

TECHNOLOGY UPDATE

SURGEONS' ROUNDTABLE

Strategies for Preventing and Treating Surgical Site Infections

In the United States, surgical site infections (SSIs) are the third most common nosocomial infection, and in surgical patients, they are the most common nosocomial infection.¹ SSIs have a significant impact on length of hospitalization, cost of care, and most importantly, morbidity and mortality. Specifically, SSIs account for nearly 88,000 deaths and cost \$5 billion annually.²

The increasing incidence of infections caused by resistant organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) has become a cause of great concern. In Europe, entire hospitals or units within hospitals (eg, operating rooms) have been closed temporarily for disinfection of resistant bacteria.

This roundtable discussion brought together surgeons from the United States and Europe to discuss current strategies for the prevention and treatment of SSIs and the need for improvements in this field.



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SSIs: Increased Risk Associated With Implants, Resistant Organisms

Contemporary Surgery: How serious is the problem of SSIs?

Di Rocco: That depends on the type of SSI. Superficial skin and soft tissue infections are more common and less dangerous than deeper infections in organs and body spaces. However, cutaneous wound infections often are emotionally upsetting for the patient and family because of the prolonged hospital stay.

Napolitano: SSIs associated with implanted foreign materials, such as prosthetic joints, vascular grafts, and prosthetic mesh for hernia repairs, represent a significant and growing problem. These types of SSIs are extremely difficult to treat.

Infection is one of the most important causes of morbidity and mortality in the ICU today.

The Center for Disease Control and Prevention's Nosocomial Infections Surveillance System (NNIS) classifies SSIs as superficial incisional (involving skin and subcutaneous tissue), deep incisional (involving deep soft tissue such as fascia and muscle), or organ/space infections. However, these criteria do not classify SSIs in terms of surgically implanted prosthetic material, although the authors did note that the time limit for diagnosing an implant-associated SSI is 1 year after implantation compared with 30 days for an SSI in patients without an implant.

Junge: Another important problem is the increasing number of SSIs caused by resistant organisms, especially in the intensive care unit (ICU).

Alfieri: Infection is one of the most important causes of morbidity and mortality in the ICU today, and the most common infection is pneumonia. ICU infections can be either patient-related or activity-related. Infections related to an activity, such as

surgery, are less frequent but have a higher mortality. In the ICU, antibiotic resistance is generally related to antibiotic use.

Dominguez-Roldan: Antibiotic resistance also is a big problem in Spain. We are seeing more resistant *Acinetobacter* and resistant *Staphylococcus*. One reason for the increased resistance may be related to patient management. Many more patients are surviving procedures than would have 10 years ago. However, increased survival has led to longer ICU stays. Another possible reason is that current antibiotic policies for empiric therapy are aggressive and use broad-spectrum antibiotics.

MRSA: Treatment-Resistant Bacteria

Contemporary Surgery: What are the common organisms currently seen in SSIs?

Dominguez-Roldan: The main organism is *S aureus*. Unfortunately, the incidence of MRSA and methicillin-resistant *Staphylococcus epidermidis* (MRSE) are also increasing.

Napolitano: Bacterial contamination of the surgical site and virulence of the organisms are 2 factors that increase risk for SSI. Hematoma has also been documented as a risk factor.³ It is not known whether antibiotic-resistant organisms, such as MRSA, grow more aggressively than nonresistant organisms—this partly depends on the host.⁴ In patients with severe SSIs caused by MRSA, it is not yet clear whether the organism is more virulent or whether initial antibiotic treatment was inappropriate, resulting in increased bacterial growth.

We have seen a significant increase in MRSA and MRSE infections in our cardiac, vascular, and orthopedic surgery patients.⁵ We have not seen increases in MRSA and MRSE infections in general surgery patients, except in those with tertiary peritonitis.

Contemporary Surgery: What proportion of patients are already colonized with resistant bacteria (ie, MRSA)?

Napolitano: In vascular surgery patients in the United States and the United Kingdom, approximately 4% to 10% are colonized with MRSA prior

to surgery.⁶ A recent French study found that of 2,347 ICU patients, 6.9% were colonized with MRSA on ICU admission.⁷ Factors associated with MRSA carriage in the multivariate analysis were age >60 years, prolonged hospital stay in transferred patients, prior hospitalization or surgery, and presence of open skin lesions in directly admitted patients. Only universal screening detected MRSA carriage with acceptable sensitivity.

