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Healing Outcomes and Predictors of Postoperative Sternal Wound Infections via Median Sternotomy Following Cardiac Surgery: A Comparative Retrospective Case-Control Study

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ABSTRACT

Background: Surgical wound infection (SWI) following cardiac surgery via median sternotomy remains a serious complication associated with significant morbidity, prolonged hospitalisation, and increased healthcare costs. Mediastinitis and superficial sternal wound infections represent a spectrum of postoperative complications that adversely affect patient outcomes.

Aim of the Study: This study aimed to assess the healing outcomes and predictors of mediastinitis and superficial sternal wound infections after cardiac surgery.

Patients and Methods: This retrospective case-control study was conducted at the Cardiothoracic Surgery Departments of Shebein Elkom Teaching Hospital and National Heart Institute. A total of 100 adult patients who underwent cardiac surgery via median sternotomy were enrolled and divided into two groups: Group I (SWI group, n = 50) comprising patients who developed surgical wound infection, and Group II (Non-SWI group, n = 50) comprising patients who did not develop SWI.

Results: Patients in the SWI group were significantly older and had higher body mass index compared to the non-SWI group. Diabetes mellitus was significantly more prevalent in the SWI group. SWI group had significantly lower preoperative hemoglobin and albumin and significantly higher white blood cell count and serum creatinine. The SWI group had significantly longer operation time, cardiopulmonary bypass time, duration of mechanical ventilation, ICU stay and total hospital stay. Postoperative mediastinitis occurred in 30.0% of SWI patients, wound dehiscence in 56.0%, clinical erythema in 86.0%, and clinical discharge in 86.0%. All SWI patients had positive wound cultures; the most frequently isolated organisms were coagulase-negative staphylococci (26.0%) and methicillin-sensitive Staphylococcus aureus (26.0%), followed by Pseudomonas aeruginosa (16.0%) and mixed bacterial flora (14.0%). All patients received antibiotics; management included regular dressing (80.0%), surgical debridement (42.0%), negative pressure wound therapy (38.0%), and muscle flap reconstruction (6.0%). The mean time to SWI diagnosis was 13.14 ± 6.08 days postoperatively, with 70.0% classified as superficial infections and 90.0% achieving complete healing within 90 days. Multivariate logistic regression identified body mass index ($p = 0.006$), diabetes mellitus ($p = 0.007$), preoperative albumin ($p = 0.002$), and operation duration ($p = 0.001$) as independent predictors of SWI.

Conclusion: Surgical wound infection after cardiac surgery via median sternotomy is associated with significant patient morbidity and prolonged recovery. Higher body mass index, diabetes mellitus, preoperative hypoalbuminaemia, and prolonged operation duration are independent predictors of SWI. Preoperative optimisation of nutritional status, glycaemic control, and meticulous intraoperative time management are essential preventive strategies.

KEYWORDS: Surgical wound infection; mediastinitis; cardiac surgery; median sternotomy; risk factors; predictors; cardiopulmonary bypass..

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INTRODUCTION

With a reported prevalence ranging from 0.5% to 6%, sternal wound infection (SWI) is one of the most serious postoperative consequences after open adult heart surgery. Although the incidence of SWI is relatively modest, it still represents a significant clinical and financial burden due to its strong association with increased morbidity and mortality, length of hospital stay, re-operation rates and overall healthcare costs [1].

Various risk factors influence the occurrence of SWI, which are usually categorized into preoperative, intraoperative and postoperative determinants. Preoperative patient factors include obesity, poor nutritional status, and diabetes mellitus. Intraoperative factors include long operative time, excessive blood loss and sternal closure problems. Poor wound care, mechanical respiration and prolonged ICU stay all increase the risk of post-operative infection [2].

The diagnosis of sternal wound infection is primarily clinical, but full laboratory and radiographic evaluation is required for a complete assessment of the extent of involvement. This may include full blood testing, chest x-rays, magnetic resonance imaging (MRI) and computed tomography (CT) . When reconstructive procedures are required, SWI is associated with problems such as wound dehiscence, mediastinitis, recurrent infection and morbidity from flap donor sites [1].

