Surgical site infection: Incidence and impact on hospital utilization and treatment costs

Gregory de Lissovoy, PhD, MPH,[a] Kathy Fraeman, SM,[a] Valerie Hutchins, BS,[a] Denise Murphy, RN, MPH, CIC,[b] David Song, MD,[c] and Brian B. Vaughn, MPA, MBA[d]

Background: Surgical site infections (SSIs) are serious operative complications that occur in approximately 2% of surgical procedures and account for some 20% of health care-associated infections.

Methods: SSI was identified based on the presence of ICD-9-CM diagnosis code 998.59 in hospital discharge records for 7 categories of surgical procedures: neurological; cardiovascular; colorectal; skin, subcutaneous tissue, and breast; gastrointestinal; orthopedic; and obstetric and gynecologic. Source of data was the 2005 Healthcare Cost and Utilization Project National Inpatient Sample (HCUP NIS). Primary study outcomes were rate of SSI by surgical category and impact of SSI on length of stay and cost. Results were projected to the national level.

Results: Among 723,490 surgical hospitalizations in the sample, 6891 cases of SSI were identified (1%). On average, SSI extended length of stay by 9.7 days while increasing cost by $20,842 per admission. From the national perspective, these cases of SSI were associated with an additional 406,730 hospital-days and hospital costs exceeding $900 million. An additional 91,613 readmissions for treatment of SSI accounted for a further 521,933 days of care at a cost of nearly $700 million.

Conclusion: SSI is associated with a significant economic burden in terms of extended length of stay and increased costs of treatment. Our analysis documented nearly 1 million additional inpatient-days and $1.6 billion in excess costs.

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Hospital-acquired infection (HAI) ranks among the 10 leading causes of death in the United States. In 2002, an estimated 1.7 million patients were affected by HAI, and 99,000 of them died as a result.[1] More than 20% of HAI is attributed to infection of a surgical site. Surgical site infections (SSI) are serious operative complications that occur in approximately 2% of surgical procedures, although rates vary widely according to type of procedure.[2] SSI can have a devastating impact on the patient's course of treatment and is associated with increased treatment intensity, prolonged length of stay (LOS), and higher costs. Although a number of studies have estimated the incidence of SSI, there is limited information on economic consequences in terms of LOS and cost of the admission. We present new estimates for the economic impact of SSI based on analysis of hospital discharge data from a representative national sample of US acute care general hospital admissions.

From United BioSource Corporation, Bethesda MD[a]; Barnes-Jewish Hospital, St. Louis, MO[b]; University of Chicago Hospitals Chicago, IL[c]; and ETHICON Inc., Somerville, NJ.[d]

Address correspondence to Greg de Lissovoy, PhD, Senior Research Scientist, United BioSource Corporation, 7101 Wisconsin Ave, Suite 600, Bethesda, MD 20814. E-mail: greg.delissovoy@unitedbiosource.com.

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METHODS

Study data

The study is based on 2005 hospital stay data from the Nationwide Inpatient Sample (NIS), a component of the Agency for Healthcare Quality and Research (AHRQ) Healthcare Cost and Utilization Project (HCUP).[3] HCUP is a federally sponsored nationally representative survey designed to approximate a 20% stratified sample of discharges from the nation's acute care community hospitals and comprises the largest available all-payer inpatient care database in the United States. The 2005 HCUP data represent 1054 hospitals from 37 states that account for 90% of all US hospital discharges. Because of the large sample size, the NIS can be used to assess uncommon conditions such as SSI.

Each HCUP record documents a single hospital discharge. Data elements include patient demographics (age, gender), reason for admission, ICD-9-CM diagnosis codes, medical or surgical procedures and tests performed during the admission (ICD-9-CM procedure codes), LOS, and discharge status. Also included in the record are the diagnostic-related group (DRG) assignment and total billed charges. We converted

