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Retrospective cohort study comparing surgical inpatient charges, total costs, and variable costs as hospital cost savings measures

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Abstract

We analyzed differences (charges, total, and variable costs) in estimating cost savings of quality improvement projects using reduction of serious/life-threatening complications (Clavien-Dindo Level IV) and insurance type (Private, Medicare, and Medicaid/Uninsured) to evaluate the cost measures. Multiple measures are used to analyze hospital costs and compare cost outcomes across health systems with differing patient compositions. We used National Surgical Quality Improvement Program inpatient (2013–2019) with charge and cost data in a hospital serving diverse socioeconomic status patients. Simulation was used to estimate variable costs and total costs at 3 proportions of fixed costs (FC). Cases (Private 1517; Medicare 1224; Medicaid/Uninsured 3648) with patient mean age 52.3 years (Standard Deviation = 14.7) and 47.3% male. Medicare (adjusted odds ratio = 1.55, 95% confidence interval = 1.16–2.09, $P = .003$) and Medicaid/Uninsured (adjusted odds ratio = 1.41, 95% confidence interval = 1.10–1.82, $P = .008$) had higher odds of complications versus Private. Medicaid/Uninsured had higher relative charges versus Private, while Medicaid/Uninsured and Medicare had higher relative variable and total costs versus Private. Targeting a 15% reduction in serious complications for robust patients undergoing moderate-stress procedures estimated variable cost savings of $286,392. Total cost saving estimates progressively increased with increasing proportions of FC; $443,943 (35% FC), $577,495 (50% FC), and $1184,403 (75% FC). In conclusion, charges did not identify increased costs for Medicare versus Private patients. Complications were associated with > 200% change in costs. Surgical hospitalizations for Medicare and Medicaid/Uninsured patients cost more than Private patients. Variable costs should be used to avoid overestimating potential cost savings of quality improvement interventions, as total costs include fixed costs that are difficult to change in the short term.

Abbreviations: CDIV = Clavien-Dindo IV, CPT = current procedural terminology, EHR = electronic health records, FC = fixed costs, NSQIP = National Surgical Quality Improvement Program, OSS = operative stress score, RAI = risk analysis index, SNH = safety-net hospitals.

Keywords: hospital costs, surgical hospitalizations, variable costs

JK and MAJ contributed equally to this work.

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The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

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1. Introduction

Healthcare costs in the United States continue to rise for hospital systems[1] and the federal government.[2,3] The federal government historically addressed rising healthcare costs with changes to existing payment models, with limited success.[4] Pay for performance programs[5–7] are the most recent example of these changes. These programs have disproportionately penalized safety-net hospitals (SNH) serving vulnerable populations.[6,8,9] Accountable care organizations have been proposed as a solution to both rising healthcare costs and improving patient quality of care.[10] As more healthcare systems transition to accountable care organizations with upside and downside risk, these systems need to understand their cost data in relation to the population served, especially to evaluate proposed cost-saving interventions.

Studies involving cost data use varied methods.[11] For example, the cost measure itself can be an estimate based on diagnostic-related groups and the length of hospitalization,[12] hospital charges divided by a rescaling ratio,[13] total costs,[12,14] or variable costs.[12,14] Which measure is used often depends on the data available, rather than a method's accuracy for the research question. Using the appropriate measure is important, as the measure used can change how much money an intervention is projected to save.[14] Inpatient operations are responsible for only 28.6% of inpatient hospitalizations but account for 48.4% of hospital costs[15] making surgery a field particularly suited for cost-saving interventions. Frailty,[16,17] operative stress,[18] and post-operative complications[19] are all related to inpatient surgical costs. Insurance type is also associated with surgical costs[20,21] and is often used as a proxy for patient social risk factors,[22] especially dual enrollment in Medicare/Medicaid.[22,23]

Our main objective was to assess appropriate cost measures to project cost savings for quality improvement projects, by examining differences between commonly used measures and the association of insurance type and complication outcomes with these measures. We used surgical inpatient hospitalization charges, total costs, and variable costs within a single healthcare system serving a diverse range of patients across the socioeconomic status spectrum to estimate relative differences in cost based on insurance type and adjusted for complications. Secondary objectives included using simulation to assess the effect of different levels of fixed cost on total cost-saving estimates.

