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# Economic aspects of deep sternal wound infections☆

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## Abstract

**Objectives:** Surgical-site infections are a very expensive complication in cardiac surgery. Thus, the total costs for coronary artery bypass grafting (CABG) surgery may substantially increase when a deep sternal wound infection (DSWI) occurs. This may be due to an extended length of stay (LOS), the need for additional surgical procedures, vacuum-assisted wound dressing and antibiotic therapy. This study compares the LOS in the hospital and on an intensive care unit (ICU) as well as the total costs for patients undergoing CABG depending upon the occurrence of a subsequent DSWI. **Methods:** A case—control study was performed. Total costs of DSWI cases were analysed and compared to patients undergoing CABG without DSWI. Inclusion criterion for cases was the development of a DSWI according to the CDC criteria during hospital stay after CABG. Two control patients without any signs or symptoms of an infection during hospital stay were matched to each case by (1) type of surgery according to their diagnosis-related group (DRG), (2) age $\pm$5 years, (3) gender and (4) duration of preoperative hospital stay $\pm$2 days, but at least as long as the time at risk of cases before infection. **Results:** Between January 2006 and March 2008, 17 CABG patients with DSWI (cases) and 34 matched controls were included. The median overall costs of a CABG case were 36,261 Euro compared with 13,356 Euro per control patient without infection ($p < 0.0001$). The median overall LOS was 34.4 days versus 16.5 days, respectively ($p = 0.0006$). The median LOS on ICU was 6.3 days versus 5.3 days (no significant difference). **Conclusion:** DSWI represents an important economic factor for the hospital as they may almost triple the costs for patients undergoing CABG. Thus, appropriate infection control measures for the prevention of DSWI should be enforced.
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*Keywords:* Coronary artery bypass; Length of stay; Reimbursement; Costs

## 1. Introduction

Deep sternal wound infection (DSWI) is a devastating complication following cardiac surgery and is associated with significant increases in hospital length of stay (LOS), costs, morbidity, and mortality [1,2]. Previous studies have reported DSWI rates from 0.5% to 3.6% [3—5]. Mortality rates may vary between 15% and 40% [3,5]. Only few studies have yet described the exact economic impact of DSWI, comparing patients with same characteristics and, to the best of our knowledge, no study did that for the German accounting system (DRG) [6].

The aim of the present study was to calculate the costs of DSWI after coronary artery bypass grafting (CABG) surgery via sternotomy.

## 2. Materials and methods

### 2.1. Setting

This study was conducted at the department of cardiac, thoracic, transplantation and vascular surgery of the Hannover Medical School, a German tertiary care university hospital. Approximately 2300 patients undergo median sternotomy per year in this department for various reasons. The investigation period included 27 months (January 2006 until March 2008). Prospective surveillance of DSWI was performed during the entire study period by trained infection control personnel. The frequency of the occurrence of DSWI ranged from 1.8% to 3.6% in this time frame [7].

### 2.2. Cases

Patients were included as cases if they developed a DSWI according to the criteria as defined by the Centers for Disease Control and Prevention (CDC) [8] during the hospital stay after CABG.

☆ Part of this study was presented at the 19th European Congress of Clinical Microbiology and Infectious Diseases (ECCMID) Helsinki, Finland, 2009.

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### 2.3. Definition of infection

The CDC criteria for a deep incisional infection (class A2) was defined by involving tissues beneath the subcutaneous tissue including one of the following findings: purulent drainage from the deep layer, surgical revision or dehiscence on the background of fever, localised pain, or tenderness, and an abscess or other observable evidence of infection on direct examination, histopathology and radiology. The criteria for an organ/space infection (mediastinitis, class A3) include purulent drainage, positive microbiology and an abscess or other observable evidence of infection.

Patients with sterile dehiscence or superficial sternal wound infections were excluded from the study. Re-admitted patients were not eligible as case patients.

