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Complications and Resource Utilization Associated With Surgery for Chiari Malformation Type 1 in Adults: A Population Perspective

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Abstract

Background—Outcomes research on Chiari Malformation Type 1 (CM-1) is impeded by reliance on small, single-center cohorts.

Objective—To study complications and resource utilization associated with adult CM-1 surgery using administrative data.

Methods—We used a recently-validated ICD-9-CM code algorithm to retrospectively study adult CM-1 surgeries from 2004–2010 in California, Florida, and New York using State Inpatient Databases. Outcomes included complications and resource utilization within 30 and 90 days of treatment. We used multivariable-logistic regression to identify risk factors for morbidity and negative binomial models to determine risk-adjusted costs.

Results—We identified 1,947 CM-1 operations. Surgical complications were more common than medical at both 30 (14.3% vs 4.4%) and 90 days (18.7% vs 5.0%) postoperatively. Certain

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comorbidities were associated with increased morbidity; for example, hydrocephalus increased the risk for surgical (odds ratio [OR]=4.51) and medical (OR=3.98) complications. Medical but not surgical complications were also more common in older patients (OR=5.57 for oldest vs youngest age category) and males (OR=3.19). Risk-adjusted hospital costs were \$22,530 at 30 days and \$24,852 at 90 days postoperatively. Risk-adjusted 90-day costs were more than twice as high for patients experiencing surgical (\$46,264) or medical (\$65,679) complications than patients without complications (\$18,880).

Conclusion—Complications after CM-1 surgery are common, and surgical complications are more frequent than medical. Certain comorbidities and demographic characteristics are associated with increased risk for complications. Beyond harming patients, complications are also associated with substantially higher hospital costs. These results may help guide patient management and inform decision making for patients considering surgery.

Keywords

Chiari Malformation Type 1; Health Care Costs; Health Services Research; Neurosurgery; Postoperative Complications

INTRODUCTION

Chiari Malformation Type 1 (CM-1) is a common and often debilitating neurosurgical disease diagnosed in approximately 1% to 4% of patients receiving magnetic resonance imaging (MRI) studies.^{1, 2} However, almost all data informing its management come from small, single-center series from academic centers. Relying on such limited patient samples leads to disparate assessments of key treatment outcomes such as operative morbidity³ and impedes identification of high-risk populations. Consequently, there is a need for large-scale, multi-center data to better understand the effectiveness of current practices, especially with regard to operative morbidity and resource utilization.

Administrative billing databases are large datasets that contain information on patient demographics, diagnosis and procedure codes, and resource utilization; they have been used to study a variety of neurosurgical conditions.^{4–7} By providing a population-level assessment of current practices, administrative billing databases offer an efficient means of evaluating surgical outcomes within a large population.^{5, 8} To date, we are unaware of any studies utilizing large databases to study CM-1 surgical outcomes.

In a separate study in this issue³³, we demonstrate the validity of International Classification of Diseases, Ninth Revision (ICD-9-CM) diagnosis and procedure codes for identifying CM-1 decompression surgeries. The objective of the present study was to use this recently validated ICD-9-CM algorithm to examine CM-1 treatment outcomes and resource utilization within large State Inpatient Databases (SIDs).

METHODS

Administrative Data Source

We retrospectively studied surgical outcomes using data from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Databases, available through the Agency for Healthcare Research and Quality (AHRQ).⁹ SIDs are billing databases that include comprehensive information on all nonfederal inpatient stays in participating states, regardless of payer status. SIDs contain billing and resource-use information, and some SIDs include an encrypted patient identifier linking hospitalizations over time.⁹ We used 2004–2010 data from California (CA) and 2006–2010 data from Florida (FL) and New York (NY). We chose these states because they: 1) contained encrypted patient identifiers linking repeat hospitalizations; and 2) had a large number of annual discharges. We selected these time periods to allow one year prior to admission to assess comorbidity status and one year after treatment to identify outcomes (CA-SID had data available beginning in 2003 and FL and NY had data beginning in 2005).

