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ORIGINAL ARTICLE

Incidence and predictors of sternal surgical wound infection in cardiac surgery: A prospective study

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Abstract

Sternal surgical wound infection (SSWI) in cardiac surgery is associated with increased morbidity. We investigated the incidence of SSWI, the main germs implicated and predictors of SSWI. Prospective study including patients undergoing full median sternotomy between January 2017 and December 2019. Patients were followed-up for 3 months after hospital discharge. All sternal wound infections up to 90 days after discharge were considered SSWI. 1004 patients were included. During follow-up, 68 (6.8%) patients presented SSWI. Patients with SSWI had a higher incidence of postoperative renal failure (29.4% vs 17.1%, $P = .007$), a higher incidence of early postoperative reoperation for non-infectious causes (42.6% vs 9.1%, $P < .001$), longer ICU stay (3 [2–9] days vs 2 [2–4] days, $P = .006$), and longer hospital stay (24.5 [14.8–38.3] days vs 10 [7–18] days, $P < .001$). Gram-positive germs were presented in 49% of the cultures, and gram-negative bacteria in 35%. Early reoperation for non-infectious causes (OR 4.90, 95% CI 1.03–23.7), and a longer ICU stay (OR 1.37 95% CI 1.10–1.72) were independent predictors of SSWI. SSWI is rare but leads to more postoperative complications. The need for early reoperation because of non-infectious cause and a longer ICU stay were independently associated with SSWI.

KEYWORDS

adult, cardiac surgery, microbiology, risk factors, surgical wound infection

Key Messages

- sternal surgical wound infection (SSWI) is not common but leads to more complications

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- gram-positive and gram-negative germs were presented in 49% and 35%, respectively of the SSWI
- patients with SSWI suffer more postoperative renal failure, bleeding, and longer ICU/hospitalization stays
- non-infectious cause early reoperation and longer ICU stay were associated with SSWI

1 | INTRODUCTION

Sternal surgical wound infection (SSWI) in cardiac surgery is a rare but serious complication that is associated with increased morbidity, mortality, and higher cost since it usually involves longer hospital stays, long-term intravenous antibiotic treatment, and eventual new surgical interventions.[1-3] The published incidence of SSWI varies between 0.5% and 10% according to different studies.[4-8]

On the other hand, the population undergoing cardiac surgery has changed in recent years. Thus, patients undergoing cardiac surgery tend now to be older, with a higher prevalence of obesity and diabetes. On the contrary, the proportion of patients undergoing isolated coronary surgery has decreased, increasing the number of polyvalvular and combined procedures, which are much more complex. In addition, the proportion of patients undergoing emergency surgery has increased in recent years.[9]

The objective of this study was to analyse the incidence of SSWIs in our center, to investigate the potential predictors of SSWIs, to understand about the germs causing these infections, and to identify preoperative, intraoperative, and postoperative factors associated with SSWI.

2 | MATERIALS AND METHODS

This was a prospective observational study performed in our tertiary care hospital between January 2017 and December 2019. All patients ≥18 years who underwent full median sternotomy in our center during the cited study period were included. Patients with an active infection at the time of surgery or operated by other surgical ways were excluded.

SSWI was classified as superficial SSWI with skin or subcutaneous tissue involvement; deep SSWI with pectoral fascia or muscle involvement but no bone involvement; and organ/space SSWI with bone, sternal wires, or mediastinum involvement below the muscle or the muscular fascia (mediastinitis), according to the criteria published by the United States CDC.[10] To simplify the analysis, patients with pectoral fascia or muscle involvement but no bone involvement were included the group of patients with organ/space SSWI patients with bone involvement, sternal wires, or mediastinum, below the muscle or muscle fascia (mediastinitis) in the deep sternal surgical wound infection group.