Table 1. Discharge categories

Surgery category and DRG	Procedure description	Number of discharges	Percent of category
Neurologic surgery			
1	Craniotomy age >17 W CC	11,925	18.33
2	Craniotomy age >17 W/O CC	7555	11.61
7	Peripheral and cranial nerve and other nervous system procedures W CC	6446	9.91
8	Peripheral and cranial nerve and other nervous system procedures W/O CC	3113	4.78
528	Intracranial vascular procedures W PDX hemorrhage	1750	2.69
531	Spinal procedures W CC	3243	4.98
532	Spinal procedures W/O CC	3701	5.69
533	Extracranial procedures W CC	13,340	20.5
534	Extracranial procedures W/O CC	13,993	21.51
	Total for surgical category	65,066	100
Cardiovascular surgery			
104	Surgical cardiac valve and other major cardiothoracic procedures W cardiac catheter	6792	10.89
105	Surgical cardiac valve and other major cardiothoracic procedures W/O cardiac catheter	13,491	21.64
106	Coronary bypass W PTCA	1475	2.37
107	Coronary bypass W cardiac catheter	19,476	31.24
108	Other cardiothoracic procedures	7772	12.47
109	Coronary bypass W/O PTCA or cardiac catheter	13,341	21.4
	Total for surgical category	62,347	100
Colorectal surgery			
146	Rectal resection W CC	4352	5.01
147	Rectal resection W/O CC	1734	2
148	Major small and large bowel procedures W CC	56,493	65.1
149	Major small and large bowel procedures W/O CC	14,988	17.27
157	Anal and stomal procedures W CC	4593	5.29
158	Anal and stomal procedures W/O CC	4622	5.33
	Total for surgical category	86,782	100
Skin, subcutaneous tissue, breast surgery			
257	Total mastectomy for malignancy W CC	6370	19.99
258	Total mastectomy for malignancy W/O CC	7261	22.79
259	Subtotal mastectomy for malignancy W CC	1191	3.74
260	Subtotal mastectomy for malignancy W/O CC	1051	3.3
261	Breast procedures for nonmalignancy except biopsy and local excision	2639	8.28
267	Perianal and pilonidal procedures	463	1.45
268	Skin, subcutaneous tissue, and breast plastic procedures	2809	8.82
269	Other skin, subcutaneous tissue, and breast procedures W CC	5950	18.67
270	Other skin, subcutaneous tissue, and breast procedures W/O CC	4129	12.96
	Total for surgical category	31,863	100
Gastrointestinal surgery			
154	Stomach, esophageal, and duodenal procedures age >17 W CC	11,585	7.41
155	Stomach, esophageal, and duodenal procedures age <17 W/O CC	5043	3.23
159	Hernia procedures except inguinal and femoral age >17 W/O CC	8041	5.15
160	Hernia procedures except inguinal and femoral age >17 W/O CC	9138	5.85
161	Inguinal and femoral hernia procedures age >17 W CC	3196	2.05
162	Inguinal and femoral hernia procedures age >17 W/O CC	2633	1.69
164	Appendectomy W complicated principal diagnosis W CC	6269	4.01
165	Appendectomy W complicated principal diagnosis W/O CC	9913	6.34
166	Appendectomy W/O complicated principal diagnosis W CC	7386	4.73
167	Appendectomy W/O complicated principal diagnosis W/O CC	37,507	24
170	Other digestive system O.R. procedures W CC	7292	4.67
171	Other digestive system O.R. procedures W/O CC	1993	1.28
191	Pancreas, liver, and shunt procedures W CC	5339	3.42
192	Pancreas, liver, and shunt procedures W/O CC	1186	0.76
193	Biliary tract proc except only cholecystectomy W or W/O C.D.E. W CC	1657	1.06
194	Biliary tract proc except only cholecystectomy W or W/O C.D.E. W/O CC	369	0.24
195	Cholecystectomy W C.D.E. W CC	1085	0.69
196	Cholecystectomy W C.D.E. W/O CC	500	0.32
197	Cholecystectomy except by laparoscope W/O C.D.E. W CC	6348	4.06
198	Cholecystectomy except by laparoscope W/O C.D.E. W/O CC	3094	1.98

Continued

Table 1. Continued

Surgery category and DRG	Procedure description	Number of discharges	Percent of category
201	Other hepatobiliary or pancreas O.R. procedures	1196	0.77
288	O.R. procedures for obesity	25,488	16.31
	Total for surgical category	156,258	100
Orthopedic surgery			
210	Hip and femur procedures except major joint age >17 W CC	36,539	70.09
211	Hip and femur procedures except major joint age >17 W/O CC	10,782	20.68
212	Hip and femur procedures except major joint age 0-17	4812	9.23
	Total for surgical category	52,133	100
OB-GYN surgery			
353	Pelvic evisceration, radical hysterectomy, and radical vulvectomy	2742	1.02
370	Cesarean section W CC	64,028	23.8
371	Cesarean section W/O CC	202,271	75.18
	Total for surgical category	269,041	100
Readmission for postoperative infection			
418	Postoperative and posttraumatic infections	18,661	100

CC, complicating condition; *CDE*, common duct exploration; *DRG*, diagnosis-related group; *OR*, operating room; *PTCA*, percutaneous transluminal coronary angioplasty; *W*, with; *W/O*, without.

hospital charges to costs by applying hospital-specific cost-to-charge ratios as given in a separate NIS hospital characteristic file. Individual patient records can be linked to the hospital file using a hospital identification number. A sampling weight is also included for each discharge record, which enables projections to the universe of US acute care general hospital stays.

Selection of surgical procedures

Our study examined some of the most common types of surgical procedures performed in the majority of community hospitals in the following categories:

- Neurological surgery;
- cardiovascular surgery;
- colorectal surgery;
- skin, subcutaneous tissue, and breast surgery;
- gastrointestinal surgery;
- orthopedic surgery; and
- obstetric/gynecologic (OB/GYN) surgery.

