

The Influence of Complications on the Costs of Complex Cancer Surgery

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BACKGROUND: It is widely known that outcomes after cancer surgery vary widely, depending on interactions between patient, tumor, neoadjuvant therapy, and provider factors. Within this complex milieu, the influence of complications on the cost of surgical oncology care remains unknown. The authors examined rates of Patient Safety Indicator (PSI) occurrence for 6 cancer operations and their association with costs of care. **METHODS:** The Agency for Healthcare Research and Quality (AHRQ) PSI definitions were used to identify patient safety-related complications in Medicare claims data. Hospital and inpatient physician claims for the years 2005 through 2009 were analyzed for 6 cancer resections: colectomy, rectal resection, pulmonary lobectomy, pneumonectomy, esophagectomy, and pancreatic resection. Risk-adjusted regression analyses were used to measure the association between each PSI and hospitalization costs. **RESULTS:** Overall PSI rates ranged from a low of 0.01% for postoperative hip fracture to a high of 2.58% for respiratory failure. Death among inpatients with serious treatable complications, postoperative respiratory failure, postoperative thromboembolism, and accidental puncture/laceration were >1% for all 6 cancer operations. Several PSIs—including decubitus ulcer, death among surgical inpatients with serious treatable complications, and postoperative thromboembolism—raised hospitalization costs by ≥20% for most cancer surgery types. Postoperative respiratory failure resulted in a cost increase >50% for all cancer resections. **CONCLUSIONS:** The consistently higher costs associated with cancer surgery PSIs indicate that substantial health care savings could be achieved by targeting these indicators for quality improvement. *Cancer* 2014;120:1035-41. © 2013 The Authors. Cancer published by Wiley Periodicals, Inc. on behalf of American Cancer Society. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

KEYWORDS: cancer, cost analysis, surgery, complication, patient safety, quality indicators.

INTRODUCTION

The costs of cancer care in the United States were estimated to reach \$124.6 billion in 2010 and could rise by 66%, reaching \$207 billion in 2020.¹ Some of this cost increase reflects the aging US population, but most represents the increasing use of costly pharmaceuticals, diagnostic modalities, and high-tech instrumentation for treatment. Growth in these 3 areas may provide significant survival benefits to cancer patients. However, some of these costs likely represent waste in the health care system that could be avoided.²

Another area of cancer care that has received less attention is the influence of complications on medical outcomes and costs of care. In cancer treatment, unlike many benign conditions, there tends to be a higher threshold of tolerance for complications. In addition, direct causality is more difficult to determine as there are complex interactions between patient, tumor, multimodality therapy, and provider factors that contribute to adverse outcomes. After high-risk surgery in general, complications have been independently associated with increased resource use.³⁻⁵ Given the complexity of care in cancer surgery patients, links between complications and costs have not been elucidated. If such linkages can be confirmed, then efforts to reduce potentially avoidable complications would not only improve patient outcomes but also would have the opportunity to slow the growth of health care costs.

The Agency for Healthcare Research and Quality (AHRQ) has worked with researchers and medical providers to develop a set of transparent outcome measures called Patient Safety Indicators (PSIs), which provide information on potential in-hospital complications and adverse events after surgeries, procedures, and childbirth. Although PSIs do not identify all complications that could occur during a hospital stay, they do provide consistent, measurable outcomes reported in administrative databases using definitions common to all hospitals. Thus, PSIs can be used to characterize and compare the incidence of complications across a wide sample of hospitals and patients.

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The frequency of PSIs and their contribution to higher hospitalization costs have been measured for hospital admissions among both community hospitals and Veterans Administration (VA) hospitals.⁵⁻⁹ However, no studies have examined the presence of PSIs among patients admitted to hospitals for cancer surgery or the relation between these PSIs and costs. The purpose of this analysis was to determine whether relations exist between PSI occurrence and costs of care for 6 cancer operations. The analyses provide guidance to hospitals on which potential adverse events and complications among cancer patients should be the focus of attention when aiming to improve patient outcomes while simultaneously controlling cost growth.

