SURGICAL-SITE INFECTION AFTER CARDIAC SURGERY: INCIDENCE, MICROBIOLOGY, AND RISK FACTORS

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ABSTRACT

OBJECTIVE: To identify risk factors associated with surgical-site infection according to the depth of infection, the cardiac procedure, and the National Nosocomial Infections Surveillance System risk index.

DESIGN: Prospective survey conducted during a 12-month period.

SETTING: A 48-bed cardiac surgical department in a teaching hospital.

PATIENTS: Patients admitted for cardiac surgery between February 2002 and January 2003.

RESULTS: Surgical-site infections were diagnosed in 3% of the patients (38 of 1,268). Of the 38 surgical-site infections, 20 were superficial incisional infections and 18 were mediastinitis for incidence rates of 1.6% and 1.4%, respectively. Cultures were positive in 28 cases and the most commonly isolated pathogen was *Staphylococcus*. A National Nosocomial Infections Surveillance System risk index score of 2 or greater was associated with a risk of surgical-site infection (relative risk, 2.4; $P < .004$). Heart transplantation, mechanical circulatory assistance, coronary artery bypass graft with the use of internal mammary artery, and reoperation for cardiac tamponade or pericard effusion were independent risk factors associated with surgical-site infection.

CONCLUSIONS: Data surveillance using incidence rates stratified by cardiac procedure and type of infection is relevant to improving infection control efforts. Risk factors in patients who developed superficial infection were different from those in patients who developed mediastinitis. Coronary artery bypass graft using internal mammary artery was associated with a high risk of surgical-site infection, and independent factors such as reoperation for cardiac tamponade or pericard effusion increased the risk of infection (*Infect Control Hosp Epidemiol* 2005;26:466-472).

Despite the use of modern surgical techniques, preoperative antibiotic prophylaxis, and careful wound treatment, surgical-site infections (SSIs) remain a feared complication of cardiac surgery, with a reported incidence of 0.25% to 2.9%.[1-17] The outcomes of these infections can be severe, including increased length of stay, high costs, and a mortality rate ranging from 10% to 29%.[2,18-22] At Laënnec Hospital, Nantes, France, cardiothoracic surgery is an important activity and the incidence of mediastinitis is not well known.[23] Because surveillance has been shown to be an important component of strategies to reduce the risk of SSI, we implemented a prospective surveillance program in cardiothoracic surgery in 2002.

The objectives of this study were to calculate the incidence of SSI, to identify risk factors for SSI according to type of infection (deep or superficial incisional) and cardiac procedure, and to assess the relevance of the National Nosocomial Infections Surveillance (NNIS) System risk index in cardiac surgery.

METHODS

Study Setting

The University of Nantes Hospital is a 3,200-bed, tertiary-care institution. The cardiothoracic surgery department has five surgeons and one fellow who perform approximately 1,700 cardiothoracic procedures per year, of which approximately 1,300 are cardiac procedures.

Selection of Case Operations and Definition of SSI

A case operation was defined as any patient who underwent cardiac surgery between February 1, 2002, and January 31, 2003. Patients operated on for thoracic disease and patients reoperated on for SSI during the study period whose first operation was performed prior to the surveillance program were excluded from the study. The surgeons in the cardiothoracic surgery department examined all wounds of patients who returned to the hospital postoperatively.

The Centers for Disease Control and Prevention

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TABLE 1
CARDIAC PROCEDURES FROM FEBRUARY 1, 2002, TO JANUARY 31, 2003

Cardiac Procedure	No. of Procedures	Median Length of Stay (Range)*		Median Duration of Surgery (Range)†
		Preoperative	Hospital	
CABG	491 (38.7%)	2 (0–39)	12 (1–70)	210 (80–400)
Valvular replacement	421 (33.2%)	2 (0–59)	12 (2–97)	180 (60–510)
CABG and valvular replacement	130 (10.3%)	2 (0–12)	13 (4–34)	230 (103–375)
Congenital cardiovascular disease	91 (7.2%)	1 (0–36)	8 (2–37)	150 (15–300)
Great vessel disease	41 (3.2%)	1 (0–32)	15 (3–46)	260 (130–580)
Pericard disease	33 (2.6%)	2 (0–83)	11 (3–85)	45 (10–100)
Heart transplantation	32 (2.5%)	1 (0–64)	34 (1–382)	245 (145–540)
Mechanical circulatory assistance	24 (1.9%)	4 (0–52)	23 (1–116)	172 (35–325)
Cardiac tumor	5 (0.4%)	1 (1–8)	16 (9–26)	225 (110–270)
Total	1,268 (100%)	2 (0–83)	12 (1–382)	195 (10–580)

