ONLINE FIRST

Costs of Postoperative Sepsis

The Business Case for Quality Improvement to Reduce Postoperative Sepsis in Veterans Affairs Hospitals

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Objective: To estimate the incremental costs associated with sepsis as a complication of general surgery, controlling for patient risk factors that may affect costs (eg, surgical complexity and comorbidity) and hospital-level variation in costs.

Design: Database analysis.

Setting: One hundred eighteen Veterans Health Affairs hospitals.

Patients: A total of 13 878 patients undergoing general surgery during fiscal year 2006 (October 1, 2005, through September 30, 2006).

Main Outcome Measures: Incremental costs associated with sepsis as a complication of general surgery (controlling for patient risk factors and hospital-level variation of costs), as well as the increase in costs associated with complications that co-occur with sepsis. Costs were estimated using the Veterans Health Affairs Decision Support System, and patient risk factors and postoperative complications were identified in the Veterans Affairs Surgical Quality Improvement Program database.

Results: Overall, 564 of 13 878 patients undergoing general surgery developed postoperative sepsis, for a rate of 4.1%. The average unadjusted cost for patients with no sepsis was $24 923, whereas the average cost for patients with sepsis was 3.6 times higher at $88 747. In risk-adjusted analyses, the relative costs were 2.28 times greater for patients with sepsis relative to patients without sepsis (95% confidence interval, 2.19-2.38), with the difference in risk-adjusted costs estimated at $26 972 (ie, $21 045 vs $48 017). Sepsis often co-occurred with other types of complications, most frequently with failure to wean the patient from mechanical ventilation after 48 hours (36%), postoperative pneumonia (31%), and reintubation for respiratory or cardiac failure (29%). Costs were highest when sepsis occurred with pneumonia or failure to wean the patient from mechanical ventilation after 48 hours.

Conclusion: Given the high cost of treating sepsis, a business case can be made for quality improvement initiatives that reduce the likelihood of postoperative sepsis.

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SEPSIS CAN DEVELOP AS A RESULT of bacterial, viral, or fungal infection and can arise from infections as common as urinary tract infection and skin infection. Severe sepsis, which occurs when sepsis is accompanied by organ failure, is a serious infection with extremely high rates of death; roughly 30% of patients die within 1 month of diagnosis and 50% die within 6 months.[1,2] Moreover, treatment that is not comprehensive may leave the patient vulnerable to ancillary insults, such as kidney failure or depressed heart rate. Postoperative complications account for approximately 30% of inpatient cases of severe sepsis.[3]

See Invited Critique at end of article

Costs associated with treating sepsis can be substantial and increase significantly as dysfunction develops in vital organs. Estimates of the cost of treating sepsis vary significantly, from $10 500 to more than $40 000 per case across studies that vary by patient inclusion criteria, country, and year of study.[2,4-7] To our knowledge, no study has specifically examined the incremental cost associated with sepsis as a complication of general surgery. As health care costs continue to climb, creating a "business case for quality" has become a mantra for sustaining quality improvement efforts.[8,9] Reducing the incidence of postsurgical sepsis represents a particularly fertile area around which a business case for quality can be made.

This study estimated the incremental costs associated with sepsis as a complication of inpatient general surgery in 118 acute care Veterans Health Affairs (VHA) hospitals, controlling for patient risk factors that may affect costs (eg, surgical complexity and comorbidity) and hospital-level variation in costs. In addition, the increase in costs with complications that co-occur with sepsis was estimated. Patient-level costs were estimated using data available through the VHA Decision Support System (DSS), and patient risk factors and postoperative complications were identified in data from the Veterans Affairs Surgical Quality Improvement Program (VASQIP). This study was reviewed and approved by the University of Iowa and Iowa City Veterans Affairs (VA) Medical Center institutional review boards.

METHODS

DATA SOURCES

The VASQIP has been used to evaluate preoperative and intraoperative factors affecting patient outcomes in at least 128 peer-reviewed publications since its inception in 1994.[10] The VASQIP collects a wide range of preoperative risk factors, information about the operative procedures and anesthesia, and postoperative complications and mortality.[11] Data are abstracted from each VA medical center for patients undergoing operations under general, spinal, or epidural anesthesia in VA hospitals; standard definitions are used to ensure data reliability.