2. Methods

2.1. Study population and data

This retrospective cohort study used data on all patients undergoing inpatient procedures contained in the 2013 to 2019 American College of Surgeons National Surgical Quality Improvement Program (NSQIP) at an academic medical center and SNH following STROBE Reporting Guidelines.[24] NSQIP variables were used for cohort identification, as well as providing standardized definitions of preoperative risk factors and complications.[25] Patient self-reported race and ethnicity were derived from NSQIP variables and electronic health records (EHR). The Institutional Review Board of the University of Texas Health San Antonio approved this study and waived informed consent.

2.2. Estimating patient frailty

Frailty was measured using the recalibrated Risk Analysis Index (RAI)[26] using NSQIP preoperative variables, as previously described.[27] RAI scores were grouped into Robust (≤20), Normal (21–29), Frail (30–39), and Very Frail (≥40).

2.3. Expanded operative stress score (OSS) assignment

The OSS estimates surgical-induced physiologic stress of procedures across surgical specialties based on Current Procedural Terminology (CPT) codes by assigning a score ranging from 1-5, with 1 and 5 representing very low and very high physiological stress, respectively. We used the expanded OSS[27] with 2343 CPT codes, providing improved case coverage for non-majority male populations compared to the original OSS.[28] After excluding cases without an expanded OSS assigned to the principal OSS, OSS was assigned using the highest score for all available procedures within each case.[27]

2.4. Clavien-Dindo IV (CDIV) 30-day complications

Clavien-Dindo classifies complications based on their treatments.[29] We approximated CDIV complications using the NSQIP variables of postoperative septic shock, postoperative dialysis, pulmonary embolus, myocardial infarction, cardiac arrest, prolonged ventilation, reintubation, or stroke, as previously reported.[27]

2.5. Insurance type

The identified, local NSQIP data were combined with EHR and managerial accounting data to classify insurance type as a proxy for social risk factors and to specify cost of the index hospitalization. Insurance type was categorized based upon billing data for the encounter, supplemented by EHR data, and defined as: Private insurance including Tricare and Workers' Compensation; Medicare including patients where Medicare was the primary payor and private insurance was listed as a secondary payor; and Medicaid/Uninsured including Medicaid, dual enrollment in Medicare/Medicaid, Charity Care, self-pay with < 1% of charges paid, or county indigent care programs.[30] "Other" included encounters billed to the Veterans Health Administration, Department of Corrections, or self-pay with > 1% of charges collected and were excluded (n = 87).

2.6. Cost data

We defined total charges as amounts billed for the index hospitalization.[31] We employed internal cost accounting to subdivide total costs into variable and fixed costs. Our hospital used EPSi for internal cost accounting. EPSi provides an array of accounting functions including real-time costing, operating margin, budgeting, capital planning, productivity measurement, and decision support. We defined variable costs as costs related directly to patient care occurring during the encounter, such as supplies and salaries, and include direct variable costs that vary directly with the quantity of resources provided for patient care. In contrast, fixed costs remain the same regardless of the number of patients served.[32] Total costs were defined as variable + fixed costs. Charges, total costs, and variable costs were consistently assigned to all patients regardless of payor type. Outpatient and professional fees were not included in variable or total costs.[33] The Personal Health Care Index[34] was used to adjust the inflation factor to 2019 dollars in this study.

2.7. Management of missing variables

Cases were excluded due to missing: expanded OSS coverage of principal CPT code, variables used to calculate the RAI, and charge/cost variables.

2.8. Study outcomes

Our primary analysis was to assess the association of insurance type with cost estimates using charges, total costs, and variable

costs. As major postoperative complications increase costs,[19,35] a sub-analysis assessed the association of insurance type as a proxy measure for social risk factors on CDIV complications.

A secondary analysis included determining appropriate cost measures to use to project cost savings for an example of a quality improvement project and used simulation to assess the effect of different levels of fixed cost on cost-saving estimates.

2.9. Statistical analysis

Categorical data were summarized using count and percentages and continuous data using mean and standard deviation. Chi-square tests and *F*-tests were used to test for differences between groups for categorical and continuous variables. Logistic regression analyses were performed to assess the association between CDIV complications and insurance type adjusting for a combination of RAI and OSS.

