

***The Impact of Surgical-Site Infections in
the 1990s: Attributable Mortality, Excess
Length of Hospitalization, and Extra Costs***

***K. B. Kirkland, J. P. Briggs, S. L. Trivette, W. E. Wilkinson,
and D. J. Sexton***

THE IMPACT OF SURGICAL-SITE INFECTIONS IN THE 1990s: ATTRIBUTABLE MORTALITY, EXCESS LENGTH OF HOSPITALIZATION, AND EXTRA COSTS

Kathryn B. Kirkland, MD; Jane P. Briggs, BSN; Sharon L. Trivette, RN; William E. Wilkinson, PhD; Daniel J. Sexton, MD

ABSTRACT

OBJECTIVE: To determine mortality, morbidity, and costs attributable to surgical-site infections (SSIs) in the 1990s.

DESIGN: A matched follow-up study of a cohort of patients with SSI, matched one-to-one with patients without SSI.

SETTING: A 415-bed community hospital.

STUDY POPULATION: 255 pairs of patients with and without SSI were matched on age, procedure, National Nosocomial Infection Surveillance System risk index, date of surgery, and surgeon.

OUTCOME MEASURES: Mortality, excess length of hospitalization, and extra direct costs attributable to SSI; relative risk for intensive care unit (ICU) admission and for readmission to the hospital.

RESULTS: Of the 255 pairs, 20 infected patients (7.8%) and 9 uninfected patients (3.5%) died during the postoperative hospitalization (relative risk [RR], 2.2; 95% confidence interval [CI₉₅], 1.1-4.5). Seventy-four infected patients (29%) and 46 uninfected patients (18%) required ICU admission (RR, 1.6; CI₉₅, 1.3-2.0). The median length of hospitalization was 11 days for infected patients

and 6 days for uninfected patients. The extra hospital stay attributable to SSI was 6.5 days (CI₉₅, 5-8 days). The median direct costs of hospitalization were \$7,531 for infected patients and \$3,844 for uninfected patients. The excess direct costs attributable to SSI were \$3,089 (CI₉₅, \$2,139-\$4,163). Among the 229 pairs who survived the initial hospitalization, 94 infected patients (41%) and 17 uninfected patients (7%) required readmission to the hospital within 30 days of discharge (RR, 5.5; CI₉₅, 4.0-7.7). When the second hospitalization was included, the total excess hospitalization and direct costs attributable to SSI were 12 days and \$5,038, respectively.

CONCLUSIONS: In the 1990s, patients who develop SSI have longer and costlier hospitalizations than patients who do not develop such infections. They are twice as likely to die, 60% more likely to spend time in an ICU, and more than five times more likely to be readmitted to the hospital. Programs that reduce the incidence of SSI can substantially decrease morbidity and mortality and reduce the economic burden for patients and hospitals (*Infect Control Hosp Epidemiol* 1999;20:725-730).

Each year, more than 18 million surgical procedures are performed in US hospitals.¹ The Centers for Disease Control and Prevention (CDC) estimates that 2.7% of these are complicated by surgical-site infections (SSIs), accounting for at least 486,000 nosocomial infections each year.² Such infections often lead to substantial morbidity and probably contribute to mortality in some patients.^{3,4} However, the extent of morbidity and mortality attributable to SSI is not known. It is generally accepted that SSIs, like other nosocomial infections, prolong hospital stays and add to the economic costs of hospitalization. However, published estimates of the actual excess days and costs attributable to SSI reflect hospitalization patterns prior to the current era of diagnosis-related groups (DRGs) and managed care.⁵⁻¹¹ We conducted a study of SSI in a community hospital in order to examine the mortality, the need for intensive care unit (ICU) admission, the need for readmission to the hospital within 30 days of discharge, the excess length of stay, and the extra costs attributable to SSI in the DRG and managed-care era.