In the Cardiovascular Surgery outpatient clinic, patients were screened for Methicillin-resistant Staphylococcus aureus (MRSA) in the nostrils, and if they were host, treatment was carried out with topical mupirocin and chlorhexidine washes throughout the body according to protocol.[11] In addition, patients received intravenous antibiotic prophylaxis the hour before the skin incision with cefuroxime, which was maintained for the first 24 hours after the intervention. If the patient was allergic to beta-lactams, teicoplanin was used. Chlorhexidine 2% was used for skin cleansing. The day before the surgical intervention, the hair on the skin was cut with an electric clipper, avoiding shaving with a blade. Strict glycemic control was sought during the intervention and the immediate postoperative period with an insulin pump if necessary, and normothermia was maintained during the surgical intervention.

The study protocol was approved by the Clinical Research Ethics Committee of our center and all patients signed informed consent (Internal Code 2021-12-9-HCUVA).

2.1 | Collection of data

The following variables were recorded: (a) Preoperative data (including age, sex, body mass index, comorbidities, preoperative NYHA functional grade, nasal colonisation, and Logistics EuroScore[12]); (b) Operative (type of surgery, cardiopulmonary bypass [CPB] time, glucose level, antibiotic prophylaxis, and type of skin shaving); (c) Postoperative (mechanical ventilation time, length of intensive care unit [ICU] stay, length of hospital stay, and postoperative outcomes).

A nurse from the Internal Medicine Department reviewed all the patients operated on a daily-basis, collecting the SSWI, infections of other surgical wounds, and any other nosocomial infection,[10] and transferring

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the data to an anonymous electronic database. Subsequently, patients attended the outpatient cardiovascular surgery clinic 1 week after hospital discharge, they were contacted by telephone 1 month after hospital discharge, and again attended the outpatient cardiovascular surgery clinic 3 months after hospital discharge. We considered as SSWI all those sternal wound infections that appeared up to 90 days after hospital discharge.

2.2 | Statistical analysis

A descriptive analysis of all the variables included in the study was carried out. Normality was tested with the Kolmogorov–Smirnov test. The quantitative variables were expressed as mean (±standard deviation) or median (interquartile range, IQR) as appropriate. Qualitative variables were expressed as absolute value (n) and percentage (%). The comparison of quantitative variables between groups was made by Student's *t* test or Mann–Whitney *U* test, as appropriate. Associations of qualitative variables were estimated using the χ^2 or Fisher's tests. A logistic regression analysis was used to identify significant prognostic factors for SSWI, and presented as odds ratio (OR) with 95% confidence interval (CI). Factors that were statistically significant by univariate analysis were included in the multivariate model.

A value of $P < .05$ was considered statistically significant. The statistical program used was SPSS v. 24.0 (SPSS, Inc., Chicago, IL, USA).

3 | RESULTS

During the study period, 1654 cardiac surgery patients were operated on in our center. A total of 1004 patients who underwent full sternotomy (65% male, with a median age of 67 years [IQR 56–74 years], mean logistic EuroScore of 9.4 ± 5) qualified for our study and therefore were included. In 273 (27%) patients, the surgery was urgent. The median CPB time was 85 (64–120) minutes.

Ninety-three (9.3%) patients died during hospitalisation, with a median survival of 6 (IQR 3–17) days. The most frequent mortality reason was multiple organ dysfunction syndrome in (57 patients, 61.3%), and only 3 (3.22%) patients died by an infectious cause (one patient died because of endocarditis and two patient because of septic shock).

During the study period, 68 (6.8%) patients presented SSWI. Thirty-two (3.2%) patients had a superficial infection (with skin and subcutaneous tissue involvement) and 36 (3.6%) patients had a deep infection (with fascia or muscle involvement or organ/space infection). Patients with SSWI had a higher prevalence of diabetes mellitus (45.6% vs 32.1%, $P = .025$) but there were not differences in terms of other baseline characteristics of the patients (Table 1).