Natural logarithms were used to normalize the skewed distributions of charge, total cost, and variable cost data for the hospitalization, as previously described.[21,36] Log-linear regression models estimated the log-normalized total charges, total costs, and variable costs using RAI, OSS, CDIV, and insurance type. The percent change of charges and costs associated with unit change of a variable was calculated with the remaining reference variables held constant. A sensitivity analyses was performed on the charge/costs outcomes that excluded cases with patient death during the index hospitalization (n = 107).

To better understand the impact of different proportions of fixed costs, and to better quantify the uncertainty in variable costs, sensitivity analyses via stochastic simulation[37] were performed. Specifically, triangular distributions were used in the simulations to obtain distributions for variable costs and total costs (total costs = variable costs + fixed costs) under 3 proportions of fixed costs (35%, 50%, and 75%), for patients with and without CDIV complications in the 3 insurance groups. The 3 proportions of fixed costs were chosen to represent the range of fixed costs present across hospital systems. The triangular distribution with 500 replications used 3 inputs from the log-linear regression model of the variable cost data; lower, expected, and upper limits of the 95% confidence intervals of the parameter estimates for each variable. Predicted costs at each of these values were obtained using the log-linear model, which then served as the minimum, most likely, and maximum cost values in the triangular simulation of variable costs. Analyses were performed using R 4.1.1 (2021-08-15) and the "triangle" package.

3. Results

3.1. Population characteristics

Our cohort included 6389 cases of inpatient procedures at a major urban SNH present in the 2013-2019 NSQIP (Fig. 1). Cases (Table 1) were more commonly performed on White patients (91.2%), followed by Black (6.3%), and other racial groups (2.3%); 67.1% of patients identified as being of Hispanic ethnicity. Patients had a mean (standard deviation) age of 52.3