METHODS

Hospital

Durham Regional Hospital (DRH) is a 415-bed hospital with an average daily census of 267 during the study period. Approximately 5,000 inpatient surgical procedures are done at DRH each year. The hospital is a teaching affiliate of Duke University Medical Center and serves the city and county of Durham (population 200,000). Since 1991, an active surveillance program for SSI has been in place at DRH. Operating room personnel report information to two infection control nurses regarding each inpatient surgical procedure performed, including the surgical personnel involved, the duration of the procedure, the wound class, and the patient's anesthesia risk score. The infection control nurses perform prospective surveillance for SSI on all hospital wards, through regular interactions with surgical staff nurses and daily review of microbiology laboratory reports, and gather additional information about each patient with SSI, including the date and site of infection and culture results. Since 1992, surgeons have been surveyed

From the Department of Medicine (Drs. Kirkland, Wilkinson, and Sexton), the Department of Community and Family Medicine (Dr. Wilkinson), Duke University Medical Center; the Durham Regional Hospital (Dr. Sexton, Ms. Briggs, and Ms. Trivette), Durham, North Carolina. Address reprint requests to Kathryn B. Kirkland, MD, Box 3306 Duke University Medical Center, Durham, NC 27710. 98-OA-148. Kirkland KB, Briggs JP, Trivette SL, Wilkinson WE, Sexton DJ. The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs. *Infect Control Hosp Epidemiol* 1999;20:725-730.

regularly to identify SSIs that are first recognized after discharge from the hospital. Risk-adjusted, surgeon-specific infection rates are calculated annually and presented to the surgical staff.

Study Design

We performed a matched follow-up study in which infected patients (patients with SSI) were matched one-to-one with uninfected controls (patients without SSI), identified from a cohort of patients undergoing a total of 22,742 inpatient surgical procedures between June 1, 1991, and July 31, 1995.

Case Definition and Selection

An infected case-patient was defined as any patient who developed SSI following an inpatient surgical procedure performed during the study period. We used CDC National Nosocomial Infections Surveillance (NNIS) System criteria to define SSI.¹² Only the first episode of SSI was included for patients who had more than one SSI during the study period.

Matching and Selection of Controls

For each infected patient, a matched uninfected control-patient was selected from among all patients who underwent inpatient surgery during the study period and who did not develop SSI ($n=22,465$), according to the following matching criteria: NNIS procedure code,¹³ NNIS risk index,¹⁴ age (within 10 years), and date of surgery (within 12 months). When possible, each infected patient was matched with an uninfected patient whose procedure was performed by the same surgeon.

Data Collection and Definitions

Data collected as part of the ongoing SSI surveillance program were available on each study patient. Additional information was obtained by retrospective review of data available on computer regarding death during the postoperative hospitalization, the need for postoperative ICU admission, the need for readmission to the hospital within 30 days of the initial discharge, and the length of the initial postoperative hospitalization and of the second hospitalization, if required. A list of direct costs of both the first and second hospitalizations for each study patient was obtained from the DRH business office, which calculated these costs using "microcosting" methodology, a technique of assigning costs that uses the actual costs of the items and services used by an individual patient, rather than using cost-to-charge ratios or average daily costs. The complete medical records of study patients who died during the initial hospitalization, when available, were reviewed by one of us (KBK). An attempt was made by this reviewer to determine whether SSI was causal or contributory to death.

Excess length of stay attributable to SSI was defined as the estimated median difference in length of the postoperative stay between an infected patient and his or her matched uninfected patient. Extra cost attributable to SSI was defined as the estimated median difference in direct

costs between an infected patient and his or her matched uninfected patient. The length of stay and the direct costs of both the initial hospitalization (during which the surgery took place) and any subsequent admission within 30 days of the initial discharge were compared.

The mortality attributable to SSI was defined as the difference between the percentage of infected patients and the percentage of uninfected patients who died during the initial hospitalization. Pairs that included a patient who died during the initial hospitalization were excluded from the analysis of the risk for readmission.

