A retrospective study of deep sternal wound infections: clinical and microbiological characteristics, treatment, and risk factors for complications

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ABSTRACT

Deep sternal wound infection (DSWI) is a feared complication following cardiac surgery. This study describes clinical, microbiological, and treatment outcomes of DSWI and determines risk factors for complications. Of 55 patients with DSWI, 66% were male and mean age was 68.2 years. Initial sternotomy was for coronary artery bypass graft in 49% of patients. Sternal debridement at mean 25.4 ± 18.3 days showed monomicrobial (94%), mainly Gram-positive infection. Secondary sternal wound infection (SSWI) occurred in 31% of patients, was mostly polymicrobial (71%), and was predominantly due to Gram-negative bacilli. Risk factors for SSWI were at least 1 revision surgery (odds ratio [OR] 4.8 [95% confidence interval {CI} 1.0–22.4], P = 0.04), sternal closure by muscle flap (OR 4.6 [1.3–16.8], P = 0.02), delayed sternal closure (mean 27 versus 14 days, P = 0.03), and use of vacuum-assisted closure device (100% versus 58%, P = 0.008). Hospital stay was significantly longer in patients with SSWI (69 days versus 48 days, P = 0.04).

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1. Introduction

Deep sternal wound infection (DSWI) is a serious and potentially fatal complication after cardiac surgery. The incidence of DSWI is low, occurring in 0.5–2% of cardiac surgery procedures (Braxton et al., 2000; El Oakley and Wright, 1996; Gardlund et al., 2002; Gummert et al., 2002; Trouillet et al., 2005), but the associated morbidity, mortality, and cost are high (Braxton et al., 2000; Lu et al., 2003; Milano et al., 1995; Raudat et al., 1997). Local signs of wound discharge, dehiscence, tenderness, and sternal instability are the most common signs of DSWI (El Oakley and Wright, 1996). Gram-positive organisms, such as coagulase-negative staphylococci (CoNS) and Staphylococcus aureus, account for the majority of identified pathogens (70–80%), followed by polymicrobial infection (16–40%), Gram-negative bacilli (15–20%) and, infrequently, fungi (El Oakley and Wright, 1996; Gardlund et al., 2002; Trouillet et al., 2005).

Risk factors for DSWI can be broadly categorized into patient-related factors (e.g., age, obesity, smoking status, comorbidities of diabetes mellitus, chronic obstructive pulmonary disease), intraoperative factors (e.g., emergency surgery, use of bilateral internal mammary arteries, prolonged operation, extensive bleeding), and perioperative factors (e.g., need for re-exploration, use of intraaortic balloon pump support postoperatively, length of stay in intensive care unit, and days on mechanical ventilation) (Abboud et al., 2004; Borger et al., 1998; El Oakley and Wright, 1996; Gummert et al., 2002; Karra et al., 2006; Milano et al., 1995; Munoz et al., 2008). In contrast to risk factors for DSWI, factors influencing the outcome of DSWI are less clear. Although general principles of surgical debridement and antibiotic therapy are widely accepted, no consensus exists regarding the optimal specific treatment modalities for DSWI, such as timing and type of sternal closure. Traditional surgical treatment modalities involved wound debridement, primary sternal closure, and mediastinal catheter irrigation with antibiotic or antiseptic solution (El Oakley and Wright, 1996). Due to unsatisfactory treatment results, alternative surgical concepts were evaluated, including delayed closure with surgical reconstruction using vascularized tissue flaps from greater omentum or pectoral muscle and, more recently, use of vacuum-assisted closure (VAC) (De Feo et al., 2011; Molina et al., 2006; Sjogren et al., 2005a; Vos et al., 2012). Some authors suggest that early sternal...
closure (Karra et al., 2006) and use of rifampin-containing antibiotic treatment (Khanlari et al., 2010) improve long-term survival, whereas the method of sternal closure did not (Atkins et al., 2011). However, evidence for the optimal management of DSWI remains limited.

This paper sought to describe the clinical presentation, microbiologic characteristics, and surgical and antibiotic management of DSWI and investigate the risk factors for complications following DSWI in a university hospital over a 3-year period.

2. Patients and methods

2.1. Study setting and study population

This study was conducted in a 1400-bed tertiary care center providing acute medical care for ~300,000 inhabitants. Approximately 1500 cardiovascular surgical interventions are performed annually. Patients with surgical site infections are treated in a dedicated 35-bed septic surgery unit, managed by a multidisciplinary team of cardiovascular, plastic, reconstructive, and orthopedic surgeons; infectious diseases physicians; and clinical pharmacists.