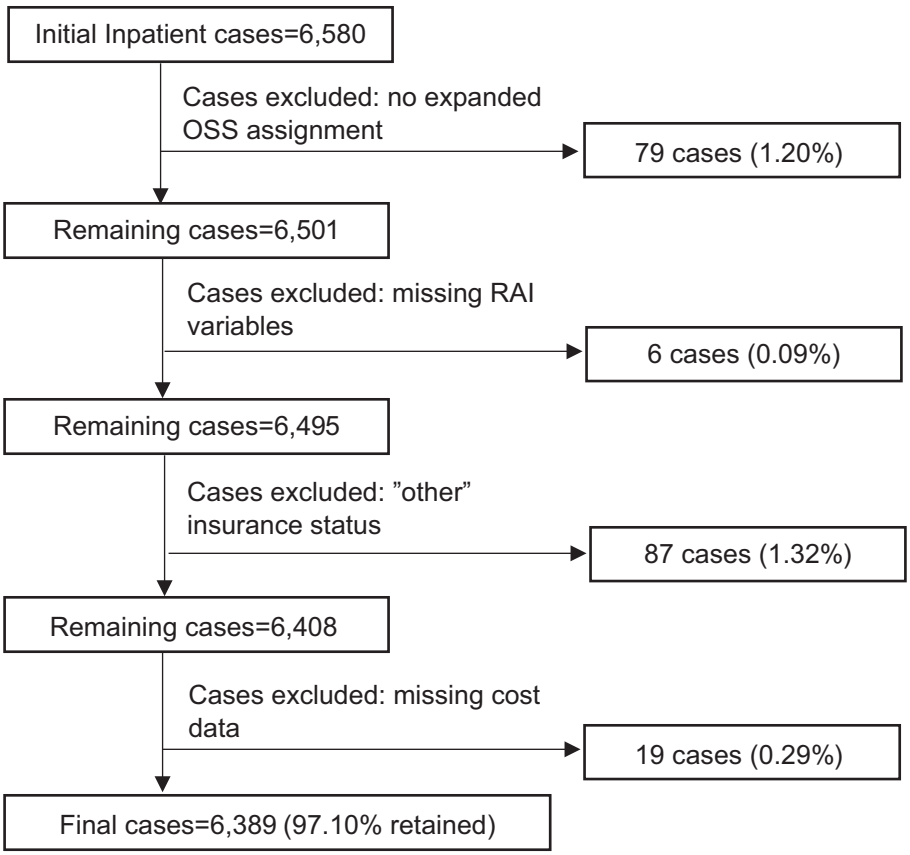

Figure 1. Flow diagram of study cohort. NSQIP inpatient cases from 2013–2019. Cases were excluded for having no expanded OSS assignment for the principal CPT code, missing variables used to calculate the RAI, "other" insurance status, and missing cost data. "Other" insurance status is defined as included encounters billed to the Veterans Administration, Department of Corrections or self-pay with > 1% of charges collected. Cases lacking an expanded OSS assignment for the principal CPT code were excluded to avoid erroneously assigning a lower stress OSS based upon additional procedures that were performed. For example, a principal CPT code for a highly stressful procedure not assigned an expanded OSS could be assigned an OSS1 (very low stress) if the additional CPT codes contained any procedure with an expanded OSS rating. CPT = current procedural terminology, NSQIP = National Surgical Quality Improvement Program, OSS = operative stress score, RAI = risk analysis index.

Table 1

Patient characteristics and clinical outcomes by insurance type.

	Overall	Private	Medicare	Medicaid/Uninsured	*P* value
Number (%)*	6389	1517 (23.7)	1224 (19.2)	3648 (57.1)	
Age mean (SD)	52.3 (14.7)	48.4 (12.4)	66.8 (11.0)	49.1 (13.7)	**<.001**
Sex					**<.001**
Female	3367 (52.7)	916 (60.4)	577 (47.1)	1874 (51.4)	
Male	3022 (47.3)	601 (39.6)	647 (52.9)	1774 (48.6)	
Race					**.01**
Black	403 (6.3)	90 (5.9)	64 (5.2)	249 (6.8)	
White	5828 (91.2)	1376 (90.7)	1137 (92.9)	3315 (90.9)`	
Unknown	11 (0.2)	4 (0.3)	4 (0.3)	3 (0.1)	
Other†	147 (2.3)	47 (3.1)	19 (1.6)	81 (2.2)	
Hispanic Ethnicity	4289 (67.1)	860 (56.7)	670 (54.7)	2759 (75.6)	**<.001**
RAI (frailty)					**<.001**
Robust (≤20)	4218 (66.0)	1200 (79.1)	327 (26.7)	2691 (73.8)	
Normal (21-29)	1544 (24.2)	224 (14.8)	657 (53.7)	663 (18.2)	
Frail (30-39)	512 (8.0)	81 (5.3)	195 (15.9)	236 (6.5)	
Very Frail (≥40)	115 (1.8)	12 (0.8)	45 (3.7)	58 (1.6)	
Expanded OSS (surgical-induced physiologic stress level)					**<.001**
OSS1 (very low)	143 (2.2)	32 (2.1)	17 (1.4)	94 (2.6)	
OSS2 (low)	1553 (24.3)	280 (18.5)	254 (20.8)	1019 (27.9)	
OSS3 (moderate)	3445 (53.9)	866 (57.1)	663 (54.2)	1916 (52.5)	
OSS4 (high)	1080 (16.9)	293 (19.3)	220 (18.0)	567 (15.5)	
OSS5 (very high)	168 (2.6)	46 (3.0)	70 (5.7)	52 (1.4)	
CDIV Complications	523 (8.2)	86 (5.7)	154 (12.6)	283 (7.8)	**<.001**

CDIV = Clavien-Dindo Level IV, OSS = operative stress score, RAI = risk analysis index, SD = standard deviation.

*Percent calculations by row, the rest of the percent calculations were by column.

†Other included 2 American Indian or Alaska Natives, 3 Native Hawaiians or Other Pacific Islanders, 82 Asian, and 60 Multi-Racial.

(14.7) years, and slightly more than half of all patients were female (52.7%). Additionally, most patients were classified as having a Medicaid/Uninsured insurance type (57.1%), followed by Private (23.7%), and Medicare (19.2%). Regarding patient frailty, RAI scores primarily assessed patients as robust (66.0%) and normal (24.2%), with only 8.0% and 1.8% of patients evaluated as being frail and very frail, respectively. Medicare patients exhibited higher rates of frailty compared to Private and Medicaid/Uninsured insurance type patients. Surgeries were primarily categorized as low or moderate stress, OSS2 (24.3%) or OSS3 (53.9%), respectively. CDIV complications were higher in Medicare and Medicaid/Uninsured patients compared to Private.