For the present study, costs of care were identified using patient-level data from the VHA DSS. In the DSS costing algorithm, costs associated with intermediate products provided during inpatient and outpatient encounters (eg, intensive care unit days of care, radiology tests, and blood products) are based on relative resource units (RRUs), which are assigned to each product by departmental managers. Relative resource units represent the relative costs of the resources required to produce a given intermediate product. Relative resource units are generated using a standard set of weights derived nationally, which are then provided to each facility's departmental managers for modification to reflect local factors. The use of RRUs is an advantage of the VHA DSS system, for, unlike hospital charges, RRUs explicitly represent the relative cost of producing different patient care products.

To calculate the costs of patient encounters, departmental costs per RRU are estimated and multiplied by the RRU assigned to the intermediate product to determine the product's cost; thus, the cost of producing an intermediate product is exactly proportional to the RRUs assigned to it. Costs are then aggregated to determine the total costs associated with each patient encounter. Overhead costs associated with nonpatient care departments (ie, security and administration) are distributed to patient care departments and then to intermediate products using a step-down method based on the square feet of space of the patient care department.

PATIENTS

Operations performed by general surgeons in VA hospital inpatient settings during fiscal year 2006 (October 1, 2005, through September 30, 2006) were identified in VASQIP data (N=16 360). Operations were excluded if they were preceded within 30 days by another operation (n=908); if they had diagnosis related group codes 452 or 453, representing complications of previous treatment (n=37); if any of the patient's demographic or preoperative comorbidity indicators were missing (n=205); or if the cost associated with the operation was a statistical outlier, defined as exceeding ±3 SDs from the mean cost (n=109). In addition, patients with preoperative sepsis (n=1209) and patients who died on the same day as the operation (n=14) were excluded because postoperative sepsis is unlikely to be detected within 12 hours of the operation. The final sample included 13 878 patients who underwent general surgery in 118 VA hospitals during fiscal year 2006.

DATA ELEMENTS

The study end point included total costs associated with the index admission and all subsequent readmissions within 30 days of discharge. Sepsis included severe sepsis and septic shock within 30 days after surgery. In the VASQIP, *sepsis* is defined as definitive evidence of infection plus evidence of a systemic response to infection, which is manifested by 2 or more of the following conditions: temperature greater than 38°C or less than 36°C; heart rate greater than 90/min, respiratory rate greater than 20/min, or Pa_{CO_2} less than 32 mm Hg (<4.3 kPa); white blood cell (WBC) count less than 12 000/μL, less than 4000/μL, or less than 10% immature (band) forms. (To convert WBC count to cells $\times 10^9$ per liter, multiply by 0.001.) In addition, the presence of septic shock is recorded if the patient meets the criteria for sepsis as well as hypotension with adequate fluid resuscitation combined with perfusion abnormalities that may include, but are not limited to, lactic acidosis or oliguria.

Additional patient characteristics were identified in the VASQIP data and administrative databases available through the VA Austin Automation Center, Austin, Texas. Patient sociodemographic factors included age, sex, race, marital status, and means category. The means category was designated as "service connected," "indigent," and all other. (*Service-connected veterans* are eligible for VA services on the basis of a service-connected disability; *indigent veterans* are those who qualify for VA services on the basis of a low income threshold.) Surgical complexity was assessed by work relative value units associated with the primary *Current Procedural Terminology* (*CPT*) code for the operation, type of operation (divided into 21 categories based on primary *CPT* code), and presence of a secondary *CPT* code concurrent with the primary operation.

