

Superficial and deep sternal wound complications: incidence, risk factors and mortality

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Abstract

Objectives: Sternal wound complications often have a late onset and are detected after patients are discharged from the hospital. In an effort to catch all sternal wound complications, different postdischarge surveillance methods have to be used. Together with this long-term follow-up an analysis of risk factors may help to identify patients at risk and can lead to more effective preventive and control measures. **Methods:** This retrospective study of 3008 adult patients who underwent consecutive cardiac surgery from January 1996 through September 1999 at Linköping University Hospital, Sweden, evaluated 42 potential risk factors by univariate analysis followed by backward stepwise multivariate logistic regression analysis. **Results:** Two-thirds of the 291 (9.7%) sternal wound complications that occurred were identified after discharge. Of the 291 patients, 47 (1.6%) had deep sternal infections, 50 (1.7%) had postoperative mediastinitis, and 194 (6.4%) had superficial sternal wound complications. Twenty-three variables were selected by univariate analysis ($P < 0.15$) and included in a multivariate analysis where eight variables emerged as significant ($P < 0.05$). Preoperative risk factors for deep sternal infections/mediastinitis were obesity, insulin-dependent diabetes, smoking, peripheral vascular disease, and high New York Heart Association score. An intraoperative risk factor was bilateral use of internal mammary arteries, and a postoperative risk factor was prolonged ventilator support. Risk factors for superficial sternal wound complications were obesity, and an age of < 75 years. The 30 day mortality was 2.7% for patients without sternal wound complications and 2/291 (0.7%) for all patients with sternal wound complications, 0.5% for superficial sternal wound complications, and 1.0% for deep sternal infections/mediastinitis. The 1 year mortality rate was 4.8% for patients without sternal wound complications and 11/291 (3.8%) for patients with sternal wound complications, 2.1% for superficial sternal wound complications, and 7.2% for deep sternal infections/mediastinitis. **Conclusions:** The risk factors found in this study have been detected and reported in previous studies. The predictive ability was stronger though for deep sternal infections/mediastinitis (those needing surgical revisions) than for superficial sternal wound complications. Earlier recognition of sternal wound complications and aggressive treatment have probably contributed to the relatively low mortality rate seen in this study. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Cardiac surgery; Surgical wound infection; Postoperative mediastinitis; Multivariate analysis; Risk factors

1. Introduction

Sternal wound infection after cardiac surgery can be a serious complication. The reported incidence of sternal infections ranges from 0.9 to 20% [1,2], and the incidence of mediastinitis is 1–2% in most studies [3–5]. The variation in incidence between studies is probably partly due to differences in classifications and partly to differences in surgical procedures and the mode of follow-up. Deep infections (mediastinitis and sternumosteitis) cause high morbidity, with a prolonged hospital stay and an increased cost of care. The reported mortality rate for patients with deep sternal infections ranges from 9.8 to 14% in different studies

[2,6,7]. The costs for patients with sternal wound complications has been estimated to be 2.8 times that for patients with uncomplicated postoperative courses [2].

Several studies have examined and identified possible causes and risk factors associated with sternal infections, although with conflicting results. They include patient-related risk factors such as age, gender, obesity, diabetes mellitus, and chronic obstructive pulmonary disease (COPD), and procedure-related factors such as prolonged preoperative stay, duration of surgery, use of bilateral mammary grafts, reoperation for control of bleeding, and the need for repeated blood transfusions [1,2,6–12]. The pathogens causing postoperative infections have also been reported [10,11,13], the most common of which are Coagulase-negative staphylococci and *Staphylococcus aureus*.

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Since the onset of a sternal wound infection is often late (weeks to months) and starts after the patient has left the hospital, a long-term follow-up is necessary. The patients themselves and the referring physicians in the region need to get involved in the assessment of sternal wound complications to improve surveillance. Analysis of risk factors enables risk assessment of both individual patients and patient groups, and thus makes it possible to improve routines in order to take more effective preventive and control measures.

This study was aimed at investigating the incidence of superficial sternal wound complications and deep sternal infections/mediastinitis after cardiac surgery and identifying preoperative, intraoperative and postoperative factors that may influence the risk of surgical site infection (SSI) after cardiac surgery.

