Six Years of Surgical Wound Infection Surveillance at a Tertiary Care Center

Review of the Microbiologic and Epidemiological Aspects of 20,007 Wounds

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Hypotheses: (1) Antibiotic restriction policies result in alteration of microbiologic features of surgical site infections (SSIs) and (2) reported SSI rates are underestimated when postdischarge surveillance is not included in SSI surveillance efforts.

Design: Retrospective analysis of prospectively collected SSI surveillance data.

Patients and Methods: We compared initial microbial isolates from SSIs between (1) January 1, 1993, and December 31, 1995, and (2) January 1, 1996, and December 31, 1998. Antibiotic restriction policies were implemented at Fairview-University Medical Center, Minneapolis, Minn, on March 1, 1995. For the combined periods (January 1, 1993, to December 31, 1998), we determined SSI rates for 20,007 operations according to the extent of bacterial contamination at surgery (wound class). Then, we analyzed SSI rates for 10,559 of these operations (selected based on availability of Anesthesia Society of America score and type of procedure) using the surgical wound risk index (wound class, Anesthesia Society of America score, and length of operation). We categorized SSI rates by 17 procedures for comparison with SSI rates reported by 286 hospitals that contributed data confidentially and voluntarily to the National Nosocomial Infections Surveillance System in 1998. We compared SSI rates with and without postdischarge surveillance.

Results: Coagulase-negative staphylococcus and group D enterococcus were the 2 most frequent isolates before and after antibiotic restriction policies were implemented. Candida albicans isolates decreased from 7.9% (1993-1995) to 6.5% (1996-1998; \( P = .46 \)). Methicillin-resistant Staphylococcus aureus (1.8% of isolates) and vancomycin-resistant enterococcus (2.4% of isolates) organisms were first identified between 1996 and 1998. Our SSI rates were 2.6% for class I wounds, 3.6% for class II wounds, and 10.5% for class III/IV wounds; 53.9% of SSIs were identified after hospital discharge.

Conclusions: Antibiotic restriction policies did not alter the microbial spectrum of SSIs during the observation period. Reporting SSI rates in the absence of postdischarge surveillance dramatically underestimates actual SSI rates, especially in tertiary care hospitals that provide care for large populations of elderly and immunosuppressed patients.

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Surgical site infections (SSIs) are the most common nosocomial infections in surgical patients—accounting for about 24% of the total number of nosocomial infections—and are associated with substantial morbidity and expense and occasional mortality. Some factors contributing to the development of SSIs are patient related and beyond the control of the surgical team, whereas others relate to the application of generally accepted principles of antibiotic prophylaxis and perioperative care of the surgical patient. Awareness of the predominant organisms likely to be encountered, and changing resistance patterns, can influence the choice of antibiotics used for perioperative prophylaxis. The Joint Commission on Accreditation of Healthcare identified nosocomial infection rates as an indicator of quality of care. Reporting results of SSI surveillance to the surgical team has been shown to affect behavior and thus, reduce infection rates. Historically, hospitals have reported SSI rates using the single risk category of bacterial contamination in the operating room (class I, clean; class II, clean and contaminated; and class III/IV, contaminated and dirty). However, this classification does not take into account important patient-derived variables for the development of SSIs. The surgical wound index includes both intrinsic and extrinsic measures of patient risk. This index is used by the National Nosocomial Infections Surveillance (NNIS) System, which collects and

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PATIENTS AND METHODS

We performed surgical wound surveillance for all services within the academic Department of Surgery at Fairview-University Medical Center, the clinical hospital for the University of Minnesota, Minneapolis, from January 1, 1993, to December 31, 1998. Services included in this analysis were General Surgery (general, plastic, pediatric, and vascular surgery cases), Transplant Surgery (kidney, pancreas, small bowel, and liver transplantation), and Cardiovascular Surgery (coronary bypass procedures, valve operations, general thoracic surgery, and heart and lung transplantsations). Surveillance was also performed for other services not within the academic Department of Surgery, including Orthopedic Surgery, Gynecology, Neurosurgery, Otolaryngology, and Oral/Maxillofacial, but these rates are not included in this analysis. Outpatient procedures were excluded from NNIS risk index analysis according to the NNIS protocol. For wound class analysis, outpatient procedures were included, beginning on January 1, 1995.