Overall, patients with SSWI presented more medical-surgical complications (60.3% vs 43.7%, $P = .005$). The incidence of postoperative infections at other levels was also higher in these patients (47.1% vs 16.7%, $P < .001$), as well as the incidence of postoperative renal failure (29.4% vs 17.1%, $P = .007$), postoperative bleeding >800 CC in the first 12 hours[13] (29.4% vs 7.9%, $P < .001$), early postoperative reoperation for non-infectious causes (42.6% vs 9.1%, $P < .001$), longer CPB time (97 [75–132] minutes *vs* 84 [63–119] minutes, $P = .026$), and longer postoperative temporary pacemaker maintenance time (5 [4–9] days vs 4 [3–6] days, $P = .008$). Patients with SSWI also presented a longer ICU stay (3 [2–9] days vs 2 [2–4] days, $P = .006$), longer hospital stay (24.5 [14.8–38.3] days vs 10 [7–18] days, $P < .001$), higher incidence of postoperative hospital stay longer than 30 days (42.6% vs 9.1%, $P < .001$), and higher rate of readmission after hospital discharge (26.5% vs 12.2%, $P = .001$). Patients with SSWI presented numerically higher in-hospital mortality but not significant (13.2% vs 9.0%, $P = .243$) and none of the patients with SSWI who died did it because of an infectious cause (Table 2).

Regarding the microbiology of SSWI, the most frequent germ was *Staphylococcus epidermidis* (23%), followed by *Pseudomonas aeruginosa* (14%), *Staphylococcus aureus* (13%), *Enterococcus fecalis* (10%), and *Escherichia coli* (6.5%). Germs from the Staphylococcus family accounted for almost 40% of the samples. Thus, gram-positive germs, including *S. aureus*, represented 49% of the cultures, gram-negative bacteria, including *P. aeruginosa*, 35%, saprophytic skin germs 6.5%, fungi 3%, and anaerobes 2% of the cultures (Figure 1). On the other hand, 20% of patients with SSWI were carriers of MRSA in the nose.

In addition, 188 patients (19%) had postoperative infections at other levels during the study period. Specifically, 68 (6.8%) patients had vascular or catheter infections, 63 (6.3%) patients suffered respiratory infections, 49 (5%) urinary infections, and 10 (1%) other infections such as bacteremia or sepsis. Overall, 265 patients (26%) had some kind of infectious complication during the postoperative period.

3.1 | Variables associates with SSWI

After a multivariate logistic regression analysis, the need for reoperation in the early postoperative period for non-

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TABLE 1 Demographic and baseline variables

	Patients without SSWI ($N = 936$)	Patients with SSWI ($N = 68$)	*P*-value
Age (years), median (IQR)	67 (56.25–74)	64.5 (56–73.75)	.734
Male sex	606 (64.7%)	42 (61.7%)	.612
BMI (kg/m^2)	28 (26–31)	29 (26–32)	.178
Comorbidities			
Diabetes Mellitus	300 (32.1%)	31 (45.6%)	.025
Obesity (BMI >30 kg/m^2)	287 (30.7%)	24 (35.3%)	.311
Dyslipemia	531 (56.7%)	43 (63.2%)	.329
Chronic kidney disease	127 (13.6%)	10 (14.7%)	.817
COPD	132 (14.1%)	9 (13.2%)	.818
Smoking habit	143 (15.3%)	11 (16.2%)	.867
Preoperative immunosuppression	66 (7.1%)	3 (4.4%)	.396
Previous surgery	78 (8.3%)	10 (14.7%)	.078
Previous hospital admission	815 (87.1%)	63 (92.6%)	.203
Type of intervention			
Coronary	204 (21.8%)	21 (30.9%)	.087
Valvular	452 (48.3%)	24 (35.3%)	
Mixed surgery	72 (7.7%)	7 (10.3%)	
Other	141 (15.1%)	15 (22.1%)	

Abbreviations: BMI, Body mass index, COPD, Chronic obstructive pulmonary disease; SSWI, Sternal surgical wound infection.

