Negative pressure wound therapy for the treatment of sternal wound infections after cardiac surgery

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Abstract

We retrospectively collected and analysed data from patients with sternal wound infections between 1995 and 2001, which were treated with different wound management strategies, and compared them with our patients from 2002 to 2011, who were treated with the sternal negative pressure wound therapy (NPWT). From 1995 to 2001, a total of 198 patients (group A) with a mean age of 65 ± 10 years developed sternal wound infection (67% deep) after cardiac surgery. Wound management consisted of surgical debridement and immediate sternal closure or open packing. From 2002 to 2011, a total of 326 patients (group B) (71% deep) were managed with NPWT at the time of surgical debridement. Total mortality was 10% in group A and 3.6% in group B. Recurrence rates were 34 and 8.5%, respectively, for the groups A and B. The meantime of NPWT was 11 days. In group B patients, 75% proceeded to sternal closure. With the introduction of NPWT, the treatment of sternal wound infections could be substantially improved. Particularly, the high recurrence rates could be minimised; furthermore, the goal to salvage the sternal bone is facilitated.

Key Messages

- sternal wound infections are a feared complication after cardiac surgery with an incidence between 1–5%
- before initiation of NPWT treatment consisted of open packing or immediate muscle flap closure, associated with a recurrence rate of 35%
- with NPWT recurrence rate could be reduced to 8.5% with a substantial shortening of therapy duration
- NPWT is effective and has a low complication rate

It is our intention here to critically evaluate our data and compare it with the wound therapy strategies used previously, in order to maintain the high standard of care for our patients.

Materials and methods

Pre-NPWT group (conventional treatment group)

We retrospectively reviewed our data before the NPWT era, which was from 1998 to 2005.
From 1995 to 2001, a total of 142 patients developed a sternal wound infection after cardiac surgery. During this 7-year period, a total of 5600 cardiac operations have been performed at our department, resulting in an overall incidence of 2.5%. The mean Euro score in this population was calculated as 3 ± 3.

From November 2001 until 2005, as some surgeons were still reluctant to use NPWT, we had the opportunity to directly compare the two treatment methods. In this period, 56 patients were treated in the conventional way. Therefore, we have in total 198 patients treated conventionally, with a mean age of 65 ± 10 years (ranging from 33 to 82) with a female to male ratio of 39–61% (Table 1).

**Definition of sternal wound infection**

Defined by center of disease control (CDC) criteria 33% had a superficial infection, whereas 67% exhibited a deep sternal infection with involvement of the sternal bone and mediastinum (20).

The mediastinitis cases were further classified on the basis of El Oakely et al. suggestions (20):

- Type I 8%
- Type IIIA 47%
- Type IIIB 3%
- Type IVA 22%
- Type IVB 19%

**Therapy**

Treatment included surgical debridement with continuous or frequent irrigation, open wound packing with subsequent secondary closure or plastic surgical reconstruction with muscle flaps as secondary closure or immediately at the time of debridement.

**Antibiotic therapy (similar for both groups)**

Perioperatively, the following was given 30 minutes before skin incision, at the end of cardio pulmonary bypass (CPB) and 8 hours postoperatively:

- 2000–10/2002 cefazolin 3000 mg
- 10/2002–4/2003 trimetroprim and cotrimoxazol 250 mg
- 7/2004–until now cefazolin 3000 mg

In the case of infection, we routinely commenced vancomycin or teicoplanin after obtaining bacterial cultures. Thereafter, the regimen was adapted according to bacterial sensitivity.

The bacterial results are depicted in Table 2.

**NPWT group**

From 2002 to June 2011, a total of 326 patients exhibited a sternal wound infection. In these 10 years, a total of 10 000 cardiac operations were carried out, which led to an overall incidence of 3.2%.

According to the CDC criteria, 93 patients (29%) exhibited a superficial infection, 228 patients (71%) exhibited a deep infection and 75 patients (19%) received NPWT perioperatively for delayed sternal closure.

Oakley classification was as follows:

- Type I 2%
- Type II 1%
- Type IIIA 69%
- Type IIIB 8%
- Type IVA 19%
- Type V 2%

The onset of infection was after a mean of 13 ± 8 days after surgery.

The preceding operative procedures were aorto-coronary artery bypass in 204 patients (62%), valve repair or replacement in 127 patients (39%) and others (congenital surgery, aortic surgery and heart transplantation) in 54 patients (17%). Combined procedures were performed in 81 patients (25%).

Risk factors predisposing to wound problems postoperatively were present as follows: chronic obstructive pulmonary disease (COPD) in 19% of the patients, diabetes in 30% of the patients and a body mass index over 30 in 21% of the patients.

The mean Euro score for this group was calculated as 6 ± 4.