2. Materials and methods

2.1. Study population and definition of infection

From January 1996 through September 1999, 3026 adult patients underwent cardiac surgery at the University Hospital in Linköping, Sweden. Major postoperative complications are referred back to the University Hospital, as this is the only hospital in the southeastern health care region at which cardiac surgery is performed. The catchment area comprises approximately 950 000 people and nine referring hospitals. Of the 3026 patients investigated, 17 patients died within 48 h and were excluded. One patient with a left ventricular device presented as an extreme outlier in the dataset and was also excluded from the risk factor analysis. The remaining 3008 patients were followed up from January 1996 through December 1999 in order to catch all sternal wound complications during the study period. Criteria for defining and reporting SSIs were published in evidence-based guidelines by the Centers for Disease Control and Prevention (CDC) in 1999 [10]. Briefly, superficial SSIs involve only skin or subcutaneous tissues, deep SSIs involve deep soft tissues (fascial and muscle layers), and organ/space SSIs involve tissues other than the incision. According to these definitions postoperative mediastinitis is an organ/space SSI. Surgeons' notes on revisions (of deep sternal infections/mediastinitis) were reviewed to ensure that definitions were in accordance with these classes.

2.2. Antibiotic regimen and surgical preparation

The patients were admitted to the hospital either from home or via referral from another unit or hospital the day before surgery. Preoperative preparation of the patient included two antiseptic showers with hexachlorophene soap. Excessive hair was removed with a special hair-cutting machine the night before surgery. Standard perioperative antibiotic prophylaxis with cloxacillin (2 g) was given intravenously starting 30 min prior to incision in a

total of three doses. Patients with a history of allergy to penicillin received three doses of clindamycin 600 mg over 1 day and patients with immunosuppression received cloxacillin in combination with an aminoglycoside. The patient's skin was disinfected with colored alcoholic 0.5% chlorhexidine (5 mg/ml). The operating rooms have laminar high-flow ventilation and HEPA-filtered air (ultraclean air).

2.3. Surgical treatment of postoperative sternal wound infection/mediastinitis

The aim of the surgical revision was to remove all infected or necrotic tissue by debridement and if possible perform a primary wound closure. It was also mandatory to stabilize any sternal instability. If the sternum to a great extent had to be surgically removed, muscle flaps or transfer of the greater omentum was used for reconstruction. Occasionally continuous mediastinal irrigation systems were used.

2.4. Surveillance and data collection

The sternal incision site was assessed on a daily basis during the patient's stay (5–8 days) in the Department of Cardiothoracic Surgery. Diagnosis of identified sternal infections was based on positive cultures, clear dehiscence of the sternotomy, fever, pain, redness, secretion, purulent drainage, and sternal instability. Operating room logs were reviewed to identify all surgical revisions and they were later classified according to the CDC criteria by a cardiac surgeon (H.G.).

All patients were followed up by phone 2 weeks postoperatively and all were given a form to be returned to the unit 6 weeks after surgery. The patients were asked to answer questions about whether they had experienced any infection after discharge and if they had received medical treatment. In connection with visits to the referring cardiologist 2 and 6 months, respectively, after surgery, further information was collected. The physician questionnaire form was designed to elicit information about signs of infection, localization, whether cultures were taken, care given by health care professionals, and whether antibiotics were prescribed for any infection. If a wound infection was present, it was classified and documented by the physician according to specified definitions for superficial infection, deep infection and need for surgical revision. Although these postdischarge data on infections collected by means of the questionnaire could not be classified by the CDC criteria as strictly as the surgical revisions, we were nevertheless able in this way to take into account the wound problems reported by an attending physician (one CDC criterion for SSI).

Additional data were collected from the patient records and cardiac surgery databases. Forty-two preoperative, intraoperative and postoperative variables were recorded. The microbiology registry was checked for cultures taken from all patients who underwent their first surgical revision

Table 1
Clinical characteristics of 3026 consecutive cardiac patients (from 1 January 1996 through 30 September 1999)^a

Mean age (years)	65.4 ± 10.5
Male/female	2192/834
Obesity (BMI ≥30)	15.3%
Diabetes	17.0%
Insulin-dependent diabetes	7.7%
Smoking	46.2%
COPD	5.6%
Peripheral vascular disease	6.8%
Unstable angina	36.6%
NYHA score (≥3)	75.7%
Serum creatinine (≥168 μmol/l)	2.7%
Emergency surgery	2.8%
Number of grafts, mean	2.8 ± 1.8
Use of IMAs	74.6%
Reoperation for bleeding	4.6%
Blood transfusions	33.8%
Ventilator support ≥24 h	9.8%
Average length of stay in ICU (days)	1.9 ± 3.4
Average length of stay (days)	9.3 ± 4.6
30 day mortality	3.0%

