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Mediastinitis and Cardiac Surgery – an Updated Risk Factor Analysis in 10,373 Consecutive Adult Patients

Original Paper

Abstract

Background: Deep sternal wound infection (DSWI) remains a serious complication after cardiac surgery. New evolving techniques including the utilization of internal mammary arteries (IMA), beating heart procedures, and minimal invasive surgery (MIC) require an updated risk factor analysis to identify high risk patients in order to improve perioperative treatment. **Methods:** 10,373 consecutive patients receiving cardiac surgery between May 1996 and August 1999 were evaluated: 9,303 underwent full sternotomy whereas a minimally invasive (MIC) approach using partial sternotomy or lateral thoracotomy was used in 1,070 patients. DSWI was defined as the evidence of mediastinitis seen at reoperation along with one or more of the following: positive culture of mediastinal fluid, positive blood culture or temperature higher than 38 °C and/or leukocytosis. **Results:** The overall incidence of DSWI in the "full sternotomy" group was 1.44% (134 of 9,303). Univariate risk factor analysis showed a significant influence of IMA use, ICU / IC treatment > 5 days, postoperative ventilator time = 72 h, need for reexploration, diabetes, surgery time = 180 min, assist device implantation (including use of IABP), peripheral vascular disease and increased body mass index. Multivariate analysis identified double IMA, ICU treatment > 5 days, single IMA, diabetes, reexploration and increased body mass as significant risk factors. No mediastinitis was observed in the MIC group. **Conclusion:** As DSWI is related to sternotomy, a MIC approach should be considered for patients at high risk for DSWI. IMA takedown as a pedicled graft should be especially avoided in patients with iabetes since the risk for postoperative mediastinitis is unacceptably high in this patient group.

Key Words

Mediastinitis · Heart surgery · Diabetes · Risk factors

Introduction

Mediastinitis (deep sternal wound infection (DSWI)) after cardiac surgery remains a serious complication. Its incidence varies from 0.16% to 2.2% in the literature [1–2] with some series as high as 8% [3]. DSWI is associated with a mortality of up to 30% [4–6]. The etiology is multifactorial. The most important source is probably intraoperative wound contamination [6]. However, an endogenous pathway has also been demonstrated [7]. A vast number of risk factors such as diabetes, COPD, use of bilateral IMA grafts, reexploration of the mediastinum for control of hemorrhage, prolonged postoperative ventilation time, age, low ejection fraction, obesity, use of blood products, bone wax and others (Table 1) have been described in individual studies. However, results are still inconclusive, and controversy remains about the predictive value of single factors identified [1,5,6,8–10].

Important new techniques including the utilization of internal mammary arteries (IMA), beating heart procedures, and minimal invasive surgery (MIC) require an updated risk factor analysis to identify high risk patients in order to improve perioperative treatment.

Table 1   Risk factors for DSWI described in recent studies.

Variable	Author				
	Basket [1]	Stahle [10]	Bitkover [5]	Milano [6]	Grossi [13]
Number of patients	9,771	13,285	111[a]	6,459	2,356
Preop variables					
Diabetes	no	yes	yes	yes	yes
COPD	yes	–[b]	no	no	–
Obesity	no	–	yes	yes	–
Age	no	yes	no	–	–
chronic steroids	–	–	no	–	–
Renal failure	no	yes	no	no	–
previous cardiac surgery	no	no	no	–	–
ventricular function	no	no	no	no	–
Intra-/postop variables					
IMA	no	yes	no	no	yes
bilateral IMA	no	yes	no	no	yes
total operation time	–	–	yes	–	–
Use of temp. pacing wires	–	–	yes	–	–
Prolonged ventilation	no	–	no	–	–
Reexploration	yes	yes	no	–	–

[a] case control study
[b] – not analyzed

Table 2   Clinical characteristics of patients receiving full sternotomy.