All patients were treated with the VAC system (KCI Int, San Antonio, TX).

**Table 1 Patient data comparison**

<table>
<thead>
<tr>
<th></th>
<th>Pre-VAC</th>
<th>VAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>198</td>
<td>326</td>
</tr>
<tr>
<td>Mean age</td>
<td>65 ± 10</td>
<td>62 ± 16</td>
</tr>
<tr>
<td>Incidence of infection</td>
<td>2.5%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Euro score</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Oakley 2A</td>
<td>33%</td>
<td>29%</td>
</tr>
<tr>
<td>Oakley 2B</td>
<td>67%</td>
<td>71%</td>
</tr>
<tr>
<td>Recurrence rate</td>
<td>34%</td>
<td>8.5%</td>
</tr>
<tr>
<td>Mortality</td>
<td>10%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Costs/pat</td>
<td>17 000 USD</td>
<td>11 000 USD</td>
</tr>
</tbody>
</table>

VAC, vacuum-assisted closure.

**Table 2 Bacterial culture results**

<table>
<thead>
<tr>
<th>Bacterial culture</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus epidermidis</td>
<td>32%</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>21%</td>
</tr>
<tr>
<td>Coagulase negative Staphylococcus</td>
<td>12%</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>9%</td>
</tr>
<tr>
<td>MRSA</td>
<td>7%</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>7%</td>
</tr>
<tr>
<td>Enterobacter cloacae</td>
<td>4%</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>4%</td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
<td>2%</td>
</tr>
<tr>
<td>Serratia marcescens</td>
<td>1%</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>1%</td>
</tr>
</tbody>
</table>
VAC implantation technique

Whenever a patient was suspected as having a sternal wound infection, treatment was straightforward with opening of the wound under aseptic conditions in the operating theatre, under general anaesthesia. When an infection was confirmed, the viability of the sternal bone was checked. If an involvement of the sternal bone or sternal instability was evident, wire removal is indicated. After careful evaluation of the mediastinum, bacterial cultures as well as bone biopsies in cases of suspicion regarding the viability of the sternal bone were taken. Subsequently, debridement with resection of all non-viable tissue was performed.

Thereafter haemostasis was obtained. In case of incomplete pericardial adaption, a single layer of a non-adherent open foam dressing as Mepitel (Mölnicke health Care, Sweden) was applied to avoid direct contact with the heart surface. The reason was to provide a movement between the sponge and the underlying structures and secondly to avoid the formation of adhesions between the heart and the sternal edges. It is therefore crucial to free the sternal edges from adhesions at the time of VAC implantation, and to prevent the sternal edges rubbing onto the right ventricle.

Thereafter, a piece of VAC sponge (KCI Inc) was cut and fitted between the sternal edges to prevent shear forces between the bony edges and the underlying right ventricle. A larger sponge was then fitted into the wound, which had to be clearly oversized to provide back-up when the patient is mobile.

After placing the adhesive drape in stripes for better fitting, two VAC pads were installed proximal and distal and connected with the Y piece, to achieve a more uniform distribution of the vacuum and to increase thoracic cage stability.

In cases of open sternum, continuous suction with 125 mmHg was used. In superficial cases, we started with 125 mmHg or in patients <60 kg, 100 mmHg continuous mode and changed to intermittent when the granulation tissue in growth was delayed (see details in Appendix A).

Patients were extubated in the operating theatre and were transferred to the regular ward between 2 and 4 hours after surgery. Mobile patients were allowed to move without restrictions, taking the VAC with them. Every 48 to 72 hours, the VAC system was changed under aseptic conditions in the operating theatre. After removal of the old dressing, the wound condition was assessed and new material for bacterial cultures was routinely taken. The necrotic tissue was then debrided. Requirements for VAC removal and employment of definitive surgery were as follows: decline of serological inflammation parameters, negative bacterial cultures and resolution of local infection signs in the wound.

For inclusion, exclusion and explanation criteria see Appendix A: guidelines.

Statistical methods

Statistical procedures were carried out by using Sigma Stat 3.1 (SPSS Inc, Chicago, IL). Data are expressed as means ± SD. Univariate analysis (ANOVA) was followed by the independent sample t-test and the Mann–Whitney U-test was used as necessary for statistical evaluation of the data.

Results

Pre-NPWT group (conventional treatment group)

The mortality in this group was 10% (n = 15), in the majority of cases owing to sepsis.

From the 142 patients, 91 (64%) needed a surgical revision; the rest were treated with local therapy only.

However, 48 patients (34%) needed a second revision, 21 (15%) needed a third and 15 patients (8%) needed four or more revisions, due to recurrence and other wound-related problems which resulted in an exceedingly high recurrence rate of 34% (47/142).