^a Data presented are mean ± SD values or the number or percent of patients. BMI, body mass index (kg/m²); COPD, chronic obstructive pulmonary disease on medication; diabetes, dependent or non-insulin dependent; emergency surgery, patients admitted from the catheterization laboratory or the coronary care unit who had surgery within hours; ICU, intensive care unit; NYHA, New York Heart Association (functional class I–IV); peripheral vascular disease, history of aneurysm and/or occlusive arterial disease with or without surgical treatment; smoking, current and during the last month before surgery; IMA, internal mammary artery.

from January 1996 through September 1999. Bacteria were identified from sternal or mediastinal tissue or fluid. Mortality data were obtained from the Swedish National Cause of Death Register.

2.5. Statistical analysis

Differences in absolute frequencies between patients with and without superficial sternal wound complications and deep sternal infections/mediastinitis with respect to sample size were analyzed using the Pearson χ^2 statistic, and differences in mean values were analyzed using a two-tailed Student's *t*-test. All variables suggested by the univariate

analysis ($P < 0.15$) in any of the groups, or judged to be clinically important such as gender were entered into a backward stepwise multiple logistic regression analysis model [14]. Risk factors for 'all sternal wound complications' were evaluated first, and then 'superficial sternal wound complications' and 'deep infections/mediastinitis' were evaluated separately. *P* values of <0.05 were considered to indicate statistical significance on two-tailed testing. Statistical precision, the goodness of fit of the logistic model, was evaluated by the Hosmer and Lemeshow test. Statistical accuracy, or model discrimination, was assessed with the area under the ROC curve (*c* value), derived from the same set of patients and computed by means of non-parametric methods for each model. Statistical analysis was performed using the SPSS statistical package version 9.0.

3. Results

3.1. Clinical findings

Clinical characteristics of the patients are given in Table 1. The mean age was 65.4 years (range 16–87 years), and 72.5% were men and 27.5% were women. The numbers of different surgical procedures are shown in Table 2. The infection rate according to surgical procedure is also shown in Table 2. A list with basic data for analysis is provided in Table 3.

3.2. Incidence of superficial sternal wound complications and deep sternal infections/mediastinitis

Of the 3008 patients studied, sternal wound complications developed in 291 (9.7%). Superficial sternal wound complications occurred in 194 (6.4%), deep sternal infections in 47 (1.6%) and postoperative mediastinitis in 50 (1.7%) patients (Table 2). In Table 3, patient characteristics and surgical data for patients with sternal wound complications are summarized and compared with data for patients without sternal wound complications. Thirty-four percent of the sternal wound complications were detected before discharge, 46% were reported by patients and 20% were reported by referring physicians. About 90% of the patients

Table 2
Incidence of superficial sternal wound complications and deep sternal infections/mediastinitis after cardiac surgery by type of procedure

Procedures ^a	Total no. (%)	All sternal wound complications		Superficial sternal wound complications		Deep sternal infections/mediastinitis	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
CABG	2108 (70.1)	224	10.6	145	6.9	79	3.7
Valve surgery	527 (17.5)	38	7.2	30	5.7	8	1.5
CABG + valve surgery	238 (7.9)	20	8.4	13	5.5	7	2.9
Other procedures	135 (4.5)	9	6.7	6	4.4	3	2.2
Total	3008 (100.0)	291	9.7	194	6.4	97	3.2

^a CABG, coronary artery bypass grafting; other procedures include repair of atrioseptal defect and ventriculoseptal defect, removal of atrial myxoma, and graft repair of the ascending aorta.