In relation to the depth of infection, SWI was categorized as deep SWI and superficial SWI by Song et al. [3]. Deep SWI was characterized as mediastinal , muscular , sternal and substernal involvement. Superficial SWI includes skin, subcutaneous tissues and deep fascia. This classification is important to direct appropriate treatment strategies. Early and aggressive treatment is the key to treating SWI. Early diagnosis should be followed by surgical debridement and deep tissue culture. Deep cultures, adequate debridement of necrotic tissue and removal of infected foreign material are crucial for successful targeted antimicrobial therapy [1].

Although diagnostic and treatment modalities have progressed, mortality rates for post-sternotomy infection still remain high, from 2.3% to 4.7%. Management strategies of SWI are yet to be discussed. Closed-chest catheter irrigation was the mainstay of treatment for long years. Redivac drainage, negative pressure wound therapy (NPWT) and plastic reconstructive procedures are emerging modalities which have shown encouraging results in the last few years and have been shown to reduce hospital stay and improve wound healing [4].

The purpose of this study was to evaluate the prevalence of superficial sternal wound infections and mediastinitis following heart surgery.

PATIENTS AND METHODS

This retrospective case-control study was conducted at the Cardiothoracic Surgery Departments of Shebein Elkom Teaching Hospital and National Heart Institute, Egypt. The study included all adult patients who underwent cardiac surgery via median sternotomy over a defined study period (from January 2020 to January 2023). The study protocol was conducted in accordance with the Declaration of Helsinki. Because of the retrospective nature of the study, informed consent was waived.

Inclusion criteria were patients ≥18 years old who had undergone open-heart surgery via full median sternotomy (coronary artery bypass grafting, valve replacement or repair, and combined procedures). Excluded were patients who underwent minimally invasive cardiac procedures without sternotomy, patients with pre-existing chest wall infections, patients who died within 48 hours postoperatively, and patients with incomplete medical records.

Data were extracted from hospital electronic records, operative notes and outpatient follow up clinics. The collected data included demographic characteristics (age, sex, body mass index), comorbidities (diabetes mellitus, hypertension, chronic obstructive pulmonary disease, chronic kidney disease), smoking status, and relevant preoperative laboratory investigations. Operative data included type of surgery, duration of operation, use of internal mammary artery grafts, need for re-exploration for bleeding, and duration of cardiopulmonary bypass. Postoperative data included duration of mechanical ventilation, intensive care unit (ICU) stay, hospital stay, and postoperative complications.

In every patient, standard anesthetic and surgical techniques were used. Perioperative antibiotic prophylaxis was performed with cefazolin 4 × 2 g i.v. within 24 hours (initial dose was administered preoperatively and infusion was finished 60–30 min before skin incision); further administration of antibiotic was done if the duration of operation was longer than expected, adding one dose to the cardiopulmonary bypass (CPB). The same protocol was used to give 3 × 600 mg intravenous clindamycin to patients with proven β-lactam allergies within 24 hours. Patients with documented colonization by methicillin-resistant Staphylococcus aureus (MRSA) received vancomycin 2 x 1g intravenously (the 1-hour preoperative infusion had to be completed at least 60 minutes before surgery). The skin was prepared by pre-operative soap baths and hair trimming. Four times the skin was prepared with the coloured antiseptic solution in the operating room before the beginning of the surgical procedure (once in the anaesthesia preparation room and three times in the operating room before draping). Draping was done at least 3 minutes after the last skin preparation.

All patients underwent cardiac surgery via full median sternotomy with CPB using a non-pulsatile roller pump and a 40 μm arterial blood filter. The procedure was carried out in hypothermia according to the surgeons' preference (oesophageal temperature, 28–34°C), with blood flow of 2.0–2.4 l/min/m2 and mean arterial pressure of 40–60 mm Hg. Postoperative ventilation was done in the intensive care unit and extubation done as per the established protocol in all patients.