As shown in Table 1, each surgical category was defined based on DRG codes as utilized by Medicare in 2005. This set of surgical procedures accounted for nearly 750,000 among a total of 8,000,000 discharge records in the 2005 NIS. We characterized each discharge according to patient age, gender, type of admission (elective vs nonelective), and type of surgery (neurologic; cardiovascular; colorectal; skin, subcutaneous tissue, and breast; gastrointestinal; orthopedic; and OB-GYN). We also identified the presence of comorbidities that have been associated with increased risk for SSI (chronic pulmonary disease,[4] coagulopathy, diabetes with chronic complications,[5,6] fluid and electrolyte disorders, obesity,[5,6] and weight loss).[4] Blood transfusion can also increase risk of SSI and was also flagged based on appearance of ICD-9-CM procedure codes in the 99.0 group.[5]

Identification of SSI cases

Because the study is based on analysis of administrative claims data, and not medical records, identification of SSI relied on specification of ICD-9-CM diagnosis codes. Many different codes can be appropriately applied to HAI. For example, code 996.61 describes "infection or inflammatory reaction due to a . . . coronary artery bypass graft." However, only 1 code—998.59—specifically refers to postoperative infection. We therefore defined an SSI case as a discharge record that listed code 998.59 as a secondary diagnosis (excluding those cases listing SSI as the primary diagnosis). We calculated the rate of SSI by surgical category as the number of records with an SSI designation divided by the total number of records in the category. Because SSI may only be identified after discharge, we also examined an additional set of records coded as DRG 418 (postoperative and posttraumatic infections) where the discharge diagnosis included the 998.59 SSI code (Table 1).

Impact on LOS and cost

Hospital-billed charges were converted to costs using the individual hospital all-payer inpatient cost/charge ratio from the NIS cost-to-charge ratio file. For hospitals without a listed all-payer inpatient cost/charge ratio, we substituted the group average all-payer inpatient cost/charge ratio. Records for hospitals in the State of Texas did not include either type of cost-to-charge ratio. For these hospitals, we substituted the average all-payer inpatient cost/charge ratio for hospitals in the same census region matched by bed size, teaching status, and urban/rural location.

Our principal study objective was to determine the additional length of stay and cost of treatment attributable to SSI. Risk factors as previously described that predispose a patient to SSI could also be associated with higher resource intensity and cost of care, independent of SSI. Not accounting for this relationship could lead to upward bias in estimating the incremental effect of SSI on LOS and cost. To perform this adjustment, we used a propensity score method to match each SSI case with a non-SSI control.[7] We first estimated a logistic regression model in which the binary left-side variable designated SSI cases (''1'') or patients without an SSI diagnosis (''0''). Right-side explanatory variables described type of surgical procedure, patient demographics, and presence of SSI risk factors (Table 2).

For each observation the regression procedure calculated a score indicating the likelihood of an SSI diagnosis. These scores were used to identify a set of non-SSI controls that matched the set of SSI patients within each surgical category. Because of the large number of non-SSI cases, the matching criterion was set at a high level such that the score for a non-SSI control matched the SSI case within ±0.01. Differences in LOS and cost of the hospital stay were calculated for each propensity score matched surgical cohort, with 95% confidence intervals for mean difference calculated via a bootstrap procedure.[8] Results were projected to the universe of US acute care general hospital discharges using the sampling weights in the NIS database and the statistical procedures specified by AHRQ.[9] All analyses were conducted using SAS (Release 9.1.3; SAS Institute Inc., Cary, NC).

RESULTS

Rate of SSI

The 7 categories of surgical hospitalizations that we selected for analysis from the 2005 NIS database comprised a total of 723,490 hospitalizations (Table 1). Among this total number of cases, we identified 6891 cases of SSI for an overall rate of 9.5 cases per 1000 surgical hospitalizations or just under 1%. Projected to the national level, the 7 surgical categories accounted for an estimated 3,544,658 admissions with 33,846 cases involving SSI. Further detail on rates of SSI as observed in the NIS data is shown in Table 3. For each surgical category, we list the 5 most common procedures by ICD-9-CM principal procedure code and the SSI rate. We also give the 5 procedures with the highest rate of SSI.

Table 2. Propensity score logistic regression model of surgical site infection

Predictors of SSI	Odds ratio (95% CI)	*P* value
Surgical category		
Obstetric and gynecologic	Reference category	
Neurologic	3.85 (3.11-4.76)	<.0001
Cardiovascular	12.00 (10.01-14.39)	<.0001
Colorectal	45.24 (38.28-53.46)	<.0001
Skin, subcutaneous, tissue, and breast	2.90 (2.16-3.89)	<.0001
Gastrointestinal	16.21 (13.73-19.14)	<.0001
Orthopedic	2.68 (2.11-3.40)	<.0001
Age (continuous)	1.003 (1.002-1.004)	<.0001
Female sex (relative to male)	0.79 (0.75-0.83)	<.0001
Elective admission (relative to nonelective)	0.82 (0.78-0.86)	<.0001
Transfusion procedure 99.0× (relative to no transfusion)	1.51 (1.34-1.69)	<.0001
Comorbid condition		
None of the comorbid conditions	Reference category	
Chronic pulmonary disease	1.13 (1.06-1.21)	.0001
Coagulopathy	1.56 (1.40-1.73)	<.0001
Diabetes with chronic complications	1.35 (1.15-1.58)	.0002
Fluid and electrolyte disorders	1.69 (1.59-1.79)	<.0001
Obesity	1.27 (1.15-1.40)	<.0001
Weight loss	2.33 (2.13-2.54)	<.0001

NOTE. C statistic 0.84.