Patient comorbidity was reflected in the multivariable models as indicators for specific preoperative conditions (eg, diabetes mellitus, myocardial infarction, hypertension, angina, congestive heart failure, weight loss, bleeding disorder, and chronic obstructive pulmonary disease). Other risk factors included preoperative wound classification (clean, clean/contaminated, contaminated, or infected), smoking status (current vs not current), functional status (independent, partially dependent, or totally dependent), American Society of Anesthesiology Physical Status class (healthy, mild disease, severe, or life-threatening/moribund), and an indicator for an emergency operation. Finally, preoperative laboratory values included serum urea nitrogen (SUN) and albumin levels and WBC count. Albumin level was included as a continuous variable, whereas the SUN levels and the WBC count were categorized to reflect the nonlinear association of those laboratory test results with costs. Laboratory values were missing for a substantial portion of patients (4.9% for SUN level, 16.0% for albumin level, and 1.4% for WBC count), and 2628 patients (18.9%) had 1 or more (but not all) missing laboratory variables. Multiple imputation was used to impute laboratory values when missing. All analyses were run with and without the imputed laboratory values.

STATISTICAL ANALYSES

Unadjusted costs for patients with and without postoperative sepsis were compared using a Wilcoxon rank sum test. Subsequently, risk-adjusted costs were estimated for patients with and without postoperative sepsis using a multivariable risk ad-

Table 1. Preoperative Patient Characteristics and Associated Postoperative Sepsis Rates

Characteristic	Total No. of Patients	No. (%) of Patients With Sepsis	*P* Value
Overall	13 878	564 (4.1)	<.001
Male sex	13 001	550 (4.2)	
Age, y			
≤54	3124	71 (2.3)	<.001
55-64	4968	172 (3.5)	
65-74	2906	140 (4.8)	
75-84	2424	153 (6.3)	
≥85	456	28 (6.1)	
Race			
White	10 067	399 (4.0)	.46
Black	2052	96 (4.7)	
Other	973	36 (3.7)	
Surgical complexity			
CPT category			
Abdomen	818	43 (5.3)	<.001
Aneurysm	20	1 (5.0)	
Pancreas	193	26 (13.5)	
Appendectomy/laparotomy	957	16 (1.7)	
Biliary tract procedure	2448	40 (1.6)	
Endocrine procedure	369	1 (0.3)	
Hemic and lymphatic systems	131	4 (3.1)	
Hernioplasty	1518	21 (1.4)	
Ileostomy	249	15 (6.0)	
Mouth	324	15 (4.6)	
Rectum excision	344	12 (3.5)	
Rectum repair	175	15 (8.6)	
Other rectum/anus procedure	225	1 (0.4)	
Respiratory	112	3 (2.7)	
Stomach operation	425	34 (8.0)	
Gastric bypass	77	1 (1.3)	
Total colon removal	397	33 (8.3)	
Partial colon removal	2700	140 (5.2)	
Bowel repair	482	22 (4.6)	
Other intestine operation	835	85 (10.2)	
Musculoskeletal procedure	963	37 (3.8)	
Other not classified	116	0	
Work relative value units, mean (SD)			
0 to <10	2937	53 (1.8)	<.001
10 to <20	6903	279 (4.0)	
20 to <30	3625	187 (5.2)	
≥30	413	45 (10.9)	
Any secondary *CPT* code	5978	309 (5.2)	<.001

(continued)

justment model developed by a multistep process. First, previous studies based on VASQIP data[12-15] were reviewed to identify important risk factors and methods of analysis. Second, bivariate relationships between log-transformed costs and individual patient risk factors were examined using the 2-tailed independent samples *t* test for risk factors measured as dichotomous variables and analysis of variance for risk factors measured as ordinal or continuous variables. Third, correlation among candidate variables was evaluated, and redundant collinear variables were eliminated. Fourth, candidate variables that were significantly related ($P < .01$) to costs were considered candidate variables for inclusion in multivariable models and were subsequently entered into generalized regression models with stepwise elimination. Fifth, selected variables were inspected for consistency with clinical expectation and previous literature based on analyses of VASQIP. The final model was generated as a generalized linear model with gamma-distributed errors and a log-link function to account for the skew of costs and included fixed effects for VA hospitals to account for hospital-level variations in costs.

The presence of sepsis was initially reflected in the multivariable model as a single indicator variable for patients who developed postoperative sepsis, including severe sepsis or septic shock. The exponentiated coefficient associated with the sepsis indicator represents the incremental change in costs for patients with sepsis relative to patients without sepsis. Risk-adjusted costs for patients with and without postoperative sepsis were also estimated from the model and based on characteristics of the average patient undergoing general surgery. A subsequent model evaluated costs associated with severe sepsis and septic shock separately. Finally, the effect on costs of other complications that occur concurrently with sepsis was investigated among the 564 patients with postoperative sepsis.

