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Treatment of the infection in deep sternal wound infections—a single center cohort study

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Background: In the treatment of deep sternal wound infections (DSWIs) using negative pressure wound therapy (NPWT), infection therapy is separated from reconstruction of the thoracic wall. It is difficult to decide when NPWT can end in order to close the wound. Often ideal conditions cannot be achieved. Must or can sterility be waited for and should antibiotics be administered and if so for how long? These questions are discussed here.

Methods: A retrospective single center analysis is performed. Patients who developed a DSWI after cardiac surgery between 2014 and 2020 are included. The following parameters are collected: baseline data, number of negative pressure dressing changes, frequency of persistence of infection and antibacterial therapy performed at closure. Either a short-term antibiotic therapy over 5 days or a therapy corresponding to the osteomyelitis treatment over 6 weeks was carried out.

Results: In 79 patients, sterility was achieved after 10.2 ± 3.9 (mean \pm standard deviation) changes of the negative pressure dressing using NPWT. In 51 patients, NPWT was terminated after 7.4 ± 5.3 changes without achieving sterility. The number of changes varied significantly. If sterility could be achieved, the frequency of infection complications was significantly lower. Long-term antibiotic therapy resulted in significantly fewer infections than short-term therapy.

Conclusions: Microbiological sterility should be achieved if possible. This requires more dressing changes, but the complications are rarer. If it is not possible to wait for sterility, long-term antibiotic therapy is required if osteomyelitis occurs.

Keywords: Deep sternal wound infection (DSWI); negative pressure wound therapy (NPWT); sternum osteomyelitis

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Introduction

The general sequence in the treatment of deep sternal wound infections (DSWI) after median sternotomy is widely accepted. If an infection occurs, the wound is reopened. Osteosynthesis material is removed and extensive wound debridement is performed. A local negative pressure wound therapy (NPWT) is then applied and changed regularly. The final stage of treatment is closure with sternal

reconstruction, muscle plasty and wound closure.

The definition of DSWI is a postoperative surgical site infection following median sternotomy that involves the soft tissues of the chest wall, the sternum, and/or the mediastinum, corresponding to deep incisional or organ/space infection according to the Centers for Disease Control/National Healthcare Safety Network (CDC/NHSN) classification (1).

In the current S3 guideline on the management of mediastinitis after cardiac surgery, several classification systems are used to classify DSWI and its most severe forms (2). The CDC/NHSN classification categorizes surgical site infections according to the depth of tissue involvement, ranging from superficial to deep infection and organ/space infection, the latter encompassing postoperative mediastinitis. This system is primarily intended for standardized diagnosis and surveillance. Other classifications [e.g., Pairolero and Arnold (3) and El Oakley and Wright (4)] adopt a more clinically oriented approach to DSWI, including the timing of presentation, risk factors, recurrence, and treatment failure, thereby providing additional guidance for therapeutic decision-making.

Yet, the criteria for ending local negative pressure therapy and performing chest wall reconstruction are not precisely defined. Several questions remain unresolved, particularly whether the therapeutic goal should be complete wound sterility or whether a controlled persistence of microorganisms can be tolerated. These are usually coagulase-negative staphylococci. There are arguments both for keeping the period of negative pressure therapy as short as possible and for continuing the therapy until the wound is aseptically and granulation has formed. Sjögren *et al.* (5) have presented a concept for NPWT in their review: a rather limited regime is proposed here.

The antibiotic regimen is also unclear. How to proceed with antibiotics during negative pressure therapy and which

regimen should be used during closure. If osteomyelitis has been confirmed, treatment should be carried out in accordance with the recommendations for osteomyelitis (6,7). The idea of NPWT is to separate infection treatment from reconstruction. But when has the infection therapy been completed to such an extent that osteosynthesis of the sternum can be performed with foreign material? The aim of this retrospective analysis is to investigate this issue:

- (I) By means of NPWT when is the rehabilitation of the infection completed to such an extent that a chest wall reconstruction can be performed? Many of these decisions are sometimes made emotionally, as time slots in the surgical program must be found for the dressing changes for NPWT. It is therefore necessary to find objective criteria for the termination of NPWT.
- (II) Optimized antibiotic therapy after chest wall reconstruction for DSWI.

