Negative-pressure wound therapy for deep sternal wound infections reduces the rate of surgical interventions for early re-infections†

Steinn Steingrimssonab, Magnus Gottfredssonb,c, Ingibjorg Gudmundsdottird, Johan Sjögrena and Tomas Gudbjartssona,b,*

a Department of Cardiothoracic Surgery, Landspitali University Hospital, Reykjavik, Iceland
b Faculty of Medicine, University of Iceland, Reykjavik, Iceland
c Department of Infectious Diseases, Landspitali University Hospital, Reykjavik, Iceland
d Department of Vascular Surgery, Landspitali University Hospital, Reykjavik, Iceland
* Department of Cardiothoracic Surgery, Skåne University Hospital, Lund University, Lund, Sweden
* Corresponding author. Department of Cardiothoracic Surgery, Landspitali University Hospital, IS 101 Reykjavik, Iceland. Tel: +354-543-1000; fax: +354-543-4835; e-mail: tomasgud@landspitali.is (T. Gudbjartsson).

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Abstract

OBJECTIVES: To evaluate the outcome of treatment for deep sternal wound infection (DSWI) in a nationwide patient cohort, before and after the introduction of negative-pressure wound therapy (NPWT).

METHODS: This was a population-based cohort of all patients treated for DSWI in Iceland out of 2446 open heart operations performed between 2000 and 2010. Length of hospital stay, survival and reoperations were compared in (i) 23 patients treated with open and/or closed irrigation before August 2005 (conventional treatment, CvT group) and in (ii) 20 patients treated after this time with NPWT as a first-line therapy (NPWT group).

RESULTS: The DSWI rate was 1.8% and did not change during the study period. Demographics were similar for both groups, except for peripheral arterial disease which was less common in the NPWT group. Coagulase-negative staphylococci were also more common (as the only pathogen identified) in the NPWT group (70% vs 30%, P = 0.01). The median length of hospital stay was 43 days in both groups and the sternum could be closed with delayed primary closure in all except 2 patients, one in each group. Eight patients in the CvT group required surgical revision for re-infections, including debridement and rewiring, when compared with 1 patient in the NPWT group (P = 0.02). Furthermore, 6 patients in the CvT group developed late chronic infections of the sternum requiring surgical revision, compared with one in the NPWT group (P = 0.10). The 30-day mortality was not significantly different between groups (4% vs 0%, P > 0.1) and the same was true for 1-year mortality (17% vs 0%, P = 0.11).

CONCLUSIONS: NPWT significantly reduces the risk of early re-infections in patients with DSWI. There was a lower rate of late chronic sternal infections and lower mortality in the NPWT group, but the difference was not statistically significant. We conclude that NPWT should be considered as a first-line treatment for most DSWIs.

Keywords: Deep sternal wound infection (DSWI) • Mediastinitis • Cardiac surgery • Negative-pressure wound therapy • Outcome • Re-infection

INTRODUCTION

Deep sternal wound infection (DSWI) following open-heart surgery is a serious and devastating complication, with an incidence between 1 and 5% in most studies [1, 2]. After conventional treatment (CvT), which usually involves surgical revision followed by open wound dressings with or without wound irrigation, mortality of up to 24% has been reported [2, 3]. Furthermore, DSWI is associated with significantly increased morbidity and costs [4], and negative effect on long-term quality of life [5].

†This research was carried out at Landspitali University Hospital, Reykjavik, Iceland.

Early and aggressive treatment is the key to effective treatment. However, negative-pressure wound therapy (NPWT) has been shown to have several advantages over CvT, including lower in-hospital mortality, improved wound healing and shorter length of stay (LOS) [2, 3]. Several studies have compared early outcome of NPWT with that of CvT, but in most of these reports, information on failure rate, including the need for surgical intervention for re-infections, is missing. However, most of these studies have involved large tertiary reference centres and thus, the outcome of NPWT treatment may not be representative of the general population. NPWT was introduced in Iceland in August 2005 as a first-line therapy for DSWI following open heart surgery and, subsequently, all patients with DSWI in Iceland have been treated with NPWT.
We evaluated the outcome of DSWI in Iceland, using a population-based registry of all cardiothoracic operations in the country, before and after the introduction of NPWT. Our main interest was early and late outcome and the need for surgical intervention due to early re-infections.