The diagnosis of wound infection was confirmed by the positive results of bacterial culture. Swabs were taken from the wounds and empirical antibiotic therapy was suggested. The specimen was obtained after cleaning the wound edges with alcohol or disinfectant. The material was taken from the center and border of the wound to remove an estimated 1 cm^2. Material was extracted from severe wounds by puncturing them with a needle and syringe. Within two hours, aspirated material was delivered to the laboratory in special thermostatic transport containers after being appropriately sealed in the transport medium. In accordance with local protocols, the pathogens were cultivated on prepared selective culture media: MacConkey agar and Columbia agar with 5% sheep blood at 35–37°C for 18–24 hours. In addition, Staphylococcus aureus was directly identified and selectively isolated by chromogenic medium (CHROMID Staphylococcus aureus Elite agar – SAIDE; bioMérieux, Marcy l'Etoile, France). Fungal infection was detected with Sabouraud agar medium (bioMérieux, Marcy l'Etoile, France) cultured for 7 days at 35–37°C. Antibiotic susceptibility testing was done by VITEK 2 Compact (bioMérieux, Marcy l'Etoile, France) automated identification system according to the laboratory and clinical standards. The managing physician was given the susceptibility profile of the organism cultured from the sternal wound. In culture-positive SWI cases, isolated organisms and antibiotic susceptibility results were recorded. Targeted antibiotics were started in conjunction with the hospital infection team according to the microbiology results.

SWI was defined and classified as superficial sternal wound infection (SSWI) and deep sternal wound infection (DSWI)/mediastinitis according to the criteria of the Centers for Disease Control and Prevention (CDC). DSWI was a deeper tissue infection involving the sternum and mediastinum as reported by Kotnis-Gěska et al. [5]. SSWI was a superficial tissue infection of the skin, subcutaneous tissue or pectoral fascia. SWIs were diagnosed based on clinical symptoms (erythema, discharge, wound dehiscence), microbiological culture results and radiological imaging when necessary within 90 days after surgery.

The primary outcome was identification of factors associated with postoperative SWI. The secondary outcome was healing time of sternal wound infections defined as the time interval between the date of diagnosis of infection and complete epithelialization, no discharge, and no requirement for additional surgical or medicinal treatment. The process of healing was followed for weeks or months.

The management of SWIs in this study included culture sensitivity-based antibiotic therapy, routine wound dressing, surgical debridement, negative pressure wound therapy (NPWT), and reconstructive surgeries such as muscle flap covering when needed. The selected method of therapy was based on the severity of the infection and the health condition of the patient.

Patients were followed for at least three months postoperatively, by telephone follow-up and/or outpatient clinic visits, to identify late infections and to more precisely estimate healing time. Infections diagnosed after discharge from hospital were also recorded.

STATISTICAL ANALYSIS

The collected data were computerized and statistically analyzed using SPSS software (Statistical Package for Social Science) version 27.0 (IBM, 2020). Qualitative data were expressed as frequencies and percentages. The Chi-square test was used to determine the difference between qualitative variables. If one or more of the cells examined showed fewer than five cases, Fisher's exact test was used to determine the difference between qualitative variables in different groups. Mean ± SD (standard deviation) was used to express quantitative data. The difference between quantitative variables in two groups of normally distributed data was determined using the independent T test. In data that was not regularly distributed, the Mann Whitney (MW) test was employed to determine the difference between quantitative variables in two groups.