Statistical Analysis

This study used a matched follow-up design¹⁵ in which infected patients (patients with SSI) were matched one-to-one with uninfected controls (patients without SSI), and the statistical analyses used were based on this design. Furthermore, since the continuous variables related to length of stay and costs, as well as the differences in these variables between matched pairs, were highly skewed, non-parametric methods were used for data presentations and analyses. More specifically, point estimates and 95% confidence intervals (CI_{95}) for median differences were based on the Signed-Rank test.¹⁶ Comparisons of dichotomous outcomes between the two groups were characterized in terms of the relative risk (RR) for the outcome associated with SSI, with confidence intervals for the RR derived from confidence intervals for the logarithm of RR.¹⁵ Statistical analyses were performed using SAS (SAS Institute, Cary, NC).

RESULTS

During the study period, a total of 22,742 inpatient surgical procedures were performed. We identified 277 SSI in 272 patients, accounting for an overall crude SSI rate of 1.2%. Rates of SSI increased with increasing NNIS risk index (Table 1). Five second episodes of SSI were excluded from the matching process.

Matching

Of the 272 patients who developed SSI, 255 (94%) were successfully matched for procedure code and NNIS risk index. Ninety percent of the pairs were within 5 years of age; the remaining 10% were within 10 years of age. Ninety percent of the pairs had surgery within 6 months of each other; the remaining 10% had surgery within 12 months of each other. In 215 (84%) of the 255 matched pairs, both patients were operated on by the same surgeon.

Seventeen patients (6%) with SSI could not be successfully matched. When compared with the 255 infected patients who were successfully matched, these 17 patients were more likely to have a NNIS risk index of 2 or 3. Their postoperative length of stay was longer, and their hospitalization costs were higher than the infected patients who were successfully matched. The matched and unmatched patients with SSI were similar with respect to age, rate of readmission, and mortality.

Characteristics of the 255 matched pairs are summarized in Table 2. Of the 255 patients who developed SSI, 205

TABLE 1
RATES OF SURGICAL-SITE INFECTION (SSI) AMONG 22,737 PATIENTS, ACCORDING TO NATIONAL NOSOCOMIAL INFECTION SURVEILLANCE (NNIS) RISK INDEX

NNIS Risk Index	Total Procedures	SSI	
		No.	%
0	8,026	50	0.6
1	11,284	124	1.1
2	3,190	92	2.9
3	237	6	2.5

Note: Five patients who developed a second SSI during the study period are excluded from the numerator and denominator.

Chi-square for trend=84.2; $P < .001$.

had wound cultures, of which 194 were positive. The most common pathogen was *Staphylococcus aureus*, isolated from 48% of patients who had SSI. Other gram-positive cocci were isolated from 31% of patients who had SSI and gram-negative rods from 34%. Twenty-three percent of SSIs were polymicrobial.

Mortality

Among the 255 matched pairs, 20 (7.8%) of the infected patients and 9 (3.5%) of the uninfected patients died during the initial postoperative hospitalization. Thus, the mortality attributable to SSI was 4.3%. The RR of death for infected patients was 2.2 (CI₉₅, 1.1-4.5). Sixteen patients (12 patients with SSI and 4 patients without SSI) died following gastrointestinal surgery, 8 (5 with SSI and 3 without SSI) following orthopedic surgery, 3 (1 with SSI and 2 without SSI) following cardiothoracic surgery, 2 (1 with SSI and 1 without SSI) following vascular surgery, and 1 each following hysterectomy and skin graft surgery (both with SSI). The median interval from surgery to death for patients who had SSI was 34 (range, 7-72) days and for patients who did not develop SSI, 8 (range, 5-54) days. The median age of patients with SSI who died was 68 (range, 52-91) years and of patients without SSI who died was 75 (range, 49-90) years. The distributions of anesthesia class and NNIS risk index were similar for patients with and without SSI who died during the postoperative period.

Among the 20 patients with SSI who died, 6 had infections due to methicillin-resistant *S aureus*, 4 had infections due to gram-negative bacilli, and 3 each had infections due to enterococci or yeast. The medical records were available for 15 of the 20 patients with SSI who died. Of these, 9 patients had deep SSI, 4 had incisional SSI, and in 2 cases the depth of the infection could not be determined from the record. Ten patients were on appropriate antibiotics for their SSI, and 5 were on inappropriate or partially appropriate antibiotics. Based on chart review, SSI was considered causal or contributory to death in 6 cases, was present at the time of death but not thought to be directly contributory in 6 cases, was resolved in 1 case, and was indeterminate in 2 cases.