**MATERIALS AND METHODS**

Landspitali University Hospital is a 750-bed teaching hospital in Reykjavik, Iceland, the only centre performing cardiac surgery in the country. During the period 1 January 2000 and 31 December 2010, 43 adults (>18 years) were diagnosed as having culture-verified DSWI following open heart surgery. The National Bioethics Committee and the Icelandic Data Protection Commission approved the study protocol.

DSWI was defined according to the guidelines from the US Centers for Disease Control and Prevention (CDC) for post-sternotomy mediastinitis [6]. An early re-infection was defined as an infection fulfilling the CDC definition of DSWI that was diagnosed after at least one adequate treatment attempt. Late chronic infections were defined as infections of the sternum that required surgical intervention, but did not fulfill the criteria for DSWI, and that were diagnosed after discharge from hospital. Examples of late infections include sternocutaneous fistulas, subcutaneous abscesses, and chronic osteomyelitis. All infections were culture verified.

All patients with DSWI were initially treated with intravenous antibiotics, surgical debridement of necrotic and infected tissue, and the removal of sternal wires. The patients were divided into two study groups according to the primary treatment used after wound debridement (CvT or NPWT).

The CvT group consisted of 23 patients who were treated between January 2000 and July 2005 with either open dressings and/or closed irrigation. Open wound dressing treatment consisted of packing of the wound with either paraffin or chlorhexidine gauze dressings that were changed twice daily, until delayed primary closure could be achieved or the skin could be sutured together to bring the edges of the wound together. When closed irrigation was performed, two to three chest tubes were placed in the mediastinum and irrigated with 0.9% saline, the chest tubes being removed when the wound was no longer considered to be infected.

The NPWT group included 20 consecutive patients who were treated after August 2005. In all cases, NPWT was used as a first-line therapy. Following wound debridement, a paraffin gauze dressing was placed at the bottom of the wound to protect the right ventricle. Subsequently, polyurethane foam was placed in the wound in two layers (V.A.C.® GranuFoam™; KCI Medical, San Antonio, TX, USA). A negative pressure of ~125 mmHg was applied using the vacuum-assisted closure system (V.A.C.®, KCI Medical). After 2–4 days, the wound was reopened and the foam changed, most often for a total of three times. When the wound was granulated and there was no sign of infection, delayed primary closure was performed—or secondary closure when necessary.

Outcome variables were the rate of early re-infections and chronic sternal infections, LOS, in-hospital mortality and 1-year survival.

All patients were followed up 1 week postoperatively by the surgical team and four times annually by their consultant cardiologist. All patients with complications were treated at our institution, but 2 patients left the country within 1 year after the operation. On 1 April 2011, the total length of follow-up was 168 person-years with an average follow-up time of 3.9 ± 3.1 years (range 0.1–10.8). In the CvT group, total follow-up was 123 person-years (average 5.4 ± 3.5 years, range 0.1–10.8) and it was 45 person-years (average 2.2 ± 1.2 years, range 0.4–4.3) in the NPWT group.

Continuous variables were compared using Student’s unpaired t-test with approximately normally distributed data, otherwise a Wilcoxon–Mann–Whitney U-test was used. Categorical variables were compared using χ² test or Fisher’s exact test. Outcome variables with censored data were compared using a log-rank test. Logistic regression analysis was used to calculate odds ratio and 95% confidence interval for recurrence of DSWI after treatment with either CvT or NPWT, thereby adjusting for known risk factors of DSWI, especially peripheral arterial disease and different pathogens. Statistical analysis was performed and graphs were plotted using the STATA software version 10. Two-tailed P values less than 0.05 were considered significant. One-year crude survival was plotted using the Kaplan–Meier method.