RESULTS

Table (1): Baseline demographic and clinical characteristics of the studied groups

Variable		SWI (n=50)	Non-SWI (n=50)	P-value
Age (years)	Mean ± SD	62.58 ± 7.50	58.76 ± 9.68	**0.030**
	Range	48 - 79	38 - 78	
BMI (kg/m²)	Mean ± SD	31.77 ± 3.77	28.71 ± 3.71	**<0.001**
	Range	24.00 - 39.70	21.00 - 35.70	
Sex	Male	38 (76.0%)	34 (68.0%)	0.504
	Female	12 (24.0%)	16 (32.0%)	
Diabetes mellitus		37 (74.0%)	18 (36.0%)	**<0.001**
Hypertension		39 (78.0%)	29 (58.0%)	0.054
COPD		10 (20.0%)	11 (22.0%)	1.000
CKD		10 (20.0%)	6 (12.0%)	0.413
Smoking		20 (40.0%)	28 (56.0%)	0.161

SWI: Surgical Wound Infection, BMI: Body Mass Index, SD: Standard Deviation, COPD: Chronic Obstructive Pulmonary Disease, CKD: Chronic Kidney Disease, n: Number, %: Percentage.

The SWI group patients were older and had a higher BMI compared to the Non-SWI group (p=0.030 and p<0.001, respectively). Also, diabetes mellitus was significantly more common in SWI patients (74% vs. 36%, p < 0.001). There were no statistically significant differences between the two groups regarding sex distribution, hypertension, COPD, CKD, or smoking status (p > 0.05), with the exception of hypertension, which had borderline significance (p = 0.054). These findings indicate that advanced age, increased BMI and diabetes mellitus may be important risk factors for the occurrence of SWI (Table 1).

Table (2): Comparison of Preoperative Laboratory Parameters between the studied groups

Variable		SWI (n=50)	Non-SWI (n=50)	P-value
Preoperative Hb (g/dL)	Mean ± SD	11.41 ± 1.22	12.48 ± 1.16	**<0.001**
	Range	9.00 - 14.00	10.00 - 14.50	
Preoperative WBC (×10^9/L)	Mean ± SD	8.78 ± 1.60	7.25 ± 1.20	**<0.001**
	Range	5.50 - 13.30	4.20 - 9.50	
Preoperative creatinine (mg/dL)	Mean ± SD	1.24 ± 0.32	1.01 ± 0.22	**<0.001**
	Range	0.70 - 1.78	0.60 - 1.51	
Preoperative albumin (g/dL)	Mean ± SD	3.40 ± 0.40	3.96 ± 0.27	**<0.001**
	Range	2.60 - 4.20	3.20 - 4.50	

SWI: Surgical Wound Infection, Hb: Hemoglobin, WBC: White Blood Cells, SD: Standard Deviation, n: Number, %: Percentage. There is a statistically significant difference between all pre-operative laboratory parameters between the studied groups as shown in the table. Patients in the SWI group had significantly lower hemoglobin and albumin levels than the Non-SWI group ($p < 0.001$) indicating worse nutritional and hematological status. Meanwhile, the preoperative WBC count and serum creatinine were significantly higher in the SWI group ($p <0.001$), reflecting increased inflammatory response and impaired renal function. These findings suggest that abnormal preoperative laboratory markers, particularly anemia, hypoalbuminemia, leukocytosis, and elevated creatinine, are strongly associated with the occurrence of surgical wound infection (Table 2).

Table (3): Intraoperative Data and Postoperative Outcomes in SWI and Non-SWI Groups

