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A Comprehensive Estimation of the Costs of 30-Day Postoperative Complications Using Actual Costs from Multiple, Diverse Hospitals

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Abstract

Background: To date, the cost of surgical care is largely measured by charges or payments, both of which are inadequate. Actual cost data from the hospital's perspective are required to accurately quantify the financial return on investment of engaging in quality improvement. Our objective was to define the cost of individual, 30-day post-operative complications using robust cost data from a diverse group of hospitals.

Methods: Using clinical data derived from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP), this retrospective study assessed postoperative complications for patients who underwent surgery at one of four diverse hospitals in 2016. Actual direct and indirect 30-day costs were obtained and the adjusted cost per complication was determined.

Results: From the 6,387 patients identified, the three complications associated with the highest independent adjusted cost per event were prolonged ventilation ($48,168, 95% CI $21,861, $74,476), unplanned intubation ($26,718, 95% CI $15,374, $38,062), and return to the OR ($20,258, 95% CI $13,537, $26,978). The three complications associated with the lowest independent adjusted cost per event were UTI (−$372, 95% CI −$1,336, $592), superficial SSI ($2,473, 95% CI −$256, $5,201) and VTE ($7,909, 95% CI −$17,903, $33,721). After colectomy, the adjusted independent cost of anastomotic leak was $10,195 (95% CI$ 5,941, $14,449) while the cost of postoperative ileus was $10,205 (95% CI $6,259, $14,149).

Conclusions: By using cost data from four diverse hospitals, the actual hospital costs of complications were estimated. These data can be used by hospitals to estimate the financial benefit of reducing surgical complications.

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INTRODUCTION

Surgical services account for >40% of inpatient health care spending in the U.S[1] and projected to account for over 7% of the U.S. GDP by 2025.[2] One of the primary drivers of surgical costs are complications which dramatically increase the intensity of healthcare utilization, including increases in testing (e.g., labs, imaging), treatments (e.g., invasive interventions, reoperation), and clinician services (e.g., nursing care, consultants).[3,4] For example, an anastomotic leak following colon surgery requires additional labs, cross sectional imaging, and almost always, an invasive intervention (percutaneous drainage or return to the operating room [OR]) which increases length of stay and increase the total cost of that episode of care.[3,4]

Hospitals work to improve surgical quality and reduce costs in several ways, including engaging in local quality improvement initiatives, clinical quality registries, and collaboratives (i.e., groups of hospitals working together to improve care). However, hospitals are unable to accurately quantify the financial benefit of their efforts as current cost estimates of individual complications are inadequate for several reasons. First, financial estimates are frequently based on one of two approaches, both of which fail to reflect the cost of a complication. One of these is to assign the payer payment as a proxy for cost, (e.g., Medicare’s Diagnosis Related Group [DRG]); another is to use hospital charges, which vary significantly from hospital to hospital and do not reflect the actual costs that hospitals experience. Second, if actual cost data are available, they are limited to estimates using single institutional cost information and are not focused on individual complications.

Estimating the actual hospital costs of complications is important for hospitals to understand the return on investment of undertaking quality improvement work and participating in registries and collaboratives to reduce surgical complication rates, all of which require substantial hospital investment and resources.[5–7] However, robust estimation of the actual hospital cost of individual complications have generally not been attempted. Therefore, our objective was to estimate the actual hospital cost of individual 30-day postoperative complications by merging detailed cost and clinical data from a diverse group of hospital types (community, comprehensive community, academic medical center).

METHODS

Data Source and Study Population

Between January 1, 2016 and December 31, 2016, patients who underwent any general surgery, colorectal, otolaryngology, gynecology, neurosurgery, orthopedic, urology or vascular procedure at one of four hospitals the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) were included in this study. The four hospitals included a quaternary care, 894-bed academic medical center, a 392-bed comprehensive community hospital, a 198-bed community hospital, and a 159-bed community hospital. Each hospital is located in a separate geographic location serving different patient populations.