CABG = coronary artery bypass graft.
*In days.
†In minutes.

definition of SSI was used.[24,25] This definition requires that the criteria selected be met within 30 days of surgery or within 1 year of surgery if an implant is inserted. Superficial and deep incisional SSIs were included in the study. Mediastinal re-exploration was performed in all cases after the diagnosis of mediastinitis. The sternum was reopened in the operating room and a mediastinal irrigation–drainage system was used. Infection was defined as purulent drainage from deep and superficial incisions with or without laboratory confirmation. Colonization was not included in this context. Most of the infections without laboratory confirmation were superficial SSIs, but the presence of purulent drainage was sufficient to diagnose infection. Drainage without pus was not considered to be associated with an infection and was not included in the study.

TABLE 2
BACTERIOLOGY OF STERNO–MEDIASTINAL FLUID AND TISSUES

Bacteria	Surgical-Site Infection		Total
	Superficial	Mediastinitis	
Enterobacteriaceae*	3	4	7 (18.4%)
Staphylococcus aureus	4	8	12 (31.6%)
Coagulase-negative staphylococci	6	3	9 (23.7%)
Undetermined	7	3	10 (26.3%)
Total	20	18	38 (100%)

**Enterobacter cloacae* (1), *Citrobacter koseri* (1), *Escherichia coli* (2), *Klebsiella oxytoca* (1), and *Proteus* (2).

Collection of Clinical Data

A prospective survey was performed and the following data were abstracted from the medical records: age, gender, obesity (body mass index [BMI], > 30), nutrition difficulty (BMI, < 20), diabetes, chronic obstructive pulmonary disease, length of hospital stay, preoperative length of stay, American Society of Anesthesiologists (ASA) physical status classification, type and duration of cardiac operations, reoperation for cardiac tamponade or pericard effusion, urgent or emergent surgery, and implant insertion. Characteristics of mediastinitis were obtained from the operating room records during reoperation. Characteristics of superficial incisional SSIs were obtained from specific records in the two surgical units for re-admitted patients and in the consultation unit for outpatients.

Statistical Analysis

Data were analyzed using Epi-Info software (version 6.04c; Centers for Disease Control and Prevention, Atlanta, GA). Univariate analysis was performed, comparing the probability of being infected when a factor was present with the probability of being infected when that factor was absent. For the significance of associations ($P < .05$), the chi-square test (Mantel–Haenszel) or Fisher's two-tailed test was used for proportions and the Student's t test was used for continuous variables. Multivariate analysis identifying independent risk factors was performed with SYSTAT software (version 7; SYSTAT, Inc., Richmond, CA).

RESULTS

Patient and Surgery Characteristics

From February 1, 2002, to January 31, 2003, 1,268 patients had cardiac surgery. The mean age of these patients was 61 years (range, 1 to 91 years) and half of them were older than 50 years; 71% were male. One hundred ninety had diabetes, 228 had a BMI greater than 30 and 139 had a BMI less than 20, and 114 had chronic obstructive pulmonary disease. One hundred eighty-eight patients (15%) under-

TABLE 3
INCIDENCE OF SURGICAL-SITE INFECTION ACCORDING TO CARDIAC PROCEDURE

	Surgical-Site Infection		Total	
Cardiac Procedure	**Superficial (No.)**	**Mediastinitis (No.)**	**%**	**No./Total No.**
CABG	2.5% (12)	1.4% (7)	3.9	19/491
Valvular replacement	0.7% (3)	0.9% (4)	1.6	7/421
CABG and valvular replacement	3% (4)	0.8% (1)	3.8	5/131
Heart transplantation	0%	12.5% (4)	12.5	4/32
Mechanical circulatory assistance	4.2% (1)	8.3% (2)	12.5	3/24

CABG = coronary artery bypass graft.

went emergency surgery. An implant was used in 49% (618 of 1,268) of the cardiac procedures. Most of the patients had an ASA score of 3 (1,001; 79%) or 4 (176; 14%); 0.4% had an ASA score of 1 (5), 5.8% had an ASA score of 2 (73), and 1% had an ASA score of 5 (13).