MATERIALS AND METHODS

Patient-level Medicare claims data from all 50 US states for the years 2005 through 2009 were used to analyze the relation between costs and patient complications for 6 cancer resections: colectomy (n = 150,733), pulmonary lobectomy (n = 52,202), rectal resection (n = 25,892), pancreatic resection (n = 12,135), esophagectomy (n = 3857), and pneumonectomy (n = 2981). These resections vary substantially in terms of their frequency performed, average mortality rate, and average cost per patient. The 100% Medicare Provider and Analysis Review (MedPAR) files (Centers for Medicare and Medicaid Services, Baltimore, Md) were merged with the Carrier files. International Classification of Diseases 9th Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes were used to simultaneously identify all patients who underwent 1 of the resections for a cancer diagnosis in this study using previously published methodology.¹⁰

Costs

Hypothetically, costs per patient depend on the characteristics of the patient as well as the characteristics of the surgeon and hospital delivering treatment to the patient. Therefore, in this study, we examined costs per entire inpatient stay rather than just hospital costs or just the cost of performing surgery.

The MedPAR data provide detailed information on hospital charges by revenue center for each discharge. Charges were adjusted by the All-Urban Consumer Price Index to reflect 2005 dollars. Costs for each hospital stay were estimated by multiplying the reported patient charge by the hospital's cost-to-charge ratio in the same year.

Economists rely on this approach when analyzing costs in large samples of hospitals.¹⁰⁻¹⁵

To calculate physician costs, all physician billings to Medicare for the patient's hospital stay were identified in the Carrier claims files and summed to represent physician costs associated with the admission. The hospital and physician costs were summed to calculate the total costs per patient.

Complications

Complications were identified using the AHRQ Hospital-level PSI methodology.¹⁶ AHRQ has defined 20 PSIs, along with corresponding ICD-9-CM codes, so that they can be readily identified in administrative data. These indicators focus on potentially preventable instances of complications and other iatrogenic events resulting from exposure to the health care system. Four PSIs were excluded from the analysis if they related specifically to birth and obstetric care. One PSI was excluded because, by AHRQ definition, it should not be used for cancer patients. Additional PSIs were excluded from the individual regressions if there were 5 or fewer observations of this indicator for that procedure.

Hospital, Surgeon, and Patient Characteristics

Regression analysis accounted for multiple aspects of care, including hospital volume, surgeon volume, surgeon specialty designation, hospital resources, patient characteristics, and tumor stage. Hospital procedure volume was determined by summing the total number of operations performed by each hospital in each year for each of the 6 cancer resections. Individual surgeon volume was calculated in the same manner. In addition to surgeon volume, the regressions controlled for the subspecialty of the surgeon operating on each patient as identified in the Medicare Physician Identification and Eligibility Registry file. Procedure volume counts based on Medicare data reflect only those patients aged ≥ 65 years.

Additional hospital characteristics included as covariates in the cost regressions were the nurse-to-patient ratio and indicator variables for complex medical technologies (whether the treating hospital has a computed tomography scanner, magnetic resonance imaging, and positron emission tomography), which are more likely to be present at high-volume hospitals. Data for these variables were obtained from the American Hospital Association Annual Survey of Hospitals.

Patient-level characteristics used for risk adjustment included sex, age, race, and income. To stratify patient comorbidity, secondary diagnosis codes were used to

