JOURNAL OF PLASTIC SURGERY AND HAND SURGERY
2020, VOL. 54, NO. 3, 182–186
https://doi.org/10.1080/2000656X.2020.1738240

ARTICLE

Impact of microbial findings on plastic reconstructive surgery outcomes in patients with deep sternal wound infection after cardiac surgery

Annika Arsalan-Werner[a], Linda Dick[a], Mani Arsalan[b], Olaf Wölfle[c], Thomas Walther[b] and Michael Sauerbier[a]

[a]Department for Plastic, Hand and Reconstructive Surgery, Hand Trauma Center (FESSH), BG Trauma Center Frankfurt am Main, Academic Hospital of the Goethe University Frankfurt am Main, Frankfurt, Germany; [b]Department of Thoracic and Cardiovascular Surgery, Goethe University Frankfurt am Main, Frankfurt, Germany; [c]Department for Plastic, Hand and Reconstructive Surgery, Main-Taunus Hospitals GmbH, Bad Soden, Germany

ABSTRACT

Deep sternal wound infection (DSWI) is a life threatening complication after cardiac surgery. In severe cases, flaps are needed to cover the wound. However, it is controversial if an aseptic environment is necessary at the time of wound closure. This is a retrospective study of 73 patients with DSWI treated by debridement and local or free flap from June 2008 until December 2017. The influence of positive microbiological findings at the time of plastic reconstructive surgery on reoperation rate and length of in-hospital stay was analyzed. Microbiological exams revealed positive results in 47 (64.4%) and no results in 26 patients. Reoperation had to be performed in 21.3% (positive cultures) versus 15.4% ($p = .54$), mean in hospital stay was 24.1 days (positive cultures) versus 21.8 days ($p = .39$) and in-hospital mortality was 6.4% (positive cultures) versus 7.7% ($p = .83$). Positive microbial findings at the time of plastic reconstructive surgery in patients with DSWI are not associated with a higher reoperation or mortality rate or a longer in-hospital stay. Repeated debridement and vacuum-assisted therapy to achieve negative microbial results might not be necessary in the treatment of these patients.

KEY MESSAGES

- Positive microbial findings at the time of plastic reconstructive surgery in patients with deep sternal wound infection seems not to be associated with a higher reoperation or mortality rate or a longer in-hospital stay.
- The influence of positive microbiological findings at the time of plastic reconstructive surgery on reoperation rate and length of in-hospital stay was analyzed in 73 patients with deep sternal wound infection.
- Microbiological exams revealed positive results in 47 (64.4%) and no results in 26 patients. Reoperation had to be performed in 21.3% (positive cultures) versus 15.4% ($p = .54$), mean in hospital stay was 24.1 days (positive cultures) versus 21.8 days ($p = .39$) and in-hospital mortality was 6.4% (positive cultures) versus 7.7% ($p = .83$).

ARTICLE HISTORY
Received 31 October 2019
Revised 11 February 2020
Accepted 27 February 2020

KEYWORDS
Deep sternal wound infection; mediastinitis; microbiological germs; wound closure; poststernotomy infection

Introduction

Deep sternal wound infection (DSWI) is a life-threatening complication after median sternotomy with an incidence of 0.75–8% [1–4]. According to the guidelines of the Center of Disease Control and Prevention in the USA [5], the diagnosis requires at least one of the following (1) an organism isolated from culture of mediastinal tissue or fluid, (2) evidence of mediastinitis seen during operation, (3) one of the following conditions: chest pain, sternal instability or fever (>38 °C), in combination with either purulent discharge from the mediastinum or an organism isolated from blood culture or culture of mediastinal drainage. The pathogenesis of DSWI is multifactorial, risk factors include obesity, diabetes mellitus, usage of bilateral internal thoracic artery grafts and previous heart surgery [1,2,4]. Although the epidemiology and risk factors of DSWI are well known, the optimal treatment strategy and especially the appropriate timing of final wound closure remains controversial and no official current guidelines exist.