The most common operations were coronary artery bypass graft (CABG) and valvular replacement (Table 1). The mean duration of surgery was 202 minutes (median, 195 minutes; 75th percentile, 240 minutes; range, 10 to 580 minutes), ranging from 45 minutes for pericard procedures to 245 minutes for heart transplantations (Table 1). Among patients operated on for coronary revascularization, 6.7% (33 of 491) were operated on with the use of saphenous vein, 71.9% (353 of 491) with the use of one internal mammary artery, and 21.4% (105 of 491) with the use of two internal mammary arteries. The median hospital and preoperative length of stay were 2 and 12 days, respectively (Table 1). The median preoperative length of stay was 2 days, ranging from 0 day for heart transplantations to 4 days for mechanical circulatory assistance (Table 1).

The NNIS System risk index was calculated using three independent factors selected by the Centers for Disease Control and Prevention. No operation was classified as contaminated or dirty. Five percent (62) of the patients had an NNIS System risk index score of 0, 68% (862) had an NNIS System risk index score of 1, and 27% (344) had an NNIS System risk index score of 2. No patients had an NNIS System risk index score of 3.

Bacteriologic Findings

Among the 38 SSIs, cultures were positive in 28 cases (74%). The most commonly isolated pathogen was *Staphylococcus*, which caused 75% (21 of 28) of the infections with a positive sample. Gram-negative organisms (Enterobacteriaceae) were the responsible pathogens in 7 (18%) of the cases. There were no polymicrobial infections (Table 2).

Incidence of SSI and Risk Factors

Thirty-eight SSIs were diagnosed during the study period: 18 were mediastinitis and 20 were superficial SSIs. The mean time from operation to diagnosis was 27 days (range, 5 to 30 days; median, 22 days) for superficial SSI and 20 days (range, 5 to 99 days; median, 15 days) for mediastinitis. The mean hospital stay was longer in patients who developed mediastinitis (58 days) than in patients who developed superficial SSI (23 days) ($P < .06$). The incidence rate was 3% (38 of 1,268), being 1.4% for mediastinitis and 1.6% for superficial SSI. The incidence rate varied according to type of operation and type of infection. No SSIs were observed in procedures for pericard disease, congenital cardiovascular disease, or vessel disease. The incidence rate for mediastinitis was 0.9% (4 of 421) for valvular replacement, 1.4% (7 of 491) for CABG, and 12.5% (4 of 32) for heart transplantation (Table 3).

No infected patient had an NNIS System risk index score of 0, 20 infected patients had an NNIS System risk index score of 1, and 18 infected patients had an NNIS System risk index score of 2. The incidence rate of mediastinitis was 1.2% when patients had an NNIS System risk index score of 1; it increased to 2.3% when patients had an NNIS System risk index score of 2 (Table 4). The mortality rate was 22.2% in patients who developed mediastinitis (4 of 18) and 5% in patients who developed superficial incisional SSI (1 of 20).

Univariate Analysis

Risk factors associated with superficial incisional SSI were mean duration of operation (240 vs 201; $P < .01$), NNIS System risk index score of 2 or greater (10 of 20 vs 334 of 1,230; relative risk, 2.6; 95% confidence interval, 1.1 to 6.3; $P < .02$), and CABG (12 of 20 vs 471 of 1,230; relative risk, 2.4; 95% confidence interval, 1.9 to 5.8; $P < .04$). Risk factors associated with mediastinitis were urgent operation (6 of 18 vs 179 of 1,230; relative risk, 2.9; 95% confidence interval, 1.1 to 7.6; $P < .03$), reoperation for cardiac tamponade or pericard effusion (4 of 18 vs 7 of 1,230; relative risk, 32.1; 95% confidence interval, 12.6 to 82.2; $P < .00001$), heart transplantation (4 of 18 vs 28 of 1,230; relative risk, 10.9; 95% confidence interval, 3.8 to 31.2; $P < .0008$), and mechanical circulatory assistance (2 of 18 vs 21 of 1,230; relative risk, 6.7; 95% confidence interval, 1.6 to 27.3; $P < .003$).