TABLE 1. Rates of Patient Safety Indicators by Hospital Characteristics

Patient Safety Indicator	Hospital Characteristic: Percentage of Patients						
	Overall	Low Volume	High Volume	Teaching	Nonteaching	Urban	Rural
Accidental puncture/laceration	2.10	2.10	2.17	2.22	1.98	2.11	1.89
Anesthesia complications	0.02	0.04	0.02	0.03	0.02	0.02	0.02
Death among surgical inpatients with serious treatable complications	1.44	1.95	1.34	1.43	1.45	1.45	1.06
Decubitus ulcer	0.63	0.78	0.59	0.63	0.63	0.63	0.44
Foreign body left in during procedure	0.03	0.04	0.02	0.03	0.02	0.03	0.07
Iatrogenic pneumothorax	0.68	0.76	0.67	0.71	0.65	0.69	0.27
Postoperative hemorrhage/hematoma	0.30	0.26	0.31	0.34	0.26	0.30	0.29
Postoperative hip fracture	0.01	0	0.01	0.01	0.02	0.01	0
Postoperative physiologic and metabolic derangement	0.09	0.06	0.09	0.10	0.07	0.09	0
Postoperative respiratory failure	2.58	2.98	2.56	2.86	2.26	2.59	1.67
Postoperative thromboembolism (PE/DVT)	1.66	1.52	1.71	1.77	1.53	1.66	1.30
Postoperative wound dehiscence	0.26	0.22	0.25	0.23	0.30	0.26	0.39

Abbreviations: PE/DVT, pulmonary embolism/deep vein thrombosis.

construct indicator variables for the 29 conditions comprising the Elixhauser comorbidity index.¹⁷ Indicator variables were included for patients who were transferred from another hospital and patients whose admission status was urgent or emergent. Cancer stage was measured using secondary diagnosis codes for lymph node involvement and organ metastasis.¹⁸ To adjust for disease-specific differences in procedure complexity and patient case mix, indicator variables were defined for particular operations and surgical approaches specific to each procedure. Procedure and tumor sites were defined on the basis of previous studies of these operations that used ICD-9-CM procedure and diagnosis codes.¹⁸⁻²³

Analysis

Regressions were estimated separately for each of the 6 cancer resections to determine the relation between complications measured by PSIs and the natural log of total costs as the dependent variable, with adjustment for the hospital, surgeon, and patient characteristics listed above. Separate regressions were estimated for each cancer operation, so that we could examine whether the association between PSIs and costs differed by procedures. Patients who underwent more than 1 of these operations were included in the regressions for each procedure they received. All regressions were performed using panel data with year indicator variables. Hospital-specific indicator variables were used to control for all observed and unobserved characteristics, such as a hospital's reputation for quality in the community.^{24,25} Regressions were estimated using the *xreg* command in Stata 12.1 (Stata-Corp, College Station, Tex) with specifications to provide robust standard errors that accounted for cluster-

ing of patient data within hospitals.²⁵⁻²⁷ By using Stata's *mfp* command to suggest the best fit multivariable, fractional, polynomial model for each procedure, more flexible specifications of provider volume were explored to determine whether they improved the fit of the equation. After complete analysis, the strength of association between variables and costs was reported in the results and tables as the percentage change in costs with confidence intervals and *P* values.

RESULTS

Independent of procedure type, overall rates of PSIs stratified by hospital characteristics (procedure volume, teaching status, and locale) are presented in Table 1. The most frequent PSIs included death among surgical inpatients with serious treatable complications, postoperative respiratory failure, postoperative pulmonary embolism or deep vein thrombosis, and accidental puncture/laceration; whereas anesthesia complications, having a foreign body left in during a procedure, postoperative hip fractures, and postoperative physiologic and metabolic derangement were the least frequent at <0.1%. The occurrence rates for low-volume and high-volume hospitals are similar for many PSIs, but each hospital volume group seems to excel in different areas. For example, low-volume hospitals have lower postoperative hemorrhage/hematoma and postoperative pulmonary embolism or deep vein thrombosis rates, but high-volume hospitals have lower rates of death among surgical inpatients with treatable complications, iatrogenic pneumothorax, and postoperative respiratory failure. For many of the study PSIs, patients treated at teaching hospitals experienced higher rates than at nonteaching hospitals, but several rates were

TABLE 2. Rates of Patient Safety Indicators by Surgical Procedure for Medicare Patients From 2005 to 2009

