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Sternal Wound Infection Following Open Heart Surgery: Incidence, Risk Factor, Pathogen, and Mortality

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ABSTRACT

Background: Due to its high morbidity and mortality after open-heart surgery, sternal wound infection (SWI) is one of the most important consequences to avoid and manage.

Aim: To assess the incidence, risk factor, causative organisms, and mortality of SWIs in patients who had open-heart surgery over a 9-year period at King Abdulaziz University Hospital, Jeddah, Saudi Arabia.

Methods: A retrospective study was done on 634 patients who underwent open heart surgery. Data was collected, including patient demographics, BMI, blood group, diabetes, hyperlipidemia, COPD, previous cardiac surgery, previous myocardial infarction, duration of the operation, blood transfusion during the operation, hospital length of stay, and bypass time with each type of sternal wound infection.

Results: The incidence of SSWI and DSWI was 8.6% and 4.1%, respectively. Coagulase-negative staphylococcus was the most frequently isolated organism from SSWI and DSWI patients. A concomitant diabetes mellitus that necessitates blood transfusion was identified as one of the risk variables for SSWI in a multivariate regression study. While concomitant diabetes, being a woman, and a lengthy hospital stay were independently linked with DSWI. Compared with the SSWI group, the 30-day mortality rate for DSWI patients was 3.8% as opposed to 3.7%, and the difference in survival was not statistically significant. Having an older, longer bypass time, and postoperative problems were independent risk factors for 30-day mortality.

Conclusion: Future studies in various healthcare settings are required in order to generalize the results because this was a single center study.

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INTRODUCTION

Surgical site infections (SSI) are a significant cause of morbidity and mortality after surgery. SSIs are found in 2% to 4% of all patients having inpatient surgical procedures [Berríos-Torres 2017]. Prevalence of SSI in cardiac surgery was 10% [Maleknejad 2019]. About 3% of patients who develop an SSI will die as a result [Awad 2012].

Previous studies reported a variation in the incidence of sternal wound infection (SWI). The overall incidence of SWIs ranges between 0.43%–2.3% worldwide [Okonta 2011]. The incidence of deep sternal wound infection (DSWI) after cardiac operations ranges from 0.5% to 2% [Yusuf 2018]. DSWI is a dreadful complication with mortality ranging between 1% and 14% [Gudbjartsson 2016]. On the other hand, superficial sternal wound infection (SSWI) has not been studied as much as DSWI due to less morbidity and mortality associated with it. It has an incidence rate differing from 2% to 6% [Gudbjartsson 2016].

Several studies reported many risk factors, but no consensus has been reached. Among these risk factors that have been described as significant in different studies are gender, age, obesity or BMI, diabetes, chronic obstructive pulmonary disease (COPD), hyperlipidemia, previous cardiac surgery, previous myocardial infarction, duration of the operation, blood transfusion, and hospital length of stay [Hosseinrezaei 2012; Floros 2011; Mannien 2011; Al-Zaru 2010; Filsoufi 2009]. However, in a retrospective study, conducted in the capital of Saudi Arabia, of 1,241 consecutive patients who underwent cardiac surgery, none of the studied risk factors, which consist of gender, coronary artery bypass graft surgery (CABG), obesity, use of statins, smoking, diabetes mellitus, and duration of surgery were found as significant [Majid 2020].

Staphylococcus species (mainly S. aureus and coagulase-negative staphylococci) are the most frequently reported bacteriological pattern in SWIs cases with positive culture [Yusuf 2018].

Following open-heart surgery, sternal wound infection (SWI) is one of the most crucial complications to prevent and manage because of its high morbidity and mortality. Also, it has an adverse effect on hospital length of stay (LOS) and cost. As reported, the average LOS prolonged by 17.9 days, with an 22,905 Euro rise in the average costs [Graf 2010].

Proper wound dressing, patient education regarding wound care, suitable environmental considerations, and scientific follow up must all be covered. Depending on the

closure technique, a referral to the patient's primary care physician or an outpatient facility typically will be required for evaluation of the recovery treatment or follow up [Al-Habib 2018].

Identification of risk factors is a fundamental part of the prevention and management of SWIs [Lemaignen 2015; Kotnis-Gąska 2018]. Few studies reported the incidence of SWIs after open-heart surgery and assess the risk factors in Saudi Arabia. Thus, this retrospective study aimed to determine the incidence, risk factor, identify the organisms, and mortality of SWIs in patients who underwent open-heart surgery over a 9-year period at our institute.