**RESULTS**

During the 11-year study period, 43 of 2446 open heart surgery patients (1.8%) were diagnosed with DSWI in Iceland. Mean age for the whole group of patients was 69 years and 74% were males. In both groups, coronary artery by-pass grafting (CABG) alone was the most common procedure (63%), followed by aortic valve replacement in combination with CABG (16%), and aortic valve replacement alone (7%). The left internal mammary artery was used as a bypass conduit in 20 cases (87%) in the CvT group compared with 15 (75%) in the NPWT group (P = 0.31). An emergency operation was performed in 2 cases (5%), and there was bilateral use of the internal mammary arteries in three (7%).

Preoperative characteristics in the CvT and NPWT groups are presented in Table 1. There were no significant differences between the groups except for peripheral artery disease.

**Table 1:** Preoperative characteristics of patients with deep sternal wound infection

<table>
<thead>
<tr>
<th>Variables</th>
<th>NPWT (n = 20)</th>
<th>Conventional treatment (n = 23)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>69 ± 8</td>
<td>69 ± 10</td>
<td>0.89</td>
</tr>
<tr>
<td>Female gender</td>
<td>5 (25)</td>
<td>6 (26)</td>
<td>0.86</td>
</tr>
<tr>
<td>Obesitya</td>
<td>9 (45)</td>
<td>8 (35)</td>
<td>0.71</td>
</tr>
<tr>
<td>Current smoker</td>
<td>9 (45)</td>
<td>10 (43)</td>
<td>0.84</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>9 (45)</td>
<td>11 (48)</td>
<td>0.90</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>16 (80)</td>
<td>21 (91)</td>
<td>0.53</td>
</tr>
<tr>
<td>Peripheral arterial disease</td>
<td>1 (5)</td>
<td>8 (35)</td>
<td>0.02</td>
</tr>
<tr>
<td>COPD</td>
<td>6 (30)</td>
<td>4 (17)</td>
<td>0.47</td>
</tr>
<tr>
<td>Renal failure</td>
<td>2 (10)</td>
<td>2 (9)</td>
<td>1</td>
</tr>
<tr>
<td>Ejection fraction (&lt;30%)</td>
<td>5 (25)</td>
<td>2 (9)</td>
<td>0.22</td>
</tr>
<tr>
<td>NYHA class IV</td>
<td>9 (45)</td>
<td>11 (48)</td>
<td>0.78</td>
</tr>
<tr>
<td>EuroSCORE (log)</td>
<td>9.5 ± 9.8</td>
<td>8.7 ± 6.2</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Continuous variables are presented as mean ± standard deviation and categorical variables are presented as n (%).

BMI: body mass index; COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association functional classification.

*Obesity is classified as BMI > 30 kg/m².
which was more common in the CvT group ($P = 0.02$). Coagulase-negative staphylococci were identified as sole pathogen in the CvT group in 7 cases (30%) when compared with 14 (70%) in the NPWT group ($P = 0.01$). *Staphylococcus aureus* was the only pathogen identified in 10 patients (43%) in the CvT group and in 4 patients (20%) in the NPWT group ($P = 0.10$). Other pathogens or multiple pathogens were identified in 6 patients (26%) in the CvT group and in 2 patients in the NPWT group ($P = 0.18$).

The surgical outcome for both groups is presented in Table 2. There was no significant difference in LOS stay between the CvT and NPWT groups: 48 ± 23 days (median 43, inter-quartile range 32–60) and 47 ± 17 days (median 43, inter-quartile range 34–60), respectively ($P = 0.84$). The same was true for ICU stay, 4.3 ± 7.4 days (median 1, inter-quartile range 0–5) when compared with 3.7 ± 7.6 days (median 1, inter-quartile range 0–4) for the CvT and NPWT groups, respectively ($P = 0.81$). One patient in the CvT group died during treatment, whereas none died in the NPWT group.