3.2. Increased odds of 30-day CDIV complications in Medicare and Medicaid/Uninsured patients

Rates of CDIV complications were 8.2% overall and were highest in the Medicare patients (12.6%, Table 1). Robust patients had lower adjusted odds of experiencing CDIV complications compared to normal patients (Table 2). Increasing OSS/operative stress was associated with increased odds of CDIV complications. Medicare and Medicaid/Uninsured insurance type patients had increased odds of CDIV complications compared to Private, (adjusted odds ratio = 1.55, 95% confidence interval (95% CI) = 1.16–2.09, $P = .003$) and (adjusted odds ratio = 1.41, 95% CI = 1.10–1.82, $P = .008$), respectively.

3.3. Increased variable and total costs, but not charges, for Medicare compared to Private patients

Log-linear regression models for charges, total costs, and variable costs were performed to compare the 3 measures (Table 3). For all 3 measures, the %change was: lower for robust patients and higher for very frail patients compared to normal, lower for OSS1-2 procedures and progressively higher for OSS4 and OSS5, compared to OSS3 procedures, and higher, ranging from 194% (95% CI = 178%–211%) - 209% (95% CI = 191%–229%), for patients experiencing CDIV complications. In contrast, the total charges of Medicare patients were similar while Medicaid/Uninsured insurance type patients were higher compared to Private insurance patients. However, Medicare and Medicaid/Uninsured insurance type patients' %changes were higher for total costs and variable costs compared to Private.

We performed a sensitivity analysis on the charge/costs outcomes excluding cases with patient death during the index hospitalization (n = 107) (see Table S1, Supplemental Digital Content, http://links.lww.com/MD/I13, for result coefficients). Results were similar to the original cohort for Medicare and Medicaid/Uninsured patients compared to Private.

3.4. Outliers in the variable costs for CDIV complication patients

We used reduction of CDIV complications in robust patients undergoing OSS3 (moderate stress) procedures as an example of a clinical improvement project to evaluate variable cost predictions for patients in the 3 insurance categories. The variable cost data for CDIV complications have a significantly higher mean than median, secondary to high-cost outliers (Table 4). The skewed cost distribution was also observed in cases without CDIV complications.

3.5. Cost savings simulation for variable costs and total costs with different proportions of fixed costs

Our cohort represents a high safety-net burden with 23.7%, 19.2%, and 57.1% of cases in the Private, Medicare, and Medicaid/Uninsured insurance type groups, respectively (Table 1). CDIV complications greatly increase costs (Tables 3 and 4). We used simulation to estimate the cost savings of reducing CDIV complications by 15% for robust patients undergoing OSS3 surgeries for patients in the 3 insurance categories. Triangular simulation from the log-linear model (Table 3) was used to estimate variable costs to better account for the variability in costs. Three proportions of fixed costs

Table 2

CDIV Complications adjusted for frailty, surgical-induced operative stress and insurance type.

	CDIV Complications	
	aOR (95% CI)	*P* value
RAI (Ref = Normal 21–29)		
Robust (≤20)	0.46 (0.37–0.57)	**<.001**
Frail (30–39)	1.31 (0.99–1.74)	.06
Very Frail (≥40)	1.36 (0.80–2.23)	.23
OSS (Ref = OSS3)		
OSS1–2*	0.77 (0.60–0.98)	**.04**
OSS4	1.63 (1.30–2.04)	**<.001**
OSS5	1.67 (1.05–2.58)	**.02**
Insurance (Ref = Private)		
Medicare	1.55 (1.16–2.09)	**.003**
Medicaid/Uninsured	1.41 (1.10–1.82)	**.008**

aOR = adjusted odds ratio, CDIV = Clavien-Dindo Level IV, 95% CI = 95% confidence interval, OSS = operative stress score, RAI = risk analysis index, Ref = reference value.

*OSS1 and OSS2 (very low and low stress surgeries) were combined due to small sample size of OSS1 procedures.

OSS3 moderate stress, OSS4 high stress and OSS5 very high stress.

Table 3

Total charges, total costs, and variable costs adjusted for frailty, surgical-induced operative stress, CDIV complications and insurance type.