TABLE 2
CHARACTERISTICS OF 255 MATCHED PAIRS* OF PATIENTS WITH AND WITHOUT SURGICAL-SITE INFECTION

Characteristic	Infected	Uninfected
	Patients	Patients
Age, median (range), y	63 (10-95)	63 (9-93)
<40 y	43	44
40-65 y	104	109
>65 y	108	102
NNIS risk index		
0	49	49
1	122	122
2	82	82
3	2	2
Anesthesia risk score		
I (Healthy)	15	25
II (Mild systemic disease)	116	109
III (Severe systemic disease, definite functional limitations)	99	108
IV (Severe systemic disease that is a constant threat to life)	24	12
V (Moribund, not expected to survive 24 h)	1	1

Abbreviation: NNIS, National Nosocomial Infection Surveillance System.

* Pairs were matched on age (within 10 y) and risk index but not on anesthesia risk score.

Need for ICU Admission

Of the 255 matched pairs, 74 infected patients (29%) and 46 uninfected patients (18%) spent at least 1 day (median, 3 days for both infected and uninfected patients) in an ICU. The RR for ICU admission in infected patients was 1.6 (CI₉₅, 1.3-2.0).

Length of Hospitalization and Need for Readmission

For infected patients, the median length of the initial postoperative hospitalization was 11 (range, 1-110) days, compared with 6 (range, 1-123) days for uninfected patients. Lengths of hospitalization varied by procedure (Table 3). The excess length of postoperative hospitalization attributable to SSI was 6.5 (CI₉₅, 5-8) days. Among the 229 pairs who survived the initial hospitalization, 94 (41.0%) of the infected patients and 17 (7.4%) of the uninfected patients required readmission to the hospital within 30 days of discharge. The RR for readmission in infected patients was 5.5 (CI₉₅, 4.0-7.7). When the length of this second hospitalization was taken into account, the total length of the combined postoperative hospitalizations for infected patients was 18 (range, 1-181) days, compared with 7 (range, 1-154) days for uninfected patients. The total excess length of hospitalization attributable to SSI was 12 (CI₉₅, 10-14) days per infected patient.

Direct Costs of Hospitalization

The median direct costs of the initial postoperative hospitalization for infected patients were \$7,486, compared to \$3,842 for uninfected patients; these costs varied by pro-

TABLE 3

LENGTH AND DIRECT COSTS OF POSTOPERATIVE HOSPITALIZATION AND COMBINED INITIAL AND SECOND HOSPITALIZATION IN PATIENTS WITH SURGICAL-SITE INFECTIONS AND MATCHED UNINFECTED CONTROL PATIENTS, BY PROCEDURE

Procedure	No. of Pairs	Median LOS		Median Total LOS		Median Direct Costs (\$)		Median Total Direct Costs (\$)	
		Infected	Uninfected	Infected	Uninfected	Infected	Uninfected	Infected	Uninfected
CABG	20	10.5	7.5	19	8	13,071	11,559	15,415	11,559
Appendectomy	7	11	2	12	2	4,645	1,039	4,984	1,039
Colon surgery	29	13	7	14	8	5,332	2,594	6,131	3,460
Laparotomy	19	24	7	29	7	9,813	3,998	14,398	4,434
Laminectomy	24	4	3	13.5	3	1,537	1,487	4,760	1,487
Spinal fusion with implant	20	11.5	7.5	28	7.5	10,152	7,797	18,798	7,797
Open reduction of fracture	8	6.5	3.5	15	3.5	3,269	2,481	6,104	2,481
Joint replacement	23	11	8	12	8	7,686	5,492	8,206	5,492
Vascular surgery	11	9	8	24	8	11,320	6,666	12,261	6,666

Abbreviations: CABG, coronary artery bypass grafting; LOS, length of stay in days.

cedure (Table 3). For the initial hospitalization, the excess direct costs attributable to SSI were \$3,089 (CI₉₅, \$2,148-\$4,136). When readmission within 30 days of the initial discharge was taken into account, the median total direct costs for infected patients were \$8,864, compared to \$4,391 for uninfected patients. Excess total direct costs attributable to SSI were \$5,038 (CI₉₅, \$4,020-\$6,289) per infected patient.

