Cardiovasc Surg Int 2022;9(3):141-146
http://dx.doi.org/DOI: 10.5606/e-cvsi.2022.1383
www.e-cvsi.org
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Cardiovascular Surgery and Interventions

Original Article Open Access

Results of negative pressure wound therapy for deep sternal wound infections after cardiac surgery

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Received: August 10, 2022 ***Accepted:*** September 13, 2022 ***Published online:*** October 14, 2022

ABSTRACT

Objectives: The aim of this study was to present the outcomes of negative pressure wound therapy (NPWT) for deep sternal wound infection (DSWI) after cardiac surgery.

Patients and methods: Sixty-eight patients (35 males, 33 females; mean age: 60.1±10.1 years; range, 18 to 80 years) who underwent coronary artery bypass surgery or valvular heart surgery between January 2017 and December 2021 were retrospectively reviewed. Patients who underwent NPWT for DSWI after cardiac surgery were included in the study. Baseline and postoperative characteristics of the patients were presented. Previously claimed risk factors for mortality were investigated.

Results: The time interval between cardiac surgery and diagnosis of DSWI was 35.8±30.2 days. The mean duration of NPWT was 21.1±11.8 days. In-hospital mortality was 14.7%. Coagulase-negative staphylococci were the most frequently isolated microorganism (n=26, 38.2%), followed by *Klebsiella* spp. (n=10, 14.7%). The only factor associated with higher mortality was the female sex in our DSWI patients.

Conclusion: Negative pressure therapy is a safe and reliable treatment option in patients with DSWI with or without sternal dehiscence.

Keywords: Cardiac surgical procedures, negative pressure wound therapy, sternum, surgical wound infection.

Despite increasing experience and advancements in surgical techniques, sternal wound infection remains a challenging complication after cardiac surgery. Deep sternal wound infection (DSWI) following cardiac operations is relatively rare compared to other surgical site infections.[2] However, DSWI is life-threatening and difficult to treat, and its incidence is reported to be between 1 and 6%.[1,2] It is associated with prolonged length of stay and increased morbidity, mortality, and healthcare costs.[2,3]

Risk factors for DSWI reported in the literature include advanced age, diabetes, obesity, use of cigarettes, chronic renal disease, and chronic pulmonary disease.[2,4] The use of bilateral internal thoracic artery (BITA) is also an operation-related risk factor known to increase DSWI risk.[2] Rupprecht and Schmid[5] have classified sternal complications of cardiac surgery according to the associated clinical findings. Noninfected sternal instability can always be treated by primary sternal closure with or without debridement. In contrast, DSWI without sternal instability needs to be treated by surgical debridement with negative pressure wound therapy (NPWT) followed by wound revision and sternal closure.[4] Deep sternal wound infection with sternal instability is a more complex pathology and often needs advanced interventions such as muscle flaps.[4]

Treatment of DSWI is challenging, long-lasting, and lacks a standardized algorithm. Conventional treatment modalities are associated with increased mortality ranging from 19 to 25%.[2,6] Negative pressure wound therapy was first described in 1997 by Argenta and Morykwas[7] for enhanced wound

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Citation:
Bayraktar FA, Özhan A, Baştopçu M, Özhan HK, Taşdemir Mete EM. Results of negative pressure wound therapy for deep sternal wound infections after cardiac surgery. Cardiovasc Surg Int 2022;9(3):141-146.

healing. Since then, their technique has been applied for sternal wound infections after cardiac surgery and with improved outcomes.[8,9] The aim of this study was to present the outcomes of NPWT for DSWI after cardiac surgery.