RESULTS

In all, 564 of the 13 878 general surgery patients developed postoperative sepsis, for a rate of 4.1%. Of those, 365 had severe sepsis and 199 had septic shock. Mean

Table 1. Preoperative Patient Characteristics and Associated Postoperative Sepsis Rates (continued)

Characteristic	Total No. of Patients	No. (%) of Patients With Sepsis	*P* Value
Preoperative wound class			
Clean	3936	71 (1.8)	<.001
Clean/contaminated	7766	345 (4.4)	
Contaminated	1217	103 (8.5)	
Infected	959	45 (4.7)	
ASA class			
Healthy patient	193	0	<.001
Mild systemic disease	2979	37 (1.2)	
Severe systemic disease	8908	353 (4.0)	
Life-threatening/moribund disease	1798	174 (9.7)	
Dyspnea			
No dyspnea	11868	405 (3.4)	<.001
Dyspnea w/minimal exertion	1816	131 (7.2)	
Resting dyspnea	204	28 (13.7)	
Preexisting conditions			
Alcohol use	1095	47 (4.3)	.69
Diabetes mellitus	1423	85 (6.0)	<.001
Paraplegia	120	8 (6.7)	.16
Quadriplegia	55	5 (9.1)	.07
Weight loss, 10% of body weight	1084	95 (8.8)	<.001
Bleeding disorders	775	69 (8.9)	<.001
Open wound/wound infection	1008	56 (5.6)	.01
Transfusion of >4 U of PRBC	89	13 (14.6)	<.001
Current pneumonia	110	12 (10.9)	<.001
History of severe COPD	2058	136 (6.6)	<.001
Ventilator dependency	65	16 (24.6)	<.001
Acute renal failure	107	12 (11.2)	<.001
Currently undergoing dialysis	153	16 (10.5)	<.001
Preoperative functional status as independent	12118	401 (3.3)	<.001
Preoperative laboratory test results			
Albumin, mean (SD), mg/dL			
0.0 to <2.0	225	31 (13.8)	<.001
2.0 to <2.5	574	44 (7.7)	
2.5 to <4.5	11 648	455 (3.9)	
≥4.5	1431	34 (2.4)	
Serum urea nitrogen, mg/dL			
0 to <6	889	38 (4.3)	<.001
6 to <15	6928	198 (2.9)	
15 to <20	2873	111 (3.9)	
20 to <30	2123	117 (5.5)	
30 to <50	834	73 (8.8)	
≥50	231	27 (11.7)	
White blood cell count, /μL			
0 to <15	12 638	492 (3.9)	<.001
15 to <20	864	37 (4.3)	
≥20	376	35 (9.3)	

Abbreviations: ASA, American Society of Anesthesiology; COPD, chronic obstructive pulmonary disease; *CPT*, *Current Procedural Terminology*; PRBC, packed red blood cells.

SI conversion factors: To convert albumin to grams per liter, multiply by 10; serum urea nitrogen to millimoles per liter, multiply by 0.357; and white blood cell count to cells $\times 10^9$ per liter, multiply by 0.001.

(SD) operative times were 3.09 (2.31) and 2.29 (1.67) hours for patients with and without sepsis, respectively. Overall, the sepsis rate increased with age, from 2.3% for patients younger than 55 years to 6.1% for patients 85 years or older (**Table 1**). The sepsis rate varied significantly by type of surgery and was generally high for procedures involving the stomach (8.0%), the pancreas (13.5%), rectum repair (8.6%), and total colon removal (8.3%) and for other intestine operations (10.2%). Other patient characteristics associated with increased likelihood of sepsis included moderate to severe dyspnea, American Society of Anesthesiology class indicating a moribund patient, and preoperative presence of diabetes mellitus, weight loss, bleeding disorder, wound infection, blood transfusion, pneumonia, chronic obstructive pulmonary disease, acute renal failure, or current receipt of dialysis, and being ventilator dependent within 48 hours before the operation. The patient's WBC count and levels of SUN and albumin were also significantly related to postoperative sepsis. The likelihood of developing postoperative sepsis increased steadily from roughly 3.0% for patients with a SUN level of 15 mg/dL or less (to convert SUN to millimoles per liter, multiply by 0.357) to 9.4% for patients with a SUN level of 30 mg/dL or higher and was 9.3% for patients with a WBC count of 20/μL or greater. The mean (SD) albumin level was also significantly lower for patients with sepsis (3.4 [0.7] vs 3.7 [0.8] g/dL [to convert albumin to grams per liter, multiply by 10]).

