Original Article

Risk Factors and Treatment of Deep Sternal Wound Infection after Cardiac Operation

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Objective: Although deep sternal wound infection (DSWI) after cardiac surgery is infrequent, its consequences are serious. The purposes of this study were to define the risk factors, and to establish the best surgical treatment for DSWI.
Methods: Retrospective analysis for 863 patients who underwent cardiac surgery was performed. The patients were divided into the DSWI group (n=17) and the non-infection group (n=846). Preoperative, perioperative, and postoperative variables were compared between the two groups using univariate and multivariate logistic regression analysis. The modality of treatment for DSWI was also analyzed.
Results: The incidence of DSWI was 1.97%. Independent predictors for DSWI were concomitant coronary artery bypass grafting (CABG) with valve or aortic surgery [odds ratio, 4.1; 95% confidence interval, (1.1, 15.1)] and postoperative use of intraaortic balloon pumping [4.4, (1.6, 12.3)]. An independent predictor in isolated CABG patients was emergency operation [10.9, (2.7, 44.7)]. Four of 17 patients died. Methicillin-resistant Staphylococcus aureus (MRSA) was cultured from 10 (58.8%) patients, and all four of the deceased subjects died of its infection. Seventeen patients were treated by debridement, primary closure, and the addition of an omentum or muscle flap if necessary.
Conclusions: Patients in poor perioperative condition are at high risk for the development of this infection. It was difficult to establish the best treatment, owing to the small series of this study. Mortality and morbidity of DSWI due to MRSA was high. (Ann Thorac Cardiovasc Surg 2003; 9: 226–32)

Key words: deep sternal wound infection (DSWI), methicillin-resistant Staphylococcus aureus (MRSA), risk factors and treatment

Introduction

Although deep sternal wound infection (DSWI) after cardiac operations with median sternotomy is infrequent, it increases mortality, morbidity, and hospital stays. The reported incidence of DSWI ranged from 0.25% to 2.3%.[1-9] It is important to define risk factors for DSWI to reduce morbidity, reduce mortality, and improve quality of life after surgery. The purposes of this study were to determine the risk factors of DSWI in cardiac surgical patients, and to establish the best surgical treatment for DSWI.

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Patients and Methods

Population

From January 1987 to December 1999, 863 consecutive cardiac surgical procedures with cardiopulmonary bypass (CPB) through full sternotomies were performed at the Tsukuba Medical Center Hospital (Table 1). Patients who

Table 1. Cardiac surgical procedures

Procedure	No. of patients
Isolated CABG	532
Combined CABG	44
CABG + valve surgery	23
CABG + aortic surgery	20
CABG + valve + aortic	1
All CABG	576
Isolated valve surgery	158
Aortic surgery	82
Congenital heart disease and other	47
Total	863

CABG, coronary artery bypass grafting; combined CABG, simultaneous CABG with valve and/or aortic surgery.

died before the postoperative day 8, who underwent partial sternotomy, or who underwent coronary artery bypass grafting (CABG) without CPB were excluded from this study. Patient data were collected and analyzed retrospectively. Patients were divided into two groups: those with DSWI (n=17, group I) and those without DSWI (n=846, group II). Preoperative, perioperative, and postoperative variables were compared between groups I and II. In addition, 576 patients who underwent CABG and 532 patients who underwent isolated CABG were analyzed by the same method.

Immediately after the diagnosis of DSWI, antibiotics were administrated and surgical intervention was made. Treatment and outcome of DSWI were reviewed retrospectively.

Definitions of infection

DSWI was defined according to the guidelines of the Centers for Disease Control and Prevention, i.e., an infection involving tissues or spaces beneath the subcutaneous tissues, and patients meeting at least one of the following criteria were diagnosed as having DSWI: (1) an organism was isolated from culture of mediastinal tissue or fluid; (2) evidence of mediastinitis was seen during operation; or (3) chest pain, sternal instability, or fever (>38°C) was present and there was either purulent discharge from the mediastinum or an organism isolated from blood culture or culture of drainage of the mediastinal area.

Superficial sternal wound infection, defined as an infection involving only skin or subcutaneous tissue at the incision site, was excluded from this study.

Perioperative management

Patients were showered and shaved the day before the operation. Cefazolin 1 g was administered into the CPB circuit (before 1998) or intravenously (after 1999). The operative field was sterilized with povidon-iodine solution and the skin was covered with an adhesive drape. Bone wax was used for all patients for hemostasis of the sternum after sternotomy. Internal thoracic arteries (ITAs) for CABG were harvested in a skeletonized fashion. The sternum was closed using five stainless wires. Two drainage tubes were placed in the mediastinum, and kept in place until the drainage volume diminished to less than 100 ml/day.