Patient Population

To identify adult patients older than 18 years who received a CM-1 decompression during the study period, we used the following validated ICD-9-CM code algorithm: patients with a primary discharge diagnosis code of 348.4 (CM-1) plus a procedure code of 01.24 (cranial decompression) or 03.09 (spinal decompression). We excluded patients whose home state differed from the state where they were treated, since such patients may be readmitted to an out-of-state hospital not represented in the SID. We also excluded patients with a CM-1 decompression in the year 2003 (CA) or 2005 (FL, NY) to ensure index surgeries did not represent complications from a recent procedure. Finally, we excluded patients with a diagnosis code of 741.0 (ie, Arnold Chiari Malformation Type II) since they may have been erroneously coded as a CM-1 decompression.

Comorbidities

We assessed the impact of pre-existing comorbidities on postoperative outcomes using the algorithm created by Elixhauser et al,¹⁰ and subsequently translated into ICD-9-CM diagnosis code classifications and updated annually by HCUP to ensure the validity of the corresponding ICD-9-CM codes.¹¹ Compared to pure composite indices such as the Charlson Index,¹² the Elixhauser groupings identify specific comorbidities that influence outcome. We excluded the variable for “other neurological deficit” due to its poor specificity. In addition to the standard Elixhauser comorbidities, we evaluated the impact of comorbid syringomyelia and hydrocephalus, two conditions with particular clinical relevance in the CM-1 population. In most cases, we identified comorbidities in the year prior to and including index hospitalization. However, for weight loss and electrolyte and fluid abnormalities, we only identified comorbidities in the year prior to index hospitalization to avoid misclassifying a postoperative complication as a preoperative comorbidity.

Outcome Variables

Our primary morbidity endpoint was the complication rate within 90 days of surgery, but we also examined complications at index admission and at 30 days postoperatively. We stratified events into two broad groupings: *surgical* complications directly related to operative intervention, and *medical*/other complications that represented adverse events associated with hospitalization and/or prolonged illness. Surgical complications included: wound infection or disruption; bleeding complication; dural graft complication; meningitis, cerebrospinal fluid (CSF)-related complication (eg, pseudomeningocele, shunt insertion or revision); cerebrovascular infarct or hemorrhage; and other nervous system complications not specified further. When reporting rates of specific surgical complications, we included a category of other “neurosurgical-specific complications.” This category included diagnoses such as dural puncture (349.31) and meninges disorders—including pseudomeningocele (349.2)—as well as diagnoses such as central nervous system complication (997.01) and other nervous system complication (997.09) which are broadly defined but may be used for complications such as pseudomeningocele or CSF leak. Medical complications included: cardiac, respiratory, thromboembolic, or urinary-renal complications; pneumonia; grade III or IV pressure ulcer; septicemia or catheter-related infection (including catheter-associated UTI); and tracheostomy or gastrostomy placement. The ICD-9-CM codes used to define various complications are listed in the Table, Supplemental Digital Content. We also examined 30 and 90-day hospital readmission rates.

We examined resource utilization by assessing total costs and lengths of stay for all hospital admissions within 90 days of index surgery. As secondary endpoints, we also evaluated resource utilization at index admission and from index admission through 30 days postoperatively. Costs were calculated using hospital charges with the HCUP cost-to-charge ratios,¹³ and were adjusted for inflation in 2014 US dollars using the medical care component of the Consumer Price Index.¹⁴

Statistical Analyses

Bivariate analyses of postoperative complications were conducted using χ^2 analyses. To determine independent predictors of surgical and medical complications, multiple logistic regression was used. Potential predictors included age (categorical variable), sex, race, payer status, and comorbidities. Variables with ≥ 10 events per cell and $P < 0.2$ in bivariate analysis or strong clinical justification were entered in the multivariate model, and those with $P < 0.1$ were retained. Model performance was evaluated with the c-statistic, which represented the area under the receiver operating characteristic curve.¹⁵

To determine risk-adjusted cost and length of stay estimates, we used negative binomial models due to the extreme skew of the data. Age (categorical variable), sex, race, payer status, and comorbidities were considered for these analyses. Conditions with ≥ 10 affected patients and $P < 0.2$ in bivariate analysis or strong clinical justification were entered in the multivariate model, and those with $P < 0.1$ or strong clinical justification were retained. Multivariate analyses were restricted to subjects with complete data, since missing data for all variables (race, $n=133$; sex, $n=57$; charges, $n=204$; and insurance status, $n=1$) were present in 10% or less of the population. Attributable costs and lengths of stay for

complications were calculated as the difference between estimated mean values in patients with and without complications. All analyses were performed using SAS versions 9.2 (SAS Institute, Cary, North Carolina). The study was exempt from review by the Washington University in St. Louis Institutional Review Board.