PATIENTS AND METHODS

Study design, setting and time: This was a retrospective study done in the Cardiothoracic Surgery Department at King Abdulaziz University Hospital, Jeddah, Saudi Arabia in the time from August to October 2022.

Study participants: The inclusion criteria were patients who underwent open heart surgery by median sternotomy in KAUH between January 2011 to December 2019. Exclusion criteria were patients under 18 years, those who suffered from immune diseases (HIV, tumor, and autoimmune diseases), patients with partial sternotomy, and those with insufficient medical file data.

Sample size: The sample size was determined using a convenient sampling technique. Our minimum representative sample size was 242 patients, calculated by Raosoft, Inc. Our bank has 647 patients who underwent open heart surgery during the period between 2011 to 2019.

Data collection: A checklist was prepared to collect data from patients' medical records about their age, gender, BMI, blood group, diabetes, hyperlipidemia, COPD, previous cardiac surgery, previous myocardial infarction, duration of the operation, blood transfusion during the operation, hospital length of stay, and bypass time with each type of sternal wound infection.

Ethical considerations: An ethical approval for the study was obtained from the research ethics committee of King Abdulaziz University Hospital, Jeddah, Saudi Arabia.

Data analysis: Statistical analysis was carried out using RStudio (R version 4.1.1). Descriptive statistics were used for categorical data (frequencies and percentages) and numerical data (medians and interquartile ranges [IQRs]). Factors associated with sternal wound infections were assessed using a Kruskal-Wallis rank sum test for numerical variables and a Fisher's Exact Test for count variables, where patients were grouped into having no sternal wound infections (no SWI), superficial sternal wound infections (SSWIs), and deep sternal wound infections (DSWIs). Risk factors of sternal wound infections were investigated by incorporating the significantly associated factors from the univariate analysis as independent variables in a multinomial logistic regression analysis model. We used the grouping SWI variables (no SWI vs. SSWI vs. DSWI) as a dependent variable, and the results were expressed as odds ratio (OR) and the respective 95% confidence intervals (95% CIs). Survival analysis was conducted by plotting a Kaplan-Meir curve for the 30-day mortality against developing sternal wound infections, and the statistical differences were computed using the log-rank test. Factors associated with the 30-day mortality were assessed by implementing univariate and multivariate cox proportional hazards models. The outcomes were presented as hazard ratios (HRs) and 95% CIs. A P-value of 0.05 indicated statistical significance.

RESULTS

Demographic and clinical characteristics: Data from 634 patients were collected in the current study. However, we excluded the records of six patients due to insufficient primary outcomes. Therefore, data of 628 ultimately were included. The majority of patients were males (74.8%) and non-Saudis (87.6%), and the median (IQR) age of patients was 55.0 years (48.0 to 63.0). Overweight and obese patients represented 36.5% and 29.9% of the sample under study, respectively. More than a half of the patients were non-smokers (53.7%). Approximately one-fifth of patients (19.6%) previously had experienced a myocardial infarction, and 11.3% of them had undergone a cardiac surgery. Percutaneous coronary interventions were the most common cardiac surgery among patients (74.3%). More details about the demographic and clinical characteristics are listed in Table 1. (Table 1)

Surgical and hospital-related characteristics: Emergency surgeries were performed for 15.4% of patients. The median (IQR) surgery duration was 272.0 minutes (227.2, 319.0), and the median (IQR) bypass time was 110.0 minutes (88.8, 139.0). A total of 8.3% of patients experienced postoperative complications. Additionally, 41.1% of patients required blood transfusion, and 6.2% of them required re-operation with signs of infection.

Characteristics of sternal wound infections and the isolated organisms: In general, 54 patients developed a superficial sternal wound infection (SSWI) with an incidence of 8.6% (95% CI, 6.6 to 11.1). Additionally, deep sternal wound infections (DSWIs) were reported among 26 patients, and the incidence was 4.1% (95% CI, 2.8 to 6.1). Among patients with SSWI, coagulase-negative Staphylococcus was the most commonly isolated organism (29.6%) followed by Klebsiella pneumoniae (20.4%). (Figure 1) For DSWI, the most common organisms included coagulase-negative Staphylococcus (26.9%), as well as Staphylococcus aureus (19.2%) and Pseudomonas aeruginosa (19.2%, Figure 1B).