Statistical methods

Univariate analysis was performed using the χ^2 test for categorical variables and two-tailed Student's t test for continuous variables. All variables suggested by the univariate analysis ($p<0.20$) were entered into a stepwise multiple logistic regression analysis model. All analysis was performed using the SPSS for Macintosh (SPSS Inc., Chicago, IL, USA.)

Results

Predictors of DSWI

The incidence of DSWI was 2.0% (17/863 patients). Univariate analysis revealed that the preoperative use of an intraaortic balloon pumping (IABP) was a significant preoperative predictor of DSWI (Table 2). Perioperative predictors by the same analysis were emergency operation, combined CABG, and an operation time longer than eight hours (Table 3). Postoperative predictors were postoperative use of an IABP, an intensive care unit stay longer than five days, postoperative hyperglycemia, and longer placement of the drainage tube (Table 4).

According to multivariate analysis, independent predictors of DSWI in all cardiac surgical patients were combined CABG [odds ratio (OR), 4.1; 95% confidence interval (CI), 1.1, 15.1] and postoperative use of IABP (OR, 4.4; 95% CI, 1.6, 12.3). Since combined CABG was an independent predictor in all cardiac surgical patients, we performed a second multivariable logistic regression analysis on all CABG patients and isolated CABG patients. DSWI occurred in 12 (2.1%) of 576 CABG patients. Independent predictors for DSWI in all CABG patients were simultaneous valve surgery (OR, 6.7; 95% CI, 1.3, 35.3) and postoperative use of IABP (OR, 6.7; 95% CI, 2.0, 21.9). DSWI occurred in 9 (1.7%) of 532

Table 2. Univariate predictors for DSWI of preoperative variables

Variable	Group I (n=17) (%)	Group II (n=846) (%)	p value
Age (mean±SD)	62.0±11.9	61.2±12.6	0.786
Male	70.5	65.4	0.666
Body mass index (mean±SD)	23.6±3.7	23.1±3.4	0.593
Smoking history	70.5	47	0.080
Hypertension	47	46.6	0.986
COPD	11.7	7.3	0.502
ASO	0	2.6	0.500
Diabetes	23.5	20.4	0.757
Insulin use	11.7	4.7	0.182
Renal failure	0	2.6	0.498
NYHA≥3	35.2	27.1	0.457
Steroid use	0	0.7	0.727
Preoperative ICU stay	29.4	16.9	0.175
Preoperative IABP use	29.4	9.1	0.005

COPD, chronic obstructive pulmonary disease; ASO, arteriosclerosis obliterans; ICU, intensive care unit; IABP, intraaortic balloon pump; SD, standard deviation.
Diabetes: patients administered insulin or oral hypoglycemic agent.
Renal failure: serum creatinine level ≥2.0 mg/dl.

Table 3. Univariate predictors for DSWI of perioperative variables

Variable	Group I (n=17) (%)	Group II (n=846) (%)	p value
Emergency operation	35.2	16.7	0.045
Previous sternotomy	0	4.7	0.358
Isolated CABG	52.9	61.8	0.456
Combined CABG	17.6	4.8	0.018
Valve surgery	35.2	22.5	0.216
Aortic surgery	11.7	17.4	0.535
LITA	47	49.4	0.847
BITA	11.7	16.6	0.590
Operation time (hours)			
≥7	52.9	39	0.245
≥8	41.1	23	0.081
CPB time ≥3 hours	52.9	35.4	0.137
Blood transfusion	58.8	45.3	0.270

CABG, coronary artery bypass grafting; LITA, left internal thoracic artery; BITA, bilateral internal thoracic artery; CPB, cardiopulmonary bypass.

isolated CABG patients. Emergency operation was an independent predictor for DSWI in isolated CABG patients (OR, 10.9; 95% CI, 2.7, 44.7) (Table 5).

Outcome of patients with DSWI

Mean age of 17 DSWI patients was 62.0±11.9 years, ranging from 38 to 79 years. Twelve of the 17 DSWI patients were male. Four of the patients died due to the infection (mortality, 23.5%) after a mean of 112.5±101.9 days from the day of surgery (range from 53 to 265 days). Initial cardiac surgical procedures were isolated CABG in 8 patients, isolated valve operation in 4, total arch replacement in 1, combined CABG and valve operation in 2, combined CABG and total arch replacement in 1, and combined CABG and carotid endarterectomy in 1 (Table 6). The mean interval between initial cardiac operation and diagnosis of DSWI was 23.6±16.0 days, ranging from 7 to 51 days. Cultured organisms from the wound were methicillin-resistant Staphylococcus aureus (MRSA) in 10 patients (58.8%), methicillin-sensitive Staphylococcus aureus (MSSA) in 2, alpha hem Streptococcus in 1, enterobacter cloacae in 1, Staphylococcus epidermidis in