The average unadjusted cost for patients with no sepsis was $24 923, whereas the average cost for the 564 patients who experienced sepsis was 3.6 times higher at $88 747 (**Table 2**). The cost for patients with septic shock was approximately $6300 higher than the cost for patients with severe sepsis ($92 829 vs $86 522). Sepsis often co-occurred with other types of complications, most frequently with failure to wean the patient from mechanical ventilation after 48 hours (35.8%), postoperative pneumonia (30.9%), reintubation for respiratory or cardiac failure (28.7%), and urinary tract infection (18.8%). Unadjusted costs associated with sepsis were highest when they occurred in conjunction with deep vein thrombosis ($134 162), failure to wean the patient from mechanical ventilation after 48 hours ($124 895), wound dehiscence ($121 801), and pneumonia ($115 182).

The 25 variables shown in Table 1 met criteria for inclusion in the cost risk-adjustment models. In risk-adjusted analyses, the relative costs were 2.28 times greater for patients with sepsis relative to patients without sepsis (95% confidence interval [CI], 2.19-2.38), with the absolute difference in risk-adjusted costs estimated at $26 972 (ie, $21 045 vs $48 017) (**Table 3**). Relative cost ratios were generally similar for severe sepsis and septic shock after controlling for patient risk factors (2.35 [95% CI, 2.52-2.19] and 2.14 [2.36-1.95], respectively). Among the 564 patients with sepsis, the co-occurrence of postoperative pneumonia and failure to wean the patient from mechanical ventilation after 48 hours increased costs by 1.23 (95% CI, 1.06-1.43; $P = .01$) and 1.72 (1.48-1.99; $P < .001$), respectively, whereas postoperative myocardial infarction was associated with 33% lower costs compared with other patients with sepsis (0.49-0.92; $P = .01$).

Table 2. Unadjusted Costs for Patients With Postoperative Sepsis Overall and in Conjunction With Other Complications

Category	No. (%) (N=13 878)	Total Cost, Mean (SD), $	P Value[a]
Patients without sepsis	13 314 (95.9)	24 923 (30 283)	<.001
Patients with sepsis, overall	564 (4.1)	88 747 (69 339)	
Cost for patients with additional complications that co-occur with sepsis (n=564[b])			
Cardiac arrest	44 (7.8)	85 424 (58 860)	.74
Myocardial infarction	22 (3.9)	69 423 (53 567)	.18
Bleeding requiring >4 U of PRBC	13 (2.3)	100 513 (52 204)	.54
DVT/thrombophlebitis	13 (2.3)	134 162 (72 999)	.02
Failure to wean patient from mechanical ventilation after 48 h	202 (35.8)	124 895 (74 366)	<.001
Pneumonia	174 (30.9)	115 182 (70 778)	<.001
Pulmonary embolism	12 (2.1)	104 395 (73 638)	.43
Reintubation for respiratory or cardiac failure	162 (28.7)	109 491 (76 345)	<.001
Acute renal failure	44 (7.8)	106 668 (89 219)	.07
Progressive renal insufficiency	38 (6.7)	95 428 (66 675)	.54
Urinary tract infection	106 (18.8)	96 805 (69 908)	.18
Deep wound infection	55 (9.8)	105 581 (88 597)	.14
Superficial infection	50 (8.9)	88 916 (56 721)	.98
Wound dehiscence	42 (7.4)	121 801 (75 558)	.001

Abbreviations: DVT, deep vein thrombosis; PRBC, packed red blood cells.
[a] *P* values are based on a 2-tailed independent samples *t* test for the difference in the log of costs. *P* value for the difference between all patients with postoperative sepsis and no sepsis is based on 13 878 total patients. *P* values for the subset of patients with sepsis reflects the difference in cost between patients with and without a particular concurrent complication (eg, wound dehiscence) and are based on the 564 patients with postoperative sepsis.
[b] Indicates the denominator for all subsequent percentages.