Early re-infection was diagnosed in 9 patients (21%), 8 (35%) in the CvT group and one (5%) in the NPWT group ($P = 0.02$) (Table 3). The time from the primary operation to surgical treatment for re-infection was 47 ± 41 days (median 35; inter-quartile range 24–48). In the CvT group, 5 patients had originally been treated with closed irrigation and three with open wound dressing. The only patient with persistent DSWI in the NPWT group was found to have a *Pseudomonas aeruginosa* infection, which was cultured from both the wound and the sponge. NPWT treatment was discontinued and acetic acid wound dressing used successfully, which made rewiring of the sternum, without tissue flap surgery, possible.

Late chronic sternal wound infections requiring surgical treatment developed in 1 patient in the NPWT group and in 6 patients in the CvT group (including 3 patients who were treated for persistent DSWI), but the difference was not statistically significant ($P = 0.10$). The same was true for 1-year survival in the two groups (Fig. 1).

There were three intraoperative complications. In the NPWT group, a bleeding from the heart that was not life-threatening occurred in 2 cases, but there was no complete rupture of the right ventricle. In both cases, direct suture with patch was performed without the need for cardiopulmonary by-pass. In the CvT group, 1 patient with a recurrent DSWI had a rupture of the right ventricle when the sternal wound was reopened, which resulted in a fatal intraoperative bleeding.

### Table 2: Surgical treatment outcome of deep sternal wound infection for patients treated with NPWT and by conventional means

<table>
<thead>
<tr>
<th>Variables</th>
<th>NPWT (n = 20)</th>
<th>Conventional treatment (n = 23)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early outcome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re-inflection</td>
<td>1 (5)</td>
<td>8 (35)</td>
<td>0.02</td>
</tr>
<tr>
<td>Median LOS in hospital (days)</td>
<td>43.0</td>
<td>43.0</td>
<td>0.39</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td>1</td>
</tr>
<tr>
<td>Late outcome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late infection</td>
<td>1 (5)</td>
<td>6 (27)</td>
<td>0.07</td>
</tr>
<tr>
<td>1-year mortality</td>
<td>0 (0)</td>
<td>4 (17)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Variables are presented as n (%) except where otherwise specified. DSWI: deep sternal wound infection; LOS: length of stay.

### Table 3: Patients who were treated surgically for early re-infections following treatment for deep sternal wound infection

<table>
<thead>
<tr>
<th>Case</th>
<th>Age/sex/operation</th>
<th>Pathogen</th>
<th>POD</th>
<th>Risk factors</th>
<th>Treatment for recurrent DSWI</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57/M/CABG</td>
<td><em>Staphylococcus aureus</em></td>
<td>19</td>
<td>DM I, obesity, transplanted kidney</td>
<td>Closed irrigation</td>
<td>Primary closure</td>
</tr>
<tr>
<td>2</td>
<td>64/M/CABG</td>
<td>S. <em>aureus</em>, <em>Enterococcus faecalis</em>, <em>Klebsiella pneumoniae</em>, <em>Haemophilus influenzae</em></td>
<td>23</td>
<td>-</td>
<td>Open wound dressing for 26 days in ICU</td>
<td>Omental flap closure with closed irrigation</td>
</tr>
<tr>
<td>3</td>
<td>84/M/CABG + AVR</td>
<td>CoNS</td>
<td>24</td>
<td>-</td>
<td>Closed irrigation</td>
<td>Secondary closure</td>
</tr>
<tr>
<td>4</td>
<td>70/M/CABG + AVR</td>
<td><em>S. aureus</em></td>
<td>31</td>
<td>PAD, smoking, Smoking</td>
<td>Open dressing changes</td>
<td>Primary closure with a steel plate</td>
</tr>
<tr>
<td>5</td>
<td>58/M/CABG</td>
<td><em>S. aureus</em></td>
<td>48</td>
<td>-</td>
<td>Closed irrigation</td>
<td>Closed irrigation</td>
</tr>
<tr>
<td>6</td>
<td>58/M/CABG + AVR</td>
<td>CoNS</td>
<td>39</td>
<td>COPD, DM I, PAD, chronic renal failure</td>
<td>Closed irrigation</td>
<td>Closed irrigation</td>
</tr>
<tr>
<td>7</td>
<td>64/M/CABG</td>
<td><em>S. aureus</em></td>
<td>49</td>
<td>DM II, chronic renal failure</td>
<td>Open dressing changes</td>
<td>Death due to rupture of right ventricle</td>
</tr>
<tr>
<td>8</td>
<td>72/F/CABG</td>
<td><em>S. aureus</em></td>
<td>153</td>
<td>PAD</td>
<td>Intraoperative death due to bleeding</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>54/F/CABG</td>
<td>CoNS + <em>Pseudomonas aeruginosa</em></td>
<td>35</td>
<td>DM II, obesity</td>
<td>NPWT for 3 weeks but treatment changed successfully to acetic acid wound dressings</td>
<td>Primary closure</td>
</tr>
</tbody>
</table>