Patient Safety Indicator	Surgical Procedure: Percentage of Patients					
	Colectomy (N = 150,733)	Pulmonary Lobectomy (N = 52,202)	Rectal Resection (N = 25,892)	Pancreatic Resection (N = 12,135)	Esophagectomy (N = 3857)	Pneumonectomy (N = 2981)
Accidental puncture/laceration	2.09	1.28	3.11	2.95	4.72	1.85
Anesthesia complications	0.01	0.05	0.03	0.03	0.03	0
Death among surgical inpatients with serious treatable complications	1.27	1.50	1.10	2.37	4.36	4.29
Decubitus ulcer	0.69	0.36	0.67	0.77	1.40	0.40
Foreign body left in during procedure	0.02	0.03	0.05	0.03	0.05	0.13
Iatrogenic pneumothorax	0.15	2.65	0.14	0.34	0	0
Postoperative hemorrhage/hematoma	0.25	0.14	0.47	1.23	0.36	0.37
Postoperative hip fracture	0.01	0.01	0.01	0	0	0
Postoperative physiologic and metabolic derangement	0.07	0.12	0.08	0.08	0.26	0.23
Postoperative respiratory failure	1.88	2.97	2.68	4.99	14.52	4.53
Postoperative thromboembolism (PE/DVT)	1.74	1.25	1.47	1.99	3.66	2.08
Postoperative wound dehiscence	0.36	0	0.24	0.30	0.23	0

Abbreviations: PE/DVT, pulmonary embolism/deep vein thrombosis.

similar between the 2 groups. Nonteaching hospitals demonstrated higher rates of postoperative hip fracture and wound dehiscence. Although patients treated at urban hospitals shared similar PSI rates to the overall sample, rural hospital rates were lower for all PSIs except having a foreign body left in during a procedure and postoperative wound dehiscence.

Table 2 lists the PSI rates by cancer surgery procedure type. Less common procedures (pneumonectomy, esophagectomy, and pancreatic resection) tended to have higher PSI rates than the more common procedures for several PSIs, including death among surgical inpatients with serious treatable complications, postoperative respiratory failure, and postoperative pulmonary embolism or deep vein thrombosis. The rate of postoperative respiratory failure was particularly high for esophagectomy patients at >14%.

Table 3 lists the risk-adjusted coefficient estimates for the impact of each PSI variable. These results indicate that several specific PSIs are associated with increased costs. After adjusting for patient, hospital, and tumor factors, costs increase by 53% to 77% for respiratory failure, 20% to 54% for death among surgical inpatients with serious treatable conditions, 28% to 37% for postoperative pulmonary embolism or deep vein thrombosis, and 28% to 60% for decubitus ulcer for all procedures ($P < .001$). These procedure-specific data are remarkable for several important findings. Having a foreign body left in the patient, iatrogenic pneumothorax, postoperative hip fracture, postoperative hemorrhage/hematoma, postoperative physiologic and metabolic derangement, and accidental

puncture/laceration all increase costs for 1 or more procedure. For colectomy, rectal, esophagectomy, and pancreatic resections, postoperative wound dehiscence increases cost by >40% ($P < .001$).

Although a table of the control variables used in the regressions has not been included, many patient covariates, such as being in an older age group, being black, or being a man, significantly increased costs. Urgent patients increased costs 35% to 50%, and transfer patients also tended to incur 20% to 39% higher costs. Cancer that metastasized significantly increased costs from 3% to 10% across the 6 procedures. There was evidence of an increase in costs for lymph node involvement in colectomy and pulmonary lobectomy, but it actually may have decreased costs by 2% to 5% for pancreatic resection and esophagectomy. There was no significant effect on the costs of rectal resection or pneumonectomy as a result of lymph node involvement. Many of the Elixhauser comorbidities were significant, although the effect on total costs varied by comorbidity and procedure. The hospital's ownership of complex medical technologies did not have a systematic effect on costs. Full regression estimates that include all of the control variables are available upon request.