Treatment of DSWI often includes radical debridement and vacuum-assisted (VAC) therapy. Microbiological samples are taken before or during debridement to choose the appropriate antibiotic therapy. Most common microbiological findings are *Staphylococcus epidermidis* and *Staphylococcus aureus* [1,2,6]. It is common practice to continue VAC therapy up to the point when the surgeon evaluates the wound as eligible for either secondary wound closure or plastic reconstructive techniques with flap coverage [6,7]. However, it remains controversial if negative microbiological findings, usually achieved by repeated debridement and VAC therapy [8–11], are mandatory at the time of wound closure [12–16].

The authors perform direct wound closure after radical debridement of all necrotic tissue and defect coverage by flap in a one-step operation regardless of microbiological findings under

CONTACT Annika Arsalan-Werner annika.arsalan-werner@bgu-frankfurt.de Department for Plastic, Hand and Reconstructive Surgery, Hand Trauma Center (FESSH), BG Trauma Center Frankfurt am Main, Academic Hospital of the Goethe University Frankfurt am Main, Friedberger Landstrasse 430, 60389 Frankfurt, Germany

most circumstances. However, some patients already showed negative microbiological findings at the time of coverage due to prolonged VAC therapy in the referring hospital. The purpose of the study was to analyze whether or not positive microbiological germs from the surgical site in patients with DSWI at the time of defect coverage influence the overall outcome.

Materials and methods

This is a retrospective study analyzing patients with DSWI according to the guidelines of the Center of Disease Control and Prevention in the USA [5]. Only patients with partial and total sternotomy due to cardiac surgery were included in this study, other patients with DSWI due to other causes were excluded. Patients were referred either with previous debridement and VAC therapy or without previous treatment. All treated patients were hemodynamically stable without signs of sepsis or septic shock at the time of reconstructive surgery [17].

Surgical procedure

Microbial swabs of the wounds were taken intraoperatively in all cases at the time of reconstructive surgery and the patients were treated with antibiotics accordingly. The samples were taken from subcutaneous tissue. Existing foreign material (e.g. sternal wires) were removed and all necrotic tissue were debrided until bleeding occurred and the wound was irrigated thoroughly. Secondary closure was performed regardless of the microbiological findings. Repeated wound revision and repeated VAC therapy to achieve negative microbial findings were not performed. All patients were instructed to wear elastic pressure garments for 6 weeks to maintain a stable chest wall during healing.

Data collection

We recorded the following variables in the database: age, sex, body mass index (BMI), left ventricular ejection fraction (LVEF), comorbidities of diabetes mellitus and chronic obstructive lung disease (COPD), details on previous cardiac surgery including type of operation, emergency procedure and bilateral use of internal mammary artery for coronary revascularization. The period of time between the initial cardiac surgery and start of wound healing disturbance was assessed. Data concerning laboratory findings at the time of wound closure (leukocytes and C-reactive protein) as well as results of microbial samples, length of hospital stay (from the day of reconstruction to the day of discharge) and mortality rate were collected. The effect of positive microbiological findings on the reoperation rate, length of in-hospital stay and mortality rate were assessed. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in approval by the institution's human research review committee and the study was approved by the ethics committee of the regional State Chamber of Medicine.

Statistical analysis

Clinical variables were tabulated according to their distribution with median and range or expressed as percentages. Comparisons between the independent groups were performed with the X^2-test for categorical variables. The continuous variables were not normally distributed and thus compared by the Mann–Whitney *U*-test. A p value of $\leq .05$ was considered statistically significant. The data analysis was performed with IBM SPSS Statistics 21 software (IBM, Corporation, USA).

Results

From June 2008 until December 2017, 73 consecutive patients (31 women and 42 men) with DSWI were treated. Previously performed cardiac surgery procedures and baseline characteristics of the patients are summarized in Tables 1 and 2.

Thirty-one patients were referred to our hospitals with VAC and 42 without (primary operation). Sixty-five (89%) patients were reconstructed by pectoralis major flap after radical sternal debridement, the other patients were treated with other local, pedicled or free microvascular flaps.