The details of the ACS NSQIP, including the sampling strategy, data abstraction procedures, variables collected, outcomes and structure have been detailed elsewhere.[8–17] In brief, hospitals collect standardized and audited clinical data on patient demographics, preoperative variables, and postoperative complications for a predefined sample of patients. Each hospital has clinical data abstractor(s) who use standardized definitions to collect and report data to ACS NSQIP. Onsite data audits are regularly performed. Patient follow up is 30-days from the index operation, irrespective of whether the patient is an inpatient, has been discharged to another facility, or has been readmitted to another hospital. Patients are followed up by surgical clinical reviewers at each participating hospital who examine the medical record, query involved clinicians, and directly contact patients when needed to ascertain the required ACS NSQIP data elements.

Cost data

Actual, 30-day internal cost data were obtained from the finance department at each hospital for each patient reported by the hospitals to ACS NSQIP. Costs were summed for each individual patient based on the index hospital stay and all subsequent inpatient or outpatient encounters that may have occurred within 30-days from the date of surgery. Total cost was defined as the sum of the fixed direct (e.g., nurse salaries), variable direct (e.g., drugs, medical supplies), fixed indirect (e.g., information technology, medical records), and variable indirect (e.g., housekeeping, food services) costs.

Outcomes

ACS NSQIP collects data on postoperative complications whether or not the event occurred at the same or a different facility within 30-days from the day of the index surgery.[18,19] Thirty-day complications were assessed using standardized definitions and included prolonged ventilation, unplanned intubation, cardiac events, sepsis, superficial Surgical Site Infection (SSI), deep/organ space SSI, renal failure pneumonia, venous thromboembolism (VTE) (deep vein thrombosis and pulmonary embolism), urinary tract infection (UTI), return to the operating room (OR), and readmission. Cardiac events included both myocardial infarction and cardiac arrest. In addition, anastomotic leak and postoperative ileus events were evaluated in a separate cohort of patients undergoing colorectal surgery as part of the ACS NSQIP Procedure Targeted program, given that colorectal procedures are frequently the focus of quality improvement initiatives.[20]

Statistical Analysis

Unadjusted costs for each complication were calculated by assessing the difference between the total median cost among patients with a single complication event (i.e., no other complications except the one being examined) and among patients without any complication events. This was performed separately for each individual complication. For example, to calculate the cost of prolonged ventilation, the total median cost among patients who experienced a prolonged ventilation event (in the absence of any other complication) was subtracted from the total median cost among patients who experience no complication events.

Adjusted costs of individual complications were calculated using median regression with robust standard errors at the facility level. A single model was constructed that included preoperative factors (ASA class, diabetes, body mass index [BMI], dyspnea, congestive heart failure [CHF], chronic obstructive pulmonary disease [COPD], and sepsis), surgical details (procedure type, emergency surgery status), and postoperative factors (inpatient or outpatient admission status). The exposure variables of interest were 30-day complications. All surgical complications except readmission and return to the OR were included in the same model. Readmission and return to the OR are intermediate outcomes and were evaluated in separate, individual models. Cost of individual complications generated from the median regression analysis reflects the added total cost of a particular complication (net of all other covariates in the model, including other complications if they were in the model) on the adjusted median cost. For example, unplanned intubation raised costs at the median by $26,718 (95% CI 15,374, 38,062) after controlling for other factors including other complications in the model.

Since anastomotic leak and postoperative ileus complication data were only available after colectomy, a separate model in this cohort of patients was constructed to estimate costs. Deep/organ space SSI was excluded from this model as it clinically could possibly represent the same complication event as anastomotic leak.

Sensitivity analyses were performed using an alternative modeling strategy with gamma regression to assess the robustness of our results. Gamma regression was chosen as it accounts for the non-normal and right-skewed nature of cost data.[21,22] Gamma regression with log link is a commonly used method for health care cost analysis.[23,24] Given that the coefficients from the log-gamma model do not have a straightforward interpretation, our analytic approach requested marginal effects[25] in terms of dollars. For each complication, it estimated predicted mean cost from the model if all cases in the data had the complication (maintaining all other covariates as they are) and also estimated the predicted mean cost from the model if all cases did not have the complication (again, with other variables taken at their actual values). The difference of the marginal effects is the cost of the complication. Estimates are not additive with this approach. Additional analyses were also performed excluding emergency cases, only including general and colorectal procedures and including interaction terms of clinically relevant complications (prolonged ventilation and unplanned intubation, sepsis and deep/organ space SSI, sepsis and pneumonia).