DISCUSSION

Significant pressure is being exerted on health care providers to simultaneously improve quality and reduce the cost of care. Improvements in patient safety with reduction or elimination of common errors are certain to improve health care quality. These same improvements in

TABLE 3. Adjusted Differences in Hospitalization Costs With Confidence Intervals and P Values by Patient Safety Indicators

Patient Safety Indicator	Risk-Adjusted Coefficient Estimate (95% CI)					
	Colectomy	Pulmonary Lobectomy	Rectal Resection	Pancreatic Resection	Esophagectomy	Pneumectomy
Accidental puncture/laceration	0.211 (0.193-0.229)	0.195 (0.158-0.232)	0.195 (0.161-0.230)	0.153 (0.097-0.210)	0.135 (0.043-0.226)	0.185 (0.029-0.342)
P	<.001	<.001	<.001	<.001	.004	.021
Anesthesia complications	-0.133 (-0.240-0.026)	0.072 (-0.075-0.219)	-0.063 (-0.335-0.209)			
P	.015	.336	.650			
Death among surgical inpatients with serious treatable complications	0.270 (0.236-0.304)	0.538 (0.484-0.591)	0.200 (0.109-0.292)	0.282 (0.176-0.387)	0.300 (0.184-0.416)	0.453 (0.312-0.593)
P	<.001	<.001	<.001	<.001	<.001	<.001
Decubitus ulcer	0.322 (0.289-0.355)	0.489 (0.398-0.580)	0.317 (0.238-0.396)	0.335 (0.225-0.444)	0.275 (0.127-0.422)	0.600 (0.329-0.871)
P	<.001	<.001	<.001	<.001	<.001	<.001
Foreign body left in during procedure	0.213 (0.008-0.417)	0.195 (-0.080-0.470)	0.251 (0.049-0.452)			
P	.041	.165	.015			
Iatrogenic pneumothorax	0.350 (0.273-0.426)	0.031 (0.0107-0.051)	0.253 (0.145-0.360)	0.157 (-0.025-0.339)		
P	<.001	.003	<.001	.091		
Postoperative hemorrhage/hematoma	0.454 (0.399-0.510)	0.353 (0.218-0.488)	0.411 (0.320-0.503)	0.447 (0.353-0.540)	0.190 (-0.198-0.578)	0.248 (-0.0545-0.550)
P	<.001	<.001	<.001	<.001	.337	.108
Postoperative hip fracture	0.638 (0.444-0.833)	0.412 (0.117-0.707)				
P	<.001	.006				
Postoperative physiologic and metabolic derangement	0.525 (0.408-0.642)	0.374 (0.243-0.506)	0.390 (0.155-0.625)	0.275 (-0.139-0.688)	0.261 (-0.213-0.735)	0.639 (-0.204-1.481)
P	<.001	<.001	.001	.193	.280	.137
Postoperative respiratory failure	0.624 (0.597-0.650)	0.765 (0.724-0.805)	0.618 (0.568-0.667)	0.533 (0.466-0.599)	0.614 (0.549-0.680)	0.580 (0.438-0.722)
P	<.001	<.001	<.001	<.001	<.001	<.001
Postoperative thromboembolism [PE/DVT]	0.369 (0.349-0.390)	0.346 (0.301-0.392)	0.352 (0.300-0.405)	0.306 (0.251-0.361)	0.284 (0.191-0.376)	0.292 (0.130-0.455)
P	<.001	<.001	<.001	<.001	<.001	<.001
Postoperative wound dehiscence	0.662 (0.614-0.710)		0.672 (0.533-0.811)	0.437 (0.272-0.602)	0.582 (0.332-0.832)	
P	<.001		<.001	<.001	<.001	

Abbreviations: CI, confidence interval; PE/DVT, pulmonary embolism/deep vein thrombosis.

patient safety indicators are suspected to reduce costs, but the potential magnitude of the effect is unclear. To address this knowledge gap, the current study was designed to determine the relation between multiple, widely accepted AHRQ PSIs and costs of care, specifically in complex procedures performed for oncologic diagnoses.