PATIENTS AND METHODS

This retrospective study was conducted with at the Istanbul Medeniyet University, Göztepe Prof. Dr. Süleyman Yalçın City Hospital, Department of Cardiovascular Surgery between January 2017 and December 2021. Patient data were collected from hospital records in a high-volume cardiac center. Laboratory workups and microbiological culture results, including blood and wound culture, were recorded. Previously known risk factors, such as diabetes, advanced age, higher body mass index, active smoking, renal disease, and chronic pulmonary disease, were investigated. The outcomes of interest were the time of DSWI onset, length of hospital stay, and mortality. The study population was selected from patients who underwent coronary artery bypass surgery (CABG) or valvular heart surgery via median sternotomy. Patients with DSWI who required NPWT were included in the study. Patients who underwent aortic or cardiac surgery other than CABG or valvular heart surgery were excluded from the study. In addition, superficial sternal infections, which do not require NPWT therapy, minimal invasive cases (e.g., J-sternotomy), patients with infection of any site before the surgery, including emergency cases, and reoperations were excluded. The follow-up records of eight patients could not be reached, and they were excluded from the study. Among the patients who operated within the study period, 68 patients (35 males, 33 females; mean age: 60.1±10.1 years; range, 18 to 80 years) with DSWI after cardiac surgery who met the criteria were included in the study. A total of 8,221 open heart surgery patients were operated on within five years in our center. Thirteen DSWI patients who did not meet the inclusion and exclusion criteria were excluded from the study. Approximately 1% of patients were diagnosed with DSWI within the study period.

The diagnosis of DSWI was made according to the presence of at least one of the following criteria: isolation of microorganism from mediastinal tissue or fluid, presence of mediastinitis, or existence of sternal instability, chest pain, or fever (>38°C). Purulent drainage from the mediastinum in addition to the isolation of microorganisms from blood culture or mediastinal discharge, purulent mediastinal discharge, or widening mediastinum in radiological imaging was also considered DSWI.[10]

All patients took a preoperative bath with chlorhexidine. The staphylococcal colonization was checked with nasal swabs, and topical mupirocin was administered to patients with staphylococcal colonization. The patients were transferred to the intensive care unit following the operation, to the ward on the first or second postoperative day, and discharged from the hospital between the 7th and 10th postoperative day. If DSWI was observed, blood and wound cultures were performed. Perioperative prophylactic antibiotics were given to all patients, and empirical antibiotics were initiated upon the recommendation of the infectious disease department to patients with suspected infections. Antibiotherapy was revised according to culture antibiogram results. In patients with DSWI, NPWT (Confort C300 NPWT Therapy Unit, Eskişehir, Türkiye) in intermittent therapy mode with standard wound closure sets was applied after a sharp and satisfactory debridement of the necrotic and infected tissue. The NPWT set was replaced every 48 to 72 h. The sternal fixation by steel wires was performed in the presence of sternal dehiscence. Diagnosis of mediastinitis in patients with DSWI was made with positive wound cultures, symptoms of infection such as fever, angina, sternal instability, and radiological findings on the computer tomography.

Statistical analysis

Statistical analysis was performed using the Jamovi version 1.2.27 software (Sidney, Avustralya). Descriptive data were expressed as mean ± standard deviation for continuous variables and number (frequency) for categorical variables. Univariate logistic regression analysis was performed for variables that were previously reported as risk factors for in-hospital mortality. A p value of <0.05 was considered statistically significant.

RESULTS

The baseline characteristics of the patients are presented in Table 1. Forty-five (66.2%) patients had diabetes mellitus, and 43 (63.2%)

Table 1
Baseline characteristics

Variables	n	%	Mean±SD
Age (year)			60.1±10.1
Female sex	33	48.5	
Hypertension	42	61.8	
Diabetes mellitus	45	66.2	
Obesity	43	63.2	
Active smoking	34	50.0	
Chronic pulmonary disease	21	30.9	
Chronic kidney disease	30	44.1	

SD: Standard deviation.

had obesity. Sternal wound cultures were taken as soon as possible after detecting DSWI. Isolated microorganisms are presented in Table 2. Coagulase-negative staphylococci were the most frequently isolated microorganism (n=26, 38.2%) in our DSWI patients, followed by *Klebsiella* spp. (n=10, 14.7%), *Staphylococcus aureus* (n=9, 13.2%]), and *Acinetobacter* spp. (n=9).

Postoperative and follow-up data are shown in Table 3. The mean time interval from the time of surgery to the detection of DSWI was 35.8±30.2 days, and the mean duration of NPWT was 21.1±11.8 days. The patients with DSWI had a longer length of stay with a mean of 58.2±49.5 days. In-hospital mortality was observed in 10 (14.7%) patients.