AVR: aortic valve replacement; CABG: coronary artery by-pass graft; CoNS: coagulase-negative staphylococci; COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus; DSWI: deep sternal wound infection; F: female; M: male; PAD: peripheral arterial disease; POD: postoperative days to treatment of re-infection.
DISCUSSION

This study shows that DSWI treated with NPWT is associated with a significantly lower rate of early re-infections requiring surgical revision. The rate of early re-infections in the CvT group and in the NPWT group corresponds well with other reports of comparison of NPWT and CvT, most of them showing around 25% lower absolute risk of re-infections following NPWT [3, 7, 8].

Not all studies have shown a lower rate of surgical re-intervention following NPWT for DSWI [9]. Bapat et al. (2008) reported that patients treated with long-term NPWT had a higher risk of recurrence than those with primary closure [10]. In these studies, NPWT was used as the only treatment and no primary closure of the wound was performed. In our opinion, one of the major strengths of NPWT is the facilitation of delayed primary closure, as the sternum and adjacent tissue are well preserved. Although coagulase-negative staphylococci were more common in the NPWT group, the risk of early re-infections could not be related to that finding exclusively. This is important as these pathogens may not be as aggressive as pathogens such as S. aureus in this setting. Furthermore, the rate of methicillin-resistant S. aureus infections in Iceland has been low and has remained low throughout the period [11].

Late chronic infections of the sternum can arise both as primary infections and following DSWI, and often result in numerous surgical procedures [12]. Although the difference was not statistically significant, there appeared to be a trend of fewer late infections following NPWT (Table 2). Previous studies have shown that up to 90% of these infections are diagnosed within the first year, and the effect of a shorter follow-up in the NPWT group should therefore be minimal [12].

There was not a significant difference in the LOS between groups. There are conflicting results regarding LOS following NPWT, some studies suggesting shorter LOS [7] while other studies similar [3, 8].

One in-hospital death occurred in the CvT group when compared with none in the NPWT group. Our results suggest that early and late mortality following both CvT and NPWT for DSWI is low [1]. Several recent reports have shown that NPWT is associated with low DSWI mortality, both early (as low as 1.1%) and late [2, 13, 14]. This is important, since early mortality as high as 24% following CvT has been reported [2, 3]. However, there may be other explanations for this reduced mortality after treatment for DSWI, e.g. improved intensive care or sepsis treatment.

Significant bleeding from the wound occurred in 3 cases (7%). This is a known complication of both DSWI and NPWT, which might be prevented in most cases with careful surgical techniques [14].

To the best of our knowledge, this is the first study to compare historically CvT and NPWT in a nationwide cohort of patients, thus minimizing the effects of referral bias on the outcome of treatment. We believe that further studies of failure rate and mortality rate in larger patient cohorts are warranted.

LIMITATIONS

The most important limitation of the study is that the groups were relatively small, which may have an effect on the analysis regarding both operative mortality and hospital stay.

CONCLUSION

NPWT seems to significantly reduce the risk of early re-infections in patients with DSWI. We think NPWT should be considered as a first-line treatment for most DSWIs.