COMMENT

This study estimated costs associated with postoperative sepsis in a nationally representative sample of general surgery patients in VA hospitals. Results suggest a greater than 2-fold increase in costs associated with postoperative sepsis compared with costs for other patients after controlling for differences in preoperative risk. Sepsis was most costly when it co-occurred with failure to wean the patient from mechanical ventilation after 48 hours.

A few previous studies[2,4-7] have attempted to estimate costs of inpatient sepsis. However, estimates vary widely, likely because of the varying cost structures in the countries where the studies were conducted, varying patient inclusion criteria, or inconsistent methods for estimating costs. To our knowledge, this is the first study to directly estimate the incremental costs associated with sepsis among patients undergoing inpatient surgery. Costs in this study were specifically assigned to reflect individual patient encounters and to provide an accurate assessment of patient resource use.

Given the extremely high mortality rates (approaching 30% within 1 month) for severe sepsis and septic shock, a primary reason to avoid postoperative sepsis may be to reduce mortality and improve subsequent quality of life. Toward that end, protocols for reducing postoperative infections have been published. For example, the Surgical Infection Prevention (SIP) system provides guidelines for administering prophylactic antibiotics within 1 hour before operating to reduce postoperative infection. (The VA implemented SIP guidelines prior to fiscal year 2006; data on SIP implementation are now available publicly [http://www.hospitalcompare.va.gov/]). Although the SIP protocols may dramatically decrease the occurrence of infections,[16] they do not specifically address severe sepsis. Interventions that specifically target sepsis generally promote early identification and prompt treatment, which are important factors in achieving good outcomes after sepsis. For example, one protocol specific to sepsis is the Surviving Sepsis Campaign,[17] which provides guidelines for early identification and treatment of sepsis. Despite widespread dissemination of the Surviving Sepsis Campaign, less than 30% of all inpatients with severe sepsis receive the recommended care.[18] Evidence suggests that adherence to the recommended sepsis treatment protocol may reduce mortality for some patients with severe sepsis,[19-22] although the effect on postoperative sepsis specifically has not been

Table 3. Risk-Adjusted Cost Associated With Postoperative Sepsis Relative to Patients Without Postoperative Sepsis and Relative Cost Associated With Additional Complication Co-occurring With Sepsis

	Relative Increase in Cost Associated With Postoperative Sepsis Relative to Patients Without Sepsis, Relative Cost Ratio (95% CI)	*P* Value	Risk-Adjusted Cost per Patient, $[a]
Patients with no postoperative sepsis	1 [Reference]	<.001	21 045 (20 718-21 375)
Patients with postoperative sepsis	2.28 (2.19-2.38)		48 017 (45 352-50 839)

	Increase in Cost Associated With Additional Complication Relative to Patients Without the Complication (95% CI) (n=564)	*P* Value	Risk-Adjusted Costs, $
Cardiac arrest	0.84 (0.67-1.06)	.84	40 334 (32 171-50 898)
Myocardial infarction	0.67 (0.49-0.92)	.01	32 171 (23 528-44 176)
Cerebrovascular accident	1.40 (0.79-2.50)	.25	67 724 (37 933-120 042)
Bleeding requiring ≥4 U of PRBCs	1.12 (0.75-1.67)	.58	53 779 (36 013-80 188)
Deep vein thrombosis	1.45 (0.95-2.22)	.09	69 625 (45 616-106 598)
Failure to wean patient from mechanical ventilation after 48 h	1.72 (1.48-1.99)	<.001	82 589 (71 065-95 554)
Pneumonia	1.23 (1.06-1.43)	.01	59 061 (50 898-68 644)
Pulmonary embolism	1.28 (0.82-1.99)	.28	61 462 (38 894-95 554)
Reintubation for cardiac/respiratory failure	1.00 (0.86-1.17)	.96	48 017 (41 295-56 180)
Renal failure	1.04 (0.82-1.31)	.75	49 938 (39 374-62 902)
Renal insufficiency	0.97 (0.76-1.24)	.81	46 577 (36 493-59 541)
Urinary tract infection	1.08 (0.92-1.26)	.35	51 858 (44 176-60 501)
Wound infection	1.21 (0.98-1.48)	.07	58 101 (47 057-71 065)
Superficial infection	1.08 (0.87-1.35)	.46	51 878 (41 775-64 823)
Wound dehiscence	1.24 (0.99-1.56)	.07	59 541 (47 537-74 906)