MICROBIOLOGIC TESTING

Gram staining and culture results were obtained for 658 of 783 wounds. Antibiotic sensitivity profiles on isolates were performed when requested. Beginning on January 1, 1996, sensitivities were routinely requested for enterococcal and Staphylococcus aureus isolates.

SURVEILLANCE

Surveillance of SSIs at Fairview-University Medical Center is part of ongoing quality assurance monitoring. Surgical site infections are identified through review of (1) patients’ hospital records, (2) Department of Surgery morbidity and mortality records, (3) pertinent culture reports, and (4) quarterly questionnaires completed by all surgeons. This information is used for observation, treatment, and follow-up of wound infections by the nurse clinician, who acts as a consultant and data manager.

Surgical site infections were defined using criteria established by the Centers for Disease Control and Prevention (CDC).16,17 Diagnosis of superficial wound infections was based on (1) clinical decision by the surgeon, who then opened the wound; (2) spontaneous drainage and opening of the wound; (3) presence of purulent drainage; or (4) demonstration of microbes in culture specimens from fluid draining from the wound. Diagnosis of deep-wound infections was based on the presence of (1) frank purulent drainage or (2) microbes in culture specimens obtained via percutaneous sampling of fluid collections radiographically (with or without catheter placement) or during abdominal reexploration.

Postdischarge surveillance included (1) clinic appointment follow-up, (2) telephone conversations with patients lost to follow-up, and (3) contact with regional infection-control practitioners regarding patients seen at other institutions. We attempted to follow up all patients for the development of SSIs for 30 days after surgery and for up to 1 year after prosthetic implantation, as recommended by the CDC.18 During previous internal attempts to quantify patient follow-up, our estimated institutional capture rate was higher than 90% for recipients of transplants and cardiovascular patients.

Denominator data were derived from the operating room database. A single trip to the operating room, in which multiple procedures were performed, counted as a single contribution to denominator data, based on the prioritized case.

WOUND CLASS

We determined SSI rates for 20,007 operations during a 6-year period using the sole risk factor of bacterial contamination in the operating room. Wound classes were defined as follows: class I, clean (no viscus entered and no breaks in sterile technique); class II, clean/contaminated (minimal contamination or minor breaks in sterile technique); and class III/IV, contaminated/dirty (large numbers of microbes are likely to be present).18

NNIS CATEGORIES

A subset of 10,559 of 20,007 operations in our wound class analysis were categorized into the 29 operations defined by the NNIS System. However, because ASA scores were not available for 1993, this set of data was not included for analysis using the NNIS system. We report SSI rates using the NNIS risk index for the 17 procedures that had sufficient denominator data (12 procedures were excluded). The NNIS risk index attempts to quantify intrinsic and extrinsic measures of patient risk for developing an SSI.19 A risk index score of 0, 1, 2, or 3 is derived from an individual patient’s Anesthesia Society of America score of 3, 4, or 5 (based on the patient’s functional status); operative time longer than a preestablished 75th percentile; and a contaminated or dirty wound.13 The NNIS risk index has recently been shown to have greater predictive power than the Study on the Efficacy of Nosocomial Infection Control index9 and attempts to make interhospital comparisons more meaningful by standardizing patient populations via the index score.10,12 We compared our infection rates with NNIS rates using the Fisher exact test (2-tailed) with the SAS statistical software (SAS Institute Inc, Cary, NC).12

From January 1, 1993, to December 31, 1998, a total of 58,082 operations were performed in the operating rooms.
of Fairview-University Medical Center, 20,007 of which were performed by surgeons in the Department of Surgery and are included in our analysis. Yearly overall SSI rates are illustrated in Table 1. Average patient age was 41 years (range, 0–99 years); 48% were female and 52% were male.

A total of 783 wound infections occurred (3.9% of 20,007 operations). For patients with superficial, deep, and combined wound infections, median time to SSI diagnosis was 16 days (mean, 20 days; range, 2–149 days) (Figure 1). Surgical site infections after discharge ranged from 44.7% to 60.9% per year (mean, 53.9%). We noted no significant differences in time to diagnosis of SSIs between superficial and deep wounds. Mean time to diagnosis of SSIs did not significantly change during the observation period.