The result of the univariate logistic regression analysis performed on known risk factors for DSWI and mortality is given in Table 4. None of the variables were found to be associated with higher mortality except for the female sex in our study group. Eight out of 33 female patients had in-hospital mortality. Except for the two deceased patients, the sternal wounds of the other patients healed. All patients were discharged with recovery. The follow-up of the patients after discharge was not included in our study.

Table 2
Isolated microorganisms in sternal cultures

Microorganism	n	%
Staphylococcus aureus	9	13.2
MRSA	4	5.9
MSSA	5	7.4
Coagulase-negative Staphylococci	26	38.2
Enterobacter spp.	5	7.4
Klebsiella spp.	10	14.7
Escherichia coli	1	1.5
Acinetobacter spp.	9	13.2
Candida spp.	6	8.8
Proteus spp.	2	2.9
Morganella spp.	1	1.5
Corynebacterium spp.	4	5.9
Serratia spp.	1	1.5
Stenotrophomonas maltophilia	2	2.9

MRSA: Methicillin-resistant *Staphylococcus aureus*; MSSA: Methicillin-susceptible *Staphylococcus aureus*.

DISCUSSION

Deep sternal wound infection is a severe complication after cardiac surgery and requires special attention. While the incidence of DSWI

Table 3
Postoperative characteristics of the patients

Variables	n	%	Mean±SD
Time from operation to detection of DSWI (days)			35.8±30.2
Time to eradication of pathogen (days)			24.3±19.3
Duration of NPWT (days)			21.1±11.8
Sternal dehiscence	17	25.0	
Reconstruction by a muscle flap	2	2.9	
Length of hospital stay (days)			58.2±36.3
In-hospital mortality	10	14.7	

SD: Standard deviation; DSWI: Deep sternal wound infection; NPWT: Negative pressure wound treatment.

Table 4
Logistic regression analysis of risk factors for DSWI in predicting mortality

		95% CI		
	HR	Lower	Upper	*p*
Age	1.003	0.938	1.070	0.927
Female gender	5.280	1.030	27.064	0.046
Diabetes mellitus	0.731	0.184	2.901	0.656
Active smoking	0.622	0.159	2.439	0.496
Obesity	2.629	0.512	13.502	0.247
Chronic kidney disease	1.320	0.344	5.062	0.686

DSWI: Deep sternal wound infection; CI: Confidence interval; HR: Hazard ratio.

after CABG is as low as 0.3 to 2.3%,[11,12] the associated mortality rate can be as high as 36%.[13] Early closure of the sternal wound following a sharp debridement in DSWI cases appears as a treatment option to prevent secondary infection. Still, it may also predispose to the spread of infection.[2,13] Sternal closure following NPWT, which provides a clean wound with granulation tissue, is a more reasonable option.[2] In DSWI cases after cardiac surgery, the mortality rate was quite higher before NPWT, and the mortality rate was noticeably decreased after the use of NPWT.[5,13] Morisaki et al.[13] reported that mortality in DSWI patients was 38% before NPWT use, and this rate decreased to 5% after NPWT use. The in-hospital mortality was 14.7% in our study population, which seems significantly lower than the mortality rates in previous studies.[13,14] The beneficial effects of NPWT on sternal wound healing could be listed as follows: it maintains chest wall stability, promotes granulation tissue, decreases wound edema, and provides drainage of excessive and infected fluid in case of a persistent infection. [11,15] Mobilization of the patient is also possible with NPWT that provides sternal stabilization.[15,16]

Deep sternal wound infection is often an early complication of cardiac surgery.[1,5] The time interval between cardiac surgery and diagnosis of DSWI is a valuable parameter in treatment outcomes. Delayed diagnosis may negatively affect the success of treatment, whereas early diagnosis may prevent the further spread of the infection.[1,11] Negative pressure wound therapy is recommended to be initiated as soon as possible, particularly if the sternal wound closure is expected to be delayed.[6,11] The DSWI study by Buğra et al.[1] reported 21.3% mortality, and the mean time between the diagnosis of DSWI after the first cardiac surgery was 50.4±172.5 days. In our opinion, relatively early detection of DSWI (35.8±30.2 days) in our study plays a vital role in the slightly better mortality rate (14.7%). In addition, NPWT was initiated as soon as possible in all patients diagnosed with DSWI, which could also explain the better outcomes in our study.