TABLE 2 Operative and postoperative variables

	Patients without SSWI ($N = 936$)	Patients with SSWI ($N = 68$)	*P*-value
Urgent surgery	249 (26.6%)	24 (35%)	.123
Surgical complications	193 (20.6%)	17 (25%)	.360
Medical-surgical complications	409 (43.7%)	41 (60.3%)	.005
Glycaemia >150 mg	213 (22.8%)	17 (25%)	.315
Infections at other levels	156 (16.7%)	32 (47.1%)	<.001
Postoperative stroke	50 (5.3%)	4 (5.9%)	.802
Postoperative renal failure	160 (17.1%)	20 (29.4%)	.007
Non-infectious cause reoperation	85 (9.1%)	29 (42.6%)	<.001
Bleeding>800 cc/12 h	74 (7.9%)	20 (29.4%)	<.001
Death	84 (9.0%)	9 (13.2%)	.243
Admission>30 days	81 (8.7%)	29 (42.6%)	<.001
CPB time (min)	84 (63–119)	97 (75–132)	.026
Mechanical ventilation time (hours)	5 (4–5)	5 (4–6)	.052
ICU stay (days)	2 (2–4)	3 (2–9)	.006
Temporary pacemaker time (days)	4 (3–6)	5 (4–9)	.008
Hospital stay (days)	10 (7–18)	24.5 (14.8–38.3)	<.001
Hospital readmission	114 (12.2%)	18 (26.5%)	.001

Abbreviations: CPB, Cardio-pulmonary bypass; ICU, Intensive care unit; SSWI, Sternal surgical wound infection.

infectious causes, which increased the risk of SSWI by almost fivefold (OR 4.90, 95% CI 1.03-23.7, $P = .046$), and a longer ICU stay (OR 1.37 95% CI 1.10-1.72, $P = .005$), were independent predictors of SSWI (Table 3). The Hosmer-Lemeshow test indicated a good fit of the model ($P = .462$).

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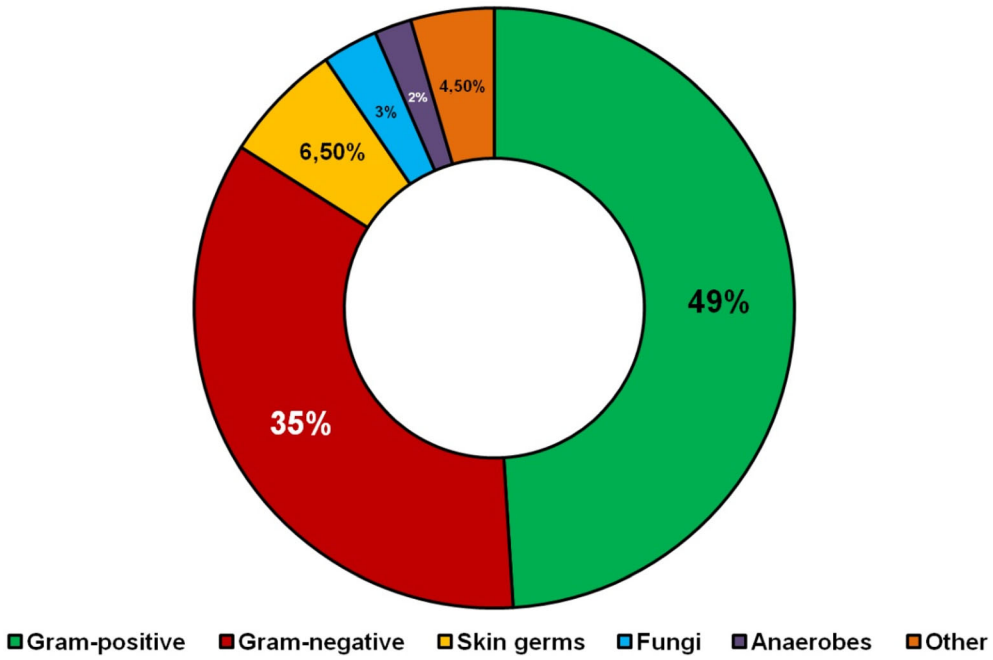

