after transfer to a telemetry unit, early initiation of pulmonary toileting, and minimal use of nasogastric tubes and drains, helped reduce patients' postoperative morbidity and LOS. We also found FTEP to be as safe as the traditional esophagectomy protocol in terms of postoperative mortality. Thus, a FTEP has positive clinical and financial implications for esophageal cancer patients, and its use should be extended to other esophageal surgical centers.

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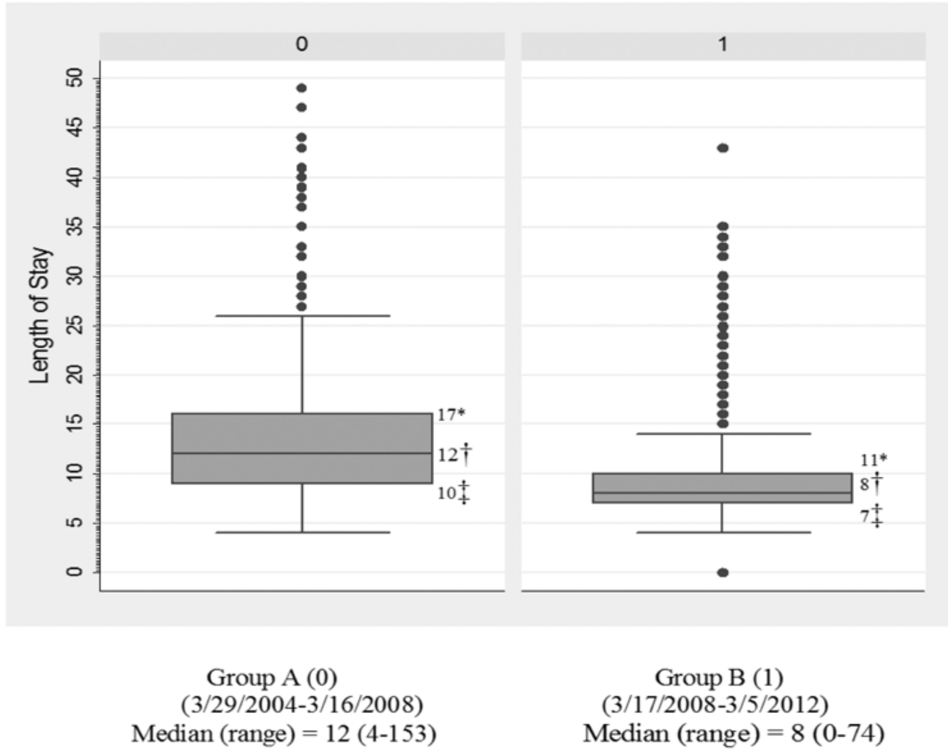

Figure 1.

Box and whisker plot for LOS. The box (interquartile range) has 50% of all data while the whiskers extend to the 5th and 95th percentile. Dotes indicate data beyond 5th and 95th percentile. On Y Axis, the unit of measurement for Length of stay is ‘number of days’.

*75th percentile

†50th percentile (median)