Univariate analysis was also used to determine the probability of developing superficial and deep SSIs. No significant difference was observed between patients who

TABLE 4
INCIDENCE OF SURGICAL-SITE INFECTION* ACCORDING TO NATIONAL NOSOCOMIAL INFECTIONS SURVEILLANCE (NNIS) SYSTEM RISK INDEX SCORE

		Surgical-Site Infection		
NNIS System Risk Index Score	Ratio SSI/ NNIS SSI	Superficial (N = 20)	Mediastinitis (N = 18)	Total
0	0/62	0%	0%	0%
1	20/862	1.2% (10)	1.2% (10)	2.4%
2	18/344	2.9% (10)	2.3% (8)	5.2%

SSI = surgical-site infection.
*Per 100 admissions.

TABLE 5
FACTORS PREDISPOSING TO SURGICAL-SITE INFECTION AFTER CARDIAC PROCEDURES

	Probability of Being Infected When the Factor Was (%)				
Factor	Present	Absent	RR	CI_{95}	*P*
Male	3.2	2.4	1.3	0.6–2.9	NS
Diabetes	2.1	3.1	0.7	0.2–2.0	NS
Obesity (BMI > 30)	1.8	3.2	0.6	0.2–1.6	NS
Nutrition difficulty (BMI < 20)	0	3.3	NC	-	-
Chronic obstructive pulmonary disease	5.3	2.7	2.0	0.8–4.6	NS
Urgent operation	4.8	2.7	1.8	0.9–3.7	NS
Implant insertion	2.5	3.5	0.7	0.4–1.3	NS
NNIS System score ⩾ 2	5.2	2.2	2.4	1.3–4.5	< .004
Cardiac procedure					
CABG	3.9	2.4	1.6	0.9–2.9	NS
CABG with use of one internal mammary artery	9.8	2.8	3.5	1.3–9.5	< .03
CABG with use of two internal mammary arteries	6.9	2.8	2.5	0.9–6.7	< .009
CABG with use of one or two internal mammary arteries	8.1	2.6	3.2	1.5–6.7	< .007
Valvular replacement	1.7	3.6	0.5	0.2–1.01	< .05
CABG and valvular replacement	3.8	2.9	1.3	0.5–3.3	NS
Mechanical circulatory assistance	12.5	2.8	4.4	1.5–13.5	< .003
Heart transplantation	12.5	2.8	4.5	1.7–12.1	< .01
Reoperation for cardiac tamponade or pericard effusion	32.0	2.4	13.3	6.7–25.9	< .00001

NS = not significant; NC = not calculable; CABG = coronary artery bypass graft; NNIS = National Nosocomial Infections Surveillance; BMI = body mass index; RR = relative risk; CI_{95} = 95% confidence interval.

developed SSI and patients who did not regarding age, gender, diabetes, obesity, chronic obstructive pulmonary disease, or preoperative length of stay. The probability of developing an infection when an implant was used (16 of 618; 2.6%) was not statistically significantly different from the probability of developing an infection when an implant was not used (22 of 650; 3.4%). Among the 38 infected patients, the probability of developing an infection caused by coagulase-negative staphylococci when an implant was used (5 of 16; 31%) was higher but not significantly different from the probability of developing an infection caused by coagulase-negative staphylococci when an implant was not used (4 of 22; 18%). The mean duration of operations was significantly greater in infected patients (247 minutes) than in non-infected patients (201 minutes) ($P < .001$).