We present this article in accordance with the STROBE reporting checklist (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-2025-aw-2201/rc>).

Methods

This retrospective single center analysis was conducted at Augsburg University Hospital. Between 2014 and 2020, all consecutive patients who underwent cardiac surgery using extracorporeal circulation via median sternotomy with DSWI were identified and included in further analyses. In these patients, the wound was reopened and all osteosynthesis material was removed. Local NPWT was then established. A microbiological sample was taken during each procedure. Material obtained during wound debridement was sent for microbiological processing. The following criteria were considered for the termination of NPWT:

- ❖ Wound status: no necrotic or putrid material, wound completely covered by granulation tissue;
- ❖ Microbiology: sterility;
- ❖ Secretion volume: <200 mL over 3 days;
- ❖ Inflammatory parameters [leukocytes below 10,000/ μ L and C-reactive protein (CRP) <10 mg/dL].

The aim was to achieve sterility. If eradication of coagulase-negative staphylococci (almost exclusively *Staphylococcus epidermidis*) was not possible despite multiple dressing changes, but all other factors applied, the negative pressure therapy was discontinued. However, the prerequisite for this was that no gram-negative bacteria were present.

Highlight box

Key findings

- Microbiologic sterility should be the aim of infection treatment in deep sternal wound infection (DSWI), but cannot be achieved in all cases.
- Reinfection is more frequent with remaining pathogens at wound closure.

What is known and what is new?

- Negative pressure wound therapy (NPWT) is a central element of infection treatment in DSWI.
- Cessation criteria for NPWT are not clearly defined.

What is the implication, and what should change now?

- NPWT should not exceed more than 10 changes to achieve sterility.
- Individual risk factors must be taken into account for NPWT duration and the time for wound closure.
- Anti-infective therapy should be administered for 6 weeks, if osteomyelitis is histologically proven.

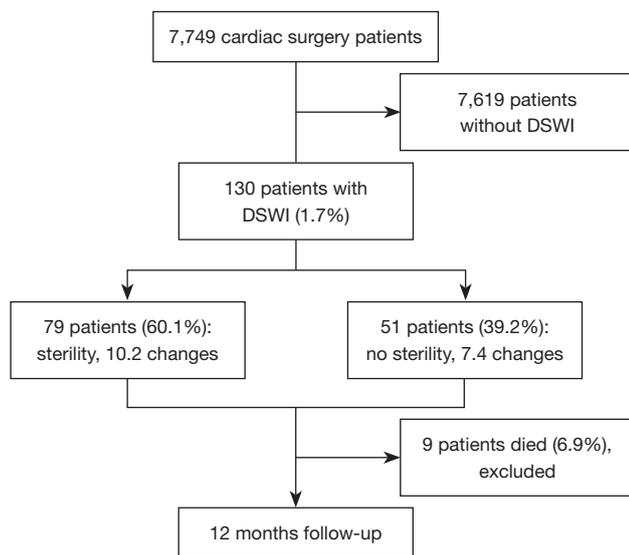


Figure 1 Patient selection and follow-up. DSWI, deep sternal wound infection.

If these conditions were met, a chest wall reconstruction was performed. For this purpose, the sternal halves were freshened and the edges straightened with an oscillating saw. Bone samples were sent for histological processing with the question of osteomyelitis. Some of the bone material was also sent for microbiological examination. The sternum was always stabilized. The osteosynthesis was covered with a bilateral pectoralis muscle displacement plasty. The skin was always closed without tension. Antibiotics were administered as follows:

In the initial inflammatory phase, all patients received an initially calculated and then test-appropriate antibiotic treatment. After normalization of inflammation criteria, this was discontinued. Only in the presence of gram-negative bacteria a test-based antibiotic treatment was continued. During chest wall stabilization, all patients received perioperative prophylaxis. This was a cephalosporin in accordance with in-house recommendations. In 28 patients, extended perioperative antibiotic therapy was carried out for 5 days with daptomycin. In the remaining patients, test-based antibiotics were only administered for 6 weeks if osteomyelitis was detected. Antibiotic management was guided by a multidisciplinary team that included an infectious disease specialist, in line with the principles of antibiotic stewardship.