In 26/73 (35.6%) patients, microbial growth was negative. In these patients, the mean length of hospital stay was 21.8 days

Table 1. Details on cardiac surgery procedures performed in the complete cohort and within the two groups.

	Total (percentage of all patients)	Patients with positive microbial findings (percentage of 47 patients)	Patients without microbial findings (percentage of 26 patients)
CABG	43 (59%)	27 (57%)	16 (62%)
Valve	14 (19%)	10 (21%)	4 (15%)
Partial sternotomy	5 (7%)	3 (6%)	2 (8%)
Combined surgery	16 (22%)	10 (21%)	6 (23%)

CABG: coronary artery bypass graft; valve: isolated valve repair or replacement; combined surgery: CABG and valve surgery.

Table 2. Patient characteristics.

	Patients with positive microbial findings ($n = 47$)	Patients without microbial findings ($n = 26$)	p Value
Age (years)	Mean 70.7 Median 73 Min 42 Max 85	Mean 68.3 Median 71 Min 49 Max 83	.26
Sex (male, %)	60	54	.64
Body mass index (kg/m^2)	Mean 29.1 Median 28.4 Min 20.9 Max 40.0	Mean 25.8 Median 24.3 Min 18.9 Max 40.4	.03
COPD (%)	30	38	.45
Diabetes mellitus (%)	49	54	.69
LVEF (%)	Mean 52 Median 55 Min 20 Max 65	Mean 47 Median 50 Min 20 Max 65	.37
Bilateral use of internal mammary artery for coronary revascularization (%)	70	85	.53
Emergency cardiac surgery procedure (%)	21	4	.05
Period of time between initial cardiac surgery and start of wound healing disturbance (weeks)	Mean 4.3 Median 2.5 Min 0 Max 20.0	Mean 12.8 Median 8.0 Min 0 Max 40.0	.04
CRP at the time of wound closure (mg/dl)	Mean 6.1 Median 4.6 Min 0.6 Max 34.1	Mean 4.1 Median 1.9 Min 0.18 Max 19.7	.04
Leukocytes at the time of wound closure (per nanoliter)	Mean 8.8 Median 8.3 Min 2.8 Max 20.7	Mean 9.1 Median 9.4 Min 5.1 Max 14.5	.27

COPD: chronic obstructive pulmonary disease; LVEF: left ventricular ejection fraction; CRP: C-reactive protein.

Table 3. Bacteria and fungi found in the patients with positive microbial findings.

	Number of patients	Percentage (total $n = 47$) (%)
Staphylococcus	33	70
Staphylococcus aureus	13[a]	28
Staphylococcus epidermidis	13[b]	28
Coagulase negative staphylococci	5	11
Candida albicans	5	11
Pseudomonas aeruginosa	4	9
Other	25[c]	53

In some patients, up to four different pathogens were isolated.
[a]Including two patients with MRSA (methicillin-resistant *Staphylococcus aureus*).
[b]Including five patients with MRSE (methicillin-resistant *Staphylococcus epidermidis*).
[c]Including three patients with ESBL (extended spectrum beta lactamase).

(range 3–93, median 15.5). Four of these patients (15.4%) had to undergo reoperation due to wound healing disturbances, resulting in an extended hospital stay of 58.7 days (range 36–93, median 47). In-hospital mortality was 7.7% ($n = 2$).

Forty-seven of 73 (64.4%) patients showed positive microbiological results. *S. aureus* and *S. epidermidis* were the most common pathogens. Table 3 summarizes the bacterial growths. There was no difference in the reoperation rate (21.3%; $p = .54$), length of stay (24.1 days; range 5–81, median 20.0, $p = .39$) and in-hospital mortality (6.4%; $p = .83$) compared to the patients without microbiological growth. Reoperations resulted in an extension of hospital stay to 42.3 days (range 18–81, median 37.0).

Discussion

This study investigates the role of positive microbial findings at the time of plastic reconstructive surgery in patients with DSWI. The results suggest that negative microbiological findings at the time of wound closure with flaps are not mandatory, as they do not influence the length of in-hospital stay or mortality rate and they are not associated with a higher short or long-term reoperation rate. There are only a few studies investigating this subject so far.