The highest rate of SSI for the major surgical categories was recorded for colorectal surgery (4.11%; 95% CI: 3.98%-4.24%). The lowest rate of SSI was seen in the OB/GYN surgery category 0.06% (95% CI: 0.05%-0.07%). Common procedures with particularly high rates of SSI included small bowel resection ICD-9-CM 45.62 with a rate of 6.24% (95% CI: 5.77%-6.74%) and left hemocolectomy (ICD-9-CM 45.62) where the rate was 4.67% (95% CI: 4.13%-5.26%). However, procedures with the highest rate of SSI tended to be uncommon. For example, in the colorectal surgical category, the 5 ICD-9 procedure codes with the highest rates of SSI ranged from 6.34% to 10.00% but, as a group, accounted for only 2.4% of colorectal surgery procedures.

Impact of SSI on LOS and costs

Effect of SSI on LOS is described in Table 4 , whereas impact on cost of the hospital admission is shown in Table 5. Tables give the mean and median LOS and cost for hospitalization with and without an SSI diagnosis, as well as the absolute difference. Relative magnitude of the SSI impact is shown in Figs 1 (LOS) and 2 (cost).

Greatest increase in LOS was observed for cardiovascular surgery where duration was extended by mean

Table 3. Most common procedures and procedures with highest rate of SSI

Surgery category	Primary procedure and DRG	Number of discharges	Percent of discharges	Number with SSI*	Percent with SSI	95% CI (binomial)
	Total for all surgical categories	723,490	100.00	6891	0.95	0.93%-0.98%
Neurologic	Most common procedures					
	38.12: Head and neck endarterectomy not elsewhere classified (DRG 533 or 534)	23,432	36.01	21	0.09	0.06%-0.14%
	01.59: Other brain excision (DRG 001 or 002)	5452	8.38	12	0.22	0.11%-0.38%
	01.31: Incision, brain, and cerebral meninges (DRG 001 or 002)	4122	6.34	14	0.34	0.19%-0.57%
	00.61: Angioplasty or atherectomy, percutaneous, precerebral (extracranial) vessel(s) (DRG 533 or 534)	2525	3.88	2	0.08	0.01%-0.29%
	39.72: Repair or occlusion, endovascular, head and neck vessels (DRG 528 or 529)	1865	2.87	5	0.27	0.09%-0.62%
	Procedures with highest rate of SSI					
	03.59: Spinal structure repair not elsewhere classified (DRG 531 or 532)	871	1.34	22	2.53	1.59%-3.80%
	81.05: Other dorsolum fusion (DRG 531 or 532)	175	0.27	4	2.29	0.63%-5.75%
	02.12: Brain meninge repair not elsewhere classified (DRG 001 or 002)	489	0.75	11	2.25	1.13%-3.99%
	01.25: Other craniectomy (DRG 001 or 002)	143	0.22	3	2.10	0.43%-6.01%
	01.53: Brain lobectomy (DRG 001 or 002)	191	0.29	4	2.09	0.57%-5.28%
	Total for surgical category	65,066	100.00%	206	0.32	0.27%-0.36%
Cardiovascular	Most common procedures					
	36.12: Aortocoronary bypass-2 coronary artery (DRG 106)	10,107	16.21	114	1.13	0.93%-1.35%
	36.13: Aortocoronary bypass-3 coronary artery (DRG 106)	10,007	16.05	113	1.13	0.93%−1.36%
	35.21: Replace aortic valve-tissue (DRG 104)	5976	9.59	90	1.51	1.21%-1.85%
	36.14: Aortocoronary bypass-41 coronary artery (DRG 106)	5434	8.72	63	1.16	0.89%-1.48%
	35.22: Replace aortic valve not elsewhere classified (DRG 104)	5150	8.26	60	1.17	0.89%-1.50%
	Highest frequency of SSI					
	35.14: Open heart valvuloplasty of tricuspid valve without replacement (DRG 104)	185	0.30	8	4.32	1.89%-8.34%
	35.84: Total correction of transposition of great vessels (DRG 108)	220	0.35	9	4.09	1.89%-7.62%
	35.91: Interatrial venous return transposition (DRG 108)	52	0.08	2	3.85	0.47%-13.21%
	37.22: Left heart cardiac catherization (DRG 107)	107	0.17	4	3.74	1.03%-9.30%
	35.28: Replace tricuspid valve not elsewhere classified (DRG 104)	54	0.09	2	3.70	0.45%-12.75%
	Total for surgical category	62,347	100.00	734	1.18	1.09%-1.27%
Colorectal	Most common procedures					
	45.73: Right hemicolectomy (DRG 148 or 149)	17,752	20.46	605	3.41	3.15%-3.69%
	45.76: Sigmoidectomy (DRG 148 or 149)	15,420	17.77	608	3.94	3.64%-4.26%
	45.62: Partial small bowel resection not elsewhere classified (DRG 148 or 149)	9790	11.28	611	6.24	5.77%-6.74%
	45.75: Left hemicolectomy (DRG 148 or 149)	5526	6.37	258	4.67	4.13%-5.26%
	48.63: Anterior rectum resection not elsewhere classified (DRG 146 or 147)	3407	3.93	117	3.43	2.85%-4.10%
	Highest frequency of SSI					
	46.74: Closure small bowel fistula not elsewhere classified (DRG 148 or 149)	240	0.28	24	10.00	6.51%-14.51%
	45.93: Small-to-large bowel not elsewhere classified (DRG 148 or 149)	476	0.55	44	9.24	6.80%-12.21%
	45.61: Multiple segmental small bowel excision (DRG 148 or 149)	481	0.55	42	8.73	6.37%-11.62%
	46.20: Ileostomy not otherwise specified (DRG 148 or 149)	163	0.19	14	8.59	4.78%-13.99%
	46.01: Small bowel exteriorization (DRG 148 or 149)	726	0.84	46	6.34	4.68%-8.36%
	Total for surgical category	86,782	100.00	3565	4.11	3.98%-4.24%