Abbreviations: CI, confidence interval; PRBCs, packed red blood cells.
[a]Risk-adjusted costs based on multivariable generalized linear model with log link and gamma-distributed errors, controlling for Veterans Affairs hospital, patient demographics, surgical complexity, preoperative risk comorbidity and severity, and preoperative laboratory values displayed in Table 1.

evaluated. Another intervention[23] used mandatory postoperative sepsis screening in the intensive care unit to reduce sepsis-related deaths among general surgery patients by 33%.

Finally, we note that several studies have found a relationship between postoperative complication rates and hospital staffing. For example, Pronovost et al[24] found lower rates of severe complications after abdominal aortic operations at hospitals with daily rounds by an intensivist compared with hospitals that did not use daily rounds. Similarly, other studies[25-27] have found that hospitals with higher nurse staffing ratios and more highly educated nurses providing care after high-risk surgery have lower morbidity and resource utilization compared with other hospitals. These studies do not directly indicate that staffing levels affect the rate of postoperative sepsis. Nevertheless, they do suggest that hospital administrators may want to consider whether a business case exists for higher staffing levels.[28]

While the studies mentioned indicate that multiple interventions have potential to reduce the impact of sepsis and improve outcomes, the effect on costs associated with sepsis care was not evaluated. If the improved outcomes are also associated with lower resource utilization, it may be possible to establish a business case for their implementation. Moreover, a large proportion of patients with sepsis have other complications as well, and addressing complications that co-occur with sepsis may also reduce costs. For example, respiratory complications were present in more than one-third of the patients with sepsis in our data, and lung expansion maneuvers (eg, deep breathing exercises and continuous positive airway pressure) have been shown to reduce respiratory complications after surgical operations.[29]

There are more than 25 000 inpatient general surgical procedures performed in VA hospitals annually, meaning that reducing postoperative sepsis by even a small fraction could result in a large cost savings. Using the estimated absolute difference in costs for the average patient of $27 000, we estimated the total savings that would be realized for a hospital performing an average number of general surgical procedures annually (roughly 210 are performed annually in VA hospitals) if sepsis rates were reduced by 10% or 15%. Assuming a baseline sepsis rate of 4.1%, an average hospital spends $230 000 annually on postoperative sepsis for general surgery patients; a 10% drop in the sepsis rate would result in a savings of $23 000 at a single hospital, while a 15% drop would save $35 000. Across the entire VA hospital system, a 10% and 15% drop in sepsis rates after general surgery would save nearly $2.8 million and $4.1 million, respectively. Nationally, rates of postoperative sepsis (including septic shock) among general surgery patients have been estimated at 3.9%.[30] With approximately 4 million general surgical procedures performed in US hospitals annually,[31] a 10% reduction in postoperative sepsis could save more than $421 million.

