Negative-pressure wound therapy following cardiac surgery: bleeding complications and 30-day mortality in 176 patients with deep sternal wound infection

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Abstract

Negative-pressure wound therapy (NPWT) has been used for the treatment of deep sternal wound infection (DSWI) with promising results. However, questions have been raised regarding the potential risk of right ventricle (RV) rupture during treatment. In the present study, we evaluate our clinical experience of NPWT focusing on RV rupture and major bleeding complications and its potentially negative impact on 30-day mortality during an 11-year period. Serious bleeding complications during NPWT were reviewed for 176 patients treated for DSWI between January 1999 and April 2010. The 30-day mortality following DSWI was 1.1% (2/176). Four patients (2.3%) suffered bleeding from the RV rupture during NPWT of the sternal wound (two spontaneous and two debridement related). Furthermore, two patients had debridement-related bleedings from the venous bypass grafts during wound dressing change. The very low 30-day mortality (1.1%) following DSWI supports the use of NPWT. Overall, even if major bleeding complications may occur, the risk of RV rupture seems to be outweighed by the benefit of superior infection control. However, surgical experience is recommended when debriding sternal wounds and we recommend the use of a wound dressing, such as paraffin gauze, in order to protect the RV from direct contact with the polyurethane foam.

Keywords: Wound infection; Sternum; Negative-pressure wound therapy; Outcome

1. Introduction

Deep sternal wound infection (DSWI) following cardiac surgery is a devastating, and potentially life-threatening complication. The early mortality is reported to be 19–25% when using conventional treatment, such as mediastinal irrigation and soft tissue flaps [1, 2]. Negative-pressure wound therapy (NPWT), also known as vacuum-assisted closure, is a modern and innovative wound therapy, which has been used successfully in DSWI treatment for a decade [3]. However, questions have been raised regarding the risk of right ventricle (RV) rupture and other bleeding complications that may be related to this technique.

There may be several co-existing conditions during DSWI, such as RV ischemia, RV dilation, severe tissue inflammation, and surgical trauma, which may cause spontaneous RV rupture [4]. RV rupture is a well-known, and potentially fatal, complication reported to occur in 5–21% of patients undergoing conventional treatment for DSWI [5–8]. However, the published data on major bleedings and RV rupture when using NPWT in DSWI is relatively scarce [9–11].

The main objective of our study was to evaluate the risk of RV rupture in our 11 years’ clinical experience of NPWT for DSWI and to assess the impact of major bleeding complications on the overall 30-day mortality.

2. Material and methods

All 176 patients treated with NPWT for culture-verified DSWI during the period January 1999–April 2010 were retrospectively reviewed with regard to RV rupture and other major bleeding complications with occurred during NPWT and within 30 days of sternal closure. Complications and variables were collected from both medical records and the department’s computerized database. During the study period 13,530 patients underwent open heart surgery at the Department for Cardiothoracic Surgery in Lund giving an incidence of 1.3% for DSWI. DSWI was diagnosed prior to discharge or after re-admission from the referring hospital. The length of hospital stay for DSWI was calculated after the onset of DSWI, if it occurred during the same period of hospitalization as the initial cardiac surgery, or the period of hospitalization following the separate re-admission for DSWI. The protocol for the present study was approved by The Ethics Committee for Clinical Research at Lund University, but since no individual patients were identified the need for individual consent was waived.

During the study period NPWT (V.A.C.*, KCI Inc, San Antonio, TX, USA) was employed as a single-line therapy
for DSWI followed by sternal re-wiring without the use of additional tissue flaps [12]. All patients treated with NPWT at our department were diagnosed according to the CDC (Center for Disease Control and Prevention) Guidelines and as an additional criterion, in order to ensure DSWI and not only sternal rupture, bacterial growth was verified by tissue cultures in all patients.

2.1. Wound debridement and foam change during NPWT

All DSWI-related surgery (the initial revision of the wound including initiation of NPWT, the following wound debridements including changing the polyurethane foam, and the final re-wiring of the sternum) was performed in the operating theatre under general anesthesia. Adherences between the sternal edges and the underlying tissue were divided and four layers of paraffin gauze (Jelonek®, Smith and Nephew Medical Ltd, Hull, UK) were placed at the bottom of the wound covering the RV, bypass grafts, and visible lung tissue. A polyurethane foam dressing (GranuFoam, KCI Inc, San Antonio, TX, USA) was placed between the sternal edges and a second layer of polyurethane foam was placed subcutaneously. Finally, the wound was sealed with a transparent adhesive drape (KCI Inc, San Antonio, TX, USA) and connected to a continuous negative-pressure source (–125 mmHg) (KCI Inc, San Antonio, TX, USA).

Major bleeding was defined according to Yellin and coworkers, i.e. bleeding that occurred during or after operation for DSWI from the heart, great vessels, or grafts, or bleeding requiring urgent exploration [5]. Follow-up was performed in May 2010 and included a total of 739 patient-year (mean 4.2 ± 2.7; range 0–11.3 years). No patient was lost to follow-up. Data on mortality during the follow-up period were provided by The National Board of Health and Welfare in Sweden.