According to the study by Lepelletier et al.,[17] *Staphylococcus aureus (S. aureus)* is the most frequently isolated microorganism in DSWI patients (40%), followed by coagulase-negative staphylococci (30%). Similarly, in our study population, the most isolated microorganisms were coagulase-negative staphylococci (38.2%), *Klebsiella* spp. (14.7%), and *S. aureus* (13.2%). Although routine preoperative nasal swabs are obtained from all patients, and mupirocin ointment is given to eradicate staphylococcal nasal colonization as the guidelines recommend, these measures cannot prevent *Staphylococcus* spp. from being the most frequently isolated microorganism in the DSWI cases.[17,18] In methicillin-resistant *S. aureus* cases, it is necessary to perform extensive and sharp tissue debridement to prevent severe tissue destruction and inflammation due to antibiotic resistance.[19]

Female sex, hypertension, diabetes mellitus, obesity, active smoking, chronic pulmonary disease, and chronic renal disease, which are considered risk factors for DSWI in the literature,[2,4,15] were observed at very high rates ranging from 30.9 to 66.2% in our DSWI patients. Among these risk factors, the only risk factor that was shown to be associated with

increased mortality was the female sex in our study population. In the literature review article for DSWI patients presented by Phoon and Hwang,[15] female sex was considered an independent risk factor for DSWI. When we looked for the impact of female sex on mortality in DSWI patients, no evidence was found on the subject. Although we found female sex as a risk factor for mortality in our study population of DSWI patients, this issue needs to be supported by further prospective studies.

The management of DSWI, particularly with sternal instability, needs special care and attention, with further interventions often necessary. Sternal dehiscence may give rise to DSWI. The Robicsek sternal closure technique is beneficial and helps to provide sternal stability in case of multiple sternal fractures.[15,20] If the primary closure of the sternum cannot be achieved, reconstructive surgery by a tissue flap can be an alternative.[14,21,22] We used the Robicsek sternal closure technique to provide sternal stability in cases with multiple sternal fractures. In two of these patients, primary closure could not be achieved, so reconstructive surgery by a muscle flap was required.

Despite several studies and reviews, there are no clear guidelines for DSWI. Dr. Lazar has extensively studied the field of sternal wound infections.[6,11,23] According to these studies, DSWI patients should be managed with a multidisciplinary approach, and NPWT should be initiated as soon as possible. There are also several reviews that propose an algorithm for the management of DSWI.[4,15,20] However, a widely accepted algorithm does not exist.

The retrospective design of the study is a significant limitation. Since we present the outcomes of NPWT after DSWI, there is no control group to compare for morbidity and mortality in the study; however, we could compare our results with previously reported outcomes with DSWI. Two patients with BITA use were both nondiabetics; therefore, BITA use was not included in the statistical analysis considering its limited number. Although the single-center design of our study may be a limitation, our clinic is a high-volume center serving a large population, allowing us to share our experience with a high number of yearly cases.

In conclusion, cardiac surgery patients can be complicated with DSWI despite the increasing surgical experience and better outcomes. Negative pressure wound therapy is a safe and reliable treatment option in DSWI patients with or without sternal dehiscence and is recommended to be initiated as soon as possible. The most frequently isolated microorganisms were coagulase-negative staphylococci (38.2%), *Klebsiella* spp. (14.7%), and *S. aureus* (13.2%). Female sex was the only factor that was shown to be associated with increased mortality in our DSWI patients.

Ethics Committee Approval: Ethical approval was obtained from the hospital's academic review board and Haydarpaşa Numune Training and Research Hospital Clinical Research Ethics Committee (No: HNEAH-KAEK 2022/103-3681). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Informed consent was waived due to the retrospective nature of the study, and the patient information had been anonymized before analysis.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, literature review, writing the article: F.A.B.; Idea/concept, design, writing the article, references and fundings: M.B.; Idea/concept, design, references and fundings: H.K.Ö.; Data collection and/or processing, analysis and/or interpretation, materials: A.Ö.; Idea/concept, control/ supervision, literature review, critical review: E.M.T.M.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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