The duration of the follow-up phase was at least 12 months. Here, a renewed infection, a persistent infection or a cutaneous fistula were detected. The study was conducted

in accordance with the Declaration of Helsinki and its subsequent amendments. The study was approved by Ethics Committee of Ethikkommission bei der LMU München (protocol code 21-0861, 23.09.2021) and individual consent for this retrospective analysis was waived.

Statistical analysis

The quantitative data mentioned above were collected from the available patient records, microbiological smears, and surgical reports and were analyzed using SPSS V31 (IBM, New York, USA). The statistical tests included the χ^2 test, with statistical significance assumed at a P value <0.05. Kaplan-Meier curves were created for the absolute and relative number of dressing changes and wound debridements until definitive wound closure. All data could be obtained in the given period.

Results

During this period, out of 7,749 cardiac surgery patients $n=130$ patients with DSWI after cardiac surgery were identified (1.7%, see *Figure 1*). Based on the CDC classification, all 130 patients were classified as stage III DSWI, indicating mediastinal or organ/space involvement. According to the Pairolero classification, 20 patients (15.4%) were classified as type I (≤ 1 postoperative week), 98 patients (75.4%) as type II (2–6 postoperative weeks), and 12 patients (9.2%) as type III (>6 postoperative weeks). In 94 patients (72.3%), DSWI occurred during the primary hospital stay, whereas 36 patients (27.7%) were readmitted after temporary discharge. Overall, 9 patients (6.9%) died and were therefore excluded from further analysis and follow-up. All 130 patients were evaluated for endogenous and exogenous risk factors (*Table 1*).

Negative pressure therapy

After an average of 26 ± 55.6 days the DSWI became apparent. The median number of dressing changes was 6 (maximum 24). In 4 patients NPWT was only maintained for 3 days without any change. Due to the risk of harm to the right ventricle or bypass grafts there was an immediate closure of the sternum. In 51 patients (39.2%) complete sterility could not be achieved despite several changes of the negative pressure therapy dressings as well as good coverage of the wound with granulation tissue. The predominant pathogen in these patients was *Staphylococcus epidermidis*.

Table 1 Endogenous and exogenous risk factors

Factor	Value
Endogenous risk factors	
Age (years)	67±15.2
Male: female	6.5:1
Obesity	109 (83.9)
BMI (kg/m ²)	29.51±4.69
Diabetes mellitus	46 (35.38)
Nicotine abuse	66 (50.77)
Postoperative delirium	53 (40.77)
Coronary artery disease	99 (76.15)
Exogenous risk factors	
CABG	84 (63.85)
CABG + AVR (mechanical)	14 (10.77)
ASD repair	2 (1.54)
MV replacement	1 (0.77)
AVR (mechanical)	5 (3.86)
AVR (bio)	7 (5.38)
MV repair	3 (2.31)
MV repair + TV repair	1 (0.77)
AAR	12 (9.23)
AAR + AVR (mechanical)	1 (0.77)
Incision-suture time (min)	183±46.75

Data are presented as mean ± standard deviation or n (%). AAR, ascending aorta replacement; ASD, atrial septal defect; AVR, aortic valve replacement; BMI, body mass index; CABG, coronary artery bypass graft; MV, mitral valve; TV, tricuspid valve.