‡25th percentile

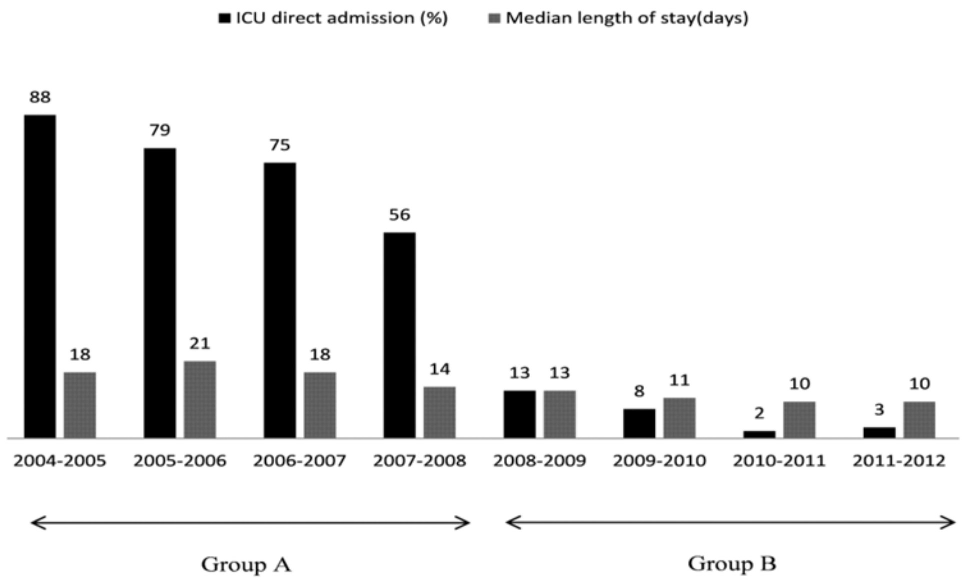

Figure 2. Direct ICU admission and LOS by year

Table 1

Patient Characteristics

Variable	Group A (N=322) (3/29/2004-3/16/2008)	Group B (N=386) (3/17/2008-3/5/2012)	*P*-Value
Gender			
Male	279(87)	338(88)	0.716
Female	43(13)	48(12)	
Age			
Mean	61	61	0.385
Median(range)	62(25-83)	62(23-84)	
COPD	21(7)	24(6)	0.121
CAD	49(15)	70(18)	0.301
Diabetes	50(16)	61(16)	0.920
Any tobacco history	231(72)	278(72)	0.934
Cigarette pack years *			
Median(range)	30(0.03-137.5)	29.4(0.2-180)	0.426
Mean	34.4	32.9	
Smoking cessation time before surgery †			
0-14 days	16(5)	24(6)	0.258
>14 days;<=1	10(3)	10(3)	
>1 mo;<=12	33(10)	60(16)	
>12 mo; <=5 y	21(7)	23(6)	
>5 y	149(47)	151(40)	
Never smoked	91(28)	108(29)	
ASA risk score			
1	0(0)	1(0)	0.029‡
2	68(21)	53(14)	
3	252(78)	329(85)	
4	2(1)	3(1)	

Note: Data are no. of patients (%) unless otherwise indicated.

*Data missing for 100 patients in Group A and for 130 patients in Group B.

†Data missing for 2 patients in Group A and for 10 patients in Group B.

‡Statistically significant.

COPD indicates chronic obstructive pulmonary disease; CAD, coronary arterial disease; ASA, American Society of Anesthesiologist.

Table 2

Tumor Characteristics

Characteristics	Group A (N=322) (3/29/2004-3/17/2008)	Group B (N=386)(3/17/2008-3/5/2012)	*P*-Value
Histology			0.683
Adenocarcinoma	294(91)	349(90)	
Squamous cell carcinoma	28(9)	37(10)	
Location			0.387
Upper/cervical	3(1)	8(2)	
Middle	26(8)	26(7)	
Lower/GEJ	293(91)	352(91)	
Grade *			0.061
Well differentiated	7(2)	2(1)	
Moderately differentiated	136(43)	129(39)	
Poorly differentiated	170(54)	201(60)	
Undifferentiated	2(1)	0(0)	
Mean Tumor Size†**, cm**	1.9	2.5	0.025‡
Clinical stage			0.008‡
0	3(1)	2(1)	
I	62(19)	46(12)	
II	104(32)	149(39)	
III	135(42)	179(46)	
IV	18(6)	10(3)	
Pathological stage			0.062
0	57(18)	88(23)	
1	79(25)	70(18)	
2	122(38)	132(34)	
3	56(17)	88(23)	
4	8(2)	8(2)	

Note: Data are no. of patients (%) unless otherwise indicated.

*Tumor grade data missing for 7 cases in Group A and 54 cases in group B.

†Tumor size data missing for 8 cases in Group A and 9 cases in group B.

‡Statistically significant.

