Increased hospital costs associated with postesophagectomy complications, primarily anastomotic leak and reintubation

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Introduction

Esophageal resection is a highly complex surgery, associated with relatively high rates of postoperative complications of 49-57%[1-3]. Postoperative complications after esophagectomy have been associated with differences in cost and survival, especially pneumonia[4,5]. There is a general consensus that the most severe and prevalent complications post-esophagectomy include respiratory failure and anastomotic leak[6-8]. For pneumonia and leak especially, these complications can lead to further, more severe events, such as sepsis, wound morbidity and necrosis, and respiratory failure, amongst others.

The burden of healthcare costs is an area of high concern in the United States. National spending on surgery procedures was estimated to cost $400 million annually and expected to outstrip economic growth over the next 10 years[9]. Postoperative complications have a significant effect on hospital costs[9-13], as they can lead to increased length of stay and greater utilization of hospital resources including imaging, laboratory tests, and medications. In-hospital postsurgical complications represent a key area for both quality improvement and cost reduction for providers. Postoperative pneumonia alone was estimated to increase hospital costs by $12,798[13] for all surgeries. Identifying and assessing the costs associated with various postoperative complications is crucial to this endeavor. We aimed to utilize actual hospital cost data from a large academic institution to analyze the increased costs of the most common complications encountered post-esophagectomy.

Methods

All patients undergoing esophagectomy at an academic medical center were identified via an IRB-approved prospective database between January 2012 and December 2014. Clinical data were obtained from the institution's database and matched with institutional cost data. Our department began using the Socrates Analytics database platform in 2012 to track surgical costs and charges associated with each patient's hospitalization. This provided the study with detailed patient, not calculated, surgical costs, tabulated on a daily basis.

Hospital cost was the dependent variable. Costs were categorized into the following cost centers: anesthesia, intensive care unit (ICU), laboratory, operating room, room and board, pharmacy, radiology, cardiac consults, and physical therapy, and all other. The total cost was calculated by summation of the separate cost center groups.

The clinical data collected included patient demographics such as age, race, and gender, as well as preoperative morbidities, perioperative characteristics, and postoperative complications. Complications were defined per the Society of Thoracic Surgeons[14]. Other patient variables, such as preoperative chemotherapy and radiation, American Society of Anesthesiologysts (ASA) score, surgery type, were also analyzed. Surgery type was classified as transhiatal (neck and abdominal incisions), open (open thoracotomy and open laparotomy), hybrid (either video assisted thoracic surgery (VATS) or laparoscopy for one part of the procedure), or purely minimally invasive (both VATS and laparoscopy). Both Ivor Lewis and tri-incisional esophagectomy could be performed using hybrid and MIE techniques. Full explanations of these procedures are available elsewhere[15].

Discrete data were analyzed using Pearson's chi-square tests. Continuous variables were analyzed with Student's t-test or Wilcoxon signed-rank test. All p values reported are 2-tailed and p<.05 was considered to be statistically significant. Multivariate regression modeling was used to analyze the independent effect of a specific complication with cost as the outcome measure. For multivariate regression, we chose to analyze the independent effect of surgical site infection, atrial fibrillation, pneumonia, anastomotic leak, and reintubation on costs because of their high frequency or severity. All data were analyzed using *R Core Team 2015* (R Foundation for Statistical Computing, Vienna, Austria).

Results

The study population consisted of 86 consecutive patients undergoing esophagectomy, performed by 4 surgeons. Six patients were excluded for incomplete records, leaving a total of 80 patients for the analysis. Median ICU stay was 2 days (IQR 1-4 days) and median length of hospital stay was 8 days (IQR 7-9 days). In-hospital and 30-day mortality rates were 0%. The cohort was predominantly male (74%) with a median age of 65 years. The majority (65%) received chemotherapy and radiation therapy prior to their surgery. The surgical approach breakdown of the 80 esophagectomies was 11 transhiatal (14%), 11 open (14%), 41 hybrid (51%), and 17 minimally invasive (21%).

Patients with and without complications were similar with regards to age, gender split, and surgery type (Table 1). However, there were several significant differences in preoperative comorbidity profiles between patients with and without postoperative complications. Patients with complications had a significantly higher incidence of hypertension (HTN), coronary artery disease (CAD), chronic obstructive pulmonary disease (COPD), and congestive heart failure (CHF). ASA class 4 patients had a significantly higher rate of postoperative complications. There was no statistical difference in previous chemotherapy or radiation therapy, diabetic, and Zubrod symptomatic status between patients with and without postoperative complications. Complications occurred in 42 patients (52%). A total of 101 complications were documented. Multiple complications affected 27 patients (34%). The frequency of individual complications is shown in Table 2. The most common complication was atrial fibrillation (12, 15%), followed by pneumonia and anastomotic leak (both 11, 14%).