Variable		SWI (n=50)	Non-SWI (n=50)	P-value
Operation duration (min)	Mean ± SD	329.70 ± 37.47	281.26 ± 36.82	**<0.001**
	Range	255 - 418	216 - 387	
CPB duration (min)	Mean ± SD	123.56 ± 23.78	103.28 ± 21.40	**<0.001**
	Range	75 - 171	60 - 148	
Mechanical ventilation (hr)	Mean ± SD	19.93 ± 6.68	9.92 ± 3.37	**<0.001**
	Range	8.00 - 37.20	4.00 - 16.60	
ICU stay (days)	Mean ± SD	6.19 ± 1.57	3.31 ± 0.99	**<0.001**
	Range	2.00 - 10.10	1.10 - 5.40	
Hospital stay (days)	Mean ± SD	18.38 ± 4.30	10.00 ± 2.78	**<0.001**
	Range	10.40 - 27.90	5.00 - 16.80	
Follow-up (months)	Mean ± SD	4.49 ± 0.95	4.32 ± 0.95	0.310
	Range	3.00 - 6.00	3.00 - 6.00	
Surgery type	CABG	25 (50.0%)	30 (60.0%)	0.569
	Valve	15 (30.0%)	13 (26.0%)	
	Combined	10 (20.0%)	7 (14.0%)	
IMA used	Yes	34 (68.0%)	31 (62.0%)	0.675
	No	16 (32.0%)	19 (38.0%)	
Re-exploration for bleeding	Yes	9 (18.0%)	3 (6.0%)	0.124
	No	41 (82.0%)	47 (94.0%)	

SWI: Surgical Wound Infection, CPB: Cardiopulmonary Bypass, ICU: Intensive Care Unit, IMA: Internal Mammary Artery, CABG: Coronary Artery Bypass Grafting, SD: Standard Deviation, n: Number, %: Percentage.

Patients with SWI had significantly longer durations of operation, CPB, mechanical ventilation, ICU stay, and total hospital stay ($p < 0.001$ for all), suggesting a more complicated postoperative course. Follow-up duration, type of surgery, use of internal mammary artery (IMA) and re-exploration for bleeding did not differ statistically significantly between the groups ($p > 0.05$). These results indicate that extended operative time and post-operative recovery parameters are significantly associated with the development of SWI (Table 3).

Table (4): Postoperative Complications of Surgical Wound Infection

Variable	SWI (n=50)
Postoperative mediastinitis	15 (30.0%)
Wound dehiscence	28 (56.0%)
Clinical erythema	43 (86.0%)
Clinical discharge	43 (86.0%)
Imaging required	18 (36.0%)

SWI: Surgical Wound Infection, n: Number, %: Percentage.
Postoperative mediastinitis, wound dehiscence, clinical erythema, discharge and the need for imaging was present in 30%, 56%, 86%, 86% and 36% respectively (Table 4).

Table (5): Microbiological Profile, and Management of Surgical Wound Infection

Variable		SWI (n=50)
Culture positive	Yes	50 (100.0%)
Culture organism	Mixed bacterial flora	7 (14.0%)
	CoNS	13 (26.0%)
	MSSA	13 (26.0%)
	MRSA	4 (8.0%)
	Enterococcus	2 (4.0%)
	Pseudomonas	8 (16.0%)
	Enterobacteriaceae	3 (6.0%)
Antibiotics	Yes	50 (100.0%)
Regular dressing	Yes	40 (80.0%)
Debridement	Yes	21 (42.0%)
NPWT	Yes	19 (38.0%)
Muscle flap	Yes	3 (6.0%)

SWI: Surgical Wound Infection, CoNS: Coagulase-Negative Staphylococci, MSSA: Methicillin-Sensitive Staphylococcus aureus, MRSA: Methicillin-Resistant Staphylococcus aureus, NPWT: Negative Pressure Wound Therapy, n: Number, %: Percentage.

All patients in the SWI group had positive wound cultures (100%), confirming the microbiological diagnosis of surgical site infection (SSI). The most commonly isolated organisms were CoNS and MSSA (26% each), followed by Pseudomonas (16%) and mixed bacterial flora (14%). MRSA was identified in a smaller proportion (8%), while Enterococcus and Enterobacteriaceae were less frequent. All patients received antibiotic therapy (100%) and the majority of patients were managed by regular dressing (80%). The fact that 42% had surgical debridement and 38% had NPWT suggested moderate wound severity. Muscle flap reconstruction was rarely necessary (6%) suggesting that most infections were managed with conservative or less invasive treatment modalities (Table 5).