All tests were two-sided and the significance level was set at $P<0.05$. All analyses were performed using STATA/MP 14.1 (College Station, TX) and SAS version 9.4 (SAS Institute, Cary, NC). The Northwestern University Institutional Review Board deemed the study exempt from human subjects review

RESULTS

From four hospitals, 6,387 patients were identified, the majority of whom underwent an orthopedic (38.8%), general surgery (15.3%) or colorectal (13.9%) procedure. There were 607 patients who underwent colon surgery and were monitored as part of the ACS NSQIP Procedure Targeted program and were included in the separate analysis of anastomotic leak and postoperative ileus events. Overall, the median age was 61 years (IQR=21). The majority of patients were ASA class I or II (61.4%) and were inpatients (61.8%). Most patients underwent a non-emergent operation (93.2%). Additional patient and procedure details are presented in Table 1.

Unadjusted complication rates are presented in Table 2. In the overall cohort, unadjusted complication rates ranged from 0.4% (renal failure) to 4.9% (readmission). Among the 607 patients who underwent colon surgery, the incidence of anastomotic leak was 4.5% and postoperative ileus was 18.6%.

The unadjusted cost of individual complications are presented in Table 3. The three complications associated with the highest median cost were prolonged ventilation ($46,237), unplanned intubation ($42,487), and cardiac event ($24,017). The three complications associated with the lowest median cost were UTI ($3,847), superficial SSI ($6,477), and readmission ($8,524). The two intermediate complications assessed were associated with a median cost of $8,524 for readmission and $15,166 for return to the OR. After colon surgery, the associated median cost of anastomotic leak was $18,903 and postoperative ileus was $15,797.

We next estimated the independent cost of individual complications after adjustment for preoperative, intraoperative, and postoperative factors including the occurrence of other complications (Table 3). The three complications associated with the highest adjusted cost were prolonged ventilation ($48,168, 95% CI $21,861, $74,476), unplanned intubation ($26,718, 95% CI $15,374, $38,062), and renal failure ($18,528, 95% CI $17,076, $19,981). The three complications associated with the lowest adjusted cost were UTI (-$372, 95% CI -$1,336, $592), superficial SSI ($2,473, 95% CI -$256, $5,201), and VTE ($7,909, 95% CI -$17,903, $33,721). For the two intermediate outcomes assessed, the adjusted cost was $8,020 (95% CI $4,597, $11,444) for readmission and $20,258 (95% CI $13,537, $26,978) for return to the OR. In the colon surgery only model, the adjusted cost of anastomotic leak was $10,195 (95% CI $5,941, $14,449), while the postoperative ileus cost was $10,205 (95% CI $6,259, $14,149).

Sensitivity analyses were performed to test the robustness of our main findings to differences in our analytic approach. First, an alternative modeling approach using gamma regression revealed qualitatively similar results for some but not all complications. However, the estimates were unstable in the gamma regression models. Since, the total cost distribution demonstrated a minimal rightward skew, we therefore choose to use median regression. In separate sensitivity analyses, after excluding emergency cases, there were no qualitative differences in risk adjusted costs (Table 4). Finally, risk adjusted costs when focused just on general and colorectal procedures were also similar, with one notable exception (Table 4). Specifically, return to the OR was 20,258 (95% CI 13,537, 26,978) in the overall model and $33,818 (95% CI 29,694, 37,941) for general surgery and colorectal procedures. Models which included clinically relevant interaction terms were either not significant or resulted in qualitatively similar findings, and therefore are not reported.

DISCUSSION

Using data from different hospital types, we sought to estimate the actual cost of individual 30-day complications after a wide range of surgical procedures. The complications with the highest risk-adjusted cost per complication were associated with organ dysfunction: prolonged ventilation, unplanned intubation, renal failure, and cardiac event. Other complications, which occurred with considerably higher frequency, were associated with moderate cost per event and included readmission, return to the OR, anastomotic leak, and postoperative ileus. To our knowledge, this is the most comprehensive, generalizable assessment of the actual hospital costs of individual postoperative complications to date and uniquely enables hospitals to estimate the return on investment of their quality improvement efforts.