The microbiologic characteristics of initial isolates from patients diagnosed as having SSIs in the 2 periods studied (1993–1995 and 1996–1998) are illustrated in Figure 2 (top and bottom). The breakpoint in the years corresponds to the institution of antibiotic restriction policies (restrictions on the use of intravenous vancomycin hydrochloride, cefazidine, fluconazole, imipenem–cilastatin sodium, aztreonam, and ciprofloxacin hydrochloride and vancomycin by mouth). Methicillin–resistant S aureus (1.8% of isolates) and vancomycin-resistant enterococcus (2.4% of isolates) organisms were first identified in initial SSI cultures between 1996 and 1998. The 3 most common SSI isolates found between 1993 and 1995 were coagulase-negative staphylococcus (28.4%), Enterococcus species (17.3%), and Candida albicans (7.9%). The 3 most common SSI isolates found between 1996 and 1998 were coagulase-negative staphylococcus (25.6%), Enterococcus species (11.5%), and S aureus (8.7%). C albicans isolates decreased from 7.9% (1993–1995) to 6.5% (1996–1998; P = .46). The overall incidence of Candida species in SSIs decreased from 12.4% between 1993 and 1995 to 9.9% between 1996 and 1998.

The frequency of different fungal SSI isolates for the 6 years of observation is shown in Table 2. The most common fungal isolate was C albicans (83 isolates), followed by Torulopsis glabrata (37 isolates).

Most cultured wounds grew polymicrobial flora (41.0%). The specific characteristics of isolates obtained from superficial, deep, and combined superficial and deep SSIs from 1993 to 1998 are illustrated in Figure 3. When isolates were divided by affected site, polymicrobial or monomicrobial gram-positive isolates predominated. Overall, 17.2% of wounds were not cultured. Of superficial SSIs, 24.0% were not cultured, compared with 4% of combined and deep SSIs.

We compared overall SSI rates with rates previously reported by wound class in Figure 4.21 Rates of SSI in our study were within published reference ranges for individual wound classes. Overall SSI rates from 1993 to 1998 were 3.2% (393/12,393) for the General Surgery service, 8.6% (266/3099) for the Transplant Surgery service, and 2.8% (124/4515) for the Cardiovascular Surgery service (Table 3). Of all wound infections, 50.2% occurred on General Surgery, 34.0% on Transplant Surgery, and 15.8% on Cardiovascular Surgery services. For the 507 patients who underwent pancreas transplantation during the observation period, overall SSI rate was 21.5%. When analyzed by wound class, only class I cardiovascular cases had an SSI rate greater than the acceptable range of 1.3% to 2.9%.21

Procedure-specific SSI rates among patients graded by NNIS risk index scores from January 1, 1994, to December 31, 1998, are shown in Table 4. Average NNIS risk index score during these 5 years was 1.18; 1923 patients had a score of 0, 5065 scored 1, 3277 scored 2, and 294 scored 3. National Nosocomial Infections Surveillance risk index SSI rates were 2.0% for a score of 0, 3.7% scored 1, 9.2% scored 2, and 23.1% scored 3.

Organ transplantation and appendectomy SSI rates, with and without SSIs identified after hospital discharge, are shown in Figure 5 (top and bottom). With inclu-
sion of SSIs identified after discharge, our SSI rates are significantly higher than NNIS rates. However, by excluding SSIs identified after discharge, our SSI rates compared favorably with NNIS-reported rates. Similarly, by excluding SSIs identified after discharge, SSI rates for the other 15 procedures evaluated were not significantly higher than NNIS-reported rates.