Total direct costs over the entire study period were \$3,721,713 for infected patients versus \$1,746,725 for uninfected patients. Thus, the total extra costs attributable to SSI at DRH during the study period were \$1,974,988.

DISCUSSION

Our study quantifies the impact of SSI in the current era of the DRG system and managed care. Changes in the patterns of hospitalization resulting from these systems prompted us to use novel measures of outcome, such as the rate of readmission to the hospital and the rate of ICU admission, in addition to more standard measures such as the length of stay and direct costs of hospitalization. Our study demonstrates a significant association between SSI and mortality. The availability of prospectively collected data regarding more than 20,000 surgical cases, from which to select 255 closely matched pairs, gave our study the power to find this association and to make precise estimates of the other human and economic costs of SSI. The study's community hospital setting strengthens the generalizability of its findings.

Most prior studies have used the length of hospitalization as an indicator of resource utilization attributable to SSI.¹¹ Estimates of the excess length of stay attributable to SSI in studies conducted in the 1950s through the early 1980s ranged from 7 to 24 days.¹¹ The advent of the DRG system in the United States in the early 1980s increased pressure on hospitals to shorten patients' hospital stays. In the one prior study that estimated the excess length of stay attributable to SSI in the "DRG era," the mean excess length of stay associated with SSI following total abdominal hysterectomy in the late 1980s was 3.6 days,¹⁷ approxi-

mately one half of what it had been in the mid-1970s.⁹ Our finding that SSIs account for a median of 6.5 excess days of postoperative hospitalization per infected patient is, as expected, lower than estimates made during the pre-DRG, pre-managed-care era. However, our study demonstrates that resource utilization attributable to SSI does not end with the initial hospital discharge.

Many SSIs do not become apparent until after discharge from the hospital^{18,21}; thus, the resource utilization associated with these infections is often shifted to subsequent hospitalizations, as well as into the outpatient setting. For this reason, we included the rate and length of readmission in our analysis of outcomes. Patients in our study who developed SSI were approximately five times more likely to require readmission to the hospital within 30 days of the postoperative discharge than matched patients who did not develop SSI. When we used the combined length of both the initial and second hospitalizations, the excess days of hospitalization attributable to SSI increased from 6.5 to 12 days per patient.

Our study actually may have underestimated both the RR of readmission and the excess days of hospitalization for patients with SSI, since we measured only early readmission to the hospital. Clearly, some patients with SSI (such as those who develop SSI after prosthetic joint replacement or spinal surgery) require multiple readmissions to the hospital over periods of months to years. Our study was not designed to measure the total human and economic impact of infections in such patients. Had we included follow-up beyond the first postoperative month, the total impact of SSI likely would have been even greater.

The use of direct (or marginal) costs of hospitalization has been proposed as a better method of estimating the costs of nosocomial infection than the use of total costs or patient charges.²² Direct costs represent the actual costs to the hospital for items and services used by the individual patient. The use of direct costs, while an appropriate estimate of the extra costs of inpatient treatment of SSI, proba-

bly underestimates the total resource utilization associated with SSI and also underestimates the total financial and personal impact of SSI on the patients themselves. For example, direct costs do not include the costs of outpatient care. In one recent study, an average of 4.6 outpatient encounters occurred within the first 30 days after surgery for each patient who developed SSI.³⁹ Furthermore, our study did not measure the costs of home antibiotic therapy and supplies, the cost of ancillary services such as physical therapy, or revenue lost as a result of patient illness and disability.