### 2.4. Controls

Control patients after CABG and without DSWI were matched to DSWI cases in a ratio of 2:1. The following matching criteria were applied: (1) age ±5 years, (2) gender, (3) identical diagnosis-related group (DRG) in the same year (= adjusting for underlying disease and reimbursement conditions), (4) preoperative LOS ±2 days (adjusting for time at risk before surgery) and (5) LOS after the thoracic surgical procedure of controls needed to be at least as long as that of cases before the onset of DSWI (= adjusting for time at risk after surgery).

### 2.5. Costs

Data on the costs for the hospital and reimbursement from the health insurance companies for DSWI cases and control patients were provided by the financial controlling department of our facility. The actual costs of surgery, ICU care, peripheral ward care, laboratory tests, other costs as well as the reimbursement were calculated for every single case individually. All costs are presented in Euro at the time of follow-up.

### 2.6. Statistic analysis

Evaluation of the application of matching criteria was done by the Wilcoxon rank-sum test for indent samples.

Differences between cases and matched control pairs with respect to LOS and costs were calculated for the overall hospital LOS, LOS at ICU, LOS after surgery, costs per patient and costs per patient. For all parameters, the medians with a 95% confidence interval (CI95) non-parametric (distribution free) were calculated. The *p*-value of differences (cases minus controls) was calculated by the Wilcoxon signed rank test and a *p*-value $<0.05$ was considered significant.

We checked for potential risk factors and co-morbidities that may have an influence on the costs and: (1) diabetes mellitus, (2) body mass index (BMI) $>25$, (3) chronic obstructive pulmonary disease (COPD), (4) renal insufficiency, (5) nicotine abuse, (6) immunosuppression, (7) length of hospital (LOS) stay before surgery, (8) ASA score, (9) wound contamination class, (10) duration of extra corporal circulation (ECC), (11) correct timing of antibiotic prophylaxis, (12) blood glucose levels, (13) duration of mechanical ventilation, (14) LOS on an intensive care unit and (15) total hospital LOS. The following demographic data and risk factors were recorded for each patient: (1) age, (2) gender, (3) BMI, (4) type of surgical procedure, (5) diabetes mellitus, (6) chronic obstructive lung disease (COLD), (7) renal insufficiency, (8) nicotine abuse, (9) immune suppression of any kind, (10) hospital length of stay (LOS) before surgery, (11) ASA score, (12) wound contamination class, (13) date of operation, (14) duration of the procedure, (15) ECC time, (16) appropriate application of an antibiotic prophylaxis using a third-generation cephalosporin, (17) preoperative, intraoperative and postoperative blood glucose levels, (18) extubation time, (19) LOS on an intensive care unit (ICU) and (20) the overall hospital LOS until discharge.

## 3. Results

### 3.1. Occurrence of DSWI

During the study period, a total of 4130 cardiac surgical procedures were performed. A total of 120 patients with DSWI were detected by surveillance; 100 (83%) of these were diagnosed during their hospital stay in our facility already or during their subsequent stay in a rehabilitation clinic. The remaining 20 (17%) patients were diagnosed when re-admitted to our hospital. In total, 27 (23%) events of DSWI occurred after discharge of the patient. Causative microorganisms were cultured in specimens from 112 (93%) sites of clinical DSWI. The most frequently cultured isolates were coagulase-negative staphylococci (39%), *Staphylococcus aureus* (23%; with a proportion of 52% MRSA) and enterococci (10%). Up to four different microorganisms were detected in a single DSWI site. The mean time after surgery until the diagnosis of DSWI was 13.4 (median: 19) days.

Usually patients with DSWI are treated by debridement, vacuum therapy and sometimes omental reconstruction. All matched cases were treated by debridement and vacuum therapy.