Most studies addressing the influence of positive microbial findings on the outcome of DSWI are conducted in patients that did not need soft tissue coverage but were closed primarily. Rodriguez et al. [13] reported in a retrospective study about 159 patients with DSWI. Fifty-four of these patients were treated with direct wound closure – regardless of the microbiological findings – and a historical control group of 105 patients was treated with VAC therapy and delayed wound closure. The latter stayed significantly longer in the hospital. There was no statistical difference in the readmission rate of patients that were closed with positive and negative microbiological results (5% and 5.1%, $p = 1.0$). Unfortunately, the reoperation rate was not reported. Of note, as only some of the patients in Rodriguez and colleagues' study required soft tissue coverage, it can be assumed that DSWI in these patients was not at such an advanced stage compared to the present study. Yet these findings are in line with our data, that negative microbiological results might not be mandatory in these patients.

Assmann et al. [18] retrospectively analyzed 192 patients, who were treated with VAC therapy and wound closure (120 patients) or primary rewiring after disinfectant irrigation (72 patients). The outcome of patients in the rewire group was significantly worse regarding the length of mechanical ventilation, longer hospital stays and higher in-hospital mortality rate. Primary rewiring failed in 45.8% ($n = 33$). Our reoperation rate is noticeably lower. This fact can probably be explained by our therapeutic approach to remove all existing sternal wires etc. and to waive the rewiring of the sternal components. Thus, the insertion of foreign material could has led to the increased reoperation rate in the study by Assmann et al. [19] as other authors have already shown, that sternal rewiring may be associated with a higher rate of treatment failure.

Very few studies investigate the impact of microbial findings in DSWI patients requiring sternal flap coverage. Phan et al. [16] retrospectively analyzed 135 patients with these problems. Reconstructive plastic surgery was only performed when the wounds were free of microorganisms. Ninety patients (69%) healed primarily without any signs of wound dehiscence and/or wound necrosis after flap coverage (mean follow up 11 months). Thirty-one percent of patients developed wound dehiscence and/or wound necrosis needing additional surgery. 23.4% of the patients with positive microbial findings in our study needed at least one additional operation due to wound healing disturbances. The mean length of hospital stay in this group of patients was 45.0 days in Phans study, and in our group with contaminated wounds with reoperation 42.3 days. The comparison between our data and the results by Phan et al. indicate that negative microbial findings might not be crucial. In a multi-regression analysis Phan et al. demonstrated that microbiological findings of more than four different species of bacteria colonizing the wound increased the risk of wound dehiscence despite negative microbiological findings at the time of wound closure. However, no patient in our cohort had a wound colonialization with more than four species.

Yu et al. [20] treated six patients with debridement and pectoralis major muscle flaps for thoracic reconstruction in a single operation. In five patients, organisms were found in the wound culture prior to debridement. There were no major wound morbidities, but one minor complication required a skin graft caused by skin flap necrosis (16.7% reoperation rate). No patient died. The authors attribute their good results mainly to the fact, that treatment with debridement and flap reconstruction was not delayed after the diagnosis, but only very few patients were treated. In an older study, Cabbabe and Cabbabe [21] analyzed a group of 497 patients that were treated with one-step radical sternal debridement and bilateral pectoral muscle flap reconstruction regardless of the bacterial growth between 1986 and 2008. Twenty-four (4.8%) developed major wound dehiscence; the average length of hospital stay was 4.7 days and five (1%) patients died. No further information about positive or negative cultures at the time of treatment is provided in the article, but presumably, a major part of the patients had positive cultures and the authors report excellent results. In extremity reconstruction, it is common clinical practice to close wounds after debridement despite positive microbiological findings under most circumstances, however only few studies support this clinical practice [15].