**COMMENT**

Coagulase-negative staphylococcus and group D enterococcus were the most common isolates in this series. Several explanations are possible. First, nearly 25% of superficial SSIs were not cultured. The most common isolate from a typical SSI was *S aureus*, which, if found in a superficial wound infection, can be treated by simply opening the wound. Coagulase-negative staphylococcus and group D enterococcus likely represent the hospital flora that can be cultured in patients with complicated SSIs and comorbid diagnoses or immunosuppression. Finding coagulase-negative staphylococcus, group D enterococcus, or *Candida* species in wounds often leads to the clinical conundrum of whether a microbial isolate represents colonization or infection. In the absence of cellulitis, if clinical signs and symptoms resolve quickly after a wound is opened, antibiotic therapy is typically not warranted. These normally indolent organisms likely indicate compromised host defenses rather than true pathogens. Attempts to eradicate colonizing organisms using antibiotics will frequently fail, and can lead to additional problems with antibiotic resistance. A much more difficult decision arises when these organisms are cultured from deep or combined wound infections. In the absence of symptoms or signs of infection, we again favor treating this finding as colonization rather than as invasive infection.

Antibiotic restriction policies at Fairview-University Medical Center were implemented with the intent to delay the arrival or prevent the spread of resistant organisms. The hypothesis that patients exposed to more varieties of broad-spectrum antibiotic therapy and for longer durations...
will develop increased prevalence of resistant organisms is supported by the different resistance profiles of SSI isolates from patients in the intensive care unit compared with the rest of the hospital. Pharmacy data at Fairview-University Medical Center indicate an initial hospitalwide decrease of 50% in use of restricted antibiotics. However, after the first year of restrictions, use of restricted antibiotics gradually but steadily returned to prerestriction levels (data not shown). In immunosuppressed patients at our tertiary care center, microbial flora seem less likely to be affected by antibiotic restriction than by host defense mechanisms.

Nationwide, reports of group D enterococcal resistance to vancomycin therapy have been increasing. For this reason, the CDC in 1995 recommended restrictions on the use of vancomycin. In addition, a relationship between the use of glycopeptides (vancomycin) and third-generation cephalosporins (ceftazidime) in the emergence of vancomycin-resistant enterococci was previously demonstrated. Before 1995, vancomycin-resistant enterococcus was not identified in the microbiologic spectrum of initial SSI isolates at our institution; however, we noted an increased incidence of vancomycin-resistant enterococcus and methicillin-resistant S. aureus from SSIs after 1995 (Figure 2). Possible explanations for this apparent increase in resistant isolates include (1) increasing prevalence within the community, (2) increasingly debilitated patients, or (3) patients with multiple previous hospitalizations with exposure to multiple antibiotics. However, the most likely explanation for the appearance of vancomycin-resistant enterococcus and methicillin-resistant S. aureus is the previous hospital policy to not test for these isolates unless requested. This policy has been changed to screen all staphylococcal isolates for methicillin therapy resistance and all enterococcal isolates for vancomycin therapy resistance. These pathogens will likely appear with much greater frequency in the future.

The CDC documented a nationwide increased incidence of Candida isolates in SSIs and other nosocomial infections. From 1993 to 1998, we saw a trend toward a decreased percentage of overall Candida species isolated from SSIs. This trend may be explained by our increased use of prophylactic antifungal agents for patients receiving pancreas transplants, who were previously identified as high risk for SSIs with Candida species. Beginning in 1996, our perioperative prophylaxis included 400 mg of intravenous fluconazole for 1 week
and perioperative broad-spectrum antibiotic coverage of bowel flora. Our experience suggests that surgical populations at high risk for fungal SSIs may benefit from perioperative antifungal prophylaxis.

In 1970, the NNIS System was created to develop a nationwide database from US hospitals regarding the type and incidence of nosocomial infections.28 Wound classification using bacterial contamination alone was the traditional means for comparing and contrasting SSI rates among hospitals.15 However, patient-derived variables were not considered by this purely extrinsic measure of risk. Thus, multivariate indices were developed and adopted by the NNIS system,30 which reports SSI rates on an annual basis and was specifically designed to aid in interhospital comparison among a variety of hospitals (286 hospitals in 1998).30 When SSIs from our tertiary care teaching hospital are expressed in terms of wound class, rates are within acceptable ranges (Figure 4).31 However, when SSI data are generated using the multivariate NNIS risk index, most operations are outside acceptable ranges.30 Rates of SSI become difficult to compare and contrast when a variety of hospitals use different schemes to collect and

Table 4. Surgical Site Infection Rates by Operative Procedure and NNIS Risk Index Score, 1994-1998 *

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<th>Procedure</th>
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<th>NNIS Rates, %</th>
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* NNIS indicates National Nosocomial Infections Surveillance; CABG, coronary artery bypass graft; and ellipses, data not applicable.
analyze data. For example, NNIS hospitals have the option to track any procedure, or any number of procedures (referred to as “targeted surveillance”). Also, patient populations in smaller community hospitals differ from those in large, tertiary care teaching hospitals. The NNIS risk index score attempts to correct for “patient mix,” but recent studies32,33 question the validity of applying the NNIS risk index system to tertiary care facilities that routinely operate on patients with advanced stages of disease and multiple comorbid diagnoses.