	Without DSWI n = 9,169	DSWI n = 134	p-value
Age (years)	65.3±10.1	66.2±9.4	0.254
Procedures			
Non-CABG procedures[a]	1,958 (20.2%)	10 (7.5%)	0.0003
CABG + additional procedure[b]	837 (9.1%)	9 (6.7%)	0.175
CABG[c]	6,374 (69.5%)	115 (85.8%)	<0.0001
IMA			
CABG w/o IMA[d]	878 (6.4%)	8 (5.2%)	0.721
CABG w IMA[d]	6,033 (65.8%)	97 (72.4%)	0.110
CABG w double IMA[d]	300 (3.3%)	19 (14.2%)	<0.0001
Co-morbidity			
Diabetes	3,145 (34.3%)	74 (55.2%)	<0.001
Renal insufficiency	388 (4.2%)	8 (6%)	0.322
COPD (n = 9,209)[e]	621 (6.8%)	10 (7.6%)	0.740

[a] Valve procedures, congenital or aortic surgery
[b] Coronary surgery combined with valve, congenital or aortic surgery
[c] Coronary surgery excluding combined procedures
[d] Coronary surgery including combined procesures
[e] Exclusive 74 patients with missing values

The purpose of this study was to identify risk factors for DSWI in a single center with a high patient volume and a consistent protocol throughout the observation period.

Methods

Study population
At the Leipzig heart center, 10,373 consecutive adult patients underwent open heart surgery between May 1996 and August 1999. A minimally invasive (MIC) approach – either an anterolateral thoracotomy (MIDCAB procedures, n = 717 patients), a lateral thoracotomy (mitral valve procedures, n = 175 patients) or a partial sternotomy (aortic valve or thoracic aortic procedures, n = 178 patients) – was used on 1,070 patients. Those patients were excluded from further analysis.

A total of 9,303 patients underwent full sternotomy. 1,968 patients in the "full sternotomy" group had no coronary artery disease, 6,489 patients underwent coronary artery bypass grafting (CABG) alone and 846 patients underwent CABG combined with other procedures (valve repair, valve replacement, aortic surgery and other procedures). CABG was done without using the heart lung machine (HLM) in 226 patients. In this "beating heart" subgroup, both IMAs were used in 33 patients (14.6%) compared to 268 patients (4.3%) in the HLM group.

More clinical characteristics of the "full sternotomy" patient population are shown in Table 2.

Perioperative standard protocol
Routine perioperative antibiotic prophylaxis consisted of cefazolin. Cefazolin was given to patients undergoing valve surgery until postoperative day 2. Antibiotic therapy was administered according to microbial sensitivity in patients with endocarditis.

Table 3   Isolated pathogens from mediastinal fluid.

Staphylococcus	71%
Staphylococcus aureus[a]	47%
Staphylococcus epidermidis	16%
Enterococcus faecalis	7%
Serratus	7%
Pseudomonas	5%
other	22%

[a] including 4 patients with MRSA

All patients were draped in the standard fashion and the chest was covered with adhesive transparent drapes. The skin incision was performed with a scalpel and the presternal tissue dissected by electrocautery. The sternotomy was performed in the standard fashion using a pneumatically driven saw, and bone wax was used at the individual surgeon's discretion. The internal mammary artery was harvested with a small pedicle using electrocoagulation, and the pleural cavity was usually opened. Standard cardiopulmonary bypass techniques were applied using membrane oxygenators and mild hypothermia. A mediastinal and pericardial chest tube were inserted in all patients, with chest tubes inserted only if the pleural cavities were opened. An epicardial pacing wire was placed on the right ventricle. The sternotomy was routinely closed with 6 to 7 steel wires. Fascia and subcutaneous tissue were closed with running vicryl sutures, and the skin was closed using a synthetic absorbable suture.

Definition of deep sternal wound infection (DSWI)
DSWI was defined using the Center for Disease Control definition [1] as evidence of mediastinitis seen at reoperation with positive culture of mediastinal fluid and/or positive blood culture and/or temperature higher than 38 °C and/or leukocytosis.

Data collection

Perioperative data were recorded prospectively using an online database system as described previously [11]. All variables analyzed were entered in a prospective fashion to accomplish a complete and valid data set for each patient. Registration of sternal wound complications was complete for all patients including late infections up to 74 days after surgery. Data validity was routinely ensured by using that information for generating text documents, thus resulting in a meticulous confirmation of the entered data by the user. The risk factors included in this analysis are listed in Table 4.

Table 4 Univariate Risk factor analysis for all sternotomy patients.