Table 3

Clinical Care Pathway for Traditional and Fast-Track Protocol

POD	Traditional Care	Fast-Track Protocol
0	• Directly transfer from OR to ICU • Kept intubated in ICU • Bed rest	• Extubation in OR • Direct transfer from OR to PACU; then to thoracic floor after 4 hrs. • Initiation of early mobilization (OOB 4h after arrival to thoracic floor) • Initiation of pulmonary toileting
1	• Bed rest • Supportive ICU care • Extubation with first 24 hours.	• Continuation of mobilization (out of bed walking 3-4×/ day, OOB to chair during day) • Continuation of pulmonary toileting (nebulizers every 6 h, incentive spirometer and acapella ten times per hour while awake) • Continuation of tube management
2	• Bed rest • Supportive ICU care	• Initiation of bowel management with stool softeners and/or laxatives
3	• Initiation of pulmonary toileting • Mobilization OOB to chair	• Initiation of tube feeds • Removal of urinary catheter • Initiation of discharge planning education
4	• Continuation of tube management (chest tubes/NGT/urinary catheter)	• Increase of tube feed rate (await bowel function to reach nutritional goal) • Initiation of NGT clamp trials or NGT to gravity
5	• Initiation of tube feeds once bowel function has returned	• Discontinuation of NGT • Transition off epidural/IV pain medications to J-tube elixir pain medications
6	• Possible transfer to thoracic floor • Mobilization protocol initiated (walking 3 - 4 times per day)	• Discontinuation of chest tubes
7	• Transition off epidural/IV pain management to J-tube elixir pain medications.	• Discharge from hospital
8	• Discontinuation of tube management (chest tubes/NGT/urinary catheter)	
9		
10	• Inpatient evaluation of esophageal leak study/ barium swallow	• Outpatient appointment for esophageal leak study/barium swallow • Initiation of nutritional evaluation and teaching for transition to oral diet
11	• Bowel management for constipation	
12-14	• Discharge from hospital	

POD indicates postoperative day; OR, operation room; ICU, intensive care unit; PACU, post-anesthesia care unit; OOB, out of bed; IV, intravenous; NGT, nasogastric tube; J-tube, jejunostomy tube.

Table 4

Treatment Characteristics

Variable	Group A (N=322) (3/29/2004-3/17/2008)	Group B (N=386) (3/17/2008-3/5/2012)	*P*-Value
Preoperative treatment			<0.001 *
Chemotherapy plus RT	235(73)	326(85)	
Chemotherapy only	5(1)	0(0)	
RT only	1(0)	1(0)	
Other	2(1)	0(0)	
None	79(25)	59(15)	
Type of esophagectomy			<0.001 *
Transthoracic (Ivor Lewis)	213(66)	249(65)	
Transhiatal	38(12)	21(5)	
Total (3-fold technique)	28(9)	21(5)	
Minimally invasive	38(12)	86(22)	
Other	5(1)	9(2)	

Note: Data are no. of patients (%) unless otherwise indicated.

* Statistically significant.

RT indicates radiotherapy.

Table 5
Short Term Post-Operative Outcomes

Outcome	Group A (N=322) (3/29/2004-3/16/2008)	Group B (N=386) (3/17/2008-3/5/2012)	*P*-Value
Median length of stay	12(4-153)	8(0-74)	<0.001 *
Mean days in SICU	4.5	1.2	<0.001 *
Mean total ventilator days	2.5	0.8	<0.001 *
Mean postoperative ventilator days	1.3	0.3	<0.001 *
Mean total telemetry days	12.7	9.7	<0.001 *
ICU-direct admission	229(71)	25(7)	<0.001 *
Any pulmonary complication †	88(27)	76(20)	0.016 *
Aspiration	20(6)	16(4)	0.213
ARDS	18(6)	2(0.5)	<0.001 *
Pneumonia	59(18)	57(15)	0.203
Discharge on home oxygen	26(8)	26(7)	0.497
Reintubation	29(9)	15(4)	0.005 *
Atelectasis requiring bronchoscopy	18(6)	14(4)	0.211
Atrial arrhythmia requiring treatment	88(27)	75(19)	0.013 *
Readmission to ICU	34(11)	33(9)	0.363
Reoperation	30(9)	41(11)	0.565
Anastomotic leak (All)‡	45(14)	49(13)	0.581
Grade 1	19(6)	8(2)	
Grade 2	6(2)	12(3)	
Grade 3	13(4)	16(4)	
Grade 4	2(1)	4(1)	
30 days perioperative mortality	11(3)	9(2)	0.386
90 days perioperative mortality	16(5)	14(4)	0.377
Readmission within 90 days	38(12)	59(15)	0.151
Discharge on J-tube feeding without barium swallow	99(31)	251(65)	<0.001 *

Note: Data are no. of patients (%) unless otherwise indicated.