Continued

Table 3. Continued

Surgery category	Primary procedure and DRG	Number of discharges	Percent of discharges	Number with SSI*	Percent with SSI	95% CI (binomial)
Breast	Most common procedures					
	85.43: Unilateral extended simple mastectomy (DRG 257/258/261)	7909	24.82	6	0.08	0.03%-0.17%
	85.41: Unilateral simple mastectomy (DRG 257/258/261)	3769	11.83	12	0.32	0.16%-0.56%
	85.32: Bilateral reduction mammoplasty (DRG 257/258/261)	1411	4.43	0	0.00	0.00%-0.26%
	86.83: Size reduction plastic operation (DRG 268)	1339	4.20	3	0.22	0.05%-0.65%
	86.30: Other local destruction skin (DRG 268)	1239	3.89	2	0.16	0.02%-0.58%
	Highest frequency of SSI					
	54.11: Exploratory laparotomy (DRG 269 or 270)	160	0.50	4	2.50	0.69%-6.28%
	84.15: Below knee amputation not elsewhere classified (DRG 269 or 270)	102	0.32	2	1.96	0.24%-6.90%
	40.11: Lymphatic structure biopsy (DRG 269 or 270)	112	0.35	2	1.79	0.22%-6.30%
	85.45: Unilateral radical mastectomy (DRG 257/258/261)	191	0.60	3	1.57	0.33%-4.52%
	54.30: Destruction abdominal wall lesion (DRG 269 or 270)	134	0.42	2	1.49	0.18%-5.29%
	Total for surgical category	31,863	100.00	63	0.20	0.15%-0.25%
Gastrointestinal	Most common procedures					
	47.01: Laparoscopic appendectomy (DRG 166 or 167)	31,977	20.46	171	0.53	0.46%-0.62%
	47.09: Other appendectomy (DRG 166 or 167)	28,632	18.32	441	1.54	1.40%-1.69%
	44.38: Lap gastroenterostomy (DRG 154 or 155)	14,373	9.20	53	0.37	0.28%-0.48%
	51.22: Cholecystectomy (DRG 170 or 171)	10,696	6.85	172	1.61	1.38%-1.86%
	53.61: Incisional hernia repair-graft (DRG 159 or 160)	9015	5.77	83	0.92	0.73%-1.14%
	Highest frequency of SSI					
	52.70: Radical pancreaticoduodenectomy (DRG 191 or 192)	1215	0.78	94	7.74	6.30%-9.38%
	43.70: Partial gastrectomy with jejunum anastomosis (DRG 154 or 155)	1385	0.89	78	5.63	4.48%-6.98%
	42.41: Partial esophagectomy (DRG 154 or 155)	398	0.25	20	5.03	3.10%-7.65%
	43.99: Total gastrectomy not elsewhere classified (DRG 154 or 155)	761	0.49	38	4.99	3.56%-6.79%
	86.22: Wound debridement (DRG 170 or 171)	684	0.44	34	4.97	3.47%-6.88%
	Total for surgical category	156,258	100.00	2032	1.30	1.24%-1.36%
Orthopedic	Most common procedures					
	79.35: Open reduction-internal fixation femur (DRG 210 or 212)	30,138	57.81	83	0.28	0.22%-0.34%
	79.15: Closed reduction-internal fixation femur (DRG 210 or 212)	11,196	21.48	20	0.18	0.11%-0.28%
	78.55: Internal fixation-femur (DRG 210 or 212)	6191	11.88	9	0.15	0.07%-0.28%
	77.35: Femoral division not elsewhere classified (DRG 210 or 212)	791	1.52	2	0.25	0.03%-0.91%
	80.15: Other arthrotomy-hip (DRG 210 or 212)	458	0.88	3	0.66	0.14%-1.90%
	Highest frequency of SSI					
	80.05: Arthrotomy/prosthesis removal-hip (DRG 210/211/212)	115	0.22	2	1.74	0.21%-6.14%
	79.85: Open reduction-hip dislocatation (DRG 210/211/212)	335	0.64	4	1.19	0.33%-3.03%
	77.85: Partial ostectomy-femur (DRG 210/211/212)	263	0.50	2	0.76	0.09%-2.72%
	77.25: Femoral wedge osteotomy (DRG 210/211/212)	288	0.55	2	0.69	0.08%-2.49%
	80.15: Other arthrotomy-hip (DRG 210/211/212)	458	0.88	3	0.66	0.14%-1.90%
	Total for surgical category	52,133	100.00	132	0.25	0.21%-0.30%
OB/GYN	Most common procedures					
	74.10: Low cervical cesarean section (DRG 370 or 371)	262,015	97.39	90	0.03	0.03%-0.04%
	74.00: Classical cesarean section (DRG 370 or 371)	3083	1.15	4	0.13	0.04%-0.33%
	68.60: Radical abdominal hysterectomy (DRG 353)	1298	0.48	15	1.16	0.65%-1.90%
	71.50: Radical vulvectomy (DRG 353)	526	0.20	18	3.42	2.04%-5.35%