Another interesting finding in this study is that the period between the initial cardiac surgery and the start of wound healing disturbances is significantly lower in the patients with positive microbiological findings (Table 2: mean 4.3 weeks vs. mean 12.8 weeks, $p = .04$). This might be a hint for a different pathophysiology in the development of DSWI in both groups and would be an interesting topic for further investigation. But it is also an indicator that the group without microbial findings was further along in the recovery process after the initial cardiac surgery and this might have led to a better clinical outcome after reconstructive surgery.

To our knowledge no existing study showed a negative impact of positive microbial findings on the outcome of wound closure after DSWI. On the contrary, the present study, as well as the reported literature suggests equal outcomes independent of the microbiological findings at the time of wound closure.

There are limitations to this retrospective study. Patients were referred either with previous debridement and VAC therapy or without previous treatment. This could have been a source of bias. On the one hand, the previously not opened wounds might not have been infected yet and therefore have a better outcome, on the other hand, previous VAC therapy after thorough debridement might lead to better results due to an earlier achievement of a clean wound.

Negative microbiological samples do not preclude that wound closure might have been performed while bacteria were still present [22]. On the other hand, the issue of contamination of the wound needs to be discussed, as positive microbial findings might occur after a period of open wound treatment. The sample size of each group is small. A group sample size of 708 would be needed in both the groups to achieve >80% power to detect a difference between the group proportions of 5.9% for re-operation.

As the groups were not randomized, the patients with positive microbial findings had a significantly lower BMI and significantly less emergency procedures were performed in this group. The C-reactive protein level in patients with microbiological positive cultures was significantly higher than in patients with negative cultures (6.1 vs. 4.1, $p = .04$). Gustafsson followed 16 patients with DSWI, that were treated with debridement of foreign material and necrotic tissue and consecutive VAC therapy until C-reactive protein level had declined to 3–7 mg/dL [23]. The median C-reactive protein level at closure was 4.5 mg/dL. All patients were free from DSWI at a follow up of 3 months after the operation. The median hospital stay was 22 days (range 12–120 days). Our treatment regime was not guided by C-reactive protein levels, but the data in our 73 patients suggest, that a C-reactive protein level, that is elevated to 6.1 at the time of wound closure does not negatively affect the outcome and the length of the hospital stay is comparable to the one in Gustafssons study. Two other patients' characteristics that differ between both groups (higher BMI and emergency procedure rate) are higher in the positive microbial finding group and are known as predictors for worse wound healing outcomes. Thus, it is particularly interesting that the outcome of both the groups did not differ.

Conclusion

In conclusion, this study shows that positive microbial findings at the time of defect coverage with flaps might not be associated with a higher long-term reoperation rate or longer in-hospital stay or higher mortality rate in patients with DSWI. Early wound closure with flap coverage can be accomplished despite positive microbiological findings at the time of wound closure. A prolonged VAC therapy to achieve negative microbial results seems not mandatory in the treatment of DSWI after cardiac surgery.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

[1] Gummert JF, Barten MJ, Hans C, et al. Mediastinitis and cardiac surgery – an updated risk factor analysis in 10,373 consecutive adult patients. Thorac Cardiovasc Surg. 2002; 50(2):87–91.

[2] Borger MA, Rao V, Weisel RD, et al. Deep sternal wound infection: risk factors and outcomes. Ann Thorac Surg. 1998;65(4):1050–1056.

[3] Nakano J, Okabayashi H, Hanyu M, et al. Risk factors for wound infection after off-pump coronary artery bypass grafting: should bilateral internal thoracic arteries be harvested in patients with diabetes? J Thorac Cardiovasc Surg. 2008;135(3):540–545.

[4] Culliford AT, Cunningham JN Jr., Zeff RH, et al. Sternal and costochondral infections following open-heart surgery. A review of 2,594 cases. J Thorac Cardiovasc Surg. 1976;72(5): 714–726.

[5] Mangram AJ, Horan TC, Pearson ML, et al.; Guideline for Prevention of Surgical Site Infection. Centers for Disease Control and Prevention (CDC) hospital infection control practices advisory committee. Am J Infect Control. 1999; 27(2):97–132. quiz 133-4; discussion 96.