Table 3

Description of the variables used in univariate and multivariate analysis of superficial sternal wound complications and deep sternal infections/mediastinitis^a

Variables	Patients without sternal wound complications (<i>n</i> = 2717)		Patients with sternal wound complications (<i>n</i> = 291)	
	<i>n</i>	%	<i>n</i>	%
<i>Preoperative</i>				
Age category (years)				
≥ 65	1632/2717	60.1	160/291	55.0
≥ 75	553/2717	20.4	45/291	15.5
Gender				
Female	749/2717	27.6	78/291	26.8
Male	1968/2717	72.4	213/291	73.2
Obesity (BMI ≥30)	378/2696	14.0	79/288	27.4
Diabetes	426/2703	15.8	85/289	29.4
Insulin-dependent diabetes	180/2703	6.7	52/289	18.0
Smoking	1168/2571	45.4	144/264	54.5
COPD	142/2672	5.3	24/287	8.4
Dialysis	9/2713	0.3	1/291	0.3
Peripheral vascular disease	173/2656	6.5	28/287	9.8
Angina	2047/2679	76.4	227/284	79.9
Unstable angina	979/2701	36.2	118/289	40.8
NYHA score (≥3)	1935/2574	75.2	217/268	81.0
Severe LV dysfunction	151/2684	5.6	20/290	6.9
Anemia (hemoglobin ≤110 g/l)	170/2715	6.3	17/290	5.9
Serum creatinine (≥168 μmol/l)	71/2708	2.6	5/290	1.7
Prior cardiac surgery	145/2717	5.3	12/291	4.1
Preoperative length of stay (days)*	2707	3.2 ± 3.6	291	3.2 ± 3.4
<i>Intraoperative</i>				
Emergency surgery	70/2716	2.6	8/290	2.8
Type of operation: CABG vs.	1884/2717	69.3	224/291	77.0
Valve surgery	489/2717	18.0	38/291	13.1
CABG + valve surgery	218/2717	8.0	20/291	6.9
Other procedures	126/2717	4.6	9/291	3.1
Duration of surgery (>300 min)	156/2592	6.0	13/273	4.8
Cardiopulmonary bypass time (min)*	2645	94.9 ± 43.9	280	94.4 ± 39.6
Aortic cross-clamp time (min)*	2646	57.6 ± 33.4	280	56.9 ± 30.3
Number of grafts (≥3)	1630/2594	62.8	185/277	66.8
Single/bilateral use of IMA	1945/2629	74.0	226/279	81.0
Bilateral use of IMA	76/2629	2.9	11/279	3.9
Inotropic agents	298/2462	12.1	27/281	9.6
Metabolic support	320/2716	11.8	40/291	13.7
Metabolic support GIK	299/2715	11.0	39/291	13.4
Metabolic support amino acids	71/2712	2.6	5/291	1.7
<i>Postoperative</i>				
IABP	43/2717	1.6	5/291	1.7
Reoperation (bleeding)	120/2715	4.4	17/290	5.9
Red blood cells (units)*	2693	1.4 ± 3.6	289	1.8 ± 4.0
Platelets/fresh frozen plasma/stored plasma (units)*	2610	0.6 ± 2.4	283	0.8 ± 3.7
Metabolic support	277/2711	10.2	32/291	11.0
Metabolic support GIK	264/2712	9.7	31/291	10.7
Metabolic support amino acids	51/2704	1.9	6/291	2.1
Ventilator support (h)*	2714	18.9 ± 52.8	289	30.4 ± 93.3

^a Preoperative length of stay, cardiopulmonary bypass time, aortic cross-clamp time, red blood cells, platelets/fresh frozen plasma/stored plasma, and ventilator support are continuous variables (*). The others are dichotomous. Continuous variables: data are shown as the mean ± SD. Dichotomous variables: number of occurrences (*n*, %). BMI, body mass index (kg/m²); CABG, coronary artery bypass grafting, other procedures include repair of atrioseptal defect and ventriculoseptal defect, removal of atrial myxoma, and graft repair of the ascending aorta; COPD, chronic obstructive pulmonary disease on medication; diabetes, dependent or non-insulin dependent; duration of operation means 'skin incision to skin closure'; emergency surgery, patients admitted from the catheterization laboratory or the coronary care unit who had surgery within hours; GIK, glucose-insulin-potassium; IABP, intraaortic balloon pump; IMA, internal mammary artery; LV, left ventricular; NYHA, New York Heart Association (functional class I–IV); other procedures includes atrioseptal defect, ventriculoseptal defect, removal of atrial myxoma, and graft repair of the ascending aorta; peripheral vascular disease, history of aneurysm and/or occlusive arterial disease with or without surgical treatment; smoking, current or during the last month before surgery.

returned the questionnaire and about 40% of the physicians' follow-up information was returned.