The median total cost of esophagectomy was $31,380 (IQR $26,500-48,906). Operation costs comprised the largest component of total hospital cost ($xx,xxx). The total hospital costs of patients with postoperative complications were significantly higher than patients without postoperative complications, by $12,450 ($p<0.0001$). The breakdown of costs by cost center for patients with and without postoperative complications is shown in table 3. Postoperative complications resulted in significantly higher costs in virtually every hospital service. The largest cost differences were in ICU costs, where postoperative complications were associated with $3,486 cost increase, followed by non-ICU room and board, then laboratory costs.

Multivariate regression analysis revealed that age, preoperative diagnosis of CAD, ASA class IV status, and minimally invasive surgery were independently associated with increase in total hospital costs (Table 4). Preoperative hypertension was significantly associated with cost savings of $16,830. Amongst the postoperative complications, leak and reintubation were significantly increases total hospital costs by $14,029 and $20,777, respectively. Pneumonia and atrial fibrillation did not lead to significantly higher total hospital costs. Multivariate regression analysis of specific cost centers revealed that postoperative complications were not significantly associated with differences in OR or anesthesia costs. However, atrial fibrillation significantly increased ICU and pharmacy costs. Leak of any grade was associated with significantly increased room and board, laboratory, and pharmacy costs. Reintubation significantly increased ICU, laboratory, and radiology costs.

Discussion

We report in this study postoperative complications after esophagectomy significantly affect costs for every measured medical service. In particular, anastomotic leak and reintubation were associated with higher total hospital costs. This finding supports previous studies' results, such as [ ].
However, most hospital centers in these studies calculate total hospital costs, which presents a major limitation as calculated costs cannot reflect the unique features of individual patients' hospital courses.

Socrates, the cost database used at our academic institution, allows us to track actual costs for every surgical patient. Additionally, it provides a detailed breakdown of total hospital cost into specific cost centers, such as OR, ICU, or laboratory. This allowed for greater transparency in our cost analysis, and may provide a more directed approach to address quality improvement programs.

Two of the four postoperative complications we chose to analyze in depth resulted in significant increases in total hospital costs, anastomotic leak and reintubation. Anastomotic leak significantly increased room and board, laboratory, and pharmacy costs, indicating that anastomotic leak leads to longer duration of stay on the general care floor, more laboratory tests, and more medications at this academic institution. Reintubation significantly increased ICU, laboratory, and radiology costs. This makes sense as imaging is often required to perform reintubation, and ICU care is necessary to monitor mechanical ventilation.

As found in a previous study from this group[], hypertension was associated with cost savings. This effect was consistent across all cost centers. That this effect is consistent across all cost centers, even OR costs, suggests that the explanation behind this cost savings effect may be in preoperative management of hypertension.

Our study was limited by several factors. Complications were not graded by severity, which has been found to be significantly associated with increased hospital costs[ ]. As such, grading the severity of complications may offer further insight on the relationship between postoperative complications and hospital costs. Additionally, the size of study population is relatively small, especially for complications as we had only 12 patients who experienced atrial fibrillation, 11 with pneumonia, leak, and reintubation. Other complications, such as laryngeal nerve paresis or chyle leak had too few subjects to analyze, but have been indicated in other studies as significant complications postesophagectomy. Finally, the full economic impact of complications is encompasses more than hospital costs from the index hospital admission, such as quality of life and future readmissions that may be related to complications. Nonetheless, we believe our data illuminates an important aspect of cost, as the index operation is a prime target for quality improvement.

Eliminating waste from the medical system while improving the quality of care is the prerogative for providers. Complications

In addition, the economic impact of complications is difficult to parse, as there are many complex interactions between patient, treatment, tumor staging, and provider factors that contribute to adverse outcomes. It is out of the scope of this paper to fully elucidate these relationships, but we attempt to account for as many of these factors as possible in our analysis. We hope the analysis will provide guidance to providers on which potential complications should be the focus of attention when aiming to improve patient outcomes while controlling hospital costs.

Conflicts

The authors report no conflicts of interest.