Continued

Table 3. Continued

Surgery category	Primary procedure and DRG	Number of discharges	Percent of discharges	Number with SSI*	Percent with SSI	95% CI (binomial)
	74.40: Cesarean section not elsewhere classified (DRG 370 or 371)	424	0.16	0	0.00	0.00%-0.87%
	Highest frequency of SSI					
	68.80: Pelvic evisceration (DRG 353)	105	0.04	11	10.48	5.35%-17.97%
	68.40: Total abdominal hysterectomy (DRG 353)	93	0.03	4	4.30	1.18%-10.65%
	40.54: Radical groin dissection (DRG 353)	24	0.01	1	4.17	0.11%-21.12%
	71.50: Radical vulvectomy (DRG 353)	526	0.20	18	3.42	2.04%-5.35%
	40.52: Radical dissection periaortic lymph node (DRG 353)	217	0.08	5	2.30	0.75%-5.29%
	Total for surgical category	269,041	100.00	159	0.06	0.05%-0.07%

DRG, diagnosis-related group.

(median) 13.7 (11) days. Smallest increase in LOS occurred with the skin, subcutaneous tissue, and breast surgery category where the absolute increase was 5.7 (4) days.

Hospitalization costs attributable to SSI increased in parallel with length of stay (Table 5, Fig 2). Cardiovascular surgery hospitalizations with SSI had the greatest absolute impact relative to non-SSI hospitalizations, increasing costs by mean (median) $37,513 ($29,239). The skin, subcutaneous tissue, and breast surgery category had the smallest absolute increase with a mean (median) of $6731 ($4696) per hospitalization. For all surgical categories, the weighted mean difference in LOS and cost between patients with SSI and without SSI was 9.7 days and $20,842, respectively.

National impact of SSI

We projected the results as reported above to the universe of 2005 US acute care hospital discharges (Table 6). For the 7 surgical categories, SSI accounted for an additional 406,730 hospital-days and $991.0 million of incremental treatment costs. Readmission for treatment of SSI was projected for 91,613 patients, representing a further 521,933 days of hospital care and $674.4 million in additional costs. Overall, we found that an estimated 928,663 additional days of hospital care and $1.6 billion in hospital costs were attributed to SSI.

DISCUSSION

In the United States, administrative databases containing diagnosis and procedure codes are generated as a by-product of processing claims for reimbursement from third-party payers. These data are widely used for purposes other than payment, including health services research and quality of care assessment. Deficiencies in claims data when used in this manner have been widely described and include the fact that payment incentives can encourage providers to underreport or overreport particular conditions.[10] Until availability of reliable and detailed clinical data from electronic medical records becomes the norm, rather then the exception, administrative databases will remain the primary source of data on the content and quality of care delivered to the US population.

The Centers for Medicare and Medicaid Services, in an effort to improve quality of care, has recently established a new policy of financial penalties for hospital-acquired conditions that will rely on diagnosis codes. Presence of specified conditions in association with designated procedures and primary diagnoses may disqualify a hospital from receiving ‘‘outlier’’ payments or DRG payments associated with a higher level of severity as a result of the condition. SSI associated with coronary artery bypass graft (mediastinitis) is included in the first group of hospital-acquired conditions.[11]

Use of administrative data to identify SSI has been investigated in several studies, and the general consensus is that coded diagnoses are imprecise in comparison with conventional surveillance. Recent evidence comes from 2 studies that compared diagnosis codes with traditional surveillance in specific surgical categories across a large number of patients. Stevenson et al (2008) utilized an extensive list of diagnosis codes derived from the system used by the Pennsylvania Health Care Cost Containment Council.[12] More than 100 distinct ICD-9-CM codes were used to identify SSI. Yokoe et al (2004)[13] adopted a more targeted approach and relied on 3 codes to identify SSI (998.5, 998.51, 998.59). Not surprisingly, results across the 2 studies were quite different. In the case of coronary artery bypass graft surgery, Stevenson et al reported positive predictive value of 0.42[12] For the same procedure, Yokoe et al give positive predictive value of 0.84.[13]

