Editorial

Surgical-Site Infections After Coronary Artery Bypass Graft Surgery: Discriminating Site-Specific Risk Factors to Improve Prevention Efforts

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The story of the surgical treatment of cardiac lesions, either traumatic, congenital, degenerative, or postinfective, is almost entirely a 20th-century story. Experimental cardiac surgery began more than 100 years ago with M.H. Block, a German surgeon, who published a report on wounds of the heart in 1882, in which he described suture of rabbit hearts. He strongly urged that the procedure be used in man.[1] At that time, Billroth is reported to have said: "A surgeon who would attempt such an operation should lose the respect of his colleagues."[1] Nevertheless, in 1896, Ludwig Rehn of Frankfort became the first surgeon to suture a human heart laceration successfully, thus inaugurating the era of cardiac surgery.[1] Nowadays, with an estimated 468,000 coronary artery bypass grafts (CABGs) performed each year in the United States,[2] cardiac surgery has become the "epitome of contemporary high-technology medical care."[3]

Approximately 2% to 20% of CABGs are complicated by a surgical-site infection (SSI).[4,5] Much of the literature on SSI following cardiothoracic surgical procedures focus on deep chest infections, which, although not frequent (complicating 0.5% to 5% of cardiac procedures[4,5]), are important because of the high morbidity, mortality, and immense costs they add to the healthcare system.

Host, surgical, and microbiological risk factors are intertwined in a complex way for an SSI to develop. Extremes of age, prolonged preoperative stay, remote infection, and duration of surgery are some of the risk factors that have been associated consistently with SSI.[6]

For patients undergoing cardiac surgery, the median sternotomy and the extracorporeal circulation both cause considerably greater stress on the host defenses than general surgical procedures.[3,7,8]

RISK FACTORS FOR SURGICAL-SITE INFECTION OF THE STERNAL WOUND

Surgical-site infection of the sternal wound includes superficial SSI, deep sternal SSI, sternal osteomyelitis, mediastinitis, and endocarditis. These often have been pooled together in the analysis of risk factors. Host intrinsic risk factors that have been linked specifically to SSI of the sternal wound include obesity,[4,9-11] diabetes mellitus,[4,9-13] current cigarette smoking,[9] and steroid therapy,[13] the former two risk factors being the most frequently reported (Table 1). Kluytmans and colleagues further demonstrated that the risk of developing SSI was higher in the diabetic patient using insulin therapy than in the diabetic patient treated with oral agents.[12] These authors also showed that preoperative nasal carriage of *Staphylococcus aureus* by patients was an independent risk factor for *S aureus* sternal-wound infections.[12] A randomized clinical trial has yet to prove

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TABLE 1
RISK FACTORS FOR SURGICAL-SITE INFECTION AT THE STERNAL SITE

Host Intrinsic Risk Factors	Surgical Risk Factors
Female gender[10,35]	Prolonged perfusion time[15]
Male gender[36]	Duration of surgery[4,11,15]
Increasing age[4,35]	Use of intraaortic balloon pump[38]
Obesity[9-11,24,35]	Postoperative bleeding[14,15]
Cigarette smoking[9]	Reoperation[11,14,15]
COPD[36]	Sternal rewiring[14]
Poor functional cardiac status[4]	Use of IMA in CABG[11,21]
Prolonged ventilation support[19,35,37]	Type of bone saw used[16,17]
Low cardiac output state[15,19,37]	Indiscriminate use of electrocautery[39]
Diabetes mellitus[9-13,24]	Shaving methods[25,40]
Steroid therapy[13]	Use of bone wax[41]
Staphylococcus aureus nasal carriage[12]	
Preoperative length of stay >5 d[9,14]	

Abbreviations: CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; IMA, internal mammary artery.

this assumption.

Surgical risk factors linked with SSI at the sternal site are numerous. Previous sternotomy,[11,14,15] complexity of surgery, type of bone saw used,[16,17] type of sternal closure,[17] use of bone wax, blood transfusions,[14] and early reexploration to control hemorrhage[11,14,15,18] are examples of these (Table 1).

According to some experts, harvesting the internal mammary artery (IMA) is a risk factor for SSI at the sternal site. It is logical to think that the significant sternal ischemia produced by harvesting one or two IMAs predisposes patients to sternal osteomyelitis and mediastinitis; yet, most opinions seem to merge toward the conclusion that single IMA grafting does not appear to increase the risk of sternal-wound infection.[11,19] Furthermore, because of the much higher patency rate of the IMA when compared to the saphenous vein (90% of IMAs are still patent 10 years after CABG vs 50% for the saphenous vein), using the IMA has become the standard of care whenever this is possible.[20] Using both IMAs remains controversial in regard to the development of SSI. Kouchoukos and colleagues found an increased risk of SSI at the sternal site from bilateral IMAs in patients with obesity, diabetes, or prolonged mechanical ventilation.[21] Therefore, other risk factors may have to be present for this risk factor to be realized.