* Statistically significant.

† Aspiration, ARDS, Pneumonia, Reintubation, Discharge on home oxygen (O_2).

‡ Leak grade data missing for 5 cases in Group A and for 9 cases in Group B.

SICU indicates surgical intensive care unit; ICU, intensive care unit; ARDS, acute respiratory distress syndrome; J- tube, jejunostomy tube.

Table 6

Technical Hospital Charges

Variable	Group A (N=322) (3/29/2004-3/17/2008)	Group B (N=386) (3/17/2008-3/5/2012)	P-Value
Charges (U.S. dollars)			<0.001
Median	76,685	68,406	
Range	40,740- 1,695,956	26,528 – 962,474	
Mean	134,983	93,858	
90 days readmission charges(U.S dollars)			0.275
Median	13,336	22,373	
Range	584-293,959	115-319,734	
Mean	32,580	42,913	
Combined Charges† (U.S. dollars)			<0.001 *
Median	79,117	65,649	
Range	40,740- 1,695,956	26,528 – 962,474	
Mean	138,828	100,417	

*Statistically significant.

†Combined charges associated with primary admission after surgery and readmission within 90 days of discharge.

Table 7

Length of Hospital Stay by Year

Group	Year	No. of Patients Admitted Directly to ICU	Mean Total LOS	Mean Total ICU days	Mean Total Ventilator Days	Mean Total Postoperative Ventilator Days
A	2004-2005	88	18	6	3	2
	2005-2006	79	21	5	3	1
	2006-2007	75	18	5	3	1
	2007-2008	56	14	3	2	1
B	2008-2009	13	13	1	1	1
	2009-2010	8	11	1	1	0
	2010-2011	2	10	1	1	0
	2011-2012	3	10	1	0	0

ICU indicates intensive care unit.

Table 8

Reason for readmission within 90 days

Complications/Events	N=708
Pulmonary *	37(38)
Nausea/vomiting/diarrhea	15(16)
Esophageal stricture/dysphagia	11(11)
Wound infection	8(8)
Pyloric stenosis	4(4)
Anastomotic leak	4(4)
J-tube malfunction/infection	4(4)
Gastrointestinal bleeding	3(3)
Small bowel obstruction	3(3)
Other†	8(8)
Total	**97**

Note: Data are no. of patients (%) unless otherwise indicated.

* pleural effusion, pneumonia, and empyema.

Table 9

Length of Total Hospital Stay (LOS)

Variables	N	Univariable linear regression				Multivariable linear regression			
			95% CI for β				95% CI for β		
		β	Lower	Upper	*P*-Value	β	Lower	Upper	*P*-Value
Group									
A*	322								
B	386	-6.37	-8.29	-4.45	<0.001†	-6.42	-8.29	-4.54	<0.001
Gender									
Male*	617								
Female	91	1.98	-0.96	4.92	0.186†				
Age Preoperative treatment	708	0.11	0.01	0.20	0.028†				
No*	140								
Yes	568	-2.028	-4.50	-0.44	0.107†				
Diabetes									
No*	597								
Yes	111	-0.03	-2.74	2.67	0.980				
COPD									
No*	663								
Yes	45	2.70	-1.33	6.73	0.189†				
CAD									
No*	589								
Yes	119	1.72	-0.92	4.35	0.201†				
Histology									
Adenocarcinoma*	643								
Squamous cell carcinoma	65	8.53	5.18	11.88	<0.001†	5.87	1.92	9.81	0.004
Tumor location									
Upper/cervical/middle*	63								