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Conflict of interest: none declared.

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Conclusions. Vacuum-assisted closure therapy for deep sternal wound infections

Authors: Agamosmnn Pericloes and Georgios Dimitrakis
Department of Cardiac Thoracic Surgery, University Hospital of Wales, Cardiff, UK
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We read with great interest the article by Steinigrsson et al. regarding the efficacy of vacuum-assisted closure (VAC) therapy for deep sternal wound infections (DSWI) in cardiac surgery [1]. The definition of DSWI as documented by the US Centers for Disease Control is an infection involving fascia or deeper with at least one of the following: evidence of infection seen at re-operation or spontaneous dehisence, positive culture of mediastinal fluid and/or positive blood culture and/or chest pain with sternal instability and temperature higher than 38°C [2]. VAC therapy has now become a standard method of treatment for DSWI. In a prospective randomized trial by Moues and colleagues in 2004, a significant reduction in the wound surface area was noted in the VAC group compared to the conventional moist gauze therapy [3.8 ± 0.5 percent/day (mean ± SEM) vs. 1.7 ± 0.6 percent/day respectively, p < 0.05]. However, the superiority of VAC therapy could not be explained by a significant reduction in the bacterial load [3].

In the retrospective cohort study by Gudlevitch and colleagues, the predictive factors identified for VAC treatment failure were the positive blood cultures (most sensitive predictor), wound depth of more than 4 cm (most specific predictor) and a high degree of sternal exposure and instability. Furthermore, the authors have suggested that these patients might be better managed by a surgical approach [4].

Lukrav and colleagues, in 2003, suggested that VAC therapy used alone or combined with other surgical modalities can offer acceptable results for the treatment of DSWI in cardiac surgery. In addition, the total cost for the hospitalization and treatment for patients in the VAC group was $16,400 per patient, compared with $20,000 per patient in the sternal rewiring and closed irrigation treatment group.

In conclusion, VAC therapy is an acceptable method for the treatment of DSWI. Patients with these devastating and potentially life-threatening complications can be assessed on an individual basis by an experienced team of cardiothoracic surgeons.

Conflict of interest: none declared.

References

eComment. A change in the microbial spectrum in deep sternal wound infections

Author: Jan J van Wingerden
Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands
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I read the article by Steinigrsson et al. with interest [1]. Since the introduction of negative-pressure wound therapy in the management of deep sternal wound infection (DSWI) in 1999, various centres, albeit without absolute comparable study populations, have reported an alarming increase in the incidence of the deceptive coagulase-negative Staphylococcus (CoNS) as the major causative organism [2]. This elegant study by Steinigrsson and colleagues supports the concern. They identified CoNS as the sole pathogen in 70% of cases with DSWI between 2005–2010, when compared to 30% between 2000–2005 (p = 0.01). Up to 2007, Staphylococcus aureus and/or CoNS were the most prevalent pathogens encountered in DSWI [3]. Recently in 2009, Ennaker et al. and Eriksson et al. reported a CoNS incidence of 38% and 62% in their single-institution case-series of DSWI, respectively. One could be forgiven in thinking this to be a purely Nordic phenomenon - this is not the case. In their study over a period of 15 years, Matros and colleagues [4] found CoNS, cultured in 49% of 285 sternal wounds, to be the most prevalent pathogen. Patients with CoNS-related DSWI may present late (>3 weeks), with less obvious symptoms and less pronounced infective markers (C-reactive protein, white blood cell count). Furthermore, these patients are often afflicted with diabetes mellitus, chronic obstructive pulmonary disease (COPD) or suffer from obesity. According to some, methicillin-resistance of the Staphylococci can be above 90% in DSWI associated with CoNS. Fortunately, as Steinigrsson and colleagues point out, the incidence of MRSA in Iceland has remained low.

A point of further interest is that bleeding occurred in both groups [1]. As expounded elsewhere, the exact relation to negative-pressure wound therapy has yet to be clarified [5].

Note: complete list of references is available from the author.

Conflict of interest: none declared.

References