Table (6): Clinical Characteristics and Outcomes of Surgical Wound Infection (SWI) Cases

Variable		SWI only (n=50)
Diagnosis day postoperatively	Mean ± SD	13.14 ± 6.08
	Range	3 - 29
Healing time (weeks)	Mean ± SD	7.62 ± 4.63
	Range	2.00 - 23.90
SWI type	Deep/Mediastinitis	15 (30.0%)
	Superficial	35 (70.0%)
Healed within 90 days		45 (90.0%)

n: Number, %: Percentage, SWI: Surgical Wound Infection, SD: Standard Deviation.

The mean time to diagnosis was approximately 13 days postoperatively, indicating that most infections occurred early in the postoperative period. Mean healing time was about 7.6 weeks and indicated a long course of recovery. The most common infections were superficial (70%) followed by deep infections and mediastinitis (30% of cases). Although the morbidity was associated, the overall outcomes were still favorable with 90% of patients having complete healing in 90 days and follow-up was extended to 6 months for the other 10% of SWI cases. The findings suggest that, while SWI is related to a delayed recovery, the majority of cases can be successfully treated with appropriate management (Table 6).

Table (7): Predictors of Surgical Wound Infection (Univariate Analysis)

Variable	OR	95% CI	P-value
Age	1.08	1.01 – 1.15	**0.030**
BMI	1.25	1.12 – 1.40	**<0.001**
Diabetes mellitus	5.00	2.10 – 11.90	**<0.001**
Hypertension	2.57	0.97 – 6.80	0.054
Preoperative Hb	0.45	0.30 – 0.70	**<0.001**
Preoperative WBC	1.80	1.30 – 2.50	**<0.001**
Creatinine	2.10	1.30 – 3.40	**<0.001**
Albumin	0.20	0.10 – 0.40	**<0.001**
Operation duration	1.03	1.02 – 1.05	**<0.001**
CPB duration	1.02	1.01 – 1.04	**<0.001**

On univariate logistic regression analysis, several factors were found to be significantly associated with development of surgical wound infection. The important clinical predictors included advanced age, high BMI and diabetes mellitus. Furthermore, abnormal laboratory parameters such as low hemoglobin and albumin levels and high WBC count and serum creatinine were strongly associated with increased risk of SWI. Operative factors such as long operation duration and cardiopulmonary bypass time were also significant predictors. Hypertension was borderline associated. These results indicate that patient-related factors and perioperative variables are important in the development of surgical wound infection (Table 7).

Table (8): Multivariate Logistic Regression Analysis of Independent Predictors of Surgical Wound Infection

Variable	Adjusted OR	95% CI	P-value
BMI (kg/m²)	1.18	1.05 – 1.33	**0.006**
Diabetes mellitus	3.85	1.45 – 10.20	**0.007**
Preoperative albumin (g/dL)	0.28	0.12 – 0.61	**0.002**
Operation duration (min)	1.02	1.01 – 1.04	**0.001**

Multivariate logistic regression analysis showed that BMI, diabetes mellitus, preoperative albumin level and operation duration were independent predictors of surgical wound infection. Higher BMI and diabetes mellitus were significantly associated with increased risk of SWI. In contrast, increased preoperative albumin was protective against infection, highlighting the importance of nutritional status. Also, longer operation duration was independently associated with increased risk of SWI. These findings indicate that both patient-related factors (obesity, diabetes, nutritional status) and intraoperative factors (operative time) play a crucial role in the development of surgical wound infection (Table 8).

DISCUSSION

In the current study, patients in the SWI group were significantly older (mean 62.58 ± 7.50 years) and had higher BMI (mean 31.77 ± 3.77 kg/m2) compared to the non-SWI group ($p = 0.030$ and $p < 0.001$, respectively).

This is consistent with a multicenter retrospective study of 9824 cases undergoing median sternotomy, reported by Chen et al. [6], showed an associated risk of SWI with each unit increase in BMI (OR=1.08, P=0.02, 95% CI, 1.01-1.16). This was related to increased wound tension, impaired microcirculation and adipocyte-mediated hypoxia.