	Log (total charges)				Log (total costs)				Log (variable costs)			
	Change (%)	Est	95% CI	*P* value	Change (%)	Est	95% CI	*P* value	Change (%)	Est	95% CI	*P* value
Intercept		11.18	11.13–11.22	**<.001**		10.19	10.14–10.24	**<.001**		9.11	9.06–9.16	**<.001**
RAI (Ref = Normal 21–29)												
OSS1–2*	–20.39	–0.23	–0.27––0.19	**<.001**	–22.66	–0.26	–0.30––0.22	**<.001**	–24.42	–0.28	–0.32––0.24	**<.001**
OSS4 OSS4	3.67	0.04	–0.03–0.10	.26	3.67	0.04	–0.03–0.10	.28	2.94	0.03	–0.04–0.10	.41
OSS5	14.11	0.13	0.02–0.25	**.03**	15.26	0.14	0.02–0.26	**.02**	14.45	0.14	0.01–0.27	**.04**
OSS (Ref = OSS3)												
OSS1–2*	–18.21	–0.20	–0.24––0.17	**<.001**	–15.38	–0.17	–0.21––0.13	**<.001**	–19.10	–0.21	–0.25––0.17	**<.001**
OSS4	43.48	0.36	0.32–0.40	**<.001**	45.94	0.38	0.33–0.42	**<.001**	47.11	0.39	0.34–0.43	**<.001**
OSS5	58.88	0.46	0.37–0.56	**<.001**	62.42	0.49	0.39–0.59	**<.001**	59.20	0.47	0.36–0.58	**<.001**
CDIV	194.17	1.08	1.02–1.14	**<.001**	207.1	1.12	1.06–1.18	**<.001**	209.3	1.13	1.07–1.19	**<.001**
Insurance (Ref = Private)												
Medicare	3.56	0.04	–0.02–0.08	.17	5.76	0.06	0.00–0.11	**.04**	7.90	0.08	0.02–0.13	**.008**
Medicaid/Uninsured	4.92	0.05	0.01–0.09	**.01**	8.22	0.08	0.04–0.12	**<.001**	7.04	0.07	0.03–0.11	**.001**

CDIV = Clavien-Dindo Level IV, 95% CI = 95% confidence interval, Est = estimates, OSS = operative stress score, RAI = risk analysis index, Robust (RAI ≤ 20), Frail (RAI 30–39), Very Frail (RAI ≥ 40), Ref = reference value.

Note: % change is calculated with marginal change of Log (outcome) for 1 unit of each variable change below.

$(e^{\text{intercept+estimated coefficients}} - e^{\text{intercept}})/e^{\text{intercept}} \times 100$, which is equal to $(e^{\text{estimated coefficients}-1}) \times 100$.

*OSS1 and OSS2 (very low and low stress surgeries) were combined due to small sample size of OSS1 procedures.

OSS3 moderate stress, OSS4 high stress and OSS5 very high stress.

(35%, 50%, and 75%) were used to obtain simulated total costs; these simulations used 500 samples for cases with and without CDIV complications for each insurance type (Table 5). The variable costs/case difference between cases with and without CDIV complications was lower in Private ($14,253) compared to Medicaid/Uninsured ($15,270) and Medicare ($15,380) insurance type patients. Increasing the percentage of fixed costs in the total costs simulation resulted in total costs/case differences ranged from $58,941-$63,605 in the 75% fixed costs scenario.

Targeting a 15% reduction in CDIV complications for robust patients undergoing OSS3 procedures, using the case numbers in Table 4, would result in 4, 3, and 12 fewer CDIV complication cases for Private, Medicare, and Medicaid/Uninsured insurance type patients, respectively (Table 5). Total estimated cost savings for all 3 insurance categories was $286,392 for variable costs. Using the estimates of total costs at the 3 proportions of fixed costs resulted in progressively higher estimated savings of $443,943 for 35%, $577,495 for 50%, and $1184,403 for 75% fixed costs.