Table 4. Univariate predictors for DSWI of postoperative variables

Variable	Group I (n=17) (%)	Group II (n=846) (%)	p value
Ventilation time (hours)			
≥24	41.1	28.1	0.237
≥48	29.4	25.7	0.734
Inotropic agents (hours)			
≥24	64.7	48.4	0.191
≥48	52.9	35.2	0.135
ICU stay >5 days	52.9	21.7	0.002
Resternotomy	11.7	4.2	0.135
LOS	5.9	1.9	0.241
IABP use	35.2	11.2	0.002
Postoperative hyperglycemia	41.1	28.8	0.036
Drainage time (days)			
>2	100	97.5	0.554
>3	82.3	56.9	0.038
Postoperative renal failure	5.9	5.8	0.988
Postoperative MI	5.9	6.9	0.837

ICU, intensive care unit; LOS, low cardiac output syndrome; IABP, intraaortic balloon pumping; MI, myocardial infarction.
Resternotomy: resternotomy refers to postoperative hemorrhage.
Postoperative hyperglycemia: blood glucose ≥200 mg/dl at 12 hours after surgery.
Postoperative renal failure: serum creatinine level ≥2.0 mg/dl during postoperative period.

Table 5. Multivariable independent predictors for DSWI

Variable	Odds ratio	95% CI
All cardiac surgery (n=863)		
Combined CABG	4.1	1.1-15.1
Postoperative IABP use	4.4	1.6-12.3
All CABG (n=576)		
Simultaneous valve surgery	6.7	1.3-35.3
Postoperative IABP use	6.7	2.0-21.9
Isolated CABG (n=532)		
Emergency operation	10.9	2.7-44.7

CABG, coronary artery bypass grafting; IABP, intraaortic balloon pumping.
CI: confidence interval.

1, and negative in 2 (Table 7). We used Vancomycin or arbekacin against MRSA, Cefazolin or ampicillin/sulbactam against MSSA, ampicillin and gentamicin against alpha hem Streptococcus, carbapenem and amikacin against enterobacter cloacae, and Cefazolin against Staphylococcus epidermidis. The initial surgical treatment for DSWI was drainage alone at the bedside in 3 patients, wound debridement and open mediastinal irrigation in 1, debridement and primary sternal closure in 8, closed mediastinal irrigation in 2, and debridement and primary closure with omentum flap in 3. Eleven of the patients needed one or more additional surgical treatment, namely, open mediastinal irrigation in 1, closed mediastinal irrigation in 3, an omentum flap in 4, a pectoralis muscle flap in 2, and a rectus abdominis flap in 3. Among the 13 survivors, 12 (70.5%) patients recovered completely, but one still has chronic osteomyelitis. The mean age of the deceased patients was higher than that of the survivors (69.5±7.0 vs. 59.6±12.2 years), but the difference was not statistically significant. It should be further noted that four of seven patients with an omentum flap died, while all of the patients with a muscle flap survived.

Table 6. Initial cardiac operation of DSWI patient

Procedure	No. of patients (dead patient)
Isolated CABG	8 (1)
Isolated valve surgery	4 (0)
Total arch replacement	1 (1)
CABG + valve surgery	2 (1)
CABG + total arch replacement	1 (1)
CABG + carotid endarterectomy	1 (0)

CABG: coronary artery bypass grafting.

Table 7. Bacteriology

Organism	No. of patients (dead patient)
MRSA	10 (4)
MSSA	2 (0)
Alpha hem streptococcus	1 (0)
Enterobacter cloacae	1 (0)
Staphylococcus epidermidis	1 (0)
Negative	2 (0)

Cultured organisms from the wound of DSWI patients. MRSA, methicillin-resistant Staphylococcus aureus; MSSA, methicillin-sensitive Staphylococcus aureus.

The four patients who died had DSWI with MRSA, and two of them had undergone total arch replacement with a prosthetic graft.

Discussion

Risk factors and prevention of DSWI

There have been many articles analyzing the risk factors for DSWI.[1-9] Identified risk factors have included advanced age, diabetes, male, chronic obstructive pulmonary disease, obesity, CABG, bilateral ITA (BITA) use, inotropic agents, postoperative resternotomy, operation time, BITA in diabetic patients, blood transfusion, and so on. In our study we identified three independent predictors of DSWI, namely, emergency operation, combined CABG and valve or aortic surgery, and postoperative use of IABP.