RESULTS

CM-1 population demographics in the SID (three states)

We identified a total of 1,947 index CM-1 surgeries in the California, Florida, and New York SIDs during the study period. CM-1 patients were typically young and middle-aged adults (19–64 years), and less than 4% of patients were 65 years or older (Table 1). Over 80% of patients were female, and 63% were white. Most patients (72%) had private insurance.

Complications

Surgical complications during the index operative admission were diagnosed in 5.9% of patients, and 3.3% were coded for an index medical complication. Within 30 days of surgery, surgical complications were diagnosed in 14.3% of patients, while medical complications occurred in 4.4%. The 30-day readmission rate after CM-1 surgery was 15.8%. Surgical complications were coded in 18.7% of patients within 90 days of surgery, and medical complications occurred in 5.0%. The 90-day readmission rate was 22.5%. As shown in Figure 1, surgical complications were coded for an extended period after index discharge, and the rate of new surgical diagnoses only decreased close to 90 days postoperatively. By contrast, medical complications were concentrated around the time of index admission, with few new diagnoses more than 30 days after index surgery.

The most common specific surgical and medical diagnoses are listed in Tables 2 and 3. The most common surgical complications were neurosurgical-specific complications that lacked unique diagnosis codes (eg, CSF leak and pseudomeningocele; 13.5%). Shunt-related complications (4.9%), meningitis (4.8%), and wound infection (3.2%) were also common. The most common medical event was a pulmonary complication/pneumonia (2.6%), followed by urinary-renal complications (0.98%).

The association between postoperative complications and various demographic characteristics and comorbidities is shown in Table 1. Surgical complications did not vary based on demographic characteristics or payer status. In contrast, medical complications were associated with older age, male gender, and Medicare insurance status. Surgical complications were more frequent in patients with comorbid hydrocephalus (7.1% of patients with surgical complications), obesity (15.1%), and psychoses (eg, schizophrenia, bipolar disorder; 4.1%). Several comorbidities were also associated with medical complications, including anemia (18.4% of patients with medical complications), diabetes (16.3%), chronic lung disease (29.6%), obesity (19.4%), and fluid or electrolyte abnormalities (11.2%). Less than 1% of patients died within 90 days of surgery.

In multivariate analysis, hydrocephalus (odds ratio [OR]=4.51), obesity (OR=1.63), and psychoses (OR=1.93) were the only significant predictors of surgical complications within 90 days (Table 4). The c-statistic for the model predicting surgical complications was 0.56.

Multiple comorbidities were associated with increased risk of medical complications, including fluid and electrolyte abnormalities (OR=4.80), hydrocephalus (OR=3.98), deficiency anemia (OR=3.85), diabetes (OR=2.01), and chronic lung disease (OR=1.67). Obesity (OR=1.63; 95% CI 0.92–2.91) was associated with marginally increased risk of medical complications within 90 days. Older age was associated with increased risk of medical complications, with persons ≥65 years having the highest risk compared to persons aged 19 to 32 years (OR=5.57). Men also had a higher risk of medical complications than women (OR=3.19; Table 4). The c-statistic for the model predicting medical complications was 0.75.

Resource Utilization

The risk-adjusted average hospital cost for index admission was \$19,420, compared to \$22,530 for index admission until 30 days after surgery and \$24,852 for 90 days of postoperative follow-up (Table 5). Resource utilization within 90 days of surgery was higher in patients experiencing postoperative complications. After adjusting for age, payer status, and comorbidities, the mean cost for patients experiencing surgical complications was \$46,264 (2014 dollars), and for patients with medical complications was \$65,679. By comparison, the adjusted mean cost for patients without complications was \$18,880. The risk-adjusted attributable cost for a surgical complication was \$27,384 and for a medical complication was \$46,799.