Patients diagnosed with DSWI between January 2009 and September 2012 were identified from the computerized hospital information system. Each episode of DSWI was evaluated by 2 independent infectious diseases specialists according to predefined criteria (see below) and independently reviewed by a surgeon. The patients were followed until hospital discharge. The study was approved by the local institutional ethics and review board.

2.2. Definitions and classifications

Deep sternal wound infection was defined by the modified US Centers for Disease Control and Prevention (CDC) criteria for surgical site infection (Horan et al., 2008). The diagnosis required at least 1 of the following criteria: 1) organisms cultured from mediastinal tissue or fluid obtained during surgical operation or needle aspiration; 2) clinical evidence of mediastinitis seen during surgical operation; or 3) fever, chest pain, or sternal instability with either purulent discharge from the mediastinal area or positive culture of organisms from blood or mediastinal discharge. The El Oakley criteria (El Oakley and Wright, 1996) were used to classify DSWI. This classification system divides DSWI into types I–IV, with type III and IV further subdivided into A and B according to time of onset after surgery, number of risk factors present, and previous treatment trials. A late onset of symptoms, multiple risk factors, and previous treatment trials would correspond to a higher classification.

Secondary sternal wound infection (SSWI) was defined as the presence of local inflammatory signs, compatible with infection and culture of new organism(s) from deep tissue not present at initial debridement after a period of 1 week or more.

2.3. Data collection

The following variables were recorded in the database: patient demographics including age, body mass index (BMI), smoking status, co-morbidities of diabetes mellitus, chronic obstructive lung disease, renal failure; operative details including type and duration of cardiac surgery, surgical debridements, use of regional flap with pectoral muscle or greater omentum, or use of VAC device; microbiology results of superficial swabs, deep tissue specimens, sternal bone biopsies, and blood cultures; and type and duration of antibiotic treatment. Information pertaining to presence of early postoperative complications (such as bleeding or sternal instability requiring reopening of the sternum), clinical signs and symptoms of DSWI, length of hospital stay, secondary wound infection, and 30-day and inhospital mortality was collected.

2.4. Surgical procedures and VAC therapy

Choice of surgical procedure was dependent on the patient’s clinical condition and treating surgeon as no standardized criteria existed in our institution. Prompt initial sternal debridement was advocated, and existing sternal hardware was removed where possible. All fibropurulent and necrotic materials were debrided until occurrence of tissue bleeding, and the wound was copiously irrigated. Where VAC therapy was used, the sponge was applied to the wound at a negative suction pressure ranging between 50 and 100 mm Hg and changed every 48–72 hours. Based on residual sternal integrity and wound condition, closure was achieved by pectoral muscle flap reconstruction, omental flap transfer, or closure without flap, as previously described (Berdajs et al., 2011).

2.5. Statistical analysis

Numbers and percentages of the demographic characteristics were calculated and presented as mean or median with their SDs or range, respectively, based on their distribution. A 2-sided χ2 or Fisher’s exact test was used for comparison of categorical variables as appropriate. For continuous variables, significance testing was done using the Mann–Whitney U test. For all tests, differences were considered significant when P values were <0.05. Significant variables of having SSWI were further investigated in a logistic regression analysis to calculate odds ratio (OR) with 95% confidence interval (95% CI) adjusted for age, sex, BMI, presence of comorbidities, and DSWI class. To explore risk factors for SSWI further, a multivariate logistic regression model was built including the variables: demographic characteristics, presence of comorbidities, characteristics of initial surgery, and DSWI class. All analyses were performed using SPSS statistical software (SPSS 20; IBM, Armonk, NY, USA).

3. Results

3.1. Demographic characteristics

Of 55 patients included, 36 (66%) were male, and mean age (SD) was 68.2 (12.0) years. Twenty-four (44%) had BMI greater than 30 kg/m2. Most patients had coronary artery bypass graft (CABG) alone (49%), CABG with valvular replacement (20%) or valvular replacement alone (16%). Emergency cardiac operation, defined as operation within 24 hours of unplanned admission, was performed in 25%. Reoperation for noninfectious causes occurred in 22 (40%), mostly due to bleeding (18 patients) or sternal instability (4 patients). Demographic characteristics of included patients are displayed in Table 1.