3. Results

The overall 30-day mortality (following sternal re-wiring) was 1.1% (2/176) when using NPWT for culture-verified DSWI. NPWT procedural data is presented in Table 1. The mean age of the patients studied was 70.2 ± 9.5 years (median 72; range 48–89 years): 141 were men (80%) and 35 were women (20%). The primary cardiac surgery performed was coronary artery bypass grafting (CABG) with or without concomitant procedures in 84% (147/176) of the study population. The other cardiac surgery procedures were aortic valve replacement (n = 11), Bentall procedures (n = 3), aortic valve repair (n = 2), aortic dissection type A surgery (n = 2), aortic arch reconstruction (n = 1), mitral valve replacement (n = 1), mitral valve repair (n = 1), pulmonary outflow tract reconstruction (n = 1), Ross procedure (n = 1), Maze procedures (n = 1), cardiac myxoma (n = 1), re-do surgery (n = 1), and heart transplants (n = 3).

3.1. Major bleeding complications

RV rupture occurred in four patients (2.3%), Table 2. In the two patients with debridement-related bleedings the tear in the RV was small and repaired by direct suturing without extra-corporeal circulatory support (Table 2). One patient had spontaneous bleeding in the intensive care unit following a severe cough and the RV was emergently repaired in the operating room with extra-corporeal circulatory support via femoral cannulation. However, the patient succumbed three days later due to multiple organ failure. One patient had spontaneous RV rupture during NPWT, but the bleeding was limited to a hematoma and could be controlled with direct suture without extra-corporeal circulation (ECC). Furthermore, two patients (2/176; 1.1%) suffered bleeding from a bypass venous graft related to surgical debridement and wound dressing change. In one of these patients the bleeding was managed with direct suture, but in one case ECC via femoral cannulation had to be used in order to safely control the bleeding.

4. Discussion

The risk of major bleeding during conventional treatment for DSWI is reported to be 5–21%, and the corresponding rate of mortality in these cases varies between 15% and 50% [5–8]. Leaving an unstable sternum open for debridement and packing is especially hazardous as ruptured steel wires or sharp bony fragments may rupture bypass grafts or the RV [8, 13]. In the present study, four of 176 patients (2.3%) suffered RV rupture during NPWT, which is similar to a previous study by Ennker et al. reporting RV rupture

**Table 1. NPWT data during the treatment of DSWI in 176 patients**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± S.D.</th>
<th>Median</th>
<th>Range</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac surgery to DSWI (days)</td>
<td>16.3 ± 13.8</td>
<td>14</td>
<td>3–117</td>
<td>–</td>
</tr>
<tr>
<td>Duration of NPWT (days)</td>
<td>11.9 ± 7.1</td>
<td>10</td>
<td>1–66</td>
<td>2089</td>
</tr>
<tr>
<td>NPWT-related debridements</td>
<td>3.9 ± 1.8</td>
<td>4</td>
<td>1–17</td>
<td>679</td>
</tr>
<tr>
<td>Total length of hospitalization (days)</td>
<td>23.8 ± 14.2</td>
<td>20</td>
<td>5–103</td>
<td>–</td>
</tr>
</tbody>
</table>

*Continuous variables are expressed as the mean ± standard deviation (S.D.). NPWT, negative-pressure wound therapy; DSWI, deep sternal wound infection.

**Table 2. Cases of right ventricle bleeding during NPWT for DSWI, 1999–2010**

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex/age</th>
<th>Previous surgery</th>
<th>Cause of RV bleeding</th>
<th>Day of NPWT</th>
<th>Type of repair</th>
<th>ECC</th>
<th>NPWT continued</th>
<th>Results 30 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/68</td>
<td>CABG</td>
<td>Revision-related</td>
<td>Day 7</td>
<td>Direct suture</td>
<td>No</td>
<td>Yes, sternum closed 12 days later</td>
<td>Alive</td>
</tr>
<tr>
<td>2</td>
<td>F/72</td>
<td>CABG</td>
<td>Revision-related</td>
<td>Day 10</td>
<td>Direct suture</td>
<td>No</td>
<td>Yes, sternum closed five days later</td>
<td>Alive</td>
</tr>
<tr>
<td>3</td>
<td>M/77</td>
<td>CABG</td>
<td>Spontaneous</td>
<td>Day 2</td>
<td>Direct suture</td>
<td>Yes</td>
<td>Gore-Tex patch</td>
<td>Dead (3 days)</td>
</tr>
<tr>
<td>4</td>
<td>M/77</td>
<td>CABG</td>
<td>Spontaneous</td>
<td>Day 2</td>
<td>Direct suture</td>
<td>No</td>
<td>No, sternum left open with Gore-Tex patch and closed five days later</td>
<td>Alive</td>
</tr>
</tbody>
</table>

NPWT, negative-pressure wound therapy; DSWI, deep sternal wound infection; RV, right ventricle; ECC, extra-corporeal circulation; F, female; M, male; CABG, coronary artery bypass grafting.
in 1/54 (1.9%) of their NPWT-treated DSWI population [14]. The majority of patients (84%) in our study population underwent CABG, this finding corresponds to a recently published study with NPWT in poststernotomy mediastinitis [15]. The relatively higher incidence of DSWI in patients undergoing CABG is probably explained by the presence of well-known factors for poor wound healing, such as diabetes mellitus, obesity, peripheral vascular disease, and chronic obstructive pulmonary disease (COPD).