An NNIS System risk index score of 2 or greater was strongly associated with a risk of SSI (Table 5). Heart transplantation, mechanical circulatory assistance, and reopera-

TABLE 6
MULTIVARIATE ANALYSIS: INDEPENDENT FACTORS PREDISPOSING TO SURGICAL-SITE INFECTION AFTER CARDIAC PROCEDURES

Factor	Estimate	SD	*P*
Constant	-4.135	0.308	< .0001
Reoperation for cardiac tamponade or pericard effusion	3.130	0.741	< .0001
CABG with use of internal mammary artery	1.780	0.596	< .003
Mechanical circulatory assistance	1.596	0.735	< .03
Heart transplantation	1.295	0.632	< .04

SD = standard deviation; CABG = coronary artery bypass graft.

tion for cardiac tamponade or pericard effusion were cardiac procedures significantly associated with a risk of SSI (Table 5). CABG was significantly associated with SSI only in patients operated on with the use of internal mammary artery. Among these patients (458), those operated on with the use of two internal mammary arteries had no additional risk of SSI (5 of 105) compared with those operated on with the use of one internal mammary artery (13 of 353).

Multivariate Analysis Using Logistic Regression

The independent factors associated with superficial and deep SSIs were cardiac procedures such as CABG with the use of internal mammary artery ($P < .003$), heart transplantation ($P < .04$), mechanical circulatory assistance ($P < .03$), and reoperation for cardiac tamponade or pericard effusion ($P < .0001$) (Table 6).

Because specific cardiac procedures could force out all other potential risk factors, we built another model excluding patients who underwent heart transplantation and mechanical circulatory assistance. The new model included 1,212 patients and 31 superficial and deep SSIs. We included in the multivariate analysis model the four variables significantly associated with SSI on univariate analysis: chronic obstructive pulmonary disease (relative risk, 5.5; 95% confidence interval, 1.4 to 21.4; $P < .03$), NNIS System risk index of 2 or greater (relative risk, 2.4; 95% confidence interval, 1.2 to 4.8; $P < .01$), CABG with the use of one internal mammary artery (relative risk, 2.3; 95% confidence interval, 1.1 to 4.8; $P < .01$), and reoperation for cardiac tamponade or pericard effusion (relative risk, 7.5; 95% confidence interval, 2.1 to 27.8; $P < .03$). The results provided a good calibration (Hosmer–Lemeshow test; $P = .395$) and a good fitness of the model assessed by McFadden's Rho squared (0.168). Reoperation for cardiac tamponade or pericard effusion was significantly associated with SSI (Table 6).

However, the 95% confidence interval of the odds ratio was large. Therefore, we built another model without this parameter. In this new model, chronic obstructive pulmonary disease was significantly associated with SSI, but the fitness of the model was not so good (McFadden's Rho squared, 0.064) (Table 7).

DISCUSSION

It is difficult to assess the real incidence of SSI after cardiac surgery because published results often include specific cardiac procedures or focus only on deep SSI. In addition, the incidence rates of SSI are not stratified on patients' risk of infection. We analyzed risk factors associated with SSI among 1,268 patients who underwent cardiac surgery according to the depth of the SSI, the cardiac procedure, and the NNIS System risk index.[26]

Although Zacharias and Habib reported that risk factors associated with superficial and deep SSIs were similar, our study showed that the two populations of patients are different.[27] Patients who developed mediastinitis were more likely to have undergone heart transplantation for terminal heart failure and mechanical circulatory assistance and were more likely to have had emergency surgery. They also had more reoperation for cardiac tamponade or pericard effusion. Patients who developed superficial SSI were more likely to have undergone CABG, with a long duration of surgery. On multivariate analysis using logistic regression, cardiac procedures such as heart transplantation, mechanical circulatory assistance, CABG with the use of internal mammary artery, and reoperation for cardiac tamponade or pericard effusion were independent risk factors significantly associated with both superficial and deep SSIs. A disadvantage to including all of the cardiac procedures

TABLE 7
MULTIVARIATE ANALYSIS: INDEPENDENT FACTORS PREDISPOSING TO SURGICAL-SITE INFECTION AFTER CARDIAC PROCEDURES WITHOUT HEART TRANSPLANTATION (N = 31) AND MECHANICAL CIRCULATORY ASSISTANCE (N = 24)