Variable	Odds Ratio	95%-CI	p-value
Double IMA (y/n)	4.9	3.0–8.0	<0.001
ICU/IC treatment > 5 days	4.1	2.9–5.8	<0.001
Postop ventilator time[a] (≥72 h)	4.3	2.8–6.4	<0.001
Reexploration (y/n)	3.1	1.9–5.1	<0.001
Diabetes[b] (y/n)	2.4	1.7–3.3	<0.001
Surgery time ≥ 180 min	2.2	1.6–3.2	<0.001
IMA[c]	2.9	1.7–4.8	<0.001
Assist devices (incl. IABP)	1.9	1.0–3.5	0.034
Peripheral vascular disease (y/n)	1.7	1.2–2.5	0.006
Body mass ≥ 30 kg/m² (y/n)	1.6	1.0–2.4	0.017
Single IMA (y/n)	1.4	0.9–2.0	0.119
Previous cardiotomy	0.3	0.1–1.4	0.124
Ischemia time > 1 h	1.0	0.6–1.5	0.231
Renal insufficiency (y/n)	1.4	0.7–3.0	0.384
Perfusion time > 2 h	1.4	0.9–2.2	0.431
Emergency (y/n)	1.0	0.5–1.9	0.536
Postop low-output syndrome	1.2	0.6–2.4	0.691
COPD (y/n)	1.1	0.9–1.2	0.753
Preop ejection fraction (<30%)	1.1	0.6–2.0	0.847

[a] Ventilator time after first procedure
[b] Taking insulin or oral hypoglycemic drugs
[c] Using either single or double IMA

Statistical analysis

Continuous variables are expressed as the mean ± standard deviation, categorical data as proportions. The chi-square-test and Student's t-test were used to compare patients with and without DSWI. Univariate analyses of risk factors were performed calculating odds ratios (OR) with 95% confidence intervals. A multivariate logistic regression model was built to assess the independent impact of risk factors on DSWI, employing a backward (Wald) procedure. Significance was assumed at p < 0.05. All statistical analyses were performed using the statistics software package SPSS 10.0.7 (SPSS Corp., Birmingham, AL, USA).

Results

Incidence of deep sternal wound infections

No mediastinitis was observed for the patient group with partial sternotomy or lateral thoracotomy (MIC group). The overall incidence for DSWI in the "full sternotomy" group was 1.44% (134 of 9,303 patients).

The bacterial pathogens isolated from the mediastinal fluid are shown in Table 3. Coagulase-negative staphylococci were the most frequently isolated organism. Pathogens could not be isolated in 12% of all DSWI patients.

The incidence of DSWI differed among subgroups. The incidence was 0.5% in the non-bypass surgery group, 1.7% in the bypass surgery group (including combinations), and 1.8% (115 of 6,489 patients) in patients undergoing exclusive coronary bypass procedures.

There was no significant difference in the incidence of DSWI between the non-coronary surgery group (0.5%) and the coronary surgery group without IMA (0.9%, p = 0.333) and the single IMA group (1.6%, p = 0.165). However, there was a significant difference in the incidence of DSWI between the single IMA and double IMA groups (6.0%, p < 0.001). The hospital mortality in the single IMA group was 4.2% compared to 5.6% in the double IMA group (p = 0.28). Thus, a selection bias in favor of the single IMA group can be ruled out.

Incidence of DSWI in the "beating heart" subgroup

The incidence of DSWI was 1.8% (4 of 226 patients) in the "beating heart" subgroup, the same incidence as in patients undergoing coronary bypass procedures with the heart-lung machine.

The incidence of DSWI in patients receiving a double IMA in the "beating heart" subgroup was 9.1% (3 of 33 patients), compared to 3.2% (16 of 286 patients) in the HLM subgroup. However, this difference was not significant (p = 0.422).