RISK FACTORS FOR SAPHENOUS VEIN HARVEST-SITE INFECTIONS

The most common infections developing after CABGs are saphenous vein harvest-site infections (HSIs), which complicate 2% to 13% of all CABGs. Because these infections often are perceived as somewhat trivial by the surgical team, and because the associated mortality is so low, HSIs probably are underreported in many published studies. Moreover, the surveillance programs in some institutions may not be sensitive enough to give accurate HSI rates; yet, HSIs equally contribute to excess length of stay, readmissions, and increased cost.[22,23]

In this issue of *Infection Control and Hospital Epidemiology,* Vuorisalo and colleagues analyzed risk factors for SSI among a population of 884 patients who underwent CABG without valve procedures.[24] By excluding valve procedures, the authors avoided one caveat of many previous studies: pooling different patient populations who may have too many different risk features. Some investigators have published a higher incidence of sternal infections after CABGs than with other open heart procedures and speculated that this was due to contamination from the donor-vein site.[9]

Harvest-site infections and sternal infections need not be studied in a combined manner, for their pathogenesis and microbiology are quite different. Vuorisalo and colleagues are among the few investigators who analyzed risk factors for HSI specifically.[24] The high infection rate found in their analysis (19.5%) mostly reflected the HSI rate (15.4%). Active surveillance certainly increased the sensitivity of their case-finding methods for HSI; yet, using antibiotic prescription as a surrogate marker for postdischarge SSI lacks specificity and may have introduced misclassification bias in their analysis. Indeed, the authors underlined the late wound complications often misdiagnosed as SSI upon discharge and the tendency to overtreat simple delay in wound healing with antibiotic. Nevertheless, despite their methodology difficulties, the authors did include postdischarge surveillance in their analysis.

Consistent with previous reports, Vuorisalo and colleagues found that diabetes and obesity (as delineated by body mass index) were major risk factors for SSI at the sternal site.[24] In contrast, the only risk factor independently associated with HSI was female gender (P=.003). Delaria and colleagues also found that women were at significantly higher risk than controls of any leg-wound complication (infection, wound separation, or hematoma) after undergoing CABG (Table 2).[23]

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PREVENTIVE MEASURES

Once risk factors are identified, one must ask if they can be modified. Most host intrinsic risk factors are not easy to change (eg, age, gender), whereas others are, but lack good scientific evidence that modification would reduce SSI rates (eg, losing weight for obese patients or stopping cigarette smoking before surgery). Vuorisalo and colleagues suggest hypotheses to take their results further in regard to preventive strategies.[24] For example, because female gender is the only independent risk factor associated with HSI, the authors suggest that women cease shaving their legs prior to elective CABG, as this practice may explain the higher HSI rate in women than men.

Preoperative preparation of the patient deserves meticulous attention. Optimizing the nutritional state of patients, eradicating foci of low-grade infections (especially of dental, respiratory, and genitourinary origin), antiseptic showers before surgery, and eliminating routine chest-hair shaving are examples of requisite preoperative adjuncts.

Surgical risk factors are more easy to change than host risk factors. Investigation of numerous outbreaks have undercovered violations of infection control standards in the operating room. In Slaughter's study, breaks in techniques in the operating room and the fact that nonexperienced residents were harvesting the saphenous vein were thought to be important factors to explain the increase in HSI rates.[13] The authors underlined that the leg and chest wounds should be considered as separate fields, that instruments should not be shared by surgeons operating on those two fields, and that personnel should change gloves when moving from one field to the other. After implementing those changes in the operating room and after hiring two physician's assistants specifically to harvest veins, the leg infection rates decreased.[13]

The polymicrobial nature of HSI with a preponderance of *Enterobacteriaceae* may warrant longer leg-skin antibacterial scrub or perhaps gastrointestinal decontamination.[25] In contrast, if *S aureus* predominates in an institution, applying mupirocin to the patients' nares preoperatively may be a plausible intervention to reduce SSI rates.

ANTIMICROBIAL PROPHYLAXIS IN CARDIAC SURGERY

The rational use of perioperative antibiotic prophylaxis in cardiac surgery has proven to be efficacious in reducing SSI rates[26,27] and is one of the most important steps in preparing a patient for surgery.

In a second article in this issue, Vuorisalo and colleagues, studying the same population, tried to demonstrate that vancomycin was not superior to cefuroxime for prophylaxis in patients undergoing CABG.[28] Their randomized clinical trial showed the same infection rates in both arms of the study: a 3.5% SSI rate in the vancomycin group (n=440 patients) vs a 3.2% SSI rate in the cefuroxime group (n=444). Therefore, the authors concluded that cephalosporins are favored for prophylaxis before CABG, as these drugs are cheaper and easier to administer than vancomycin. Furthermore, the authors underlined the overuse of vancomycin linked to the vancomycin-resistant *Enterococcus* problem, which has plagued many hospitals in the past few years.