### 3.2. Case–control study

After applying the matching criteria, as described above, 17 cases and 34 matched controls out of 120 potential control patients were included. The total number of patient days of cases was 585 days and of controls was 560 days. As shown in

Table 1
Costs and length of stay of cases and controls.

| | Cases[a] ($n$ = 17) | Controls[a] ($n$ = 34) | $p$-value[*] |
|---|---|---|---|
| LOS in hospital (day) | 34.4 | 16.5 | 0.0006 |
| 95% CI | (30.1–38.6) | (14.0–17.5) | |
| LOS on ICU (day) | 6.3 | 5.3 | n.s. |
| 95% CI | (5.5–6.7) | (4.1–5.9) | |
| Costs per patient (€) | 36.261 | 13.356 | $<0.0001$ |
| 95% CI | (31.028–48.060) | (12.060–17.930) | |
| Costs per patient day (€) | 1011 | 1167 | n.s. |
| Mortality rates (%) | 17.6 | 8.8 | 0.03 |

LOS: length of stay; ICU: intensive care unit; 95% CI: 95% confidence interval; n.s.: not significant.
[a] Data presented as medians.
[*] Wilcoxon signed rank test was used.

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Table 2
Comparison of controls.

| | Matched controls only[a] ($n$ = 34) | All controls[a] ($n$ = 120) | $p$-value[*] |
|---|---|---|---|
| Preoperative LOS (day) | 2.0 | 4.0 | 0.02 |
| 95% CI | (2.4–3.0) | (3.4–4.8) | |
| LOS on ICU (day) | 5.3 | 3.6 | n.s. |
| 95% CI | (4.1–5.9) | (1.6–7.0) | |
| LOS in hospital (day) | 16.5 | 14.0 | n.s. |
| 95% CI | (14.0–16.5) | (9.0–17.0) | |
| Age (year) | 72 | 72 | n.s. |
| 95% CI | (68–73) | (65–73) | |

LOS: length of stay; n.s: not significant; 95% CI: 95% confidence interval.
[a] Data presented as medians.
[*] Wilcoxon signed rank test was used.

Table 3
Risk factors of all cases and controls.

| | Cases[*] ($n$ = 120) | Controls[*] ($n$ = 120) |
|---|---|---|
| LOS before surgery (h) | 70 | 68 |
| Duration of OP (min) | 195.5 | 189 |
| Bypass time (min) | 90.5 | 83.5 |
| Preoperative blood glucose level (mmol/l) | 6.8 | 6.0 |
| Intraoperative blood glucose level (mmol/l) | 8.3 | 8.0 |

[*] $p$-values have been calculated (Wilcoxon rank sum test). LOS, Duration and bypass time showed no significance. Preoperative blood glucose level: $p$ = 0.006, Intraoperative blood glucose level: $p$ = 0.002.

Table 1, the median hospital LOS was twice as long in cases as in controls (34.4 days vs 16.5 days, $p$ = 0.0006). The median LOS on ICU was also increased for cases but failed to reach statistical significance (6.3 days vs 5.3 days). The median postoperative LOS was approximately 4 times longer in cases (32.2 days) than in all controls without infection (8.0 days; $p$ = 0.04). In a 30-day follow-up, the mortality rates of the cases were 17.6% versus 8.8% in controls. Table 2 indicates that, besides the preoperative LOS, the control patients as chosen for our case–control study are a representative subgroup of all patients lacking DSWI.

The risk factors and co-morbidities of cases and controls are shown in Tables 3 and 4.

### 3.3. Costs

Table 5 presents an overview on costs of cases and control. The median cost of cardiac surgery procedure in control patients was 13356 Euro. These costs consisted of costs for ward care (13.0%), surgical costs (28.3%), costs for ICU care (29.6%), costs for laboratory tests (16.4%) and other costs (12.7%). The median cost of case patients who required DSWI treatment was 36261 Euro, including costs for ward care (24.7%), surgical costs (19.0%), ICU care (27.7%), laboratory tests (15.0%) and other costs (13.6%). Costs of cases for the need for treatment that derived from additional admissions are not included in this calculation. The median reimbursement from health-care insurance companies was 27,107 Euro per case patient, which means a financial loss of 9154 Euro per patient or 269 Euro per patient day while control patients ended up with a financial profit of 21 Euro per patient day.