Preliminary results from a 6-month study in which nasal swabs were obtained from all patients before admission to our surgical ICU indicated that 13.7% of patients were colonized with MRSA.⁸ Risk factors for subsequent SSI were colonization, open wound, previous hospitalization, and previous surgery.

Junge: In Germany, approximately 15% to 40% of all adult patients are colonized with *S aureus*. In those with wound infections, about 15% of isolates containing *S aureus* are MRSA-positive.

Contemporary Surgery: What are the most important patient-specific risk factors for SSIs?

Junge: The guidelines for prevention of SSIs published by Mangram et al¹ list both patient-related and surgery-related factors operative characteristics that influence risk (**Table 1**).

Napolitano: The most important risk factors in my practice are diabetes and malnutrition. Patients with insulin-dependent diabetes tend to have more infectious complications than patients who are able to control their blood glucose with diet. We try to maintain blood glucose concentrations <150 mg/dL preoperatively to improve neutrophil function and hopefully prevent SSI.

Alfieri: Blood glucose control is vital, not only to decrease the risk of SSI but also to facilitate the healing process. We try to control blood glucose both before and after surgery.

Dominguez-Roldan: Malnutrition is one of the most important risk factors for infection. Unfortunately, we do not have a good test for evaluating nutritional status. Biochemical and anthropometric parameters can be analyzed; anthropometric measurements are probably the best way to assess nutritional status in

TABLE 1 Characteristics That May Influence the Risk of SSIs

Patient

- Age
- Nutritional status
- Diabetes
- Smoking
- Obesity
- Coexistent infections at a remote body site
- Colonization with microorganisms
- Altered immune response
- Length of preoperative stay

Operative

- Duration of surgical scrub
- Skin antisepsis
- Preoperative shaving
- Preoperative skin prep
- Duration of operation
- Antimicrobial prophylaxis
- Operating room ventilation
- Inadequate sterilization of instruments
- Foreign material in the surgical site
- Surgical drains
- Surgical technique
 - Poor hemostasis
 - Failure to obliterate dead space
 - Tissue trauma

Source: Mangram AJ, Horan TC, Pearson ML, et al. Guideline for prevention of surgical site infection, 1999. *Infect Control Hosp Epidemiol.* 1999;20(4):247-278. Reprinted with permission.

patients at medium risk of malnutrition.

Junge: Malnutrition is a serious risk factor; however, it is hard to define. Is it anemia? Hypoalbuminemia? Hypoproteinemia? A BMI of less than 20 kg/m²? We also try to improve nutritional status prior to elective surgery.

Napolitano: Interestingly, we recently reviewed 5,000-plus noncardiac surgical patients and found that age was not a risk factor for SSIs.⁹ Some 60- or 70-year-old patients are extremely healthy; in contrast, some 40-year-old patients are not very healthy because of chronic medical comorbidities.

Di Rocco: In children, age is a very good indicator of risk. For example, children <6 months of age are predisposed to gram-negative infections. An SSI following implantation of a shunt in an infant <6 months old is typically caused by a gram-negative organism originating in the abdomen. Preterm infants also have an increased risk of SSIs.

Identifying Other Risk Factors

Contemporary Surgery: Are there patient-specific risk factors not mentioned in the guidelines?

Junge: One risk factor not included and not well defined is genetic predisposition. Why do SSIs not develop in some patients with several risk factors, yet do develop in patients with no risk factors?

Napolitano: A genetic disposition to infection may be related to cytokine polymorphisms. Although the relationship has not been confirmed in patients with SSIs, it has been studied in other types of nosocomial infections and in sepsis. It is well-documented that some people are genetically predisposed to develop more infections than others.

We also use the American Society of Anesthesiology (ASA) Physical Status Score to eval-

uate risk of SSI (**Table 2**). The ASA score, which is a composite score of overall health, is an independent risk factor for SSI.¹⁰ We tend to rely on our anesthesia colleagues to establish the score.

Dominguez-Roldan: Hepatopathy is another risk factor not included in the U.S. guidelines.

Contemporary Surgery: Are obesity and smoking risk factors for SSI?

Alfieri: Obesity is certainly a risk factor for SSIs but it is often associated with other risk factors like diabetes and pulmonary problems.