Unfortunately, we were not able to retrieve accurate data for the therapy duration and hospital stay in this group. However, considering that the average patient had 2.5 revisions, we can arrive at a therapy duration of at least 20 days and hospital stay of 24 days.

NPWT group

The mean time of NPWT therapy was 11 ± 8 days with 2.8 ± 1.7 for dressing changes.

The overall recurrence rate was 8.5% with 24 patients developing a recurrence of infection. However, when reviewing these cases possible reasons of failure could be:

- Unseen abscess formation in the third right rib, n = 1.
- No VAC implantation at the first time of surgical debridement and revision, n = 5.
- No appropriate sternal closure, n = 8.
- Unknown osteomyelitis, n = 1.
- Too early VAC implantation and secondary closure, n = 6.
- Not known allergy to the sternal wires, n = 1.
- Not opening of the entire wound at the time of VAC implantation, n = 6.

Regarding sternal wound closure, the intention was to save the sternal bone whenever possible.

A primary closure was possible in 246 patients (79%), whereas 68 patients (21%) were referred to plastic reconstructive surgery owing to the inability to salvage the sternal bone. In all the patients who received a perioperative VAC, a primary sternal closure was possible. In 80% of these patients normal steel wires were used or secondary closure, in the remainder the osteosynthesis system from Synthes Europe (Zuchwil, Switzerland) or the Sternal Talon system (Martin Inc, Tuttlingen, Germany) was used.

Mortality

Total mortality in this cohort was 3.6% (12/326), none was related to the VAC use but was mostly due to sepsis in four patients (patient was referred too late for revision) or cardiac-related in the remainder.
Mean hospital stay for the entire group was 22 ± 19 days, which was prolonged by 14 days through the wound infection. Patients were admitted to the intensive care unit (ICU) after VAC implantation, only if their hemodynamic situation was unstable through sepsicaemia caused by the surgical debridement, which was the case in only a few patients.

**Adverse events and treatment safety data**

During the entire study period, we experienced no VAC-related complications or adverse events. There were no bleeding episodes (defined as a decline in haemoglobin of more than 2 mg/dl over 4 hours) or pericardial pressure with hemodynamic compromise: seen as central venous pressure (CVP) rise, RR decrease, tachycardia and especially no ventricular laceration or rupture.

**Risks associated with NPWT therapy in clinical practice**

We encountered the following risks during VAC therapy, all of which could be handled in the ward by our trained nurses and physician staff:

- Disconnecting of the trac pad
- Loosening of drape
- Empty battery of the VAC pump
- Breakage of connection seals

The patients were also made aware of the above risks and the importance of continuous negative pressure was explained to them.

In patients with disorientation, adequate fixation of the VAC had to be ensured.

**Discussion**

The development of sternal wound infections has two distinct pathways. Either the infection starts as osteomyelitis in a localised part of the bone with minimal or no external signs, followed by sternal instability and subsequent skin breakdown. Others hypothesise that sternal instability occurs first, followed by skin breakdown and contamination of bacteria from the outside, which initiates infection (2,3).

For the consistency of reporting and comparing data, the definition and criteria of sternal wound infection should be uniform.

The CDC criteria divide surgical site infections into three groups (superficial, deep and organ space) (20).

We, as well as others mainly rely on the definition by the CDC as well as the Oakley classification, which elaborate sternal wound infections in detail; this facilitates data comparison (21).

In brief, the Oakley classification is outlined as:

- Type 1: mediastinal dehiscence without infection.
- Type 2A: superficial infection confined to the subcutaneous layer.

Type 2B: deep infection with involvement of the sternal bone and eventually the mediastinum (this is further divided into five mediastinitis subtypes depending on the onset of infection and the presence of risk factors) (21).

NPWT with the VAC system for sternal wounds has been used extensively in clinical practice at the Department of Cardiothoracic Surgery, Medical University of Vienna, Austria, since 2001. Furthermore, a large number of publications, both clinical and experimental, have been published in scientific journals during the last years (4,10–19).

With the implementation of NPWT for the treatment of sternal wound infections, we were able to substantially improve our results. Not only the mortality, the recurrence rates also could be decreased significantly. The therapy duration in conjunction with a shorter hospital stay led to a decrease in costs. Our pre-VAC data are in accordance with a report by Eklund *et al.* who used the same treatment methods and had to operate the patients between two and five times with an average hospital stay of 1 month (1).

Recurrence rates were 34 and 8.5%, respectively, for the pre-NPWT and NPWT group. As the high recurrence rate in the pre-NPWT group has already been published by us previously, we now tried to evaluate the causes for recurrence in the NPWT group in order to optimise the results.