The adjusted mean lengths of stay for index admission, 30 days and 90 days postoperatively were 4.7, 6.2, and 7.1 days, respectively (Table 6). The adjusted mean 90-day length of stay for patients experiencing a surgical (16.3 days) or medical (21.9 days) complication was longer than for patients without complications (4.7 days). The attributable length of stay for a surgical complication was 11.6 days and for a medical complication was 17.2 days.

DISCUSSION

Key Results

In this study, we used administrative billing data from three states to study complications and resource utilization associated with CM-1 surgery. We found that surgical complications after CM-1 treatment were common, and were diagnosed more than three times as frequently as medical complications within 90 days after surgery. We also identified several risk factors for postoperative complications, including comorbidities such as hydrocephalus and demographic characteristics, such as older age. Moreover, we found patients experiencing a complication incurred substantially higher costs and had longer lengths of hospital stay than routine admissions.

Previous studies based on small, single center series have reported widely disparate complication rates following CM-1 surgery.³ For example, one meta-analysis in pediatric CM-1 patients found that the rate of CSF-related complications reported for the same

surgical approach ranged from 8% to 67% in different series.³ In this population-level analysis using SIDs, we found that surgical complications after CM-1 surgery occurred in almost one-fifth of the population within 90 days of treatment. Notably, the rate of new surgical complication diagnoses did not decrease substantially until almost the end of the 90-day follow-up period, whereas medical complications were diagnosed at index admission or soon after. While clinical experience suggests that various complications such as pseudomeningocele and hydrocephalus often occur in a delayed fashion, current single-center cohorts provide minimal information regarding the time-course of such events.^{16–18} These results emphasize the importance of assessing complications occurring at hospital readmission, a key strength of the SIDs with the encrypted patient-level identifier. By comparison, other administrative datasets commonly used in neurosurgery outcomes studies, such as the Nationwide Inpatient Sample and Kids' Inpatient Database,^{7, 19–21} only report events from individual admissions and lack longitudinal follow-up data.

To effectively counsel patients and identify targets for improved operative safety, knowledge of patient-specific risk factors is essential. While demographic features and preexisting comorbidities are known to be important risk factors for complications from a variety of surgeries,^{22–24} their impact on CM-1 outcomes is unknown. We did not find any demographic characteristics associated with surgical complications, but did identify several comorbidities (hydrocephalus, obesity, and psychoses) that were associated with increased risk. However, the overall poor discrimination of the surgical complication model likely reflected the lack of some important predictors of surgical complications in the SIDs. In particular, variations in surgical technique (eg, extradural decompression versus decompression with dural augmentation/duraplasty), surgical indications, and surgeon experience may have been associated with differing complication rates and are likely important factors not accounted for in our analysis.³ Likewise, there may have been additional variables (eg, nutritional status) confounding the relationship between comorbid conditions and postoperative outcomes. Future studies using more detailed datasets should examine these factors and should also assess whether particular comorbidities such as hydrocephalus have a stronger association with some surgical complications (eg, CSF leak) than others (eg, wound infection).

The overall performance of the model predicting medical complications was substantially better than for surgical complications. Both comorbidities and demographic variables were associated with significantly increased risk of medical complications within 90 days. The marginal significance of obesity likely resulted from the known undercoding of obesity in administrative data.²⁵ While the increased risk of medical complications associated with older age likely reflected general frailty and is consistent with other results,^{24, 26} the association between male gender and medical complications is less clear. This risk may have resulted from unmeasured confounders such as tobacco use or physical fitness and should be assessed further in future studies.

Beyond harming individual patients, complications also imposed a significant financial toll on the healthcare system. Notably, complications were associated with more than doubling of hospital costs and length of hospital stay. These estimates do not account for provider charges or for the additional societal loss imposed by time away from work and family,

suggesting the true cost of complications may be higher. Therefore, by focusing on patients most likely to suffer adverse events, physicians may help reduce patient suffering while also lessening the economic burden associated with CM-1 treatment.