FIGURE 1 Microbiology of sternal surgical wounds infections

TABLE 3 Multivariate analysis for sternal surgical wound infection

	Odds ratio	95% CI	*P*-value
Male sex	0.36	0.06–2.10	0.311
Diabetes mellitus	2.30	0.40–13.40	0.545
Previous surgery	0.79	0.05–12.40	0.812
CPB time (min)	1.01	0.98–1.03	0.084
Temporary pacemaker time (days)	1.11	0.91–1.36	0.306
ICU stay (days)	**1.37**	**1.10–1.72**	**0.005**
Postoperative renal failure	0.67	0.06–7.41	0.615
Non-infectious Cause reoperation	**4.90**	**1.03–23.70**	**0.046**
Bleeding >800 cc/12 h	6.60	0.30–14.80	0.343
Mechanical ventilation time (hours)	1.00	0.89–1.14	0.789
Type of intervention	0.26	0.06–1.21	0.087

Note: Statistically significant results are highlighted in bold.
Abbreviations: CPB, Cardiopulmonary bypass; ICU, Intensive care unit.

4 | DISCUSSION

Our results demonstrated that SSWI had an incidence of ≈7% in our population, a figure that is within what has been reported in other studies.[4-8] This incidence is divided between 3.2% of superficial SSWI and 3.6% of deep SSWI. When comparing the results of different studies, it must be taken into account that the published incidence of SSWI may vary depending on the definition adopted. In our study, we fulfilled the criteria of the American CDC for nosocomial infections, merging in the group of deep SSWI the cases of frank mediastinitis and the cases of more localised deep infection such as sternal osteomyelitis.[10,14] However, other studies only analyse cases of mediastinitis, separating them from cases of deep infection.[15]

In our study, patients with SSWI did not suffer significantly higher mortality, a finding also indicated by other groups.[14,16] Of note, in the entire population, the logistic EuroScore was well-adjusted to the in-hospital mortality obtained. On the other hand, the incidence of SSWI varied in our population according to the type of surgical operation. Thus, valve surgery was the one with the lowest incidence (5%). These data agrees with the results of other authors.[17,18]

From a microbiological point of view, the most frequently cultured germ was coagulase-negative staphylococci that are part of the normal flora of the skin,

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specifically *S. epidermidis*. Gram-positive germs accounted for almost half of the cultures and gram-negative germs for more than a third. This proportion differs from other studies in which the weight of gram-negative germs was lower.[1,17,18] In fact, *P. aeruginosa* was the second most frequently isolated germ in our study, followed by *S. aureus*. This could be because of the effort made in screening, decolonisation and the use of adequate antibiotic prophylaxis against *S. aureus* in particular, and gram-positive germs in general. If in the future gram-negative germs continue to grow as a cause of SSWI, perhaps changes in our antibiotic prophylaxis should be considered.[19] On the other hand, previous studies have tested different prophylaxis regimens and therapies. For example, a study using gentamicin-containing collagen implants to standard infection prophylaxis reduced SSWI (both, superficial SSWI and deep SSWI) in high-risk patients undergoing cardiac surgery.[20] Another study evaluated the use of platelet-rich plasma (PRP) applied inside the sternotomy wound and found that it significantly reduced the occurrence of deep SSWI and superficial SSWI in cardiac surgery patients.[21]

In addition, more than a quarter of our patients presented some type of postoperative infection, a figure lower than that published by other European groups, which reaches up to 35%.[15] Patients with SSWI in the postoperative period also had a higher incidence of postoperative infections at other levels.

The fact that patients with SSWI presented a higher prevalence of diabetes mellitus is consistent with previous studies.[1,2,4,6,8,14,16,22] Patients with SSWI had longer CPB times, suggesting more complex and prolonged surgical processes[1,22,23] and perhaps as a consequence, a higher incidence of postoperative renal failure. Patients with SSWI also kept the temporary pacemaker leads longer suggesting that these patients suffered more heart rhythm problems in the postoperative period, which would make it necessary to keep these temporary epicardial leads longer. In any case, it is interesting to know that after the fifth postoperative day with temporary epicardial pacemaker leads, the probability of SSWI could be increased.