A number of prior studies have attempted to evaluate the cost of complication. In a study that used ACS NSQIP data merged with institutional direct cost data, Dimick and colleagues estimated cost of complications in categories (e.g., infectious, cardiovascular, respiratory).[26] This study reported the highest complication cost was associated with respiratory events (adjusted cost, $52,466). Similar to our study, their analysis adjusted for patient, procedure, and postoperative factors including the occurrence of other complications. However, individual complications were not assessed, precluding estimating cost savings of targeted efforts which focus on the structural and process of care related to an individual postoperative complication event. In a more recent study by Healy et al., complication costs were estimated based on total direct and indirect costs of care at a single academic medical center.[27] They report complications increased the cost of care, on average, by nearly $20,000. Seven individual complications were assessed. In addition, their focus was on relative changes in the hospital profit margin rather than absolute estimated costs of these complications. While instructive, this study was from a single academic medical center limiting a broader generalizability.

In our study, we comprehensively evaluated the unadjusted and adjusted cost of 14 complications using high-quality clinical complication data and total internal cost data from four diverse hospitals. When considered as individual events, we found that several complications were associated with a substantial cost burden. These high-cost complications represented organ dysfunction events, particularly respiratory events, as demonstrated by Dimick et al.[26] For example, the most costly complication was prolonged ventilation which was associated with a median adjusted cost of $48,168. This is nearly 2-fold higher when compared to the next most costly complication (unplanned intubation, $26,718), and 5-fold higher than others (e.g., pneumonia, $9,401).

When assessing complication cost in the context of their overall financial burden, it is important to also consider their frequency and potential preventability. Low cost but frequent, modifiable events may represent a more important target for hospital quality improvement efforts. For example, one of the most common complications after colon surgery is postoperative ileus. Although this event was associated with a lower adjusted cost ($10,205), it occurred in nearly 1 in 5 colon resection patients in our study. Prior work has demonstrated that enhanced recovery pathways can greatly reduce colorectal complications such as ileus.[28] Therefore for a hospital commonly performing colon surgery, ileus may represent a more impactful cost saving target while other centers may have high rates of postoperative pneumonia and tailored process improvement interventions focused on pulmonary events could be an appropriate focus.

Additional work has reported costs of complications estimated based on hospital charges or insurance payments. Charges have little association with actual costs of care.[29] Insurance reimbursement is widely variable depending on payer and hospital-specific negotiations, limiting its utility in cost analyses.[29] Medicare payments are additionally limited in that they are based on DRGs, blunting the relationship between individual complications and costs.[30] It is also important note that cost data is not publicly available. Increased transparency and reporting of healthcare costs at individual hospitals would allow patients, providers, and payers the ability to better understand and select high value hospitals.

There are several limitations to consider. First, there is unclear generalizability to other hospitals as our data may be unique to region and specific hospital cost structure. We attempted to address this limitation by including a diverse group of hospital types from different regions including small community, comprehensive community and a single large academic medical center. Second, methodological challenges exist when assigning cost to individual events as complications are often not mutually exclusive. We attempted to account for this by adjusting for all complications in the same model and estimating their individual contribution to the cost of care. We also addressed complications which may represent the same postoperative event by performing separate analyses, (e.g., reoperation, readmission). Furthermore, the complications included in the same median regression model are additive. Third, this study only addressed hospital-based costs, not costs that may have occurred outside that specific hospital. Costs of care outside the index hospital is relatively infrequent and unlikely to bias our results.[31,32] Nevertheless, including any external costs would only increase the magnitude of our findings and therefore, our results can be considered conservative estimates. Fourth, this study does not evaluate hospital level variation in complication costs. This may bias the finding in the direction of the higher volume facilities which include the 894-bed academic medical center and the 392-bed comprehensive community hospital. Finally, there are substantial secondary costs associated with regulatory constraints, for example value-based purchasing evaluations, of certain complications (e.g., catheter associated urinary tract infections). These efforts are not captured by our data.