This study has some limitations. First, there is variation across VA hospitals in the estimation of costs. Cost estimates are derived from a standard set of RRU weights derived nationally, although departmental managers within facilities have some discretion in how costs for personnel, supplies, and equipment are allocated to reflect local factors. Our models included fixed coefficients for hospitals; the use of fixed coefficients controlled for unobservable factors that may affect variation in costs across hospitals. Second, results may not be generalized to the private sector. Although complication rates in the VA and private sector are comparable,[32,33] cost structures may differ in private sector hospitals, and private sector hospital costs do not include most physician services. Third, our analyses do not reflect other costs to society, such as lost wages for the patient and patient's family due to prolonged hospital stay, disability compensation if the complication results in long-term dysfunction, and opportunity costs to the hospital. Opportunity costs occur when the use of available bed-days for a patient with sepsis means that another patient is denied a hospital bed or diverted to another hospital for care. For private sector hospitals, this may mean the loss of additional patient revenues, whereas for VA hospitals the diversion likely results in a fee-based admission to a private sector hospital. Fourth, as with any investigation that relies on observational data, unmeasured confounders may produce misleading results. In our study, preexisting differences between patients who did and did not develop sepsis were controlled using multivariable risk-adjustment models. Thus, a patient with multiple conditions that are difficult to treat would likely cost more than a patient without such conditions, even without sepsis. Nevertheless, the VASQIP data used for this study contain a rich array of patient laboratory test results, clinical status, and comorbid conditions that reduce the likelihood that the results are biased owing to unmeasured risk. Fifth, the assumption of a direct relationship between the rate of postoperative sepsis and costs may not be valid. Any reduction in postoperative sepsis is not likely to affect certain costs, such as equipment, personnel, and facilities, in the short-term. Finally, identification of sepsis is subject to nuances that we are unable to address. For example, multiple nonseptic conditions (eg, diabetes mellitus and human immunodeficiency virus) can cause inadequate oxygen delivery and lead to lactic acidosis.[34] A patient with one of these conditions and associated bacteremia may or may not be considered septic.

Achieving meaningful reductions in complications of surgery requires sustained institutional commitment to encourage quality improvement efforts that bring together surgeons, anesthesiologists, nurses, and other individuals in the surgical process. This study documents that, although time consuming and often expensive, successful efforts to reduce postoperative sepsis may result in substantial cost savings. The number of severe sepsis cases is expected to grow at a rate of 1.5% per annum, partly as a result of the growing use of invasive procedures.[2] Hospitals that adopt and refine existing protocols to prevent postoperative infection and to treat postoperative infection and sepsis may avoid the expense of treating this serious and life-threatening illness.

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INVITED CRITIQUE

A Congressman's Legacy

During the 1980s, the Department of Veterans Affairs (VA) came under widely publicized congressional concern for the quality of surgical care in Veterans Health Affairs (VHA) hospitals, as prominently articulated by then Representative Ted Weiss (D-New York). At issue for the congressman was a VA Inspector General's report revealing that operative mortality rates for coronary artery bypass graft procedures in VHA hospitals were significantly higher than estimates of mortality in private-sector hospitals published at that time by the National Center for Health Statistics. Ironically, Rep Weiss died prematurely of coronary artery disease after undergoing 2 coronary artery bypass grafts.[1]

Encouraged by Congress, the VA began the National VA Surgical Risk Study, which subsequently became the VA National Surgical Quality Improvement Program (NSQIP). These projects have sought to develop robust, comprehensive databases and to use highly sophisticated data analyses, which can be translated to improvement in outcomes, not only in cardiac surgery but also for several procedures across many specialties. Arguably, the effort has yielded remarkable results with substantially reduced morbidity and mortality after major surgery in VHA hospitals. Indeed, in 2002, the Institute of Medicine referred to VA NSQIP as the "best in the nation" for measuring surgical quality and outcomes.[2] Building on the success of VA NSQIP, the American College of Surgeons (ACS) established ACS NSQIP[3] and TQIP (Trauma Quality Improvement Program[4]); these 2 programs compare outcomes and seek to improve patient care in participating private-sector hospitals and the nation's trauma centers, respectively.

The Original Article by Vaughan-Sarrazin et al[5] in this issue of the *Archives* and a related article published elsewhere[6] demonstrate that surgical quality improvement efforts continue to mature. The authors report their analysis of financial outcomes relative to septic complications following surgery in the VHA hospital system. Furthermore, Vaughan-Sarrazin et al[5,6] suggest that an investment in quality improvement leading to a reduction in surgical complications could decrease costs, implying a return on investment. At a time when the health care percentage of gross national product continues to soar toward an unsustainable number, these carefully written articles are profoundly relevant and potentially critically important.

In what manner might the array of stakeholders[7] in health care policy interpret these studies? Will the published data be appropriated to support positions that by debate and argument drift beyond the authors' cautious