One hundred thirty-two surgical revisions of sternal infections were performed. Of these 47 patients (1.6%) were classified as having deep sternal infections and 50 (1.7%) as having mediastinitis. The median interval between initial operation and surgical revision due to infection was 19 days (range 3–433 days). Seventy-six percent of the patients who underwent revisions had previously been discharged without symptoms. Twenty-eight of the infected patients needed two or more revisions and antibiotics before the infection was cured. The average hospital stay in the Department of Cardiothoracic Surgery was 9.1 ± 3.9 days for patients without sternal infection and 16.3 ± 11.7 days (range 5–52 days) for patients who underwent surgical revisions.

The 30 day mortality was 2.7% for patients without sternal wound complications and 2/291 (0.7%) for all patients with sternal wound complications, 1/194 (0.5%) for superficial sternal wound complications, and 1/97 (1.0%) for deep sternal infections/mediastinitis. The 1 year mortality rate from January 1996 through December 2000 was 4.8% for patients without sternal wound complications, and 11/291 (3.8%) for patients with sternal wound complications. The patients with superficial sternal wound complications had a 1 year mortality of 4/194 (2.1%), and those with deep sternal infections/mediastinitis had a 1 year mortality of 7/97 (7.2%).

3.3. Pathogenesis

Of the 97 patients who underwent surgical revisions, 91 were cultured. Twenty-two patients were culture-negative. The most commonly isolated pathogen from wound cultures taken at the first surgical revision was Coagulase-negative staphylococci, which caused 36/91 (39.6%) of the infections. The second most common pathogen, *Staphylococcus aureus*, caused 15/91 (16.5%) of the infections and was more common in patients with mediastinitis (12/15, 80%) than in patients with deep sternal infections (3/15, 20%). Other pathogens responsible for sternal infections and mediastinitis were *Propioni*, *Acinetobacter*, *Enterobacter cloacae*, *Escherichia coli* and *Klebsiella*.

3.4. Risk factors

The risk factor analysis was divided into preoperative, intraoperative and postoperative factors. By means of univariate analysis 23 of 42 variables were associated with increased risk of sternal wound complications in any of the three groups (Table 4). Twenty-four variables were included in a multivariate analysis; the following independent predictors of superficial sternal wound complications and deep sternal infections/mediastinitis were identified: an age of <75 years, obesity, insulin-dependent diabetes, smoking, peripheral vascular disease, a NYHA score of ≥ 3 , bilateral use of IMAs, and prolonged ventilator support.

There were six preoperative patient-related risk factors, one intraoperative risk factor and one postoperative risk factor (Table 5). The addition of non-significant variables did not substantially improve the multivariate prediction model. The Hosmer and Lemeshow Goodness of Fit test showed that model fit was good for 'the three groups' ($P = 0.99$, $P = 0.56$, and $P = 0.83$, respectively). The discriminating ability of the models by ROC area analysis was low for all sternal wound complications and superficial sternal wound complications (ROC, 0.64 and 0.62), and relatively strong for deep infections/mediastinitis (ROC, 0.82).

4. Discussion

The main finding of this study is that with diligent follow-up more sternal wound complications can be detected, which in turn is a prerequisite for an early and aggressive treatment that may reduce mortality. Postoperative sternal SSIs occurred in 9.7% of the patients during the study period, and 66% of them had a late onset (weeks to months after discharge) indicating the importance of postdischarge surveillance for more complete case-finding. By CDC's surveillance criteria [10], a SSI should be reported if infection occurs within 30 days after the operation or within 1 year if the implant is left in place and the infection appears to be related to the operation. This seems to be a short time period to really catch deep sternal infections with often late and insidious onset.

The rates of deep sternal infection and mediastinitis that we found were somewhat higher than in other studies [4–7,15]. There is no other hospital in our region providing cardiac surgical services, and patients in need of surgical revisions must therefore return to our center. Due to a low response rate from the referring physicians (40%), the true risk of superficial sternal wound complications may nevertheless still be underestimated. Early diagnosis and accurate classification of the depth of sternal wound infections remains difficult and requires increased clinical suspicion and specified parameters. Because of the increased pressure for early discharge, it has become increasingly important to instruct referring physicians about assessment and documentation of sternal wound complications and advise the patient about whom to contact in order to report any problems. Intensified co-operation between the Departments of Infectious Diseases in the region and the Department of Cardiothoracic Surgery at the University Hospital has led to earlier recognition of sternal infections and more aggressive surgical management when needed, as well as reduced antibiotic consumption and a shorter postoperative stay [13].