Further, Ortega-Loubon et al. [7] presented biological plausibility for this association by explaining that fatty acid oxidation in obese patients impedes subcutaneous blood supply and lymphatic drainage which are essential for wound healing by disrupting vasoconstriction and generating biotoxicity.

Diabetes mellitus was significantly more common in the SWI group (74.0% vs. 36.0%, $p < 0.001$, univariate OR 5.00, 95% CI 2.10–11.90). This finding is consistent with a large meta-analysis of 258,454 patients undergoing CABG by Moshtaghi et al. [8] who found significantly higher incidence of superficial SWI (OR = 1.93) and deep SWI (OR = 2.13) in diabetic patients compared to non-diabetic patients. Corazzari et al. [9] also confirmed the relevance of perioperative glycaemic management in a meta-analysis of 34,650 patients from 30 studies; there was an independent association between preoperative glycosylated haemoglobin and risk of SWI. Pathophysiology is characterized by dysregulated inflammatory cytokine cascades, insufficient angiogenesis and hyperglycemia-induced mitochondrial dysfunction, leading to delayed wound closure and increased susceptibility for bacterial colonization [10].

There was a borderline correlation between hypertension and groups ($p = 0.054$) but no significant change in the distribution of sex, COPD, CKD and smoking status between groups. Ridderstolpe et al. [11] in a retrospective review of 3,008 consecutive cardiac surgical patients found smoking and peripheral vascular disease as significant predictors of deep SWI.

SWI patients had significantly lower hemoglobin (11.41 ± 1.22 vs. 12.48 ± 1.16 g/dL, $p < 0.001$) and albumin (3.40 ± 0.40 vs. 3.96 ± 0.27 g/dL, $p < 0.001$) before surgery. This is in line with Brunet et al. [12] who showed that preoperative anemia was an independent risk factor for SWI in patients undergoing cardiac surgery CABG with pedicled internal mammary arteries. This finding may be attributed to the thoracic wall ischemia and a reduced nutritional reserve.

The SWI group had significantly higher preoperative WBC counts (8.78 ± 1.60 vs. 7.25 ± 1.20 $\times 10^1$/L, $p < 0.001$) and serum creatinine (1.24 ± 0.32 vs. 1.01 ± 0.22 mg/dL, $p < 0.001$). This is consistent with the results of You et al. [13] who reported that renal failure was a significant risk factor for SWI, and established a nomogram prediction model of sternotomy complications. Moreover, in their meta-analyses, Öztürk et al. [14] and Chen et al. [6] determined that renal insufficiency was a medium risk factor for mediastinitis due to immunological dysfunction caused by uraemia and impaired wound healing.

The SWI group had longer cardiopulmonary bypass (CPB) time (123.56 ± 23.78 vs. 103.28 ± 21.40 minutes, $p < 0.001$) and operation time (329.70 ± 37.47 vs. 281.26 ± 36.82 minutes, $p < 0.001$) significantly. This finding is consistent with the meta-analysis of Chen et al. [6] who identified longer CPB time and longer surgery time as high and medium risk factors for SWI respectively.

In a case-control study of deep SWI after off-pump CABG, Enginoev et al. [15] reported a significantly higher prevalence of prolonged operating time (>4 hours) in the DSWI group than in the non-DSWI group (3.9% vs 1.4%, $P<0.001$). The risk has been indicated to occur when the procedure is >5 hours long [16] and has been raised to 7 hours by Sajja [17].

The SWI group experienced longer duration of mechanical ventilation (19.93 ± 6.68 vs. 9.92 ± 3.37 hours, $p < 0.001$), ICU (6.19 ± 1.57 vs. 3.31 ± 0.99 days, $p < 0.001$) and hospital stay (18.38 ± 4.30 vs. 10.00 ± 2.78 days, $p < 0.001$). This is consistent with the finding of Perrault et al. [18] that in a Polish cohort prolonged mechanical ventilation was significantly associated with subsequent development of mediastinitis after heart surgery.