Adopting NPWT in a structured approach for DSWI, as suggested by us previously (Lund University Hospital Mediastinitis algorithm), necessitates several surgical debridements in the operative theatre [12]. However, one should bear in mind that even in conventional techniques repeated surgical procedures are relatively frequent [3]. The number of NPWT-related operations in the present study was 3.9 ± 1.8 (median 4) which included one initial NPWT-operation, two debridements/dressing changes, and the final secondary wound closure. This finding is similar to a previously published report by Petzina et al. [15]. One could hypothetically argue that the number of wound debridements may be a risk for iatrogenic bleeding complications, or that a prolonged wound treatment time (11.9 ± 7.1 days with NPWT) would increase the risk of RV rupture. However, when looking at the 30-day mortality data, the risk of revision-related bleedings or the possible risk of ventricle rupture, seem to be outweighed by the advantages in microbiological control and repeated surgical revisions. Multiple microbiological testing facilitates optimal antibiotic therapy while repeated debridements offers a major advantage in surgical control of DSWI with the possibility of step-wise removal of necrotic tissue. Furthermore, during NPWT the sternum is splinted by the foam dressing which facilitates early mobilization and physiotherapy in the ward and reduces additional infectious complications, such as pneumonia.

As previously stated, special attention should be directed to the left and right hemisternum and their relationship to the RV when applying NPWT [12]. We agree with previous authors recommending thorough lysis of adherences between the sternal edges and the anterior surface of the RV [6, 8]. Furthermore, we separate underlying structures from the sternal edge with four layers of paraffin gauze each time the foam dressing is changed. We have used paraffin gauze as a heart-protecting barrier with dual action: it reduces the formation of adherences between the sternum and the RV and it also reduces the negative-pressure acting on the surface of the heart. In order to further minimize the risk of rupture during sudden episodes of excessive shearing forces we apply an elastic corset during NPWT which stabilizes the chest [12]. In concordance with the findings presented by Abu-Omar et al. [9], we believe the use of a soft corset is important, especially in patients with risk factors for RV rupture, such as severe obesity or high-risk of postoperative coughing, i.e. those with COPD [7, 9].

4.1. Limitations of the study

One limitation of the study is the retrospective design, however, we believe that our 11 years’ experience add significant scientific value to the cardiothoracic community since we defined our treatment algorithm in the beginning of the study. Furthermore, one should bear in mind that a prospective, randomized design may cause practical problems since only four of 176 patients suffered RV rupture during NPWT. In order to achieve sufficient power in a randomized study between NPWT and conventional treatment one would have to include a very large number of patients in the parallel study arms. The time perspective for this study design would therefore, be over 20 years in our clinic and therefore, not feasible for practical reasons. One solution in order to solve this problem in the future may be a multi-center study design. However, there are well-known pitfalls when designing studies regarding new surgical techniques since surgeons are reluctant to randomize their patients until they are proficient in a technique and once they are convinced of the value of a technique, surgeons argue that it is too late to randomize.

In conclusion, the risk of RV rupture during NPWT is low when dividing adherences behind the sternum and protecting the RV from direct contact with the foam with a wound dressing. During our 11 years of using NPWT for DSWI the frequency of major bleedings has not been high compared to previously reported frequency of bleedings when using conventional treatments. In our opinion, the risk of bleeding complications in the present study was outweighed by the benefit of excellent 30-day mortality and supports our belief that NPWT is a safe and effective treatment for DSWI.

References

Delegating the task of a 'simple' sternal VAC dressing change to a less experienced junior surgeon or non-surgeon is potentially dangerous and iatrogenic bleeding may arise from overzealous debridement. As the authors' suggest, foam dressing changes should ideally be carried out in the operating theatre under general anaesthesia or sedation which provides for a sterile, well illuminated and controlled environment in contrast to the intensive care or ward. Spontaneous VAC related RV bleeding or rupture is obviously more difficult to manage with catastrophic consequences. The presence of the paraffin gauze as an interface between the polyurethane foam and anterior wall of the RV is vital and should never be omitted. There is also probably no indication for the applied topical suction to exceed the recommended −125 mmHg. Spontaneous RV rupture can occur due to sudden forward displacement of the RV (following a sudden bout of coughing for example) with resulting shearing forces applied bilaterally onto the ventricle by the sternal halves. In this regard, meticulous removal of any sharp bony periosteal fragments and removal of all dehisced sternal wires at the very initial debridement is important. Thoracic lysis of adhesions between the anterior RV wall and sternal edges might be beneficial but paradoxically can precipitate haemorrhage as well. Infection related spontaneous RV rupture may be difficult to distinguish from concurrent VAC therapy and may be a surrogate of overwhelming sepsis despite appropriate antimicrobial therapy.

References