Napolitano: Studies clearly show that smoking is an independent risk factor for SSI; however, this risk factor also is clearly related to the type of surgery performed. In our review of >5,000 general surgery patients, smoking was not a risk factor for SSI.⁹ In contrast, tobacco and nicotine use have been documented as significant risk factors for SSIs in patients undergoing cardiac and vascular surgery.

Junge: A few studies have shown increased risk of infection following hernia surgery in patients who smoke. We are conducting a study at our clinic to determine if patients who smoke have a greater risk of SSI with implantation of foreign material.

TABLE 2 American Society of Anesthesiology (ASA) Physical Status Score

ASA 1	A normal healthy patient
ASA 2	A patient with a mild to moderate systemic disturbance that results in functional limitations (eg, poorly controlled hypertension, diabetes mellitus with vascular complications, angina pectoris, prior myocardial infarction, pulmonary disease that limits activity)
ASA 3	A patient with a severe systemic disturbance that results in functional limitations (eg, poorly controlled hypertension, diabetes mellitus with vascular complications, angina pectoris, prior myocardial infarction, pulmonary disease that limits activity)
ASA 4	A patient with a severe systemic disturbance that is life-threatening with or without the planned procedure (eg, congestive heart failure, unstable angina pectoris, advanced pulmonary, renal or hepatic dysfunction)
ASA 5	A moribund patient not expected to survive with or without the operative procedure (eg, ruptured abdominal aortic aneurysm, pulmonary embolism, head injury with increased intracranial pressure)
E	Any patient in whom the procedure is an emergency (eg, ASA 4E)

Source: Barie PS. Modern surgical antibiotic prophylaxis and therapy—less is more. *Surg Infect* (Larchmt). 2000;1:23-29.

Contemporary Surgery: Are coexisting infections and colonization significant risk factors for SSIs?

Napolitano: Yes, they are highly significant risk factors. A recent study showed that French ICU patients colonized with MRSA had approximately a fourfold higher risk of *S aureus* infections than non-colonized patients.¹¹ Coexisting infections such as pneumonia or bacteremia also increase SSI risk.

Operative Risk Factors for SSIs

Contemporary Surgery: What are the most important operative risk factors?

Di Rocco: The insertion of catheters, the skill of the person doing the insertion, and the number of people in the operating room during surgery.

Napolitano: Increased duration of surgery and inappropriate use of antimicrobial prophylaxis. All patients should receive appropriate intravenous antimicrobial prophylaxis prior to surgical incision, ideally 30 minutes before incision. Antibiotics should be readministered at the recommended intervals (3 hours) based on duration of surgery and extent of blood loss. An operative risk factor not included in the guidelines (**Table 1**) is the degree of bacterial contamination at the surgical site.

Contemporary Surgery: Are there any postoperative risk factors?

Napolitano: Decreased tissue oxygenation may decrease oxidative bacterial killing and increase the risk of SSI. Part of our protocol is to immediately administer 100% FiO₂ to all postoperative patients to improve tissue oxygen concentrations. Supplemental perioperative oxygen was documented to reduce the incidence of SSI in a prospective randomized controlled trial of 500 patients undergoing colorectal resection. Patients were randomized to receive 30% or 80% inspired oxygen during the operation and for 2 hours afterward, resulting in reduced SSI (5.2% vs 11.2%) in the treatment group.¹² We also try to avoid blood transfusions because they are immunosuppressive.^{13,14} Maintenance of perioperative normothermia is also important.¹⁵

Why do SSIs not develop in some patients with several risk factors yet do develop in patients with no risk factors?

Consequences of SSIs in Specific Populations

Contemporary Surgery: What is the impact of SSIs?

Alfieri: That depends on the severity of the infection. Serious infection can result in death; less severe infection can prolong hospitalization and decrease patient satisfaction.

Junge: Less severe superficial SSIs do not really prolong hospitalization. We manage such patients in our outpatient clinic. Superficial SSIs are more of a psychologic and socioeconomic problem than a clinical problem.

Di Rocco: SSIs in the children are a different matter. A mild brain infection can change a child's life forever. Not only do these patients require longer hospital stays, averaging from 1 to 4 weeks more than uninfected, but also they may be handicapped for life. As expected, direct patient costs are increased; they can be 10 to 12 times greater than for a patient without infection.