Perhaps the most important source of variability, however, is that 70% of NNIS hospitals do not perform SSI surveillance after the patient’s hospital discharge.3,4

Results of recent studies11,12 show that 13% to 61% of SSIs did not manifest until after discharge, so limited or no postdischarge surveillance will artificially lower SSI rates. Postdischarge surveillance is labor intensive, with no clear consensus regarding the most effective techniques.14 However, some form of surveillance standardization would greatly enhance the validity of interhospital comparisons of SSI rates. Our institution’s SSI rates were generally higher than NNIS rates. However, with exclusion of SSIs identified through postdischarge surveillance (53.9%), our reported rates were similar to or better than NNIS rates. Some form of standardized postdischarge surveillance is key to decreasing the variability and enhancing the validity of interhospital SSI rate comparisons. In the era of managed health care, accurately representing SSI rates is imperative because they are frequently—although perhaps inappropriately—used as indices of quality of care.

At our institution, implementation of antibiotic restriction policies did not alter SSI microbiologic findings because it did not cause any long-term change in the use of restricted antibiotics. Regarding SSI surveillance, failure to include postdischarge surveillance in reporting SSI rates will significantly underestimate actual SSI rates, particularly in tertiary care centers. Shorter hospital stays, sicker patients, and more complex surgical procedures all contribute to increasing numbers of SSIs diagnosed after hospital discharge. Developing postdischarge surveillance performance standards is essential to enhance the validity of SSI rates for interhospital comparison and to ensure uniform quality of patient care.


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REFERENCES


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DISCUSSION

Robert E. Condon, MD, Clyde Hill, Wash: We have just heard a retrospective review of a large experience with surgical site infections. It may be the largest such report since the classic 1980 paper by Peter Cruse and Rosemary Foord. The authors’ database encompasses 20,000 operations, among which 783 wound infections were identified. Unfortunately, about 15% of all these infections were not cultured, and antibiotic sensitivities were done only when requested by the clinicians, and these limitations need to be kept in mind when interpreting the reported data.

There has been a prodigious effort at follow-up, for which the authors are to be commended. One of their arresting observations is that 56% of infections were identified only after discharge from the hospital. This is a sea change from the experience we reported two decades ago and, of course, one of the many changes initiated by our current adventures with managed care.

Furthermore, I have calculated from their data that fully 17% of their infections were identified more than 30 days after the index operation, and that bit of information calls into question current recommendations about the duration of follow-up needed to uncover infections. This issue was not addressed in the paper, but I would appreciate the authors’ comments about this important topic.

Antimicrobial use restrictions were put into place in Minnesota in 1993, and the authors report that, following implementation of this new policy, they observed—among other changes in outcomes—a decrease in fungal infections, especially among transplant patients, which they attribute in the paper to “aggressive” antifungal prophylaxis. What is meant, Dr Weiss, by “aggressive” vs more ordinary prophylaxis, and how did your prophylaxis regimen fit into the antimicrobial restriction program?

Finally, review of procedure-specific SSI rates sometimes identified infection rates at Minnesota that exceeded those reported by NNIS. The authors express concern about this adverse finding, and attribute it in part to their better follow-up compared to practices at NNIS-reporting institutions.

That may be, but I point out to the authors that the differences in their experience are, in fact, bidirectional; thoracic surgery infection rates were lower in your institution, for example, and the number of infections in most subsets examined is less than 100, so you cannot calculate a percentage.

Under those circumstances, I would be very cautious not to overinterpret the data or succumb to a tyranny of numbers. Not every statistically significant difference represents a significant biologic difference. In particular, I would be cautious in drawing any conclusions about quality of care. Your numbers may only represent the large element of biologic variation that is not under the control of the surgical staff.