Factors associated with SWI: A larger proportion of females had DSWI (53.8%) compared with those who had SSWI (25.9%) and no SWI (23.7%, P = 0.004). Additionally, patients with DSWI had significantly higher BMI values (median = 30.7, IQR, 26.4 to 33.6) than those with SSWI (median = 26.7, IQR, 24.5 to 30.3) and patients with no SWI (median = 27.2, IQR, 24.1 to 31.0, P = 0.033). Regarding comorbid conditions, only diabetes mellitus was associated with DSWI, where 80.8% of patients with DSWI had diabetes compared with 64.8% and 47.6% of patients with SSWI

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Table 1. The association between demographic and clinical characteristics and the development of sternal wound infection

Parameter	Category	Overall (*N* = 628)	None (*N* = 548)	SSWI (*N* = 54)	DSWI (*N* = 26)	*P*-value
Age (years)	Numerical 55.0 (48.0, 63.0)	55.0 (48.0, 63.0)	55.5 (46.2, 61.8)	54.0 (47.2, 63.2)	0.932	
Gender	Male	470 (74.8%)	418 (76.3%)	40 (74.1%)	12 (46.2%)	0.004
	Female	158 (25.2%)	130 (23.7%)	14 (25.9%)	14 (53.8%)	
BMI (kg/m2)	Numerical	27.2 (24.1, 31.0)	27.1 (23.8, 31.0)	26.7 (24.5, 30.3)	30.7 (26.4, 33.6)	0.033
Blood group	A+	171 (27.2%)	151 (27.6%)	13 (24.1%)	7 (26.9%)	0.244
	A-	20 (3.2%)	17 (3.1%)	3 (5.6%)	0 (0.0%)	
	B+	122 (19.4%)	98 (17.9%)	19 (35.2%)	5 (19.2%)	
	B-	8 (1.3%)	8 (1.5%)	0 (0.0%)	0 (0.0%)	
	AB+	36 (5.7%)	30 (5.5%)	5 (9.3%)	1 (3.8%)	
	AB-	2 (0.3%)	2 (0.4%)	0 (0.0%)	0 (0.0%)	
	O+	250 (39.8%)	224 (40.9%)	14 (25.9%)	12 (46.2%)	
	O-	19 (3.0%)	18 (3.3%)	0 (0.0%)	1 (3.8%)	
Comorbidities	DM	317 (50.5%)	261 (47.6%)	35 (64.8%)	21 (80.8%)	<0.001
	HTN	317 (50.5%)	269 (49.1%)	29 (53.7%)	19 (73.1%)	0.052
	Hyperlipidemia	78 (12.4%)	69 (12.6%)	5 (9.3%)	4 (15.4%)	0.648
	IHD	146 (23.2%)	126 (23.0%)	14 (25.9%)	6 (23.1%)	0.863
	COPD	4 (0.6%)	4 (0.7%)	0 (0.0%)	0 (0.0%)	>0.999
Previous cardiac surgery	Yes	71 (11.3%)	61 (11.1%)	7 (13.0%)	3 (11.5%)	0.838
Previous myocardial infarction	Yes	123 (19.6%)	104 (19.0%)	12 (22.2%)	7 (26.9%)	0.485

Table 2. The association between surgery-related characteristics and the development of sternal wound infection

Parameter	Category	Overall (*N* = 628)	None (*N* = 548)	SSWI (*N* = 54)	DSWI (*N* = 26)	*P*-value
Length of hospital stay (days)	Numerical	7.5 (6.0, 12.0)	7.0 (6.0, 11.0)	12.0 (7.0, 20.8)	17.0 (8.2, 51.8)	<0.001
Surgery duration (minutes)	Numerical	272.0 (227.2, 319.0)	271.5 (226.2, 319.0)	263.5 (223.2, 306.5)	277.5 (259.2, 357.0)	0.282
Bypass time (minutes)	Numerical	110.0 (88.8, 139.0)	111.0 (88.0, 143.0)	105.0 (92.8, 122.0)	106.5 (96.2, 139.0)	0.607
Complications	Uncomplicated	570 (90.8%)	500 (91.2%)	47 (87.0%)	23 (88.5%)	0.551
	Complicated	52 (8.3%)	42 (7.7%)	7 (13.0%)	3 (11.5%)	
Blood transfusion	Yes	258 (41.1%)	212 (38.7%)	31 (57.4%)	15 (57.7%)	0.009
Number of bags used for blood transfusion	1	97 (37.5%)	86 (40.2%)	6 (20.0%)	5 (33.3%)	0.040
	2	93 (35.9%)	71 (33.2%)	17 (56.7%)	5 (33.3%)	
	3	42 (16.2%)	37 (17.3%)	2 (6.7%)	3 (20.0%)	
	4	25 (9.7%)	19 (8.9%)	5 (16.7%)	1 (6.7%)	
	5	2 (0.8%)	1 (0.5%)	0 (0.0%)	1 (6.7%)	
Re-exploration for bleeding	Yes	39 (6.2%)	15 (2.7%)	7 (13.0%)	17 (65.4%)	<0.001