Variables	N	Univariable linear regression				Multivariable linear regression			
			95% CI for β				95% CI for β		
		β	Lower	Upper	*P*-Value	β	Lower	Upper	*P*-Value
Lower/GEJ	645	-8.47	-11.87	-5.07	<0.001†	-5.04	-9.04	-1.04	0.014
Type of esophagectomy					0.001†				
Ivor Lewis*	462								
Transhiatal	59	1.92	-1.67	5.50	0.294				
Total	49	7.84	3.95	11.73	<0.001				
Minimal invasive	124	-1.49	-4.10	1.14	0.267				
N/A	14	0.55	-6.48	7.58	0.877				
Minimal invasive surgery									
No*	584								
Yes	124	-2.35	-4.93	0.24	0.075†				
Pathological stage									
0*	145								
I	149	-1.50	-4.56	4.56	0.337				
II	254	-0.92	-3.65	1.81	0.509				
III	144	-0.71	-3.79	2.38	0.654				
IV	16	1.62	-5.30	8.52	0.647				
Clinical stage									
0*	5								
I	108	4.99	-7.00	16.97	0.414				
II	253	3.60	-8.23	15.44	0.550				
III	314	5.22	-6.60	17.03	0.386				
IV	28	4.94	-7.78	17.67	0.446				
ASA-risk scale									
1-2*	122								
3-4	586	1.293	-1.31	3.90	0.330				
Salvage operation									
No*	612								

Variables	N	Univariable linear regression				Multivariable linear regression			
			95% CI for β				95% CI for β		
		β	Lower	Upper	*P*-Value	β	Lower	Upper	*P*-Value
Yes	96	2.87	0.002	5.74	0.050†				

*Reference group.

†Statistically significant for univariable analysis (p<0.25).

βindicates odds ratio; CI, confidence interval; COPD, chronic pulmonary obstructive disease; CA, coronary artery disease; GEJ, gastroesophageal junction; ASA, American Society of Anesthesiologist.

Table 10

Pulmonary Complication

Variables	N	Univariable logistic regression				Multivariable logistic regression			
			95% C.I for OR				95% C.I for OR		
		OR	Lower	Upper	*P*-Value	OR	Lower	Upper	*P*-Value
Group									
A*	322	1.00							
B	386	0.65	0.46	0.93	0.017†	0.66	0.46	0.94	0.022
Gender									
Male*	617	1.00							
Female	91	1.48	0.91	2.41	0.117†				
Age	708	1.03	1.01	1.05	0.001†	1.03	1.01	1.05	0.001
Preoperative treatment									
No*	140	1.00							
Yes	568	0.64	0.42	0.97	0.033†				
Diabetes									
No*	597	1.00							
Yes	111	1.28	0.81	2.03	0.294				
COPD									
No*	663	1.00							
Yes	45	1.92	1.02	3.63	0.045†				
CAD									
No*	589								
Yes	119	1.15	0.73	1.81	0.562				
Histology									
Adenocarcinoma*	643	1.00				1.00			
Squamous cell carcinoma	65	1.42	0.81	2.50	0.226†	1.77	0.92	3.38	0.087
Tumor location									

Variables	N	Univariable logistic regression				Multivariable logistic regression			
			95% C.I for OR				95% C.I for OR		
		OR	Lower	Upper	*P*-Value	OR	Lower	Upper	*P*-Value
Upper/cervical/middle *	63	1.00							
Lower/GEJ	645	0.61	0.35	1.08	0.093 †				
Type of esophagectomy					0.045 †				0.052
Ivor Lewis *	462	1.00				1.00			
Transhiatal	59	1.61	0.88	2.95	0.126	1.36	0.73	2.54	0.329
Total	49	2.30	1.24	1.30	0.009	2.27	1.20	4.29	0.011
Minimal invasive	124	1.32	0.83	2.10	0.24	1.44	0.89	2.31	0.137
N/A	14	2.20	0.72	6.73	0.17	2.48	0.80	7.74	0.117
Minimal invasive surgery									
No *	584	1.00							
Yes	124	1.13	0.72	1.77	0.594				
Pathological stage									
0 *	145	1.00							
I	149	0.77	0.45	1.32	0.34				
II	254	0.90	0.56	1.45	0.67				
III	144	0.77	0.44	1.33	0.346				
IV	16	1.75	0.60	5.15	0.31				
Clinical stage									
0 *	5	1.00							
I	108	0.55	0.09	3.47	0.52				
II	253	0.37	0.06	2.27	0.28				
III	314	0.48	0.08	2.92	0.42				
IV	28	0.50	0.07	3.63	0.49				
ASA-risk scale									
1-2 *	122	1.00							
3-4	586	1.21	0.75	1.95	0.442				
Salvage operation									