All patients with a sternal infection are now evaluated by a cardiac surgeon, and revisions are more frequently done at an early stage. Although this approach increases the number of revisions, we believe that it contributes to the relatively low mortality rate due to infection that is seen in this study:

Table 4
Univariate risk factor analysis of superficial sternal wound complications and deep sternal infections/mediastinitis^a

Variables	All sternal wound complications (n = 291) (P < 0.15)	Superficial sternal wound complications (n = 194) (P < 0.15)	Deep sternal infections/mediastinitis (n = 97) (P < 0.15)
<i>Preoperative</i>			
Age category (years)			
≥ 65	0.102	0.006	> 0.15
≥ 75	0.053	0.020	> 0.15
Gender: female/male	> 0.15	> 0.15	> 0.15
Obesity (BMI ≥ 30)	< 0.001	< 0.001	< 0.001
Diabetes	< 0.001	0.007	< 0.001
Insulin-dependent diabetes	< 0.001	0.008	< 0.001
Smoking	0.005	> 0.15	0.001
COPD	0.042	> 0.15	0.020
Peripheral vascular disease	0.048	> 0.15	0.001
Angina	> 0.15	> 0.15	0.140
Unstable angina	0.140	> 0.15	0.032
NYHA score (≥ 3)	0.036	> 0.15	< 0.001
Severe LV dysfunction	> 0.15	> 0.15	0.070
Preoperative length of stay (days)	> 0.15	> 0.15	0.112
<i>Intraoperative</i>			
Type of operation: CABG	0.007	> 0.15	0.013
Single/bilateral use of IMA	0.011	0.114	0.055
Bilateral use of IMA	> 0.15	0.041	< 0.001
Metabolic support	> 0.15	> 0.15	0.002
Metabolic support GIK	> 0.15	> 0.15	0.001
<i>Postoperative</i>			
Reoperation (bleeding)	> 0.15	> 0.15	0.082
Red blood cells (units)	> 0.15	> 0.15	0.020
Platelets/fresh frozen plasma/ stored plasma (units)	> 0.15	> 0.15	0.092
Metabolic support GIK	> 0.15	> 0.15	0.080
Ventilator support (h)	0.040	0.084	0.004

^a Twenty-three variables were selected by univariate analysis ($P < 0.15$) and gender was included due to its clinical relevance. P values of < 0.15 are in bold type. Reported P values are two-sided. BMI, body mass index (kg/m^2); CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease on medication; diabetes, dependent or non-insulin dependent; GIK, glucose–insulin–potassium; IMA, internal mammary artery; LV, left ventricular; NYHA, New York Heart Association (functional class I–IV); peripheral vascular disease, history of aneurysm and/or occlusive arterial disease with or without surgical treatment; smoking, current or during the last month before surgery.

an early mortality rate of 1.0%, and a late mortality rate of 7.2% for deep sternal infections/mediastinitis, compared to 9.8–14% reported by others [2,6,7]. Our finding that prognosis of deep sternal infections can be influenced by adequacy and quickness of treatment are supported by other authors [15]. Coagulase-negative staphylococci, known to be important pathogens in cardiac surgery [4,13], were the most frequent pathogens isolated from deep sternal infections at the first surgical revision, even in the mixed cultures in this material. In this investigation we focused on infections in the chest area, although we recognize that leg wounds have a substantial impact on morbidity related to cardiac surgery, and an estimated rate as high as 20% in the follow-up.

In this study we evaluated the whole population of cardiac surgical patients using a multivariate analysis to identify high-risk patients or procedures. In this kind of study the aspects of statistical significance versus clinical importance need to be considered. Most earlier studies have

focused on deep infections or mediastinitis [4–8], whereas others have examined superficial infections [9,11] or exclusively studied risk factors for SSIs in specific cardiac procedures [2,12,16–19]. By analyzing risk factors for superficial sternal wound complications as well as deep sternal infections/mediastinitis, a pattern of different risk factors was shown. Obesity was independently associated with an increased risk of sternal infections in all groups. The patients with severe infections needing surgical revisions were older and showed signs of more advanced atherosclerotic disease as indicated by more peripheral vascular disease and a higher NYHA score.