3.2. Characteristics of DSWI

Clinical symptoms of DSWI occurred after a mean of 20.4 (15.1) days after initial sternotomy (Table 2). Common clinical symptoms were dehiscence (75%), wound discharge (69%), sternal instability (51%), and fever (29%). Most DSWIs were classified as types IIIA and IIIB according to the El Oakley criteria (El Oakley and Wright, 1996). Sternal debridement was performed in 87% after a median of 3 days (range 0–37 days) of first clinical symptom. Sternal wires were removed during initial debridement in 60%. On average, 2 debridements were performed before definitive sternal closure after a mean of 17.9 days from initial debridement. VAC device was used in most patients (76%) for a mean duration of 20.1 days. Sternal closure was performed in most cases by primary closure (53%), followed by a muscle flap (22%) and secondary intention by granulation (13%). Mean duration of intravenous antibiotics (SD) from the initial DSWI was 39.1 (27.5) days, most commonly with vancomycin in 57%. Subsequent oral antibiotics were prescribed for a mean (SD) of 41.2 (30.0) days, with oral rifampicin in 55%, quinolone in 45%, and co-trimoxazole in 39% of patients.
3.3. Microbiology

At initial debridement, cultures of intraoperative samples were positive in 62% (Table 3). Infections were mostly monomicrobial (94%) with predominance of Gram-positive organisms (56%). Methicillin resistance was found in 68% of CoNS and 63% of *S. aureus*. Superficial swabs were obtained in 76% of patients. In 24 patients with superficial swabs obtained within 3 days of operation, there was 75% agreement with operative

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All patients (n = 55)</th>
<th>SSWI (n = 17)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean age (SD), y</td>
<td>68.2 (12.0)</td>
<td>67.2 (10.8)</td>
<td>70.0 (14.4)</td>
</tr>
<tr>
<td>Male sex (%)</td>
<td>36 (66)</td>
<td>26 (68)</td>
<td>10 (59)</td>
</tr>
<tr>
<td>Mean BMI (SD), kg/m²</td>
<td>28.8 (4.3)</td>
<td>28.7 (4.1)</td>
<td>29.1 (5.0)</td>
</tr>
</tbody>
</table>

**Comorbidities, n (%)**

- Hypertension: 43 (78)
- Diabetes mellitus: 17 (31)
- Renal insufficiency: 12 (22)
- COPD: 5 (9)
- Current smoker: 21 (38)
- Steroid treatment: 3 (6)

**Type of initial surgery, n (%)**

- CABG: 27 (49)
- CABG + valve replacement: 11 (20)
- Valve replacement: 9 (16)
- Aortic replacement: 6 (11)
- Others: 2 (4)

**Mean time from index sternotomy to onset of symptoms, d (SD)**

- All patients: 20.4 (15.1)
- SSWI: 21.9 (15.9)
- P value: 16.8 (12.8) 0.3

**Clinical and radiological symptoms, n (%)**

- Sternal dehiscence: 41 (75)
- Wound discharge: 38 (69)
- Sternal instability: 28 (51)
- Fever (≥38 °C): 16 (29)

**Fluid collection on CT thorax (n = 55)**

- All patients: 16 (20)
- SSWI: 11 (13)
- P value: 8.5 (71) 0.3

**Classification of DSWI on initial presentation according to the El Oakley criteria (2)**

- I: 4 (7)
- II: 7 (13)
- IIIa: 17 (31)
- IIIb: 20 (36)
- IVa: 0
- IVb: 0
- V: 7 (13)

**Surgical treatment**

- Debridement performed, n (%): 48 (87)
- Mean number of debrideaments (SD): 2.4 (1.1)
- Mean time from initial debridement to sternal closure, d (SD): 17.9 (18.6)
- Use of VAC: 42 (76)
- Duration of VAC use prior to outcome, d (mean ± SD): 20.1 (17.5)

**Type of sternal closure, n (%)**

- Primary closure: 29 (53)
- Use of muscle flap: 12 (22)
- Secondary intention by granulation: 7 (13)

**Antimicrobial treatment**

- Mean duration of intravenous antibiotics, d (SD): 2.1 (1.1)
- Mean duration of oral antibiotics, d (SD): 41.2 (30.0)
- Use of rifampin, n (%): 30 (55)

**Outcome**

- Mean length of hospital stay, d (SD): 54.2 (47.0)
- Inhospital mortality, n (%): 2 (3.6)
- 30-d mortality, n (%): 0

CT = computed tomography.