Table 4
Co-morbidities of cases and controls.

| | Cases* ($n$ = 17) | Controls* ($n$ = 34) |
|---|---|---|
| *D. mellitus* (no. of cases) | 8 | 6 |
| BMI ≥25 (no. of cases) | 12 | 25 |
| COPD (no. of cases) | 3 | 5 |
| Renal insufficiency (no. of cases) | 3 | 4 |
| ASA >3 (no. of cases) | 1 | 2 |
| Timely administration of perioperative antibiotic prophylaxis (no. of cases) | 13 | 31 |
| Extubation within 24 h after operation (no. of cases) | 13 | 30 |
| Preoperative MRSA-screening (no. of cases) | 14 | 30 |

Table 5
Difference of costs and reimbursements for deep sternal wound infections in cases and control patients.

| | Cases[a] ($n$ = 17) | Controls[a] ($n$ = 34) |
|---|---|---|
| Costs per patient (€) | 36261 | 13355 |
| Reimbursement per patient (€) | 27107 | 13710 |
| Financial loss or profit per patient (€) | −9154 | +355 |
| Financial loss or profit per patient day (€) | −269 | +21 |

[a] Data presented as medians.

## 4. Discussion

Patients who develop DSWI following cardiac surgery require longer and more costly care and experience worse clinical outcomes than patients who do not suffer from this complication [2,9,10]. Our data show that at least 1.8% of patients undergoing open-heart surgery suffered from DSWI. Such a DSWI rate of 1.8% is in line with the earlier reported rates of 0.5% and 3.2% [4,5]. Inclusion criteria for patients in our case–control study are in accordance to the criteria and characteristics as used by others before [11–14].

In our study, patients with sternotomy who developed DSWI had a doubled mortality rate, a need for 18 additional days of LOS and led to much higher costs (€ 22,905 in addition) when compared with patients undergoing sternotomy without developing DSWI. By this our data from a German university hospital confirms the previous findings in principle [10]. Because DSWIs are associated with more costly outcomes [9], we did not include superficial chest infections and leg infections in our cost estimates. This may also explain why the estimates of the economic impact of DSWI after cardiac surgery showed to be substantially higher in our study than in others [8,9]. The main proportion of costs in DSWI case patients was among ward care, costs for additional surgical procedures and costs for prolonged ICU care. The difference in costs between cases and control can be attributed to a shorter hospital LOS of controls, as the proportion of costs for care on peripheral wards were diminished while the proportion of costs for the initial surgical procedure and ICU care are relatively high.

Some limitations have to be kept in mind when interpreting the data presented in our study:

(1) As mortality rates were determined by a 30-day follow-up only, we do not know for sure whether all fatal cases were detected by our surveillance. A longer post-discharge

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surveillance time frame would be necessary to clarify this issue. Thus, our data might even underestimate the true mortality due to DSWI.

(2) We only included the costs of patients with DSWI that derived from their first stay in our hospital but not from re-admissions that may have occurred later on. Thus, our data might also even underestimate the true costs due to DSWI.

(3) This is a single-institution survey in a German university hospital. Our findings may not exactly apply for thoracic surgery departments in hospitals, for example, in other countries.

(4) Costs calculated in this study were based on the hospital costs as generated by our financial controlling department of our hospital. Thus, we cannot rule out that there might have been some additional hidden costs that have been missed by our approach of cost determination. Further we cannot say if the prolonged stay after developing DSWI is caused by the infection only or if other co-morbidities may have had an influence.

## 5. Conclusion

DSWI is a serious clinical complication in thoracic surgery, and it is also an important economic factor for the hospital and health-care systems. In median, the costs for DSWI patients were almost 3 times as high as the costs of non-infected patients. A total of 9154 Euro were lost for every single case of DSWI during the study period. One may therefore assume that infection control measures for the reduction of DSWI will likely become cost-effective. More data are needed on the absolute amount of such costs from different settings. In addition, more studies that deal with cost-effectiveness of infection control in thoracic surgery are very much appreciated.

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