and no SWI, respectively ($P < 0.001$, Table 1). Furthermore, the length of hospitalization was significantly longer among patients with DSWI (median = 17.0 days, IQR, 8.2 to 51.8) than patients with SSWI (median = 12.0, IQR, 7.0 to 20.8) and no SWI (median = 7.0, IQR, 6.0 to 11.0, $P < 0.001$). Blood transfusion was required by significantly higher proportions of patients with DSWI (57.7%) and SSWI (57.4%) compared with those without SWI (38.7%, $P = 0.009$). The

Table 3. Risk factors for sternal wound infections

Outcome	Parameter	Category	OR	95% CI	*P*
SSWI	Gender	Male	-	-	
		Female	0.88	0.45, 1.72	0.706
	BMI	Numerical	1.00	0.95, 1.06	0.949
	DM	No	-	-	
		Yes	1.96	1.08, 3.56	0.026
	LOS	Numerical	1.01	0.99, 1.02	0.063
	Blood transfusion	No	-	-	
		Yes	2.10	1.16, 3.80	0.014
DSWI	Gender	Male	-	-	
		Female	2.62	1.08, 6.37	0.034
	BMI	Numerical	1.05	0.98, 1.12	0.157
	DM	No	-	-	
		Yes	5.56	1.78, 17.4	0.003
	LOS	Numerical	1.01	1.01, 1.02	0.001
	Blood transfusion	No	-	-	
		Yes	1.59	0.65, 3.88	0.309

number of required bags differed significantly among different groups (P = 0.040). The proportion of patients who required re-exploration for bleeding was higher in the DSWI group (65.4%) than the SSWI (13.0%) and no SWI groups (2.7%, P < 0.001). (Table 2)

Risk factors for sternal wound infections: Based on the multivariate regression analysis, the risk factors for SSWI included diabetes mellitus (OR = 1.96, 95% CI, 1.08 to 3.56, P = 0.026) and requiring blood transfusion (OR = 2.10, 95% CI, 1.16 to 3.80, P = 0.014). Furthermore, DSWI was independently associated with the female gender (OR = 2.62, 95%CI, 1.08 to 6.37, P = 0.034), diabetes (OR = 5.56, 95% CI, 1.78 to 17.4, P = 0.003) and long periods of hospitalization (OR = 1.01, 95% CI, 1.01 to 1.02, P = 0.001). (Table 3)

Characteristics of the 30-day mortality: Generally, 30-day mortality occurred in one patient in the DSWI group (3.8%) and two patients in the SSWI group (3.7%). (Figure 2) Factors associated with 30-day mortality included the patient's age, whether they underwent a previous cardiac surgery, had COPD, experienced postoperative complications as well as having a longer surgery duration and longer bypass time. Notably, sternal wound infection did not impact the risk of 30-day mortality in the current study.

DISCUSSION

Incidence, risk factors, pathogens, and mortality associated with sternal wound infection following open heart surgery all were evaluated in this study.

In the current study, the incidence of superficial sternal wound infections was 8.6% (54 patients), while the incidence of deep sternal wound infections (DSWIs) was 4.1% (26 patients). Patients with DSWI were more likely to have SSWI (65.4%). A prior 7-year single center prospective study conducted in France discovered that 292 (4.1%) of the 7170 individuals experienced SSI [Lemaignen 2015]. Higher rates were noted in a Polish investigation, when 68-year-old patients acquired SWI in 69.5% of cases. The elderly individuals who were studied may be to blame for this high prevalence [Kotnis-Gąska 2018]. Despite improvements in prophylaxis, there still is a high incidence of deep sternal wound infection (DSWI), which ranges from 0.5% to 6.8% [Litwinowicz 2016; Cotogni 2015; Galvao Tabosa do Egito 2013].