Napolitano: Superficial SSIs also can cause big problems in patients with prosthetic implants, such as mesh for hernia repair or a prosthetic vascular graft, resulting in major infections, which frequently necessitate removal of the prosthesis. If not properly cared for, a mild, superficial SSI can be limb- or life-threatening in such patients.

Deep incisional infections are associated with high morbidity and mortality. We have been able to reduce that with percutaneous drainage, especially for intra-abdominal abscesses. We favor using percutaneous drainage in all patients with deep SSIs, except when the infection is related to pancreatitis or caused by yeast; these patients do not do well with percutaneous drainage.

In cardiac surgery, a recent study compared the outcome of poststernotomy mediastinitis caused by

methicillin-resistant and methicillin-susceptible *S aureus* (MSSA). Both early (1 month to 1 year) and late survival rates (3 years) were worse following MRSA infections than after MSSA infections. Logistic regression analysis confirmed that MRSA was the only independent risk factor for increased mortality.¹⁶ Similarly, studies of vascular surgery have reported significant adverse outcomes related to MRSA SSIs. In one such study, all patients with MRSA-infected prosthetic infrainguinal bypass had to undergo extremity amputation.¹⁷

Healthcare personnel costs, drug costs, and equipment costs are increased in patients with SSIs. In addition, an open wound may delay the patient's return to work, resulting in loss of income. A recent study found that the average cost of an SSI diagnosed after hospital discharge was approximately \$5,000.¹⁸

Strategies to Decrease SSIs

Contemporary Surgery: What are some current practices and protocols aimed at decreasing the incidence of SSIs?

Junge: One of the most important things we can do is minimize tissue trauma during surgery. Tissue trauma is analogous to leaving a culture plate inside the patient. Careful handling of tissue during the operation is of major importance, as is perioperative antibiotic prophylaxis.

Napolitano: We have implemented protocols during the preoperative period. For example, approximately 70% of our surgeries are same-day admit or outpatient surgeries. Patients receive chlorhexidine sponges in our nursing preop clinic and are taught how to use them while showering the night before and the morning of surgery. Patients are tested for MRSA colonization before surgery, and if cultures come back positive, we attempt decolonization with chlorhexidine body washes and nasal mupirocin (pseudomonic acid) ointment twice daily. Mupirocin has been shown to be 97% effective in reducing *S aureus* nasal carriage. If MRSA colonization persists, then vancomycin pro-

phylaxis is administered. A prospective randomized study in >4,000 surgical patients found that prophylactic intranasal mupirocin did not significantly reduce the overall rate of *S aureus* SSIs, but did significantly decrease the rate of nosocomial *S aureus* infections among patients who were *S aureus* carriers.¹⁹

Contemporary Surgery: How can tissue trauma be reduced?

Di Rocco: In abdominal surgery, tissue trauma can be decreased by using laparoscopy instead of laparotomy. For other types of surgery such as colon, liver, pancreas, rectum, and stomach, trauma-reducing procedures are well described.

Napolitano: Studies have clearly documented that laparoscopy is associated with fewer SSIs than is laparotomy.²⁰ So if a procedure can be done laparoscopically, it should be.

Contemporary Surgery: What role would a hemostat with bactericidal properties such as Surgicel (absorbable hemostat [oxidized regenerated cellulose], Johnson & Johnson Wound Management, a division of Ethicon) have in treating your patients?

Junge: Using Surgicel seems to be a plausible approach and may lead to decreased local bacterial contamination or colonization. However, there have been no studies in humans that prove that it will have any effect on patient morbidity or mortality. I would try Surgicel if there were adequate laboratory data documenting local antimicrobial effects. I would not need human studies, but they should follow.

Alfieri: I agree about the theoretical advantages of this product. I am not sure, however, that we can demonstrate a positive effect in humans; it would require many cases to statistically prove that the lower infection risk can be attributed to the antibacterial product. However, with a randomized group of patients undergoing contaminated surgical procedures (ie, close of ostomy), it would be easier to show an effect on superficial SSIs because the rate of wound infections is higher and fewer cases will be needed.