Microbiology

In the majority of patients 114 (87.69%) the swabs were positive for pathogens. Thirty-one (23.85%) patients developed sepsis during their hospital stay. In 95 (73%) the pathogen was *Staphylococcus epidermidis*, in 20 (15.38%) *Staphylococcus aureus*, in 8 (6.5%) *E. coli*, in 8 (6.5%) *E. faecalis*, in 7 (5.38%) *Enterobacter cloacae*, in 6 (4.62%) *Candida albicans*, *Staphylococcus capitis* and *Propionibacterium acnes*. The results are displayed in Figure 2. One hundred and seventeen (90%) patients received anti-infective therapy during local negative pressure therapy. Osteomyelitis was diagnosed histopathologically in 102 (78.5%) patients.

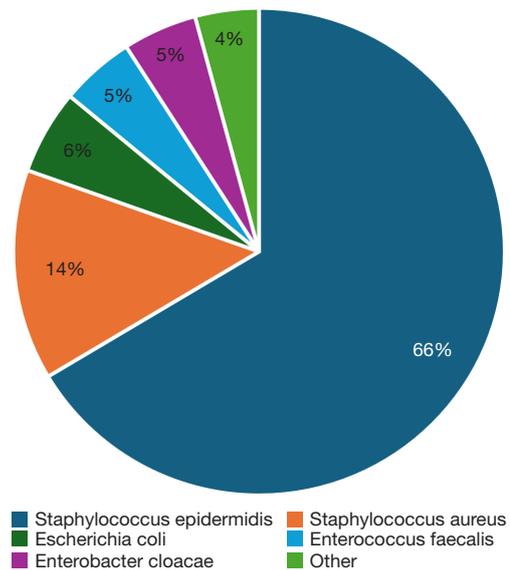


Figure 2 Pathogens at first diagnosis of deep sternal wound infection.

Consequences

The average length of stay for patients with DSWI was 60±22.5 days. Nine (6.9%) of the patients died in hospital. Three (33.33%) as a consequence of DSWI, 2 (22.22%) of sepsis, 1 (18.18%) of septic erosion of the left ventricle. Causes of death of the others not related to DSWI were trauma, asystole and hemorrhagic shock. Thirty (23.1%) developed a wound healing disorder again after sternal reconstruction. The spectrum of pathogens in the wound of these patients was mainly *Staphylococcus epidermidis*. Ten (7.69%) of these patients had other pathogens in addition such as *Propionibacterium acnes*, *Klebsiella oxytoca* and *Staphylococcus lugdunensis*.

In these patients all osteosynthesis material was removed 6 weeks after sternal reconstruction. Despite removal of the osteosynthesis material, all patients retained a stable sternum, none of them developed pseudarthrosis.

Statistics

Sterility was achieved in 79 patients with negative pressure therapy (60.8%). Here, 10.2±3.9 (mean ± standard deviation) changes of negative pressure dressing were performed (median 6). In 51 patients (39.2%), negative pressure therapy was terminated after 7.4±5.3 changes (median 6), although a pathogen still remained in the wound. The number of negative pressure dressing changes

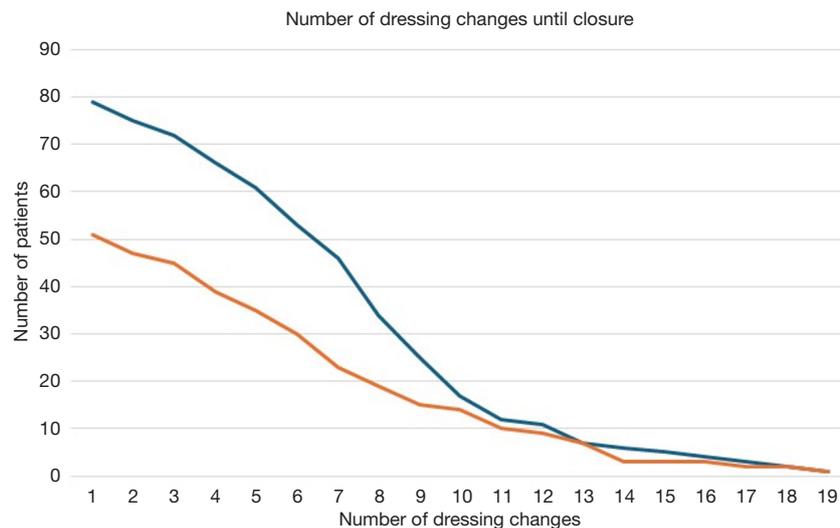


Figure 3 Kaplan-Meier curve: number of patients *vs.* number of dressing changes until closure. Blue, sterility at last dressing change; orange, no sterility at last dressing change.