Finally, the need for reoperation in the immediate postoperative period for non-infectious causes and a longer stay in the ICU, both postoperative factors, were independent predictors of SSWI. It is possible that carrying out more careful preoperative preparation in relation to the management of perioperative blood glucose levels, preoperative lavage, and skin preparation, the use of strict antibiotic prophylaxis, preoperative screening for MRSA nasal carriers, and the operative management in normothermia, have reduced the impact of preoperative factors on SSWI, highlighting the impact of postoperative factors.[24] On the other hand, the high prevalence of diabetes mellitus (34%) and obesity (32%) in the entire population analysed could have diminished their influence on SSWI. The need for reoperation for non-infectious causes could be because of a greater presence of urgent surgery, the presence of patients with double antiplatelet therapy or oral anticoagulation at the time of surgery, as well as increasingly complex procedures[9] that require prolonged surgical times. In any case, this factor underlines the need for a careful hemostatic technique throughout the surgical procedure, especially at the end of long and complicated cases. This independent predictor of SSWI is also present in other studies.[6,7,14,16-18,22,23,25-27] In addition, Boeken et al. showed that if the reintervention occurred before the first six postoperative hours, the risk of SSWI problems, sepsis, renal failure, or prolonged mechanical ventilation is reduced compared to when the reintervention was performed later.[28] Thus, the need to open the surgical wound again could facilitate the access of germs from the patient's skin, from the surgeons or from the operating room external environment, forms of infection of the surgical wound that could be included in the exogenous route of surgical site infection.

On the other hand, the stay of patients in the ICU could be the most sensitive period to infection in cardiac surgery, according to our data and to previous studies,[6,7,26] since the patient is subjected to invasive mechanical ventilation, invasive hemodynamic monitoring with arterial and venous lines, urine is collected through a bladder catheter and chest drainage through drainage tubes. All of them are gates of infection that could cause SSWI through the hematogenous route. In our study, almost 1/5 of the patients had an infection at these levels. The longer stay in the ICU of patients with SSWI may be because of the presence of some medical or surgical complication, but the stay of cardiac surgery patients in the ICU should not be prolonged for other reasons than clinical ones, since each extra day in the ICU increases the possibility of SSWI by 37%. Perhaps the development of intermediate care units where patients are monitored without invasive monitoring could be a solution for earlier discharge from the ICU.

Patients with SSWI not only had a longer stay in the ICU but they also had a longer hospital stay, data already indicated by other researchers.[2,7,14,29,30] These patients often remained hospitalised for more than a month and were readmitted to the hospital after discharge more than twice as patients without SSWI. All this raises the human and economic cost of treating patients with SSWI. Limiting only to the economic cost of the longer stay in the ICU and the hospital for these patients, we can hypothesise a mean excess cost of €11 312 per patient with SSWI compared to patients without SSWI,[31] a figure somewhat lower than the calculations of other groups.[3,30]

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4.1 | Limitations

Some limitations regarding our study should be acknowledged. Our work is a single-center, observational, and retrospective data analysis study, so our results may not be applicable to other hospitals. Variables such as the number or type of coronary grafts or whether transfusions of packed red blood cells were performed were not collected (factors that in other studies have shown to influence on SSWI[6,7,14,18,25]), although we found that patients with SSWI bled more in the immediate postoperative period than patients without SSWI. Finally, we have no data about serial assessment of the microbiology of the SSWI during hospitalisation as this is not done by routine in our hospital, and this was an observational study not modifying the routine clinical practice. However, we believe that our work reflects the daily clinical activity of a modern cardiac surgery unit that faces increasingly complex patients trying to maintain high levels of quality of care.

5 | CONCLUSION

SSWI is a rare but a serious complication of cardiac surgery. Patients with SSWI are more frequently diabetic, have more infections at other levels, suffer more postoperative renal failure, bleeding, longer ICU, and hospital stays, and are readmitted more frequently after hospital discharge. Postoperative factors such as early reoperation for a non-infectious cause and a longer stay in the ICU were independently associated with SSWI.

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DATA AVAILABILITY STATEMENT

Research data are not shared because other sub-analyses are still pending.

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