According to multivariate regression analysis, having concomitant diabetes mellitus and requiring blood transfusions are risk factors for SSWI. While concomitant diabetes, being a woman, and lengthy hospital stays independently were linked to DSWI.

The risk factors identified in the current study are consistent with those in the literature [Lepelletier 2005; Fowler 2005; Dai 2013; Chen 2012], where SSI was linked to preoperative comorbidities like diabetes mellitus, obesity, and critical preoperative status as well as complex postoperative outcomes. An earlier study highlighted female sex and blood transfusion as risk factors [Lemaignen 2015]. It was discovered that after continuous insulin infusion during open heart surgery was introduced, the significance of diabetes mellitus as a separate risk factor for deep sternal SSIs decreased [Al-Ebrahim 2010; Furnary 1999; Alebrahim 2020; Elassal 2020; Al-Ebrahim 2020]. It is unknown whether gender plays a role in deep sternal SSI risk; reports have linked female sex to both increased and decreased risk [Furnary 1999]. The prevalence of deep sternal wound infections (DSWIs)

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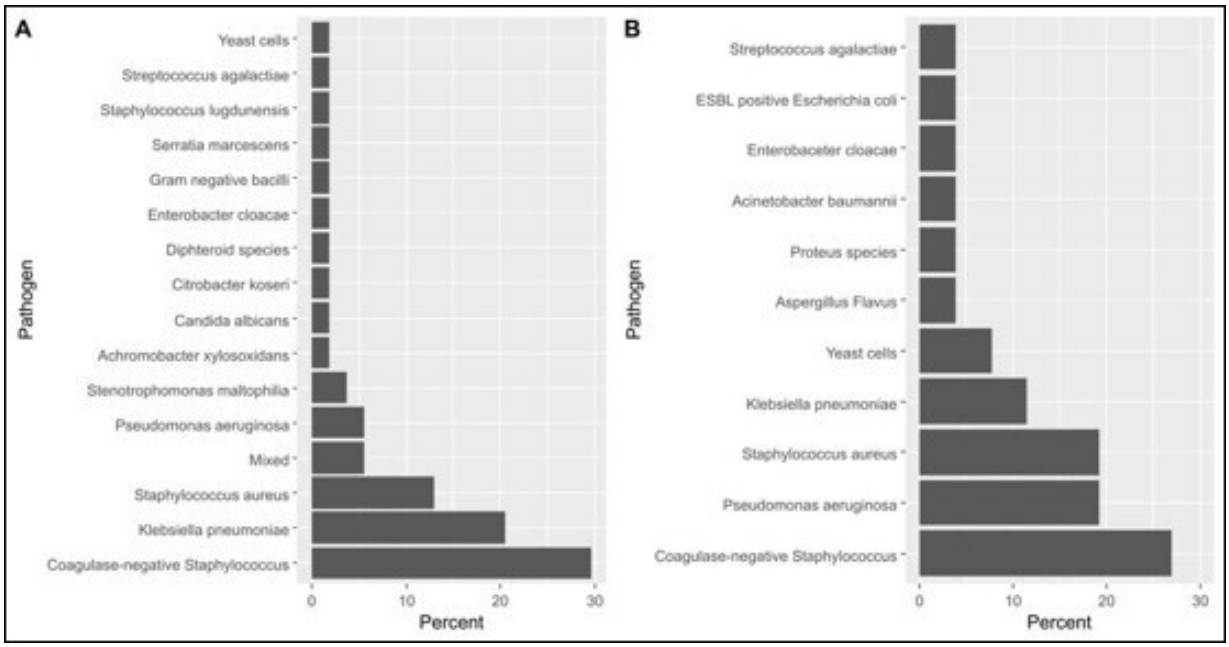

Figure 1. The percentages of isolated pathogens among patients with SSWI (A) and DSWI (B). The values were based on 54 and 26 patients, respectively.

described in the current study (4.1%) is consistent with that seen in Gudbjartsson et al. study, in which 1-3% of patients experienced potentially deadly DSWIs [Gudbjartsson 2016].

According to this study, one patient in the DSWI group (3.8%) and two patients in the SSWI group (3.7%) died. An investigation conducted in Poland on patients aged 68 years (interquartile range: 60-76) revealed an in-hospital death rate of 21.0% [Kotnis-Gąska 2018]. Older age, longer bypass time, and having postoperative problems were independent risk variables linked to the 30-day mortality in the current study. Studies conducted in the United States and elsewhere found the same mortality risk variables [Majid 2020; Lemaignen 2015].