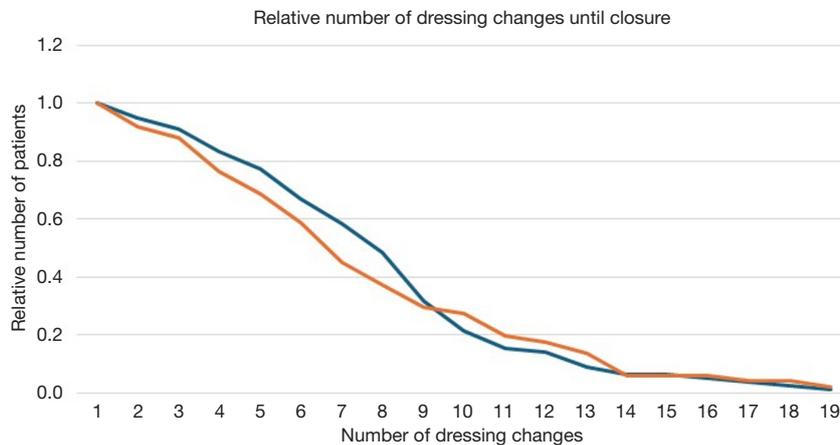


Figure 4 Kaplan-Meier curve: relative number patients *vs.* changes until closure. Blue, sterility at last dressing change; orange, no sterility at last dressing change.

was significantly lower in this group ($P < 0.001$). In *Figure 3*, Kaplan-Meier analysis is shown for the number of dressing changes per patient until closure of the wound. *Figure 4* shows the percentage of patients versus the number of changes in NPWT for both groups. The group in which a pathogen was detected in the wound during closure was initially closed more quickly. This was done because of the individual risk of serious complications such as bypass injury or ventricular arrosion. At 31.4%, the occurrence of a reinfection was significantly more frequent in the group with remaining pathogens in the wound at wound closure

than in the patients in whom sterility could be achieved (15.2%). The difference is significant $P = 0.03$ (χ^2).

Twenty-eight patients received daptomycin for 5 days perioperatively at closure. This group is compared to patients who received test-appropriate antibiotics for 6 weeks in case of osteomyelitis detection; 35.7% of patients in the daptomycin group had a recurrent or persistent infection. In contrast, only 17.6% of the patients in the group receiving test antibiotics had a recurrence or persistent infection. This difference was also statistically significant $P = 0.042$ (χ^2). Considering the very high rate

of persistent infections or reinfections in the daptomycin group, it had no influence in this group whether the closure was performed while there was still a bacterium in the wound or not ($P=0.31$).

Discussion

Several conclusions can be drawn or discussed from the results of this retrospective single center study. Two significant results will be discussed here: what is the effect of the number of changes of negative pressure therapy on the bioburden and which antibiotic regimen is appropriate for this.

The fact that negative pressure therapy should be used for DSWIs is well recommended in guidelines. It is also superior to other treatment regimens such as immediate sternal closure, irrigation-suction-drainage treatment or open wound therapy (8-10). It was seen early on as an important bridge in the treatment of infection between reopening the wound and sternal closure (11). And the importance of treating the infection as effectively and quickly as possible is also shown by the relevant number of sepsis patients in this study, including those who died. However, this therapy also carries risks. It can lead to serious complications. Here, too, a rupture of the right ventricle occurred during negative pressure therapy (12). This risk must be assessed with every dressing change, especially in the early phase, and if necessary, the therapy must be terminated and a sternal closure performed.