Most patients undergoing emergency operation or requiring IABP are in poor physical condition, for example, in shock or with low cardiac function. Often, the poor condition will continue after the postoperative period. In addition, the intravenous catheter and endotracheal tube frequently have to be kept in place longer in patients in poor physical condition. The deterioration of a patient's condition results in an infectious barrier malfunction that allows microorganisms to migrate to the mediastinal wound. Though the preoperative use of IABP was not an independent predictor in multivariate analysis, univariate analysis revealed it was a significant preoperative predictor. We consider the patients requiring IABP preoperatively are also in poor physical condition, namely, in shock or with low cardiac function. In patients undergoing combined operations, the CPB is more invasive and time-consuming than isolated cardiac operation. Use of CPB may induce suppression of the immune system.[10]

Several of the risk factors reported in the literature, namely, advanced age, lots of inotropic agent, low cardiac output syndrome, and a long operation time, seem to reflect poor general condition and greater surgical invasion.[1-4)]

Kouchoukos et al. reported that BITA use in CABG was an independent predictor of DSWI.[11] Carrier et al. reported that the impairment of the blood supply to the sternum after ITA harvesting is associated with DSWI.[12] In reports noting the significantly greater residual sternal blood flow on the side of the skeletonized ITA than on the side of the pedicle ITA, Parish et al. and Uva et al. proposed that DSWI may be preventable by adopting a skeletonization technique.[13,14] In this study, BITA use did not increase the risk of the DSWI whatsoever. We employed a skeletonization technique during ITA harvesting, and this helped to maintain an adequate blood flow in the mediastinum during the postoperative period.

Diabetes is cited as one of the major risk factors for DSWI in other reports. While univariate analysis in our study revealed a significant incidence of postoperative hyperglycemia in groups I, diabetes was not selected as a predictor for DSWI. In addition, the incidence of preoperative insulin use was not different between groups I and II. We presume that a poor perioperative condition, e.g., IABP use, combined surgery, or emergency surgery induced the secretion of endogenous catecholamine resulting in postoperative hyperglycemia. Furnary et al. reported that a continuous intravenous insulin infusion reduced the perioperative blood glucose level and incidence of DSWI.[15] Fully concurring with their opinion, we have vigorously controlled the blood glucose level after surgery in recent years.

In this study, BITA use, preoperative insulin use, and diabetes did not increase the risk of DSWI. Since the ITAs were regarded as ideal graft materials in view of their resistance to atherosclerosis, the use of BITA in diabetic patients is likely to be beneficial. Although it has been controversial, we think that this result justifies the use of BITA in diabetic patients.

Treatment and outcome of DSWI patients

The mean age of the patients who died of DSWI tended to be higher than that of survivors. This suggests that DSWI was difficult to cure in elderly patients.

The type of microorganism causing DSWI has been changing. DSWI due to MRSA is the most serious problem today. Since its outbreak in our hospital in 1990, MRSA has rapidly proliferated. Although the infection was sensitive to Vancomycin, this drug was not available for clinical use in Japan until November 1991. Before the emergence of MRSA, DSWI could be controlled by debridement and close irrigation of the mediastinum. On the other hand, DSWI due to MRSA was difficult to control by that simple strategy. Even though we treated it vigorously with reoperation using an omentum or muscle flap to control infection, the outcome was unsatisfactory. The mortality of DSWI due to non-MRSA was zero among our patients, whereas died from DSWI due to MRSA as many as 40% (four of 10 patients). Even in survivors, multiple surgical intervention was needed due to the recurrence of infection in the MRSA group.

Regarding the material to fill in the dead space,[16-20] our first choice was the omentum flap and the second was the muscular flap until now. The reason was that we could use the omentum flap relatively easy. We thought the muscular flap had a few technical difficulties for cardiovascular surgeons, but it was extremely useful for the large dead space and the large skin defect. This study showed that the muscular flap was markedly superior to the omentum flap. While the mortality of the muscular flap was zero, that of an omentum flap was 57% (four of seven patients).

On the basis of our experience thus far, we believe that the best method for the surgical treatment of DSWI is the combination of effective debridement and the use of a muscular flap in the incipient stage of infection. However, owing to the small number of patients treated by muscular flap, we think that it is difficult to establish a decisive conclusion.

Conclusion

The incidence of DSWI in cardiac surgery was 2.0%. Independent risk factors for DSWI were emergent surgery, combined surgery, and postoperative IABP use. Systematic measures have to be taken for patients in poor condition to prevent DSWI. The mortality and morbidity of DSWI due to MRSA are still high. We believe that the best surgical treatment of DSWI is the combination of debridement and muscular flap. However, it has not been established whether the muscular flap is superior to the omentum flap.

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