Dr Weiss: Your first question was regarding the ideal duration of postdischarge surveillance. You mentioned that 17% of wound infections manifested after 30 days, so within reason, 1-month postdischarge surveillance would be reasonable, and our study would suggest that you could find 85% of the total number of infections. So 30 days is probably a good place to start.

In terms of the definition of “aggressive” antifungal prophylaxis, the manuscript I sent to you evoked over the last weeks, and especially the last 48 hours, so that verbiage was deleted. But the fact of the matter is, we gave 400 mg IV preoperative fluconazole, 7 days’ duration, so that is essentially the protocol that was followed.

In terms of antibiotic restriction policies, fluconazole in fact was restricted, but for use in transplant populations following protocol.

In terms of our hospital-wide antibiotic consumption, pharmacy data indicate that, at the time when our antibiotic restriction policies were instituted, the amount of restricted antibiotic use of vancomycin, cefazidime, fluconazole, etc, essentially fell off by one third, but over time, the quantity of antibiotics that were used hospital-wide eventually over this last year have returned to our prerestriction levels.

Donald E. Fry, MD, Albuquerque, NM: I would emphasize that the NNIS data are actually from a pool of 1986-1998 data in its present iteration, and I think everybody in this audience would agree that what went on in our hospitals in 1986, 1987, and 1988 may have no semblance to what goes on today.

Unfortunately, our hospital administrators and our quality assurance personnel want to benchmark all of our practices. I think it is impossible to benchmark practices across hospitals that have vastly different arrays of practice activity. The practice at the University of Minnesota, a hospital rich in transplantation compared to mine with a large volume of trauma, are going to have bacteriology and incidence of infection that are going to be so dramatically different. It is unfair to try to create any national benchmark to cover all of those eventualities.

The median day of identifying an infection in this report was the 16th postoperative day, the average was on the 20th postoperative day. The reality is that hospital-based surveillance almost seems to have no value at all except for acute catastrophic infection. It really raises the issue, Dr Weiss, of whether wound infection surveillance is really worth the effort.

In your hospital and my hospital, we have consolidated clinics, but in most of the private hospitals around the community, you would have to send out a whole group of surveillance people to go to all physician offices to try to identify every last minor wound infection, which probably has no relevance to anything in the world. So I guess the question I would ask is, does wound surveillance have any role whatsoever in the new era as we are practicing it? And I couldn’t help but miss this opportunity to ask whether the 17 patients who had no cultures done do any worse than the 83% who had them?

Dr Weiss: In terms of the utility of wound surveillance, there is a role for it. We need to know what our rates are, and when our rates are dramatically different from those published by the remainder of the hospitals in the country. Having said that, we have to find a reasonable way to detect postdischarge surveillance wound infections. The most sensitive way may be to look at the readmission records of patients who have been readmitted through the emergency room with a diagnosis of wound infection.

I think a reasonable way to start with postdischarge surveillance is to say that a hospital needs to achieve a specific rate. You don’t need to tell hospitals how to conduct postdischarge surveillance, but they need to find what works best for the individual institution. You don’t need to allot thousands of man-hours and dollars, but hospitals need to find a reasonable way to just get an idea of what the overall wound infection rates are.
knob binds to MHC class I alpha2 domain at the surface of human epithelial and B lymphoblastoid cells. EMBO J. 1997;16:2294-2306.


Errors in Figures. In the article by Weiss et al titled “Six Years of Surgical Wound Infection Surveillance at a Tertiary Care Center: Review of the Microbiologic and Epidemiological Aspects of 20 007 Wounds,” published in the October issue of the ARCHIVES (1999;134:1041-1048), errors appeared in Figures 1 and 3. In Figure 1 on page 1043, the y-axis was incorrectly labeled. The y-axis label should have read “No. of Patients.” In Figure 3 on page 1045, errors occurred in the reproduction of shaded pie chart components. Figure 3 is reprinted correctly here. The journal regrets the errors.

Figure 3. Overall microbial pathogenesis of wound infections, 1993 through 1998. Surgical site infections (N = 783) included 555 superficial, 94 combined, and 134 deep wound infections.