Table 1 Preoperative and intraoperative characteristics of cohort

Patient variables	Median (IQR) or N Frequency (%)			p-value (2-sided)
	All	Patients with no complications	Patients with complications	
N (%)	80 (100)	38 (47.5)	42 (52.5)	
Age	65 (60.0-75.0)	66 (57.8-74.8)	65 (60.0 -76.8)	0.4874
Gender				
Male	59 (73.8)	26 (68.4)	33 (78.6)	0.1570
Female	21 (26.2)	12 (31.6)	9 (21.4)	
Preop Comorbidities				
Hypertension	44 (55.0)	14 (36.8)	30 (71.4)	<0.0001
COPD	10 (12.5)	2 (5.3)	8 (19.0)	0.0001
CAD	15 (18.8)	4 (10.5)	11 (26.2)	0.0009
CHF	5 (6.3)	1 (2.6)	4 (9.5)	0.0053
Prior CTS	11 (13.8)	4 (10.5)	7 (16.7)	0.1947
Diabetes	16 (20.0)	6 (15.8)	10 (23.8)	0.1540
Preop Chemo	52 (65.0)	26 (68.4)	26 (61.9)	0.3636
Preop XRT	51 (63.8)	25 (65.8)	26 (61.9)	0.5956
Zubrod Class				
Normal Activity	33 (41.3)	14 (36.8)	19 (45.2)	0.2593
Symptomatic	47 (58.8)	24 (63.2)	23 (54.8)	
ASA Class				
II	7 (8.8)	4 (10.5)	3 (7.2)	<0.0001
III	69 (86.3)	34 (89.5)	35 (83.3)	
IV	4 (5.0)	0 (0)	4 (9.5)	
Operative variables				
OR time (min)	441 (399.4-511.2)	444.3 (401.7-493.2)	441.0 (398.7-522.4)	0.9424
LOS (days)	8.0 (7.0-9.0)	7.0 (7.0 – 8.0)	9.0 (7.0-13.0)	<0.0001
ICU stay (days)	2.0 (1.0-4.0)	1.5 (1.0-2.0)	3.0 (2.0-5.8)	0.0002
Surgery type				
Transhiatal	11 (13.8)	6 (15.8)	5 (11.9)	0.5799
Open	11 (13.8)	4 (10.5)	7 (16.7)	
Hybrid	41 (51.2)	20 (52.6)	21 (50)	
MIE	17 (21.2)	8 (21.1)	9 (21.4)	

Table 2 Frequency of complications

Post-operative Events (n=80)	**N Frequency (%)**
Atrial fibrillation	12 (15%)
Leak of any grade	11 (14%)
Pneumonia	11 (14%)
Readmission within 30 days	11 (14%)
Reintubation	8 (10%)
Unexpected ICU admission	5 (6%)
Postoperative transfusions	4 (5%)
Laryngeal nerve paresis	3 (4%)
Urinary tract infection	3 (4%)
Pulmonary embolism	2 (3%)
Atelectasis	2 (3%)
Gastric outlet obstruction	2 (3%)
Chyle leak	2 (3%)
Tracheostomy	1 (1%)
Surgical site infection	1 (1%)
Other (esophageal stricture, sepsis, urinary retention)	3 (4%)
Any complication	42 (53%)
30 day return to OR	16 (20%)
Reoperation for bleeding	1 (1%)
Reoperation for anastomotic leak	2 (3%)
Reoperation for chyle leak	2 (3%)
Reoperation for empyema	1 (1%)
Endoscopy for evaluation and/or treatment of leak	2 (3%)
Bronchoscopy for atelectasis	1 (1%)
Surgical management of recurrent laryngeal nerve paresis	1 (1%)
Endoscopic evaluation and/or treatment of delayed gastric empyting (pyloric stenosis)	3 (4%)
Other (splenectomy, jejunostomy tube complications)	3 (4%)

Table 3 Median of costs by cost center between patients with and without complications

Cost Center	Median (IQR)			Difference (%[a])	p-value (two-sided)
	All patients (n=80)	Patients without complications (n=38)	Patients with complications (n=42)		
OR	$10,449 ($9,108-14,599)	$10,091 ($8,775-11,727)	$11,030 ($9,327-16,499)	$939 (9%)	.041
Non-ICU room and board	$8,294 ($6,791-10,995)	$7,948 ($5,728-8,334)	$9,613 ($6,945-12,974)	$1,665 (21%)	.011
ICU	$4,414 ($3,111-8,632)	$4,058 ($2,158-4,541)	$7,544 ($4,316-14,190)	$3,486 (86%)	<.001
Anesthesia	$2,204 ($1,918-2,713)	$2,146 ($1,862-2,426)	$2,401 ($2,042-3,149)	$255 (12%)	.013
Lab	$1,807 ($1,274-3,027)	$1,566 ($1,116-2,119)	$2,583 ($1,568-4,596)	$1,017 (65%)	.001
Pharmacy	$1,801 ($1,409-2,330)	$1,531 ($1,103-1,829)	$2,156 ($1,717-3,043)	$626 (41%)	<.001
Radiology	$1,373 ($1,177-2,439)	$1,215 ($1,084-1,408)	$2,027 ($1,319-2,786)	$813 (67%)	<.001
Other[b]	$589 ($0-1,533)	$306 ($0-868)	$1,277 ($336-2,505)	$971 (318%)	.002
Total	$31,375 ($26,487-48,484)	$26,740 ($25,355-31,668)	$39,194 ($30,176-60,981)	$12,453 (47%)	<.001