Conclusion

In one of the first studies to detail actual cost of individual complications, we found organ failure or dysfunction events were uncommon but associated with the greatest cost per event. More frequent, potentially preventable events, such as ileus and SSI, were associated with lower cost per event. This study defines a replicable methodology which can be efficiently implemented in other hospitals for useful local estimates of the cost of complications. These data can be used to estimate the financial benefit of engaging in local quality improvement initiatives and participation in registries and quality improvement collaboratives.

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Table 1.

Characteristics of patients who underwent surgery at one of four hospitals in 2016 (n=6,387).

Patient Characteristics	
Age, median (IQR)	61 (21)
	N (%)
Gender (%)	
Female	3745 (58.63)
Male	2642 (41.37)
Race (%)	
White	5323 (83.34)
Black	400 (6.26)
Asian	140 (2.19)
American Indian or Alaska Native	10 (0.16)
Other/Unknown	514 (8.05)
Diabetes (%)	
Insulin	282 (4.42)
Oral	569 (8.91)
No	5536 (86.68)
BMI (kg/m ^{2}) (%)	
Underweight (<18.5)	79 (1.24)
Normal (18.5–24.9)	1385 (21.68)
Overweight (25.0–29.9)	1997 (31.27)
Class 1 Obese (30.0–34.9)	1514 (23.70)
Class 2 Obese (35.0–39.9)	781 (12.23)
Class 3 Obese (≥ 40.0)	631 (9.88)
Dyspnea (%)	
At rest	3 (0.05)
Moderate exertion	96 (1.50)
No	6288 (98.45)
Congestive heart failure (%)	
Yes	50 (0.78)
No	6337 (99.22)
History of COPD (%)	
Yes	206 (3.23)
No	6181 (96.77)
ASA classification (%)	
I	519 (8.13)
II	3402 (53.26)
III	2292 (35.89)

Patient Characteristics	
IV–V	174 (2.72)
Functional Status (%)	
Independent	6364 (99.64)
Dependent	23 (0.36)
Preoperative sepsis	
Sepsis	68 (1.06)
SIRS	121 (1.89)
None	6198 (97.04)
Pre-operative Renal failure	
Yes	7 (0.11)
No	6380 (99.89)
Surgery Setting (%)	
Inpatient	3949 (61.83)
Outpatient	2438 (38.17)
Emergency Surgery	
Yes	432 (6.76)
No	5955 (93.24)
Procedure Type	
Orthopedics	2481 (38.84)
Gen surgery	975 (15.27)
Colorectal	887 (13.89)
Breast	380 (5.95)
Gynecology	361 (5.65)
Neurology/Spine	338 (5.29)
Urology	251 (3.93)
Vascular	239 (3.74)
Hepatopancreatobiliary	236 (3.7)
Ear/Nose/Throat	160 (2.51)
Foregut	79 (1.24)

SIRS, systemic inflammatory response syndrome

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Table 2.

Unadjusted thirty-day complication rates after surgery (n=6387).

Complication	Number of Events	Complication Rate (%)
Prolonged ventilation	38	0.6
Unplanned intubation	39	0.61
Cardiac	27	0.42
Renal failure	26	0.41
Pneumonia	55	0.86
Sepsis	59	0.94
VTE	100	1.57
Deep/Organ Space SSI	80	1.25
UTI	78	1.22
Superficial SSI	66	1.03
Readmission	310	4.85
Return to operating room	135	2.11
Anastomotic leak*	27	4.45
Postoperative Ileus*	113	18.62

*Colectomy only, N=607

VTE, venous thromboembolism; SSI, surgical site infection; UTI, urinary tract infection

Table 3.