Therefore, the criteria for terminating NPWT need careful consideration, particularly as microbiological sterility could not be achieved in all patients prior to reconstruction. In our cohort, NPWT was generally discontinued when meeting the above-mentioned cessation criteria. However, sterility was not achieved in 39% of patients at the time of closure. In these cases, earlier reconstruction was deliberately chosen based on patient-specific risks. Prolonged NPWT or repeated dressing changes were considered potentially harmful, particularly with regard to right ventricular injury or graft adherence. In four patients, NPWT was therefore limited to three days without dressing changes, followed by immediate sternal closure. These decisions were guided by individualized risk-benefit assessment rather than microbiological criteria alone.

However, this study has also shown that sterility is more likely to be achieved with longer therapy. Considering the Kaplan-Meier curve, which shows the number of dressing changes until sternal stabilization, there is a turning point in

the curve around the tenth change. At this point, the curve becomes very flat. It can therefore be postulated that the optimum number of changes is between 6 and 10. However, it is worth waiting for this period, as the study showed that significantly more changes were necessary in patients with sterility. But these patients also had significantly fewer persistent infections. It must also be pointed out that no external constraints such as tightness of the surgical capacity should lead to early sternal closure. This is because the study also showed that a persistent bacterial load leads to increased persistent wound infections after sternal stabilization. It is also important that gram-negative bacteria in particular are eradicated, as these are responsible for a high risk of recurrence of the infection (13).

A therapy regime for treating these pathogens has not been investigated specifically for DSWIs. In the German S3 guidelines, anti-infective therapy together with surgical therapy is regarded as crucial. However, no studies can be found in the literature analyzing that call for a specific approach. The closest thing to a specific regimen for this entity is prophylaxis of the DSWI by eradication in the nose (14). There are studies that deal with the question of the choice of antibiotic but duration and indication are not investigated (15-17). The eradication of gram-negative specimen appears to be important (18). This is also required in this patient population. However, it is unclear whether antibiotics should be administered during closure and, if so, for how long. While commonly used, a 5-day perioperative antibiotic course was not associated with improved outcomes in our cohort and may need reconsideration. Daptomycin was used as a highly effective antibiotic, which is particularly effective against the remaining coagulase-negative staphylococci. A significantly better regimen is the treatment of histologically proven sternal osteomyelitis for 6 weeks. This regimen has shown superiority to the short-term use of even highly effective antibiotics. A limitation of this comparison is that prolonged (6-week) antibiotic therapy was reserved for patients with histologically confirmed osteomyelitis, rendering the short- and long-term groups not fully comparable.

Our findings should be viewed in regard to recent work on the management of DSWI, particularly the timing of NPWT, microbiological control, and the risk of recurrence. NPWT is an effective tool for stabilizing the wound, but prolonged use without timely reconstruction may allow infection to persist. Saltarocchi *et al.* reported that delayed wound management, prolonged hospitalization, and ongoing microbial colonization are associated with higher

reinfection rates in complex postoperative wounds (19). These observations are in line with our own results, which show that persistent bacterial colonization at the time of closure strongly predicts recurrence. Taken together, the evidence suggests that NPWT should be used as a temporary bridge, and that definitive sternal reconstruction should be performed only after adequate infection control has been achieved. This approach aims to avoid chronic infection and reduce the risk of recurrent DSWI after reconstruction.

Conclusions

In summary, the following additions can be made to the above criteria for termination of NPWT and sternal closure:

- ❖ The NPWT should aim for sterility but should not exceed 10 changes.
- ❖ The individual risk must be taken into account each time NPWT is changed.
- ❖ Anti-infective therapy should be carried out for 6 weeks in accordance with the recommendation for osteomyelitis if osteomyelitis is histologically proven.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at <https://jtd.amegroups.com/article/view/10.21037/jtd-2025-aw-2201/rc>

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Ethical Statement: The authors are accountable for all

aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The study was approved by Ethics Committee of Ethikkommission bei der LMU München (protocol code 21-0861, 23.09.2021) and individual consent for this retrospective analysis was waived.

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