[a] Calculated as percentage of patients without complications' median cost for relevant cost center

[b] Other includes cardiology consults and physical therapy

Table 4: Multivariate regression

Variable		Total		OR		ICU		Anesthesia	
		Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value
Age (y)		$720	<.001	$143	.016	$174	.005	$31	.013
HTN		($16,830)	<.001	($3,825)	.006	($3,457)	.015	($507)	.078
CAD		$11,907	.041	($1,401)	.422	($3,670)	.037	$130	.715
Preop ChemoXRT		($5,357)	.242	$94	.946	($338)	.806	($350)	.221
COPD		($7,666)	.289	($658)	.757	($4,055)	.064	($396)	.377
CHF		($3,494)	.734	($1,732)	.571	($827)	.222	$39	.586
Diabetes		($1,459)	.788	$537	.740	$3,882	.714	($255)	.452
Zubrod symptom		($1,132)	.795	($267)	.837	$315	.810	($12)	.966
ASA Class	II								
	III	$9,888	.184	$3,397	.124	$1,808	.415	$462	.316
	IV	$44,895	<.001	$5,545	.177	$8,597	.027	$2,278	.005
Proc type	THE								
	Open	$8,813	.262	$4,211	.073	$4,168	.084	$860	.080
	Hybrid	$1,037	.872	$2,631	.174	($902)	.648	$829	.043
	MIE	$14,789	.042	$10,920	<.001	$206	.924	$1,826	<.001
Postop comp	A-fib	$1,622	.772	($505)	.762	$3,545	.038	$311	.374
	PNA	$9,898	.184	$1,209	.290	$3,145	.164	($404)	.381
	Leak	$14,029	.050	$2,927	.164	$1,953	.359	$608	.169
	Reintub	$20,777	.007	$422	.878	$10,469	<.001	$123	.789
Constant		($15,252)		$49		($6,633)		($431)	
R-Squared		.508		0.3476		.5002		.2377	

Variable		Room and board		Laboratory		Pharmacy		Radiology		Other	
		Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value
Age (y)		$111	.048	$46	.067	$12	.244	$40	<.001	$71	.056
HTN		($2,961)	.025	($1,474)	.011	($73)	.756	($843)	.002	($1,001)	.243
CAD		$1,130	.488	$1,090	.102	$636	.031	$455	.167	$1,710	.114
Preop ChemoXRT		($750)	.564	($9)	.888	($105)	.647	($285)	.288	($374)	.662
COPD		($1,305)	.524	($776)	.367	($573)	.121	($474)	.255	$1,331	.324
CHF		($2,258)	.441	$171	.953	($36)	.947	($177)	.771	($116)	.952
Diabetes		($373)	.809	$228	.696	($81)	.772	($97)	.769	($18)	.986
Zubrod symptom		($1,550)	.213	($123)	.137	$63	.775	($78)	.755	$381	.640
ASA Class	II										
	III	$1,171	.578	$1,358	.024	$167	.651	$396	.344	$1,002	.469
	IV	$8,893	.017	$3,309	.021	$1,586	.015	$2,253	.003	$3,950	.101
Proc type	THE										
	Open	$3,887	.084	$743	.589	$1,223	.004	$1,001	.039	($1,174)	.423
	Hybrid	$3,942	.035	$1,548	.293	$526	.131	$379	.335	($1,383)	.255
	MIE	$6,543	.002	($660)	.303	$977	.011	$996	.022	($979)	.464
Postop comp	A-fib	$504	.752	$404	.403	$598	.036	$286	.388	($1,528)	.148
	PNA	$1,391	.509	$744	.304	$577	.133	$461	.287	$2,441	.081
	Leak	$4,152	.042	$1,062	<.001	$1,058	.005	$710	.088	$485	.713
	Reintub	($1,507)	.475	$4,488	<.001	$522	.189	$1,132	.014	$288	.835
Constant		($1,507)		($641)		$63		($1,309)		($4,181)	
R-Squared		.2122		.4909		.4307		.4134		.2037	

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16.