TABLE 3 In Vitro Activity of 3 Surgicel Products: Percent Kill After 24 Hours (P-value)

Microorganism	Source	Surgicel Absorbable Hemostat	Surgicel Nu-Knit	Surgicel Fibrillar
<i>Staphylococcus aureus</i> (MRSA)	Clinical isolate	99.9999 (< 0.001)	99.9999 (< 0.001)	99.9999 (< 0.001)
<i>Streptococcus pneumoniae</i> (PRSP)	Clinical isolate	99.9999 (< 0.001)	99.9999 (< 0.001)	99.9996 (< 0.001)
<i>Enterococcus faecium</i> (VRE)	Clinical isolate	99.9565 (0.004)	99.9998 (0.001)	99.9413 (< 0.001)
<i>Enterococcus faecalis</i> (VRE)	Clinical isolate	99.9045 (< 0.001)	99.9735 (0.003)	99.9992 (0.003)
<i>Enterococcus faecium</i> (VRE)	ATCC	35.15 (0.001)	63.0939 (0.001)	99.9723 (0.002)
<i>Staphylococcus epidermidis</i> (MRSE)	ATCC	99.9999 (< 0.001)	99.9999 (< 0.001)	99.9999 (< 0.001)
<i>Staphylococcus aureus</i>	ATCC	99.9999 (< 0.001)	99.9999 (< 0.001)	99.9999 (< 0.001)
<i>Staphylococcus aureus</i> (MRSA)	ATCC	99.9147 (< 0.001)	99.9831 (< 0.001)	99.9999 (< 0.001)
<i>Pseudomonas aeruginosa</i>	ATCC	99.9999 (< 0.001)	99.9997 (< 0.001)	99.9999 (< 0.001)

MRSA, methicillin resistant *Staphylococcus aureus*; PRSP, penicillin resistant *Streptococcus pneumoniae*; VRE, vancomycin resistant enterococcus; MRSE, methicillin resistant *Staphylococcus epidermidis*; ATCC, American Type Culture Collection

Source: Spangler D, Rothenburger S, Nguyen K, Jampani H, Weiss S, Bhende S. In vitro antimicrobial activity of oxidized regenerated cellulose against antibiotic-resistant microorganisms. *Surg Infect (Larchmt)*. 2003;4:255-62.

Napolitano: When I use Surgicel as a hemostatic agent, I do not leave it in my patients because it can act as a foreign body. Foreign bodies can cause fever, become encapsulated with fluid and fibrin, and be mistaken for an abscess on diagnostic radiologic imaging studies. So, it could cause problems over the long-term. To leave it in, I would need to see a study demonstrating its antibacterial properties.

Having said that, it would be a paradigm shift to start using Surgicel in this manner with potential applications in cases of high bacterial contamination such as an intestinal perforation and its high risk of abscess. If you lay a piece of Surgicel at the perforation, will it help prevent abdominal abscess formation? This could easily be evaluated in an animal model before moving to human studies.

There are other questions that need to be answered. For example, in a patient with a high risk for organ/space infection, like someone with perforated diverticulitis, where would I put the Surgicel? Where within the surgical site do you try to prevent

infection—in the peritoneal cavity or in the abdominal wall incision? Similarly, in a patient undergoing reoperation for an infected vascular graft, will Surgicel work when the surgical field is already infected and infected prosthetic material is in place? **Contemporary Surgery:** What impact do you see Surgicel having on the overall burden of SSIs?

Napolitano: I don't believe Surgicel would have much of an impact on elective cases that have very low SSI rates. In contrast, using Surgicel in combination with other products such as antibacterial sutures could potentially be beneficial in high-risk patients, where SSIs could have devastating consequences, even if the infection risk was reduced by only a small degree.

The cost of Surgicel is very low in terms of the total operating room budget. If it reduces SSIs, it really could be cost effective.

Dominguez-Roldan: Infection is one of the standards by which the quality of hospital care is measured. Hospital managers will accept anything that decreases the rate of infection and reduces length of stay.

Contemporary Surgery: A recent study examined the antimicrobial activity of Surgicel against resistant organisms. What are your impressions of the results?

Alfieri: The results are impressive and convincing (**Table 3**). A limitation of the study is that it was conducted in vitro rather than in vivo.

Junge: I would be interested in data on the effect of Surgicel after 24 or 48 hours. With some of these bacteria, there are still up to 10,000 colony forming units/mL of culture medium at that time. If the antimicrobial effect of Surgicel diminishes after 24 to 48 hours, will there be enough bacteria left to cause an infection? Another study should be performed to show what is happening after 3 to 5 days.

Napolitano: I am intrigued by these results and also the earlier results from in vivo studies. The preponderance of evidence shows that Surgicel has antimicrobial activity. It would be nice to see similar results in clinical studies.

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