3.3. Microbiology

At initial debridement, cultures of intraoperative samples were positive in 62% (Table 3). Infections were mostly monomicrobial (94%) with predominance of Gram-positive organisms (56%). Methicillin resistance was found in 68% of CoNS and 63% of *S. aureus*. Superficial swabs were obtained in 76% of patients. In 24 patients with superficial swabs obtained within 3 days of operation, there was 75% agreement with operative
Table 3
Intraoperative cultures at initial debridement and at secondary wound infection of patients with DSWI.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>At initial debridement (n = 55)</th>
<th>At secondary wound infection (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with positive cultures, n (%)</td>
<td>34 (62)</td>
<td>17 (100)</td>
</tr>
<tr>
<td>1 organism</td>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>≥2 organisms</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>No. of total cultured organisms</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Gram-positive bacteria, n (%)</td>
<td>34 (69)</td>
<td>20 (63)</td>
</tr>
<tr>
<td>CoNS</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Enterococci and streptococci</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Propionibacterium acnes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Corynebacterium jeikeium</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Peptostreptococcus spp.</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Gram-negative bacilli, n (%)</td>
<td>4 (10)</td>
<td>9 (28)</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Klebsiella spp.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Morganella morganii</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Citrobacter freundii</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Proteus spp.</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Serratia marcescens</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Enterobacter cloacae</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nonfermentative bacilli</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Fungi</td>
<td>0</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Candida glabrata</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

3.4. Secondary sternal wound infection

SSWI occurred in 17 patients (31%). The prevalence of preoperative risk factors for initial DSWI including BMI, diabetes, chronic obstructive pulmonary disease, and use of immunosuppressive drugs was not significantly different in patients with SSWI. Operative factors such as emergency operation, type of cardiac surgery, cardiopulmonary bypass time, aortic cross-clamp time, and blood transfusion were also similar for the 2 groups (Table 1). Patients with SSWI had delayed sternal closure (27 days versus 14 days, P = 0.03), increased number of debridements (3.5 versus 0.9, P = 0.009), use of VAC device (100% versus 66%, P = 0.008), and sternal closure by muscle flap (P < 0.001) compared to patients without SSWI (Table 2).

Using multivariable regression analysis, patients with at least 1 revision surgery had 4.8 (95% CI 1.0–22.4, P = 0.047) higher risk for SSWI compared to patients without revision. The OR of SSWI was 4.6 (95% CI 1.3–16.8, P = 0.02) in patients who had sternal closure by muscle flap than patients without muscle flap. Increased risk was found for VAC closure (OR 4.6 [95% CI 0.5–42.7], P = 0.2) and delayed sternal closure >14 days (OR 2.2 [95% CI 0.6–8.3], P = 0.2), but the difference was not statistically significant. Demographic characteristics, presence of comorbidities, characteristics of initial surgery, and DSWI class were not associated with SSWI (data not shown).

Secondary wound infection was associated with longer hospital stay (mean, 69 days versus 48 days, P = 0.04). Inhospital mortality was low (3.6%). One death from multiorgan failure from severe sepsis was attributable to DSWI at 42 days and a further unrelated death from ventilator-associated pneumonia at 134 days. In contrast to initial debridement findings, polymicrobial infection was more common in patients with secondary wound infection (71% versus 6%), including Gram-negative bacilli and Candida spp. (Table 3).

4. Discussion

This study describes the clinical presentation, microbiological characteristics, and treatment outcomes of DSWI in a university hospital. Development of secondary wound infection (SSWI), as defined by presence of local inflammatory signs compatible with infection and culture of new organism(s) from deep tissue not present at initial debridement, was common and resulted in prolonged hospital stay. We identified several risk factors for SSWI such as ≥1 revision surgery and sternal closure by muscle flap. Patients with SSWI often had delayed sternal closure and received VAC treatment. While DSWI is a devastating and feared complication of cardiac surgery, optimal management of DSWI remains controversial. Traditional techniques of wound debridement, primary sternal closure, and closed mediastinal catheter irrigation were introduced in the 1960s (Shumacker and Mandelbaum, 1963; Thurer et al., 1974). More recently, surgical revision with debridement, open dressing, and secondary closure, with or without pectoral muscle or omental flap transfer, are now used (Douvillé et al., 2004; Krabatsch and Hetzler, 1995; Krabatsch et al., 1995). The interval to closure by this method remains unclear; variations in clinical practice include early closure within 48 hours or multiple debridements and packing until bacteriology samples are negative before closure with or without flap (Berdajs et al., 2011; Deniz et al., 2012).