Differences in SSI prevalence could partially account for the contrasting positive predictive value as reported by Stevenson et al[12] relative to Yokoe et al.[13] However, specification of diagnosis codes used to identify SSI is

Table 4. Observed incidence and consequences of surgical site infections: Propensity-score adjusted impact of surgical site infections on length of stay by surgical category

Surgery category	Number of discharges			Median LOS, days*		Mean LOS, days*				
	Without SSI		With SSI	LOS without SSI	LOS with SSI	LOS without SSI	LOS with SSI	Difference in mean LOS	95% Confidence interval for difference in mean LOS	
	Actual	Matched	Actual						Lower	Upper
Neurologic	64,503	206	206	4	14	7.7	18.6	10.9	8.4	13.2
Cardiovascular	61,518	730	732	8	19	10.2	23.9	13.7	12.6	14.9
Colorectal	82,954	3525	3560	8	15	10.2	19.1	8.9	8.4	9.5
Skin, subcutaneous, tissue, and breast	31,219	63	63	2	6	3.7	9.4	5.7	3.6	8.0
Gastrointestinal	151,682	2025	2030	4	12	7.0	17.0	10.0	9.3	10.7
Orthopedic	51,918	132	132	5	12	6.0	15.6	9.5	7.7	11.7
Obstetric and gynecologic	268,733	159	159	3	6	4.8	10.8	6.0	3.7	7.9

*Based on number of patients with nonmissing LOS > 0.

Table 5. Observed incidence and consequences of surgical site infections: Propensity-score adjusted impact of SSI on cost of hospital stay by surgical category

Surgery category	Number of discharges			Median cost*		Mean cost*				
	Without SSI		With SSI	Cost without SSI	Cost with SSI	Cost without SSI	Cost with SSI	Difference in mean cost	95% Confidence interval for difference in mean cost	
	Actual	Matched	Actual						Lower	Upper
Neurologic	63,506	201	205	$13,410	$30,347	$20,090	$45,987	$25,897	$20,323	$31,778
Cardiovascular	60,548	715	703	$31,652	$60,891	$41,066	$78,579	$37,513	$33,136	$41,606
Colorectal	81,663	3473	3491	$14,172	$27,794	$20,441	$38,396	$17,955	$16,820	$19,149
Skin, subcutaneous, tissue, and breast	30,554	61	61	$6932	$11,628	$8658	$15,389	$6731	$3616	$10,246
Gastrointestinal	149,576	1982	1995	$9519	$22,804	$16,239	$37,068	$20,829	$19,105	$22,542
Orthopedic	51,071	130	129	$10,749	$23,330	$13,373	$28,502	$15,129	$11,882	$18,753
Obstetric and gynecologic	263,859	155	153	$4274	$10,103	$5457	$19,425	$13,968	$10,704	$17,687

*Based on number of patients with non-missing cost and LOS > 0.

most likely the major factor. Stevenson et al took a highly inclusive approach, with numerous codes flagging a possible SSI, and, as a result, their approach is highly sensitive but lacking in specificity. Yokoe et al relied on a much narrower strategy based on only 3 codes, which is less sensitive but more specific.

Our procedure was even more conservative than Yokoe et al[13] and utilized a single code (998.59) to designate SSI; this follows the Centers for Medicare and Medicaid Services criteria for identifying SSI in coronary artery bypass graft surgery. Reliance on this single code should yield relatively low sensitivity and high specificity in terms of the number of SSI cases that we identified among the selected surgical procedures in the NIS database. Evidence for low sensitivity can be seen in the incidence of SSI we report for coronary artery bypass graft surgery: approximately 1.2% compared with the much larger and nearly identical figures reported by Stevenson et al (8.0%)[12] and Yokoe et al (7.4%).[13] This disparity parallels the considerable variability in published estimates for rates of SSI in the categories of surgery that we examined:

- Neurologic surgery: 0.5%-29%[14-17];
- cardiovascular surgery: 0.8%-4.7%[18-22];
- colorectal surgery: 2.6%-15%[23-25];
- skin, subcutaneous tissue, and breast: 0.4%-16.3%[13,26,27];
- gastrointestinal: 1.3%-15.5%[28-30];
- orthopedic: 0.6%-1.4%[31-35]; and
- OB/GYN: 1.6%-9.6%.[13,25,36]

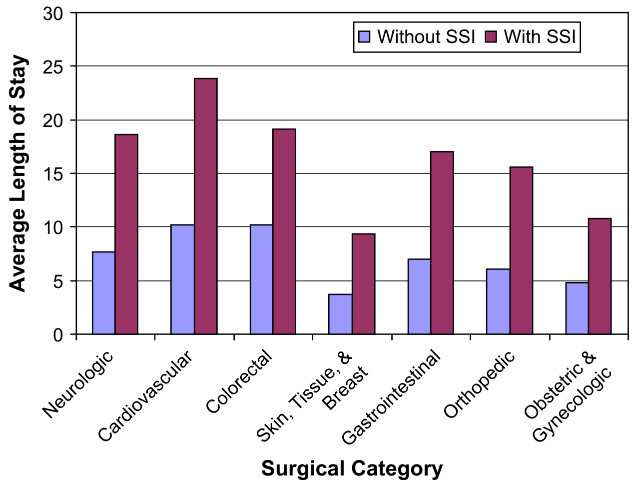

Fig 1. Impact of surgical site infection on length of stay.