Unadjusted and adjusted thirty-day total cost of individual complications after surgery

	Single Complication		Multiple Compilations		Median Regression		
Complication	**Number of Events[∞] N, (%)**	**Unadjusted Cost[*] ($)**	**Number of Events N, (%)**	**Unadjusted Cost[*] ($)**	**Adjusted Cost**	**95% Confidence Interval**	**P value**
Prolonged ventilation	2 (0.03)	46,237	36(0.56)	102,608	48,168	(21861, 74476)	<0.001
Unplanned intubation	7 (0.11)	42,487	32(0.5)	89,388	26,718	(15374, 38062)	<0.001
Cardiac event	13 (0.2)	24,017	14(0.22)	62,584	15,109	(9601, 20618)	<0.001
Renal failure	12 (0.19)	17,729	14(0.22)	116,381	18,528	(17076, 19981)	<0.001
Pneumonia	24 (0.38)	16,905	31(0.49)	77,036	9,401	(5878, 12925)	<0.001
Sepsis	8 (0.13)	18,158	51(0.8)	35,392	12,440	(5905, 18974)	<0.001
DVT/VTE	72 (1.13)	9,720	28(0.44)	89,926	7,909	(−17903, 33721)	0.548
Deep+Organ Space SSI	41 (0.64)	17,990	39(0.61)	37,681	12,135	(6321, 17949)	<0.001
UTI	62 (0.97)	3,847	16(0.25)	30,034	(372)	(−1336, 592)	0.449
Superficial SSI	48 (0.75)	6,477	18(0.28)	23,716	2,473	(−256, 5201)	0.076
Readmission[†]	134 (2.10%)	8,524	176(2.76)	17,494	8,020	(4597, 11444)	<0.001
Return to OR†	38 (0.59%)	15,166	97(1.52)	30,305	20,258	(13537, 26978)	<0.001
Anastomotic leak[ǂ]	9 (1.48)	18,903	18(2.97)	46,048	10,195	(5941, 14449)	<0.001
Ileus[ǂ]	48 (7.91)	15,797	65(10.71)	42,545	10,205	(6259, 14149)	<0.001

[∞] Number of events is lower here because the complication had to occur in isolation without any other complications.

[*] Unadjusted costs determined by subtracting median cost of the single complication in isolation or if it occurred with other complications from the median cost if no complication occurred

[†] Estimated from separate models that did not include other complications

[ǂ] Colectomy only N=607

VTE, venous thromboembolism; SSI, surgical site infection; UTI, urinary tract infection

Table 4.

Sensitivity analyses of the risk adjusted total thirty-day costs after excluding emergency cases or including only general and colorectal procedures.

	Median Regression without emergency procedures			**Median Regression with general surgery and colorectal procedures only**		
Complication	**Adjusted Cost ($)**	**95% Confidence Interval**	**P value**	**Adjusted Cost ($)**	**95% Confidence Interval**	**P value**
Prolonged ventilation	48,263	38073, 58452	<0.001	45,312	41353, 49272	<0.001
Unplanned intubation	26,732	15154, 38310	<0.001	20,550	20107, 20994	<0.001
Cardiac event	15,056	13183, 16930	<0.001	14,222	6468, 21977	<0.001
Renal failure	18,555	17184, 19926	<0.001	23,154	15241, 31068	<0.001
Pneumonia	9,374	5901, 12847	<0.001	3,536	−7270, 14342	0.521
Sepsis	8,320	5361, 11279	<0.001	13,033	9905, 16160	<0.001
VTE	7,926	−13649, 29502	0.471	13,214	6860, 19567	<0.001
Deep/Organ Space SSI	12,148	8600, 15696	<0.001	14,315	−11272, 39902	0.273
UTI	(346)	−715, 22	0.066	(43)	−1703, 1618	0.96
Superficial SSI	2,462	−172, 5095	0.067	2,477	1653, 3301	<0.001
Readmission *	8,024	4369, 11679	<0.001	7,225	2935, 11514	0.001
Return to OR *	20,258	13570, 26946	<0.001	33,818	29694, 37941	<0.001
Anastomotic leak †	10,389	4491, 16288	0.001	10,195	5942, 14449	<0.001
Postoperative Ileus †	10,187	7540, 12835	<0.001	10,205	6260, 14149	<0.001

* Estimated from separate models that did not include other complications

† Colectomy only N=607

VTE, venous thromboembolism; SSI, surgical site infection; UTI, urinary tract infection