4. Discussion

This study analyzed cost measures across diverse combinations of surgical procedures and patient socioeconomic status, approximated by insurance type. We used insurance type as a proxy measure for social risk factors. The demographics of the Private and Medicaid/Uninsured insurances type patients were similar regarding age and frailty score distribution in contrast to Medicare patients that were older with higher frailty scores. However, variable and total costs were higher in patients with Medicare and Medicaid/Uninsured insurance type compared to Private, for both cases with and without CDIV complications. Consistent with prior studies, we observed variation in costs by insurance type,[20,21] with major complications having the highest associated costs.[19]

Cost-to-charge ratios are often used to compare costs across hospital systems. However, hospitals may strategically overcharge for some services and undercharge for others[11]; therefore, the same service may have different markups across hospitals.[38] In addition, charges can be more than double the costs.[39] Our analyses demonstrated that hospital charges were

Table 4

Variable cost distributions in 2019 dollars for robust patients undergoing OSS3 procedures by insurance type and CDIV complications.

	Private	Medicare	Medicaid/Uninsured
CDIV complications (N)	**28**	**19**	**79**
Minimum ($)	3568	5071	3687
Q1–Q3 ($)	13,877–60,611	15,788–58,332	15,277–51,720
Maximum ($)	137,135	106,505	251,891
Median ($)	27,608	22,949	27,181
Mean ($)	43,082	36,812	40,083
No CDIV (N)	**678**	**163**	**1381**
Minimum ($)	1086	1945	1093
Q1–Q3 ($)	4584–8914	4930–11,254	4636–10,173
Maximum ($)	114,231	101,555	305,545
Median ($)	6012	7467	6599
Mean ($)	8395	10,484	9324

CDIV = Clavien-Dindo Level IV, OSS3 = expanded operative stress score (3 = moderate stress surgeries), Q1–Q3 = Quartile 1–Quartile 3.
Robust patients are Risk Analysis Index < 20.
All variable costs shown as 2019-dollar values adjusted using the Personal Health Care Index.

Table 5

Variable and total costs simulations in 2019 dollars by insurance type and CDIV complications with different fixed costs levels and estimated cost savings with a 15% reduction in CDIV complications in robust patients undergoing OSS3 cases.

	CDIV Complications	No CDIV Complications	Estimated Cost Savings		
Simulations	Costs/ Case ($) (95% CI)	Costs/ Case ($) (95% CI)	Savings/ Case ($)	Cases (N)*	Total ($)
Private Insurance					
Variable Costs	21,070 (20,998–21,142)	6817 (7332–7379)	14,253	4	57,012
Total Costs with 35% FC	32,661 (32,436–32,885)	10,566 (10,450–10,632)	22,095	4	88,380
Total Costs with 50% FC	42,484 (42,139–42,830)	13,746 (13,639–13,854)	28,738	4	114,952
Total Costs with 75% FC	87,125 (85,753–88,497)	28,184 (27,748–28,619)	58,941	4	235,764
Medicare Insurance					
Variable Costs	22,736 (22,645–22,826)	7356 (7332–7379)	15,380	3	46,140
Total Costs with 35% FC	35,242 (34,989–35,494)	11,401 (11,325–11,475)	23,841	3	71,523
Total Costs with 50% FC	45,842 (45,457–46,225)	14,833 (14,713–14,951)	31,009	3	93,027
Total Costs with 75% FC	94,019 (92,521–95,516)	30,414 (29,938–30,889)	63,605	3	190,815
Medicaid/Uninsured Insurance					
Variable Costs	22,574 (22,490–22,656)	7304 (7283–7324)	15,270	12	183,240
Total Costs with 35% FC	34,990 (34,746–35,232)	11,320 (11,325–11,475)	23,670	12	284,040
Total Costs with 50% FC	45,523 (45,141–45,904)	14,730 (14,610–14,848)	30,793	12	369,516
Total Costs with 75% FC	93,350 (91,870–94,830)	30,198 (29,727–30,668)	63,152	12	757,824
Total Estimated Cost Savings (sum of 3 insurance groups)					
Variable Costs					286,392
Total Costs with 35% FC					443,943
Total Costs with 50% FC					577,495
Total Costs with 75% FC					1184,403

CDIV = Clavien-Dindo Level IV, 95% CI = 95% confidence interval, FC = fixed costs, OSS3 = expanded operative stress score 3.
Triangular simulation was conducted using Robust (Risk Analysis Index ≤ 20) patients and OSS3 (moderate stress) procedures.
All costs shown as 2019-dollar values adjusted using the Personal Health Care Index.
*Number of cases with a 15% reduction in CDIV complications using case numbers from Table 4.