Mortality rates associated with deep SWI range from 15% to 47% [Maleknejad 2019; Gudbjartsson 2016; Hosseinrezaei 2012]. Other studies found lower rates of between 5% and 15%. Fatality rates in more recent reports range between 1% and 14% [Sjogren 2011; Baillot 2010; Tarzia 2014].

Previous research has shown that patients with DSWIs who frequently undergo surgery need a prolonged hospital stay and many procedures to treat the infection, and their postoperative quality of life is not as enhanced as it would be for patients without sternal wound infections [Jideus 2009]. According to a long-term study by Braxton et al., DSWIs are inversely related with long-term mortality and morbidity. In patients with DSWIs, the adjusted hazard ratio for all-cause mortality 10 years after the original operation was nearly quadrupled [Braxton 2004]. Re-exploration for bleeding also is a risk factor for SWI [Elassal 2021].

For patients with SSWI, coagulase-negative Staphylococcus and Klebsiella pneumoniae were the most frequently isolated causal pathogens seen in the current investigation. Additionally, coagulase-negative Staphylococcus, Staphylococcus

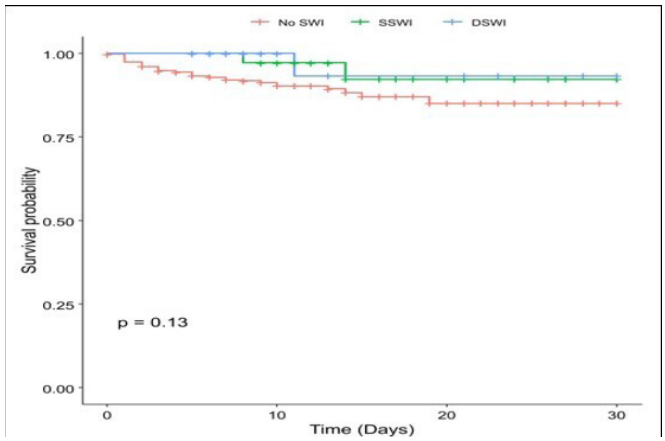

Figure 2. A Kaplan-Meier curve of the 30-day mortality among different groups based on the status of sternal wound infections.

aureus, and Pseudomonas aeruginosa were the most prevalent microbes for DSWI. In recent years, Staphylococcus epidermidis, a type of Coagulase-negative staphylococci (CoNS), has overtaken Staphylococcus aureus and Gram-negative bacteria as the most often reported pathogenic organisms linked with SSIs after open heart surgery [Friberg 2007].

According to Kotnis-Gąska et al., Pseudomonas aeruginosa, Enterococcus faecium, Klebsiella pneumoniae, Staphylococcus aureus, and Staphylococcus epidermidis were the most prevalent pathogens [Kotnis-Gąska 2018]. A growing number of methicillin-resistant (MR) Gram-positive infections, particularly Staphylococcus epidermidis, which is one of the most prevalent bacteria in post-sternotomy mediastinitis and about 75% of strains are MR, are causing DSWI,

according to recent research [Cotogni 2015; Slack 2007]. Gram-positive cocci (60.3%), CoNS (24.6%), and Gram-negative bacilli Enterobacteriaceae (23.0%), which are the most frequently found pathogens in wounds after CABG, were found to be the most common pathogens in wounds following CABG, according to surveillance data for surgical site infection (SSI) from 16 countries that included 422,201 surgical operations from 1,332 hospitals published in 2012 [Annual epidemiological report 2013].

SWI accounts for about 50% of emergency room revisits post-cardiac surgery and unplanned readmission [Almramhi 2022].

Limitation: A limitation of the present study was being a single center study that will hinder the generalization of the study results.

CONCLUSION

This study found an incidence of SSWI and DSWIs of 8.6% and 4.1% respectively. Coagulase-negative Staphylococcus was the most commonly isolated organism from patients with SSWI and DSWI. Multivariate regression analysis showed that risk factors for SSWI were having a comorbid diabetes mellitus, requiring blood transfusion. While DSWI independently was associated with the female gender, comorbid diabetes, and long hospitalization period. The 30-day mortality was 3.8% for DSWI patients compared with 3.7% for SSWI group, and the difference in survival was not statistically significant. Independent risk factors for 30-day mortality include older age, longer bypass time, and having postoperative complications. Being a single-center study necessitates future studies in other healthcare settings for the generalized of the revealed results.

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