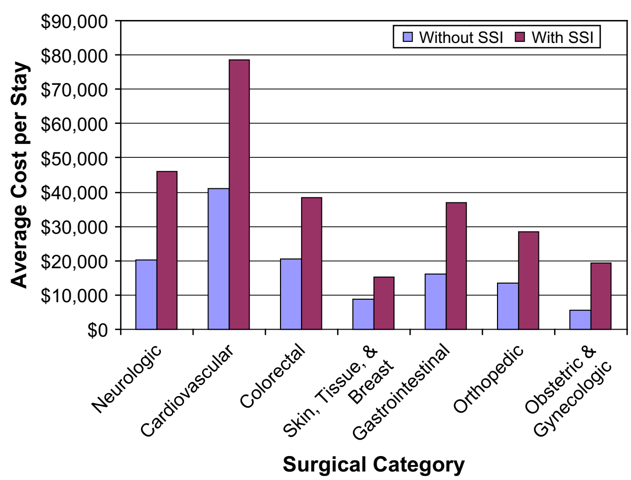

Fig 2. Impact of surgical site infection on cost of hospital stay.

Impact of SSI on LOS and cost of admission

Although we report a lower rate of SSI than many other studies, the impact of SSI on LOS and cost that we observed appears consistent with other reports. Across the entire group of surgical categories considered, our analysis revealed that SSI increased mean length of stay by 9.7 days and of mean cost treatment by $20,842. In a study of pediatric patients, Sparling et al reported that SSI prolonged LOS by 10.6 days and that costs were raised by $27,288.[37] A retrospective medical records review of coronary artery bypass graft patients at a Midwestern hospital compared the course of treatment for cases with SSI (n = 41) and without SSI (n = 160). SSI was associated with an average of 20 additional inpatient-days at an incremental cost of $20,000.[38]

National impact of SSI

Projected to the national level, our analysis identified over 125,000 cases of SSI where approximately 34,000 were recorded with the initial surgical admission, and the remaining 91,000 involved a readmission for treatment of SSI. These cases represent nearly 1 million excess hospital-days and just under $1.6 billion in added costs. Whereas the magnitude of these figures is substantial, the 125,000 SSI cases we identify comprise less than half of the 274,000 SSIs estimated by the Centers for Disease Control and Prevention.[1] In addition to hospital cases that our algorithm fails to identify, a substantial proportion of SSI cases are identified following discharge. A review of SSI associated with breast cancer surgery revealed that 96% of cases were detected after discharge.[27] Although our tabulation included rehospitalization for treatment of SSI, our estimate does not include counts and costs for cases treated in an outpatient setting or via home antibiotic therapy.

Our results document substantial economic costs attributable to SSI in terms of excess hospital-days and costs for inpatient treatment. However, a full accounting of the economic impact of SSI should also consider the additional burden on patients. Treatment of SSI often requires antibiotic therapy, contributing to the problem of antimicrobial resistance. Prolonged hospital stays place patients at risk for other adverse outcomes such as medication reactions or errors, pressure ulcers, or use of urinary or bloodstream catheters, which could result in subsequent HAIs. Pain management, recovery time, and follow-up physician visits interrupt work and personal lives, all adding to the burden on individuals, family caregivers, employers, insurers, and society as a whole.

CONCLUSION

Measures to reduce rates of preventable SSI and their associated adverse outcomes will improve the safety and quality of care while avoiding substantial costs, thereby benefiting all consumers of health care. Change in Medicare payment policy eliminating additional payments for health care-associated infection underscores the urgent need for hospital leaders to address this important problem.

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Table 6. Projected national impact of SSI on LOS and cost

Category	Discharges with SSI		Additional hospital days		Additional hospital costs	
	Number	Percent of total discharges	Number	Percent of total days	Number	Percent of total costs
Initial surgery admission						
Neurologic	1014	0.32	11,212	0.65	$26,497,137	0.52
Cardiovascular	3643	1.19	49,987	1.69	$137,997,023	1.20
Colorectal	17,491	4.11	156,993	3.97	$315,196,097	4.06
Skin, subcutaneous, tissue, and breast	309	0.20	1857	0.37	$2,218,288	0.19
Gastrointestinal	9971	1.30	101,197	2.77	$209,790,245	2.29
Orthopedic	647	0.25	6140	0.41	$9,870,979	0.32
OB-GYN	772	0.06	4694	0.10	$10,859,542	0.17
Total, initial discharge*	33,846	0.95	406,730	2.14	$921,013,240	2.08
Rehospitalization for SSI	91,613	—	521,933	—	$674,439,663	—
Total projected impact of SSI	125,459		928,663		$1,595,452	

*Because of the nature of NIS data and weights assigned to different hospital records, this figure is not the sum of the additional costs per hospitalization category.

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