higher for Medicaid/Uninsured, but not Medicare patients, compared to Private insurance. However, Medicaid/Uninsured and Medicare total costs and variable costs were higher than for Private insurance patients. These findings highlight some of the challenges with using charge and cost-to-charge data, that charges are not proportional to healthcare costs and may not be used as a substitute.[40]

While using cost data from a single institution, our study is generalizable in several ways. First, our results suggest that variable costs should be used to estimate potential cost savings. Fixed costs include money used on facilities and equipment and do not vary with the number of patients served.[32] Fixed costs represent a substantial portion of a hospital's budget[32,41] and cannot be reduced in the short term.[42,43] Using total costs, which include fixed costs, will overestimate the projected savings of an intervention. This distortion is greater for institutions with larger fixed cost percentages, such as critical access hospitals[44] and Level 1 Trauma centers.[45,46] Moreover, fixed costs are highly variable between institutions,[47,48] making total costs and charges difficult to compare between hospitals. Second, we used simulation to estimate variable costs more conservatively, due to outliers in the cost data. Using the actual, highly skewed cost data would have resulted in predicting increased costs savings. We used both total costs and variable costs to estimate the predicted costs savings of reducing CDIV complications by 15% on patients from 3 insurance categories. Third, we also demonstrated the cost savings overestimation for total costs, and that higher proportions of fixed costs further inflate potential cost savings.

These results emphasize the cost differences inherent in diverse patient populations and the need for healthcare systems to understand their unique cost structures and populations

served. Accurate assessment of costs becomes increasingly important as more healthcare systems move to capitated contracts with upside and downside risk. The number of patient encounters is also an important consideration, as fixed costs can be spread over more cases/hospitalizations. Health system business models have complicated revenue structures; insurance plans pay at different rates, and uninsured patients provide minimal, if any, revenue. Safety-net burden is also an important factor, as Medicare and Medicaid/Uninsured insurance type cases cost more and reimburse less than private insurance.[2,3] As Medicare and Medicaid populations differ greatly between states,[49] such studies need to be within healthcare systems, rather than across. Finally, clinical quality improvement projects and care pathway alterations are often funded through projected cost savings. We chose reducing CDIV complications in a robust, healthy patient population as a potentially achievable quality improvement project to illustrate the differences in cost savings using variable and total costs with progressively higher percentages of fixed costs.

4.1. Limitations

Our findings are limited in several ways. First, this is a retrospective cohort study; findings are limited to associations. Second, variable costs can differ based on surgeons' preferred technique and use of disposable supplies, therefore potentially affecting the variable costs. While a recent study[50] demonstrated that patient-level factors contributed 8-fold more to complications compared to surgeon-level factors, the increased odds of CDIV complications in Medicare and Medicaid/Uninsured patients driving increased costs may be influenced by outcome variation among individual surgeons. Third, reimbursement for surgical hospitalizations varies across insurance types. In addition, populations served by healthcare systems vary, including the safety-net burden of patients without insurance. We did not attempt to determine reimbursement or profitability, as our primary objective was evaluating costs and cost projection. Fourth, we used charge, total cost, and variable cost data from a single SNH. It is important that each healthcare system assess their costs accounting for local factors and populations served. Fifth, while we incorporated frailty[26,27] and expanded OSS[27] for risk adjustment; multiple other variables could have been included. Finally, NSQIP captures a representative sample of surgeries in a hospital; not all surgeries performed at our institution were included.

5. Conclusions

Hospital charges did not identify increased inpatient surgical costs for Medicare patients compared to patients with Private insurance, while increased total costs and variable costs were associated with Medicare and Medicaid/Uninsured insurance type patients compared to Private. The occurrence of CDIV complications was associated with over a 200% change in both total and variable costs. Variable costs, rather than total costs, should be used to avoid overestimating the potential cost savings of a proposed intervention, as total costs include fixed costs that are difficult to change in the short term.

Author contributions

Drs Shireman, Kim, Mr. Jacobs, and Ms. Manuel had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors have read and approved the manuscript.

Concept and design: Shireman, Schmidt, Kim, Brimhall, and Damien.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Jacobs, Kim, and Shireman.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Kim, CP Wang, and Damien.
Obtained funding: Shireman, Brimhall, Schmidt, Damien, and CP Wang.
Administrative, technical, or material support: All authors.
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