Variables	**N**	**Univariable logistic regression**				**Multivariable logistic regression**			
			95% C.I for OR				**95% C.I for OR**		
		OR	**Lower**	**Upper**	***P*-Value**	**OR**	**Lower**	**Upper**	***P*-Value**
No *	612								
Yes	96	1.62	1.01	2.60	0.045 †				

* Reference group.

† Statistically significant for univariable analysis (p<0.25).

OR indicates odds ratio; CI, confidence interval; COPD, chronic pulmonary obstructive disease; CA, coronary artery disease; GEJ, gastroesophageal junction; ASA, American Society of Anesthesiologist.

Table 11

Technical Hospital Charges

Variables	N	Univariable Linear regression				Multivariable linear regression			
			95% C.I for β				95% C.I for β		
		β	Lower	Upper	P-Value	β	Lower	Upper	*P*-Value
Group									
A*	322								
B	386	-41125	-63623	-18627	0.000†	-41714	-63706	-19722	0.000
Gender									
Male*	617								
Female	91	35479	1803	69154	0.039†				
Age	708	953	-150	2057	0.090†				
Preoperative treatment									
No*	140								
Yes	568	-17911	-46263	10441	0.215†				
Diabetes									
No*	597								
Yes	111	-485	-31577	30607	0.976				
COPD									
No*	663								
Yes	45	39700	-7549	84849	0.101†				
CAD									
No*	589								
Yes	119	3022	-27209	33253	0.844				
Histology									
Adenocarcinoma*	643								
Squamous cell carcinoma	65	105620	67255	143984	0.000†	77707	31525	123889	0.001
Tumor location									

Variables	N	Univariable Linear regression				Multivariable linear regression			
			95% C.I for β				95% C.I for β		
		β	Lower	Upper	P-Value	β	Lower	Upper	*P*-Value
Upper/cervical/middle *	63								
Lower/GEJ	645	-96793	-1.5849	-57738	0.000 †	-51569	-98401	-4737	0.031
Type of esophagectomy					0.001 †				
Ivor Lewis *	462								
Transhiatal	59	185575	-22562	59714	0.376				
Total	49	95169	50463	139875	0.000				
Minimal invasive	124	-1567	-31661	28528	0.919				
N/A	14	26220	-54501	106941	0.524				
Minimal invasive surgery									
No *	584								
Yes	124	-12056	-41786	17672	0.426				
Pathological stage					0.460				
0 *	145								
I	149	-21222	-56297	13852	0.235				
II	254	-13090	-44385	18205	0.412				
III	144	1774	-33599	37147	0.922				
IV	16	34742	-4464	113947	0.389				
Clinical stage									
0 *	5								
I	108	34574	-103001	172150	0.622				
II	253	34545	-101275	170365	0.618				
III	314	54507	-81057	190071	0.430				
IV	28	44978	-101036	190991	0.546				
ASA-risk scale									
1-2 *	122								
3-4	586	16962	-12946	46870	0.266				
Salvage operation									

Variables	N	Univariable Linear regression				Multivariable linear regression			
			95% C.I for β				95% C.I for β		
		β	Lower	Upper	P-Value	β	Lower	Upper	*P*-Value
No *	612								
Yes	96	22361	-10617.6	55340	0.184 *				

*Reference group.

†Statistically significant for univariable analysis (p<0.25).

βindicates the regression coefficient; CI, confidence interval; COPD, chronic pulmonary obstructive disease; CAD, coronary artery disease; GEJ, gastroesophageal junction; ASA, American Society of Anesthesiologist.