[6] Sjogren J, Malmsjo M, Gustafsson R, et al. Poststernotomy mediastinitis: a review of conventional surgical treatments, vacuum-assisted closure therapy and presentation of the Lund University Hospital mediastinitis algorithm. Eur J Cardiothorac Surg. 2006;30(6):898–905.

[7] Doss M, Martens S, Wood JP, et al. Vacuum-assisted suction drainage versus conventional treatment in the management of poststernotomy osteomyelitis. Eur J Cardiothorac Surg. 2002;22(6):934–938.

[8] Morykwas MJ, Argenta LC, Shelton-Brown EI, et al. Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. Ann Plast Surg. 1997;38(6):553–562.

[9] Moues CM, Vos MC, van den Bemd GJ, et al. Bacterial load in relation to vacuum-assisted closure wound therapy: a prospective randomized trial. Wound Repair Regen. 2004; 12(1):11–17.

[10] Braakenburg A, Obdeijn MC, Feitz R, et al. The clinical efficacy and cost effectiveness of the vacuum-assisted closure technique in the management of acute and chronic wounds: a randomized controlled trial. Plast Reconstr Surg. 2006;118(2):390–397. discussion 398–400.

[11] Weed T, Ratliff C, Drake DB. Quantifying bacterial bioburden during negative pressure wound therapy: does the wound VAC enhance bacterial clearance? Ann Plast Surg. 2004;52(3):276–279. discussion 279–280.

[12] Berdajs DA, Trampuz A, Ferrari E, et al. Delayed primary versus late secondary wound closure in the treatment of postsurgical sternum osteomyelitis. Interact Cardiovasc Thorac Surg. 2011;12(6):914–918.

[13] Rodriguez Cetina Biefer H, Sundermann SH, Emmert MY, et al. Negative microbiological results are not mandatory in deep sternal wound infections before wound closure. Eur J Cardiothorac Surg. 2012;42(2):306–310; discussion 310.

[14] Rao N, Ziran BH, Lipsky BA. Treating osteomyelitis: antibiotics and surgery. Plast Reconstr Surg. 2011;127(Suppl 1): 177S–187S.

[15] Diefenbeck M, Mennenga U, Guckel P, et al. [Vacuum-assisted closure therapy for the treatment of skin and soft-tissue infections. Are wound specimens of use in planning

secondary wound closure?]. Z Orthop Unfall. 2011;149(3):324–329.
[16] Phan TQ, Depner C, Theodorou P, et al. Failure of secondary wound closure after sternal wound infection following failed initial operative treatment: causes and treatment. Ann Plast Surg. 2013;70(2):216–221.
[17] Singer M, Deutschman CS, Seymour CW, et al. The third international consensus definitions for sepsis and septic shock (Sepsis-3). JAMA. 2016;315(8):801–810.
[18] Assmann A, Boeken U, Feindt P, et al. Vacuum-assisted wound closure is superior to primary rewiring in patients with deep sternal wound infection. Thorac Cardiovasc Surg. 2011;59(01):25–29.
[19] Rashed A, Gombocz K, Alotti N, et al. Is sternal rewiring mandatory in surgical treatment of deep sternal wound infections? J Thorac Dis. 2018;10(4):2412–2419.
[20] Jang YJ, Park MC, Park DH, et al. Immediate debridement and reconstruction with a pectoralis major muscle flap for poststernotomy mediastinitis. Arch Plast Surg. 2012;39(1):36–41.
[21] Cabbabe EB, Cabbabe SW. Immediate versus delayed one-stage sternal debridement and pectoralis muscle flap reconstruction of deep sternal wound infections. Plast Reconstr Surg. 2009;123(5):1490–1494.
[22] Misfeld M. Editorial comment: Re: negative microbiological results are not mandatory in deep sternal wound infections before wound closure. Eur J Cardiothorac Surg. 2012;42(2):310–311.
[23] Gustafsson R, Johnsson P, Algotsson L, et al. Vacuum-assisted closure therapy guided by C-reactive protein level in patients with deep sternal wound infection. J Thorac Cardiovasc Surg. 2002;123(5):895–900.