Despite these limitations, data concerning direct costs provide a useful estimate of the costs incurred by the hospital as a result of SSI and of potential savings. Our data may allow other institutions to estimate the costs attributable to SSI at their hospitals. An appreciation of these aggregate costs may in turn motivate them to allocate resources to programs designed to prevent SSI. Even community hospitals such as ours that have very low overall rates of SSI can benefit from programs that reduce SSI rates. For example, at DRH, following institution of a program designed to provide individual surgeons with risk-adjusted surgeon- and procedure-specific SSI rates, SSI rates decreased from 1.6% to 1% over a 2-year period. This decline in SSI rates saved the hospital an estimated \$166,000 in direct costs.

Excess days of hospitalization and direct costs attributable to SSI measure the economic impact of these infections. However, these indicators do not fully measure the human costs of SSI.²⁵ We used postoperative ICU admission as a surrogate marker of the impact of SSI on the patient. Almost one third of infected patients spent at least 1 day in the ICU postoperatively; the rate of ICU admission was 60% higher in infected patients than in uninfected patients.

The ultimate human cost of infection is death. Perhaps the most important finding of our study is that patients who developed SSI were more than twice as likely to die during the postoperative hospitalization as closely matched patients who did not develop SSI. Previous studies have suggested an association between SSI and death, but these studies either lacked the statistical power to confirm this association or lacked adequate controls.^{3,4} In a review of NNIS data regarding nosocomial infections in surgical patients, Horan et al reported that, in 89% of patients who died following the development of deep SSI, death was determined to be related to the infection.³ Poulsen et al reported an increased mortality rate in patients with deep SSI compared with uninfected patients; however, cases and controls were not matched for their risk of developing SSI or for any index of underlying health status.⁴

To demonstrate a credible association between SSI and increased mortality, infected patients and uninfected patients should have a similar preoperative risk of postoperative death. Preoperative risk factors for postoperative death include older age and an anesthesia risk class greater than II. The similarity of the distribution of age and anesthesia class among infected patients and uninfected patients in our study (Table 3) suggests that the preoperative risk of postoperative death in our matched pairs was probably similar.

Potential limitations of our study relate to the matching schema that we used. Even pairs that are well-matched on criteria including age, service, and operative procedure sometimes are mismatched on underlying diseases and other potential predictors of prolonged hospitalization.¹¹ We did not attempt to match our infected patients with uninfected patients who had the same or similar underlying diagnoses. However, the similarity of the distribution of anesthesia scores in infected patients and uninfected patients (Table 2) suggests that at least the overall severity of disease was similar in the two groups. Moreover, matching infected patients and uninfected patients by specific medical diagnoses is thought to be less important in studies measuring the impact of SSI than in studies that measure outcomes of other nosocomial infections.¹¹ Selection bias is another potential limitation of studies that use matched pairs, if many unmatched cases are excluded from the analysis. The availability of a large pool of potential uninfected control patients enabled us to match successfully 94% of the 272 infected patients. The 17 unmatched patients in our study had longer hospitalizations and higher costs than infected patients who were matched successfully. Thus, if their exclusion had an effect on our outcome measures, it most likely led us to underestimate the excess hospital days and costs attributable to SSI.

As more patients undergo outpatient and short-stay surgical procedures, fewer SSIs are detected prior to discharge. This trend may in turn lead to underestimates of the rate of SSI and of the human and economic costs of such infections. Our study demonstrates the enormous negative impact that SSIs continue to have and the importance of looking beyond the initial postoperative hospitalization to determine the total costs of these infections. At our hospital, SSI accounted for five deaths, a total of 107 days in the ICU, 920 days of hospitalization, and \$473,997 in direct costs each year. If our estimates of the impact of SSI at DRH are applied to the entire United States, SSI are responsible for approximately 20,000 in-hospital deaths and cost hospitals over \$3 billion each year for inpatient care alone. Infection control programs that include SSI surveillance coupled with feedback to surgeons regarding their infection rates are effective in reducing the rate of SSI.^{24,27} Our study demonstrates both the enormity of the human and financial costs associated with SSI and the benefits to patients and the size of potential savings to hospitals if effective prevention programs are instituted and maintained.

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