Limitations

By analyzing complications and resource utilization in a large, population-based dataset, this study makes important contributions to the CM-1 literature. However, it also has limitations. First, while the ICD-9-CM code algorithm used to identify CM-1 surgeries was validated in a multicenter setting, that validation was based on academic centers and did not include community hospitals or hospitals from states utilized in this study, potentially limiting the generalizability of that validation to this analysis. Likewise, although variations of definitions used to identify certain complications have been validated in other populations,^{27–29} to the best of our knowledge, these variables have not been validated in CM-1 patients, and prospective data collection by trained evaluators remains the gold standard for assessing postoperative complications. However, ICD-9-CM diagnosis codes for complications from surgery are generally reliable and have been shown to be more accurate than coding for complications from medical therapy.³⁰ In addition, since complication coding typically has high specificity but potentially lower sensitivity,²⁶ the true complication rates may in fact be higher than those reported. Another limitation is that SIDs do not detail certain factors, such as technical variations in surgical approach, patient functional status, surgical indications, or surgeon experience. All of these are potentially important determinants of postoperative outcome and should be explored in future studies. Moreover, our inability to stratify based on surgical indications and prognostic severity emphasizes the need for a preoperative severity index for CM-1.³¹ In addition, with the exception of weight loss and fluid and electrolyte abnormalities, we recorded preoperative comorbidities in the year up to and including index admission. While this approach was necessary because most patients did not have hospital admissions in the year prior to surgery, it also created the possibility that certain diagnoses recorded as preoperative comorbidities were not present at the time of index admission. This shortcoming reflects the limitations inherent in administrative data research. Finally, due to limitations in the use of billing data available in the SIDs, this analysis only provides insight into the complications and resource utilization associated with CM-1 surgery. To address key questions related to improvement in symptoms and quality of life, pre-specified patient-defined outcome metrics must be utilized with a defined cohort of CM-1 patients.³²

Generalizability

Beyond these specific limitations, the generalizability of these results to diverse clinical practices must be considered with appropriate reservation. In particular, while the SID includes a broad cross-section of hospitals—ranging in size, academic affiliation, and geographic location—the results presented represent a composite of those settings and may not fully reflect variations in practice and outcome in each unique context. In addition, while we included three geographically diverse states in this study, we did not include hospitals in several areas, including the Midwest, which may also limit the generalizability of these results. These points may be investigated in more detail in future studies.

CONCLUSION

This study provides comprehensive, population-level evidence that complications following CM-1 surgery are common and impose a substantial economic burden on the healthcare system. While overall complications rates are high, certain patients such as those with select comorbidities are at greater risk. These results should inform patient counseling and help guide preventative efforts and future studies directed at decreasing operative morbidity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Cumulative incidence curves with 95% confidence intervals for postoperative surgical and medical complications.

Table 1
Demographic characteristics and comorbidities associated with postoperative complications.