Obesity, insulin-dependent diabetes, and a high NYHA score have also been identified previously as risk factors for deep sternal infections [1,6,9,12]. Prolonged time on a ventilator has been shown to increase the likelihood of sternal infections, and may contribute to extended exposure to risk factors in the ICU environment due to a prolonged stay and subsequent microbial colonization of patients [1,2].

Table 5
Backward stepwise multivariate logistic regression analysis of superficial sternal wound complications and deep sternal infections/mediastinitis^a

Risk factors	All sternal wound complications (n = 291)		Superficial sternal wound complications (n = 194)		Deep sternal infections/mediastinitis (n = 97)	
	OR (95% CI)	P < 0.05	OR (95% CI)	P < 0.05	OR (95% CI)	P < 0.05
<i>Preoperative</i>						
Age category: <75 years			1.90 (1.10–3.30)	0.022		
Obesity (BMI ≥30)	2.10 (1.51–2.92)	< 0.001	1.74 (1.17–2.60)	0.007	2.65 (1.54–4.56)	< 0.001
Insulin-dependent diabetes	2.91 (1.96–4.30)	< 0.001			5.82 (3.30–10.28)	< 0.001
Smoking	1.39 (1.05–1.86)	0.023			2.41 (1.42–4.10)	0.001
Peripheral vascular disease					2.11 (1.09–4.09)	0.028
NYHA score (≥3)					3.36 (1.19–9.47)	0.022
<i>Intraoperative</i>						
Bilateral use of IMA					4.23 (1.71–10.51)	0.002
<i>Postoperative</i>						
Ventilator support (h)	1.004 (1.002–1.006)	< 0.001			1.006 (1.004–1.008)	< 0.001

^a CI, confidence interval; OR, odds ratio. P values of <0.05 are in bold type. Reported P values are two-sided. The sample size for each model was 2401 cases because of missing data. BMI, body mass index (kg/m²); IMA, internal mammary artery; NYHA, New York Heart Association (functional class I–IV); peripheral vascular disease, history of aneurysm and/or occlusive arterial disease with or without surgical treatment; smoking, current or during the last month before surgery.

Other studies have also shown that the incidence might be higher when bilateral IMAs are used [6,9], whereas others have failed to show such a relationship in properly selected patients [18]. According to a review of published studies, patients receiving internal mammary grafts tend to be younger and are more often male [1]; this agrees with our findings. Bilateral use of the IMA deprives the sternum of blood supply, and places the patient at high risk of sternal infection development [18–20]. Use of bilateral IMA should be restrictive in patients with obesity, insulin-dependent diabetes, COPD, and peripheral vascular disease [7,18,19]. All risk factors are not modifiable, but a proper prophylactic antibiotic dose with ultimate timing and careful skin preparation in obese patients, as well as maintaining controlled blood glucose levels in diabetic patients before and after surgery, may reduce major infections [10,17,21]. In our study over 50% of the patients with sternal infections were current smokers. Cigarette smoking compromises the immune system, has devastating effects on the respiratory system, decreases circulation to the skin, and delays primary wound healing and may increase the risk of SSI [10,20].

Patients who underwent coronary artery bypass grafting accounted for the highest rate of infections in all groups, followed by combined procedures for deep sternal infections/mediastinitis and valve surgery for superficial sternal wound complications. The risk factors we found in this study are mainly related to the patient, although one intraoperative risk factor and one postoperative risk factor were found. Risk factors identified in one institution may not be relevant in another, mainly due to changes in the process of care. Larger and more specific databases may be necessary in order to develop a risk model to identify the high-risk patient in different institutions and thereby modify treatment and reduce risk.

Actions to reduce infections and continuously control the effect of all preventive measures require early recognition and aggressive management, adequate registration, and established criteria for defining superficial and deep sternal infections. For comparisons to be valid over time, the same surveillance methods and classifications of sternal infections must be used [4,10]. The most appropriate use of collected SSI data is timely feedback to practicing surgeons and healthcare workers, as this leads to increased awareness and knowledge about these patients, and a more structured management in all affiliated centers.

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