Factor	Estimate	SD	OR	CI_{95}	*P*
Constant	5.420	0.749			
CABG	0.819	0.764	2.3	0.5–10.1	.28
Chronic obstructive pulmonary disease	1.516	0.789	4.6	1.0–21.3	.05
NNIS System score ⩾ 2	1.124	0.781	3.1	0.7–14.2	.15
Reoperation for cardiac tamponade or pericard effusion	4.011	1.106	55.2	6.3–482	.000

SD = standard deviation; OR = odds ratio; CI_{95} = 95% confidence interval; CABG = coronary artery bypass graft; NNIS = National Nosocomial Infections Surveillance.

is the possibility of forcing out all other potential risk factors. In the multivariate model built without specific cardiac procedures such as heart transplantation and mechanical circulatory assistance, chronic obstructive pulmonary disease was also an independent risk factor associated with SSI. This finding, although previously identified,[28-30] needs further evaluation.

Previous studies have also provided conflicting evidence as to whether an increased risk of mediastinitis is associated with the use of internal mammary artery as a CABG. The risk could be higher with the use of two internal mammary arteries for the graft, particularly in the presence of diabetes and in obese patients.[30-36] However, mammary artery grafts have been shown to achieve greater long-term patency than saphenous vein grafts, and their continued use is encouraged. In addition, patients undergoing CABG with the use of internal mammary artery had a lower risk of reoperation and a lower risk of death compared with patients who underwent only saphenous vein grafting.[37] In our study, the use of internal mammary artery was associated with SSI, but there was no additional risk in patients operated on with two internal mammary arteries versus one.

We stratified the incidence rate of SSI using the NNIS System risk index. The Centers for Disease Control and Prevention advocates the widespread use of the NNIS System risk index to compare SSI rates among surgeons and hospitals.[26] The NNIS System risk index uses data available on the days of the procedure and includes the duration of the procedure (represented by the 75th percentile of duration for that procedure), the probability of wound contamination at the time of the procedure (wound classification), and the host's intrinsic susceptibility to infection, as estimated by a version of the ASA physical status classification. Patients receive one point for each criterion that they meet on the day of the procedure, and their NNIS System risk index total score is the sum of the points. The risk of acquiring an SSI increases as the total score increases (eg, from 1.5% if the NNIS System risk index total score is 0 to 13% if it is 3). In cardiac surgery, the NNIS System risk index total score cannot exceed 3 because almost all of these procedures are clean. In our series, the incidence of mediastinitis was 0% when patients had an NNIS System risk index total score of 0, 1.2% when it was 1, and 2.3% when it was 2, with a relative risk of 2.4, which is higher than the odds ratio of 1.75 in data published by the NNIS System and the odds ratio of 1.83 ($P < .01$) published by Roy et al.[26,38] Because most of the patients in our series had an ASA score of 3 or 4, the duration of the procedure was often the only component of the index that stratified the population by risk of SSI. More research is needed to develop a risk index that adequately stratifies the risk of SSI after cardiac operations.[38,39] Variables such as reoperation due to complications such as cardiac tamponade or pericard effusion and use of internal mammary artery for revascularization could be used to construct a cardiac risk index.[40]

Surveillance for SSIs reduces their rates, thereby improving medical care and decreasing healthcare costs.[41-43] This surveillance program, implemented in a cardiac surgery department of a hospital during 2002, was followed by a specific infection control program. In February 2003, one of the five surgeons changed the patient skin preparation per a published guideline on preventing SSI.[25] In May 2003, the other surgeons agreed to follow this change in the operating room. In July 2003, we introduced two preoperative antiseptic showers (povidone–iodine is used in our institution, except for children). From August to December 2003 (674 cardiac procedures), we observed only 7 SSIs (incidence rate, 1.3% vs 3% during the study period; $P < .006$): 5 superficial (incidence rate, 0.7% vs 1.6%; $P < .12$) and 2 mediastinitis (incidence rate, 0.3% vs 1.4%; $P < .02$).

Data surveillance using incidence rates stratified by cardiac procedure and type of infection is relevant to improving infection control efforts. Risk factors in patients who develop mediastinitis are different from those in patients who develop superficial SSI. CABG using internal mammary artery was associated with a risk of SSI, and independent factors such as reoperation for cardiac tamponade or pericard effusion increased the risk of infection.

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