	No. Patients	Index Admission (%)				30 Days (%)				90 Days (%)			
		Surgical Complication	Medical Complication	Surgical Complication	Medical Complication	Surgical Complication	Medical Complication	Surgical Complication	Medical Complication	Surgical Complication	Medical Complication	Surgical Complication	Medical Complication
Total	1947	115 (5.9)	61 (3.3)	278 (14.3)	85 (4.4)	364 (18.7)	98 (5.0)						
Age (years)													
19–32	624 (32.1)	41 (35.7)	15 (24.6)	107 (38.5)	22 (25.9)	136 (37.4)	24 (24.5)						
33–44	627 (32.2)	35 (30.4)	12 (19.7)	83 (29.9)	19 (22.4)	110 (30.2)	25 (25.5)						
45–64	628 (32.2)	33 (28.7)	27 (44.3)	77 (27.7)	34 (40.0)	105 (28.8)	36 (36.7)						
65	68 (3.5)	a	a	11 (4.0)	a	13 (3.6)	13 (13.3)						
Sex ^b													
Male	351 (18.6)	23 (20.2)	22 (36.1)	52 (18.8)	30 (35.3)	75 (20.8)	33 (33.7)						
Female	1539 (81.4)	91 (79.8)	39 (63.9)	224 (81.2)	55 (64.7)	285 (79.2)	65 (66.3)						
Race ^b													
White	1147 (63.2)	70 (61.4)	34 (55.7)	173 (63.4)	46 (54.1)	232 (65.2)	56 (57.1)						
Black	239 (13.2)	21 (18.4)	13 (21.3)	43 (15.8)	18 (21.2)	48 (13.5)	19 (19.4)						
Hispanic	319 (17.6)	16 (14.0)	13 (21.3)	40 (14.7)	16 (18.8)	55 (15.4)	17 (17.4)						
Other	109 (6.0)	a	a	17 (6.2)	a	21 (5.9)	a						
Insurance ^b													
Private	1405 (72.2)	76 (66.1)	33 (54.1)	192 (69.1)	47 (55.3)	248 (68.1)	52 (53.1)						
Medicaid	264 (13.6)	17 (14.8)	a	38 (13.7)	15 (17.7)	50 (13.7)	16 (16.3)						
Medicare	148 (7.6)	11 (9.6)	12 (19.7)	25 (9.0)	16 (18.8)	34 (9.3)	21 (21.4)						
Other	129 (6.6)	11 (9.6)	a	23 (8.3)	a	32 (8.8)	a						
Hydrocephalus	53 (2.7)	*17 (14.8)	a	*23 (8.3)	a	*26 (7.1)	a						
Obesity	208 (10.7)	15 (13.0)	*13 (21.3)	*49 (17.6)	*17 (20.0)	*55 (15.1)	*19 (19.4)						
Psychoses	50 (2.6)	a	a	*12 (4.3)	a	*15 (4.1)	a						
Chronic lung disease	329 (16.9)	23 (20.0)	*16 (26.2)	53 (19.1)	*26 (30.6)	67 (18.4)	*29 (29.6)						
Deficiency anemia	109 (5.6)	11 (9.6)	*11 (18.0)	22 (7.9)	*17 (20.0)	25 (6.9)	*18 (18.4)						
Diabetes	107 (5.5)	a	a	14 (5.0)	*16 (18.8)	16 (4.4)	*16 (16.3)						
Fluid and electrolyte disorders	39 (2.0)	a	a	a	a	a	*11 (11.2)						

		<u>Index Admission (%)</u>		<u>30 Days (%)</u>		<u>90 Days (%)</u>	
	No. Patients	Surgical Complication	Medical Complication	Surgical Complication	Medical Complication	Surgical Complication	Medical Complication
Syringomyelia	365 (18.8)	24 (20.9)	a	54 (19.4)	17 (20.0)	73 (20.1)	22 (22.5)

* Differences among subgroups is significant at $p < 0.05$ (chi-square test).

^a Suppressed due to cell size of 10 or less.

^b Sum of all groups is less than 1947 due to the presence of missing data for sex (n=57), race (n=133), and insurance status (n=1).

Table 2

A list of the individual surgical complications diagnosed within 90 days of CM-1 surgery.

	n (%) ^a
Shunt insertion, revision, or exploration	96 (4.9)
Meningitis	93 (4.8)
Wound infection	62 (3.2)
Dural graft complication	34 (1.8)
Wound disruption	25 (1.3)
Iatrogenic cerebrovascular infarction or hemorrhage	13 (0.67)
Other neurosurgical-specific complications (e.g. CSF leak, pseudomeningocele)	262 (13.5)
Bleeding complication	^a
Total surgical complications	364 (18.7)

^a Suppressed due to cell size of 10 or less.

* % refers to the percentage of the total population diagnosed with the respective complication.

CSF = cerebrospinal fluid.

Table 3

A list of the individual medical complications diagnosed within 90 days of CM-1 surgery.

	n (%)^a
Pulmonary complication/Pneumonia	54 (2.6)
Urinary-renal complication	19 (0.98)
Septicemia	17 (0.87)
Cardiac complication	16 (0.82)
Thrombotic complication	13 (0.67)
Gastrostomy	12 (0.62)
Tracheostomy	a
Pressure ulcer	a
Catheter-associated infection	a
Total medical complications	98 (5.0)

^aSuppressed due to cell size of 10 or less.