Furthermore, a meta-analysis published by Chen et al. [6] demonstrated that ICU stay was a risk factor for SWI, suggesting that there is an increased risk of colonization with nosocomial pathogens and severity of underlying cardiopulmonary dysfunction.
There were no significant differences between groups in terms of internal mammary artery (IMA) utilization and type of surgery (CABG, valve or combined) performed ($p > 0.05$). In contrast, Risnes et al. [19] reported a higher risk of SWI among patients receiving IMA grafts.

In the SWI group, mediastinitis developed in 30.0% of patients, wound dehiscence (56.0%), clinical erythema (86.0%), discharge (86.0%) and need for imaging (36.0%). Omran et al. [20] identified 44 SWI cases prospectively in 9,201 CABG patients and reported that 22% were profound SWI, frequently in the context of sternal osteomyelitis and mediastinal abscess formation, consistent with the CDC classifications.

The most frequently isolated organisms were Coagulase-Negative Staphylococci (CoNS) and Methicillin-Sensitive Staphylococcus aureus (MSSA) (26% each), followed by Pseudomonas aeruginosa (16%), mixed bacterial flora (14%), MRSA (8%), Enterococcus (4%) and Enterobacteriaceae (6%). All SWI patients had positive wound cultures. Wound cultures were positive in all patients. **Al Majid et al. [21]** who aimed to determine the prevalence, types, risk factors, causative organisms and outcomes of surgical wound infections (SWIs) following heart surgery in a tertiary hospital in Riyadh, Saudi Arabia, found that the causative agent was methicillin-susceptible Staphylococcus aureus (MSSA) in 18 (45%) of the patients, methicillin-resistant S. aureus (MRSA), Klebsiella species, and Pseudomonas species in 5 (12.5%) of the patients.

In the current study, using univariate analysis, the significant predictors of SWI were advanced age (OR = 1.08), higher BMI (OR = 1.25), diabetes mellitus (OR = 5.00), lower hemoglobin (OR = 0.45), elevated WBC (OR = 1.80), elevated creatinine (OR = 2.10), lower albumin (OR = 0.20), prolonged operation duration (OR = 1.03) and prolonged CPB time (OR = 1.02), (all $p < 0.05$). This is in agreement with the comprehensive meta-analysis of Chen et al. [6] where renal insufficiency was a medium risk factor and BMI, diabetes and longer duration of operation were high risk factors. Similarly, these variables were also found to be reliable predictors of sternal incision complications in the nomogram model developed by You et al. [13] with good predictive accuracy (AUC = 0.78).

Using multivariate analysis showed that BMI, diabetes mellitus, preoperative albumin level and duration of operation independently predicted SWI. Specifically, increased BMI (adjusted OR = 1.18, 95% CI = 1.05–1.33, p = 0.006), presence of diabetes mellitus (adjusted OR = 3.85, 95% CI = 1.45–10.20, p = 0.007), decreased preoperative albumin level (adjusted OR = 0.28, 95% CI = 0.12–0.61, p = 0.002), and increased operative duration (adjusted OR = 1.02, 95% CI = 1.01–1.04, p = 0.001) were significantly associated with increased risk of SWI.

CONCLUSION

This study showed that postoperative SWI following cardiac surgery via median sternotomy was associated with several patient-related and perioperative factors. Although advanced age, anemia, leucocytosis and increased creatinine had significant univariate relationships, higher BMI, diabetes mellitus, preoperative hypoalbuminemia and longer operation time were identified as independent predictors of SWI. CoNS and MSSA were the main microbiological profile with Pseudomonas aeruginosa being the most prominent Gram-negative pathogen. 90% of cases had favourable healing results within 90 days due to management regimens consisting of antibiotic medication, frequent dressing, and the selective use of debridement and NPWT. These findings underscore the importance of preoperative risk stratification, optimization of nutritional and metabolic status and judicious intraoperative time management to reduce the risk of SWI.

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