TABLE 2
RISK FACTORS FOR SAPHENOUS VEIN HARVEST-SITE INFECTIONS

Risk Factor	Reference
Female gender	23, 24
Obesity	13, 23
Staphylococcus aureus nasal carriage	42

Some caveats have to be underlined before reaching these conclusions. First, having too few patients in each arm of the study population may have precluded a statistically significant difference between the two drugs. In contrast with Vuorisalo's study, at least two articles showed that vancomycin was superior to cephalosporins for prophylaxis in CABG. Maki and colleagues showed that vancomycin was associated with a statistically significant reduced rate of SSI when compared to cefazolin and cefamandole (P=.05)[29]; the mean length of stay after surgery also was lowest in the vancomycin group (P<.01). Nafziger and colleagues, in a preliminary report, reached similar conclusions: prophylaxis with a first-generation cephalosporin appeared to be a risk factor for mediastinitis when compared to vancomycin (OR, 4.5). Logistic regression showed that the best-fitting model in this case-control study included diabetes and type of antimicrobial prophylaxis (P<.001).[30] We need more evidence to show that cephalosporins are at least as good as vancomycin for CABG prophylaxis before withdrawing the latter antibiotic for this purpose in response to the threat of vancomycin-resistant enterococci. Furthermore, if methicillin-resistant *S aureus* (MRSA) or methicillin-resistant *Staphylococcus epidermidis* are major causes of SSI in an institution, one must consider vancomycin as prophylaxis.

In analyzing prophylaxis, one also must consider timely administration of the drug, as this variable is of utmost importance in having good tissue levels of the drug when the surgeon performs the incision.[31] Vuorisalo and colleagues mention that all drugs were given at induction of anesthesia, but did not detail further.[28] We have shown in a preliminary report that prescribing an antibiotic at induction of anesthesia does not ensure necessarily that the drug is given on the proper timing before incision.[32] Among 204 patients who received either cefazolin or cefoxitin as prophylaxis for surgery, 35% did not receive the drug on time, of whom 22% received it too early (>2 hours before incision) and 8% received it after the surgeon performed the incision, thus precluding proper concentration of the antibiotic in tissues. Yet, all antibiotics were prescribed at induction of anesthesia.[32]

Furthermore, to achieve high tissue levels throughout the surgical procedure, one must give an optimal dose of the drugs. Although Vuorisalo and colleagues delineated that obesity might explain inappropriate concentrations of antibiotic in tissues, they still prescribed suboptimal doses of antibiotic (750 mg for postoperative doses of cefuroxime and 1 g of vancomycin)[28]; yet, 24% of their study population was considered obese. Higher doses of cephalosporins should be used for patients who weigh >80 kg (eg, 2 g of cefazolin instead of 1 g),[33] and this full dose should be repeated intraoperatively if the procedure extends beyond 3 hours. For vancomycin, at least 15 mg/kg should be administered preoperatively (provided that the patient does not have renal insufficiency), particularly because this drug adheres to the bypass apparatus.[34] Because postoperative doses are unnecessary for most surgical procedures (including CABG), the total dose for the day is not excessive, and high tissue levels of antimicrobial are achieved while the wound is open, which is clearly what matters in surgical prophylaxis.

Therefore, clinical trials on antimicrobial prophylaxis should address not only the choice of the drug but also other important variables which, when properly controlled, reduce SSI rates: timely administration of the antibiotic before incision; the need to repeat intraoperative doses when the surgical procedure is long; giving appropriate full doses, particularly when the patient is obese; and the particular pharmacokinetics of the antibiotic, such as its removal by the extracorporeal circulation during CABG.

CONCLUSION

Over the last decade, prevention of SSI after cardiac surgery has become an important component of quality assurance and hospital cost containment; yet, with the amalgam of studies published, it is hard to delineate which risk factors for SSI are most important and where infection control practitioners and surgeons can intervene. To answer these questions, one must interpret the results of these studies with caution and compare what truly can be compared.

The potential differences in patient populations, the reliability of criteria used for the diagnosis of SSI, the sensitivity of the surveillance methods and whether or not postdischarge surveillance was performed, the many different variables and endpoints included, the study design (most often case-control designs), the choice and timely administration of antimicrobial agents for prophylaxis, the types of procedures, and the use of one or both IMAs as graft all make results among studies difficult to compare.

In this era of attention to quality heath care, many authorities have turned to surveillance of CABGs and cardiac catheterizations to evaluate and compare hospital performance. Hence, it will be increasingly relevant to compare the same populations, the same endpoints, and the same procedures before reaching conclusions on one's performance.

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