This analysis confirmed that, after adjusting for patient, provider, and tumor factors, multiple PSIs were associated with increased costs. In our regression analysis, we observed that a majority of PSIs were associated with higher costs. This is consistent with a previous study, in which PSIs resulted in significant excess charges for patients.⁷ Furthermore, the magnitude of cost difference, commonly ranging from 20% to 70%, was dramatic and highly significant. These data indicate that, even in the complex cancer care environment, in which many controllable and uncontrollable variables may contribute to complications, improvements in patient safety indicators are highly likely to reduce costs.

In addition, several hospital characteristics were examined individually to analyze the difference in PSI rates between hospitals and to identify potentially systemic differences in the capture of different types of complications. For instance, there may be coding variability at individual institutions that has an impact on the data, although the breadth of the study should minimize this effect. Similar to our results, a previous study on the association between teaching hospitals and PSIs indicated that the PSI rates were higher for teaching hospitals.²⁸ There are many factors that may contribute to these findings. It is possible the higher PSI rates for teaching hospitals are a result of trainee expertise, a more complex case mix, or a higher risk patient population, but it has also been suggested that teaching hospitals may better document adverse events.²⁹ The general finding that PSI rates in rural hospitals are lower than those in urban hospitals is similar to results from a past comparison.⁶ Intuitively, it may be believed that this has something to do with hospital size, but this relation has been validated further by a study of small urban hospitals versus small rural hospitals that produced the same difference in rates.³⁰

Many PSIs that were included in this study are potentially avoidable occurrences. This is clearly the case for having a foreign body left in the patient. Other conditions, such as accidental puncture/laceration, may be related to tumor factors that are unavoidable but, in other circumstances, may reflect a need for more careful dissection. Another condition, which is actually easier to prevent than treat, is decubitus ulcer. Each of the above PSIs

has a positive significant value for 1 or more procedure, providing a strong rationale for the development of targeted quality-improvement programs in an effort to improve patient outcomes and to simultaneously lower the costs of care.

Other safety issues may not be prevented by the surgeon or hospital. For instance, even with appropriate prophylaxis regimens, there are many cases in which postoperative pulmonary embolism or deep vein thrombosis occurs in cancer patients with pre-existing or chronic thromboembolic disease.³¹ Wound dehiscence could be caused by a mixture of factors, some of which may be addressed by the provider, including proper surgical technique (eg, incision type and infection prevention) and factors such as obesity, malnutrition, and hypertension that predispose a patient to this complication.^{32,33} These results indicate that quality-improvement efforts may need to account for patient and tumor factors when attempting to influence patient outcomes and costs. Given the magnitude of cost differentials in this analysis and the scope of health care expenditure on cancer care, it is possible that the resource allocation required for quality improvement will be more than offset by the cost reductions that result.

Past studies have demonstrated the ability to identify complications using administrative data and have produced results suggesting that these complications are important determinants of costs.^{3,34} However, the set of hospitals and procedures examined in those studies was limited. One study used VA data and did not focus on cancer, whereas the other examined only 2 cancer procedures in 1 state. Using Medicare data limited us to patients aged ≥ 65 years, but it provided a large data set with data that were comparable across the United States.

The data used in this study are not linked across multiple admissions for a given patient. Therefore, they do not identify PSIs that may result in a readmission to the hospital. If available, costs associated with these readmissions reasonably could be included in the total costs for the patient. Without the link to readmissions, the total costs and the number of complications per patient may be underestimated.

Applying hospital cost-to-charge ratios to patient charges provides an indirect estimate of patient costs for cancer resection. This technique may introduce measurement error in the dependent variable (costs) that could lower the chance of finding a significant association between each PSI and costs. Nevertheless, we identified a statistically significant relation between several PSI measures and costs. Moreover, analysis of a treatment with

large, fixed costs like complex cancer surgery yields a more homogeneous hospital sample, which mitigates any bias introduced by the use of hospital-level cost-to-charge ratios.¹²

We may not identify all complication measures that are important determinants of surgeon and hospital costs. However, because we know so little about the links between provider volume, care processes, complications, and costs, this analysis represents an important first step in examining these relations.

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CONFLICT OF INTEREST DISCLOSURES

Dr. Aloia reports personal fees from Medtronic, Inc., outside the submitted work.

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