The observation that repeated debridements and delayed sternal closure are associated with the risk of secondary infection can be explained by the increased opportunity for bacterial inoculation and multiplication, either from repeated interventions or exposure of the open wound to the environment. Sternal closure by muscle flap may possibly also increase the risk for bacterial inoculation when compared to primary closure. In patients with SSWI, the findings of polymicrobial infections of Gram-negative and fungal organisms are of concern for the development of antimicrobial resistance and resultant need for broad-spectrum antibiotics.

VAC was introduced in the late 1990s as a novel therapeutic wound healing method (Argenta and Morykwas, 1997; Hersh et al., 2001; Morykwas et al., 1997). The continual drainage of bacteria, debris, and exudates by negative wound pressure enhances microcirculation and accelerates tissue granulation (Argenta and Morykwas, 1997; Morykwas et al., 1997). Promoted by its increasing use, several studies have found the clinical effect of VAC to be comparable to traditional closed drainage or open packing, with improvement in sternal wound healing, reinfarction rates, length of intensive care unit stay, and possibly mortality (Deniz et al., 2012; Risnes et al., 2012; Sjogren et al., 2005a, 2005b; Vos et al., 2012). The effect of bacterial load with VAC, however, has had conflicting results (Assadjan et al., 2010; Lallas et al., 2010; Moues et al., 2004) with some studies showing bacterial accumulation, up to 10⁶–10⁷ colonies of bacteria per gram of tissue (Weed et al., 2004; Yusuf et al., 2013). The significance of these observations remains unclear. In our study, we found that patients with SSWI had VAC therapy more often than patients without secondary infection. This suggests the potential risk of using a foreign body to assist wound healing. Positive bacterial cultures at sternal closure were present in 51% in our study, mostly with CoNS in 61% and Propionibacterium spp. in 13%. A recent study showed that total bacterial clearance might not be mandatory for wound closure after DSWI, with no increase in readmission rate for recurrence reported (Roddig et al., 2012). This suggests that shortening the duration of VAC to allow early closure of the sternal wound may be possible despite positive microbiology results.

Data on optimal antibiotic treatment in DSWI are scarce, in particular the duration and choice of antibiotics. Combination therapy of rifampicin and fluoroquinolones has been shown to be effective against bacteria embedded in biofilms in prosthetic joint infections (Drancourt et al., 1997; Widmer et al., 1992; Zimmerli et al., 1998). In
a retrospective study, a rifampicin-containing antibiotic regimen was shown to improve the outcome of rifampicin-susceptible staphylococcal DSWI (Khanlari et al., 2010). In our institution, targeted intravenous antibiotics are used while the wound remains open. After sternal closure, a switch to oral antibiotics is recommended based on local expert opinion, for a duration of 6 or more weeks. An earlier switch is avoided to prevent the rapid emergence of resistance while the bacterial load remains high in the open wound. Cerrage wires are removed when possible, to remove existing biofilm and prevent future relapse. Although long-term follow-up was not available, patients had good hospital recovery with low mortality based on this antibiotic strategy.

Our study has several limitations. First, the decision for sternal repair, interval to sternal closure, and adjunctive therapy was based on the preference of the treating team, reflecting daily clinical practice. Despite the lack of randomization, we did not find any significant differences in baseline patient demographics or operative characteristics between the 2 groups. Second, due to the retrospective nature of this study, no systematic follow-up with respect to further infection or mortality could be described.

In conclusion, this study adds to the body of the literature on clinical, microbiological, and treatment and complication of DSWI. Developing SSWI was common, associated with multiple revision surgeries, delayed sternal closure, closure by muscle flap, and use of VAC. These risk factors require further investigation in future studies.

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Conflict of interest

None declared.

Previous communication to a society or meeting

Part of this work was presented at the 23rd European Congress of Clinical Microbiology and Infectious Diseases, April 26–30, 2013, Berlin, Germany.

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Atkins BZ, Onaitis MW, Hutcheson KA, Kaye K, Petersen RP, Wolfe WG. Does method of sternal closure, closure by muscle and prevent future relapse. Although risk factors associated with multiple revision surgeries, delayed sternal closure, closure by muscle flap, and use of VAC. These risk factors require further investigation in future studies.

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