We also believe that we can lower the recurrence rate in the NPWT group with appropriate management, as the causes for recurrence were mostly improper management, which in turn was based on not having enough experience in treating this entity. Therefore, we now emphasise on training in VAC implantation, change and secondary closure for all new colleagues as well as uniform guidelines for all to follow (Appendix I). Owing to our strict policy of early recognition and aggressive treatment with opening of the entire wound, we were able to improve our previous recurrence rate from 11% to now 8.5% (14).

Total mortality was 10% in the pre-NPWT group and 4.7% in the NPWT group which proves the known benefits of NPWT (21). Nearly all patient deaths in the pre-NPWT group were because of mediastinitis, whereas in the NPWT group it was predominantly caused by cardiac failure.

The cost of treating a sternal wound infection before the VAC was 17 000 USD per patient, which summarise to around 8000 USD for VAC rent, 2600 USD for surgery costs, and 7800 USD for 14 days hospitalisation (4,18). NPWT is cheaper and more efficient and therefore shorter hospitalisation.

This is in accordance with a recent paper by Jenney *et al.* who calculated the costs of surgical site infections after coronary artery bypass surgery in Australia (5).

We have previously shown that the cost of treating a sternal wound infection with VAC therapy is 11 000 USD, which includes 800 USD for VAC rent, 2600 USD for surgery costs, and 7800 USD for 14 days hospitalisation (4,18). NPWT is cheaper and more efficient and therefore shorter hospitalisation.

The organs in the mediastinum are crucial in terms of hemodynamic function and eventual compromise. Therefore in NPWT of sternal wounds, unlike as in other wounds, one has to consider the potential effect on the heart, bypass grafts and thoracic stability as well as respiratory function. The
best way to prevent complications associated with the use of the VAC system in clinical practice is proper training of all the persons involved in the treatment of sternal wound infections. Fortunately, following this policy, so far, we have encountered no major adverse events related to NPWT, but we are particularly aware of the potential risk of right ventricular rupture during NPWT (see Appendix I for guidelines).

Fuchs et al. published an interesting study where they compared their experience with VAC and conventional treatment. They are in accordance with the therapy duration and mortality rate. They experienced one fatal complication which was due to absence of underlying dressing layer. Furthermore, they also suggest that training with VAC is mandatory for proper handling and prevention of complications (6).

Regarding the ideal pressure one has to consider that low pressures provide insufficient thoracic stability which leads to shear forces of the sternum down towards the right ventricle, which increases the risk of bleeding and laceration of the right ventricle. More important than weight and body surface area is the anatomical shape of the thorax as it determines the amount of foam that has to be implanted. Oversizing plays an important part in the sternal dressing, as there has to be a reserve when the patient moves. Optimisation of the sizing, training and understanding of the special mechanism of the VAC is crucial for success (15).

Furthermore, shear forces of the sternal edges are very painful for the patient. If the dressing is appropriate, a patient on VAC feels no pain.

One of the significant advantages of the VAC system is that the patient can be mobilised with the VAC in situ, as it stabilises the splinted sternum. With this the risks of immobilisation, such as pneumonia, thrombosis and muscle atrophy, are efficiently prevented (10,15,22).

As effective prevention strategies for ventricular tears and bleeding we use the combination of technique training, using an underlying dressing layer, freeing the edges of the sternum from adhesions and meticulous haemostasis, with pausing platelet inhibitors during VAC therapy as the mainstay of ensuring the safety during sternal VAC therapy (14–16).

When we look into literature regarding complications associated with the use of NPWT we usually find the cause as lack of knowledge and training. For example, Yi et al. report a ventricular rupture during VAC therapy. The reason for this is easy to identify: they used intermittent mode. They also encountered some bleeding complications. The reason for that was no underlying dressing layer as well as no sufficient foam oversizing, which can be deduced as they cite that the patients were coughing repeatedly, which is indicative of insufficient thoracic stability (8).

In a report by Gdalevitch, we also see examples of lack of knowledge as they did not perform any surgical debridement at the time of VAC implantation, which led to positive blood cultures and a VAC duration of 27 days. Nevertheless, they correctly reflect that bacteraemia might indicate inadequate debridement, which is mandatory before VAC implantation (23).

Encouraging results were also obtained in our heart transplant recipients (12). Especially in these patients, there was special concern regarding the effects of immunosuppression on the wound healing. With VAC therapy, we saw an adequate reaction in terms of infection decline and wound improvement, without any reduction in immunosuppression, which is favourable, as it does not increase the risk of rejection.

Conclusion

With the introduction of NPWT the treatment of sternal wound infections could be substantially improved during the last few years. Particularly, the high recurrence rates can be minimised, and furthermore, the goals to salvage the sternal bone are facilitated by NPWT. However, especially in a high volume centre as ours, certain guidelines in treating patients with wound infection have to be determined and followed in order to ensure the best outcome with excellent survival and low rate of therapy failure.

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References