* % refers to the percentage of the total population diagnosed with the respective complication.

Table 4

Independent predictors of complications in multivariate analysis.

	Odds Ratio (95% CI)	
	Surgical complication	Medical complication
Hydrocephalus	4.51 (2.59–7.84)	3.98 (1.78–8.89)
Obesity	1.63 (1.16–2.28)	1.63 (0.92–2.91)
Psychoses	1.93 (1.04–3.58)	-
Chronic lung disease		1.67 (1.01–2.74)
Deficiency anemia	-	3.85 (2.08–7.14)
Diabetes	-	2.01 (1.04–3.89)
Fluid and electrolyte abnormalities	-	4.80 (2.11–10.92)
Age		
19–32	-	Reference
33–44	-	1.12 (0.61–2.04)
45–64	-	1.56 (0.88–2.75)
65	-	5.57 (2.50–12.43)
Sex		
Female	-	Reference
Male	-	3.19 (1.98–5.13)

Variables tested for inclusion in the model included: age (categorical variable), sex, race, payer status, and the comorbidities specified in the methods. Variables with $P < 0.2$ and 10 events per cell were entered into the multivariate model, and variables with $P < 0.1$ were retained. Dashed lines indicate variables not included in the respective multivariate model. Fluid and electrolyte abnormalities were only diagnosed in the year prior to index hospitalization, whereas other comorbidities in the model were diagnosed in the year up to and including index hospitalization.

Table 5

Risk-adjusted index admission, 30-day, and 90-day hospital costs in patients with and without complications.

	Index costs, US \$ (95% CI)^a	30-day costs, US \$ (95% CI)^a	90-day costs, US \$ (95% CI)^a
Total	19,420 (19,099–19,752)	22,530 (21,995–23,065)	24,852 (24,192–25,512)
No complication	17,832 (17,707–17,958)	18,575 (18,409–18,742)	18,880 (18,715–19,045)
Surgical complication	32,507 (29,516–35,497)	40,662 (38,409–42,914)	46,264 (44,182–48,347)
Medical complication	51,100 (46,659–55,543)	60,069 (54,094–66,044)	65,679 (59,482–71,876)

^aEstimated mean costs are adjusted for age, payer status, and comorbidities with $P < 0.1$ in the final model (anemia, congestive heart failure, chronic lung disease (index and 30-day models only), coagulopathy, fluid and electrolyte abnormalities (30-day model only), hypertension, hydrocephalus, liver disease (30 and 90-day models only), paralysis, and syringomyelia). Although statistically significant, race was not retained in the final model since it had a minimal impact on cost predictions and introduced missing data.

Table 6

Risk-adjusted index admission, 30-day, and 90-day lengths of stay in patients with and without complications.

	<u>Index length of stay, days (95% CI)^a</u>	<u>30-day length of stay, days (95% CI)^a</u>	<u>90-day length of stay, days (95% CI)^a</u>
Total	4.7 (4.6–4.8)	6.2 (5.9–6.4)	7.1 (6.8–7.4)
No complication	4.1 (4.1–4.2)	4.6 (4.5–4.7)	4.7 (4.6–4.7)
Surgical complication	10.5 (9.2–11.8)	14.1 (13.0–15.1)	16.3 (15.3–17.3)
Medical complication	13.9 (11.8–16.0)	18.7 (15.8–21.6)	21.9 (18.7–25.0)

^a Estimated mean lengths of stay are adjusted for age, payer status, and comorbidities with $P < 0.1$ in the final model (anemia, congestive heart failure, chronic lung disease, coagulopathy, fluid and electrolyte abnormalities (30-day model only) hypertension, hydrocephalus, liver disease (30-day model only), paralysis, syringomyelia, and weight loss). Although statistically significant, race was not retained in the final model since it had a minimal impact on length of stay predictions and introduced missing data.