Diabetes and deep sternal wound infection

Fig. 1 reveals the incidence of DSWI in patients with and without diabetes. The overall incidence in the diabetes group (n = 3,219 patients) was 2.30% vs. 0.99% in patients without diabetes (n = 6,084 patients, p < 0.001). The incidence of DSWI was twice as high for diabetics compared to non-diabetics receiving a single IMA (p < 0.001). There was a higher incidence of DSWI in patients with a double IMA and diabetes as compared to non-diabetics (p = 0.016). The mortality in diabetic patients was significantly higher than in the non-diabetic group (6.2% vs. 5.1%; p = 0.044).
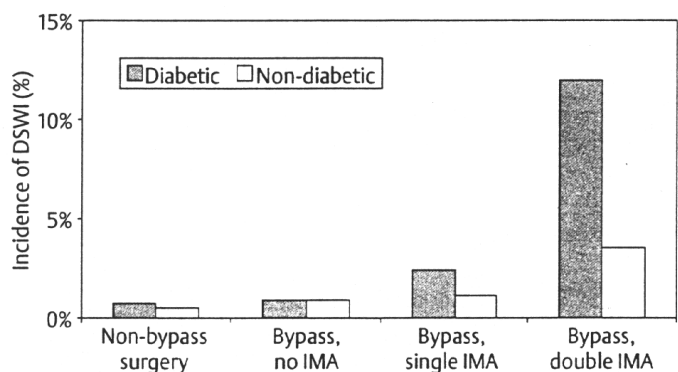

Fig. 1 Incidence of DSWI in patients with and without diabetes: The overall incidence in the diabetes group (n = 3,219 patients) was 2.30% versus 0.99% in patients without diabetes (n = 6,084 patients, p < 0.001). The incidence of DSWI doubles between diabetics and non-diabetics in the single IMA-group (p < 0.001). The risk of DSWI also significantly increases (p = 0.009) in double IMA patients who are diabetic compared to non-diabetics.

Univariate analysis of risk factors

Univariate analysis of risk factors in the "full sternotomy" group showed a significant influence of double IMA (OR = 4.9), prolonged intensive care treatment (OR = 4.1), postoperative ventilator time (OR = 4.3), need for surgical reexploration (OR = 3.1), diabetes (OR = 2.4), duration of surgery (OR = 2.2), perioperative use of an assist device (OR = 1.9), peripheral vascular disease (OR = 1.7), and increased body mass index (OR = 1.6). Other factors (preoperative ejection fraction, renal insufficiency, COPD, cross-clamp time, bypass time, specific operating room) had no significant impact (Table 4). The risk for DSWI could not be associated with a specific surgeon (p = 0.169, only surgeons with more than 50 procedures included).

Logistic regression analysis of risk factors

A multivariate logistic regression analysis was performed to investigate the independent impact of risk factors on DSWI. All variables analyzed in Table 4 were included in the regression model and were excluded stepwise. The use of a double IMA, presence of diabetes, use of a single IMA, and increased body mass index (BMI) were identified as significant independent preoperative risk factors for postoperative development of DSWI. The mortality rate in patients with a BMI more than 30 kg/m² was lower than in patients with a BMI less than 30 kg/m2 (3.1 % vs. 6.0 %, p < 0.001), thus ruling out a selection bias. Perioperative independent risk factors were prolonged intensive care treatment and the need for surgical reexploration (Table 5).

Table 5 Multivariate logistic regression analysis.

Variable	Odds ratio	95%-CI	p-value
DIMA	12.5	6.4 – 24.4	< 0.001
ICU/IC treat. > 5 days	4.2	2.9 – 6.0	< 0.001
Single IMA	2.8	1.7 – 4.6	< 0.001
Diabetes (y/n)	2.1	1.5 – 3.0	< 0.001
Reexploration (y/n)	1.8	1.1 – 3.1	0.023
Body Mass ≥ 30 kg/m²	1.5	1.0 – 2.3	0.036

Mortality and DSWI

The overall hospital mortality rate in the DSWI population was 21.6 % (29 of 134 patients) as compared to 5.3 % (483 of 9,169 patients) in patients without DSWI (p < 0.001). In the CABG group, the mortality after DSWI was 17.1 % (19 of 111) and 43.5 % for all other patients (10 of 23).

76 out of the 134 patients with DSWI were treated successfully with a single revision of the sternum, 31 patients required two revisions and 27 patients required more than two revisions due to recurrent infection or sternal instability. Fig. 2 illustrates the increase in mortality in association with recurrent infection requiring more than one sternal revision (p = 0.0003).

Discussion

Deep sternal wound infection after cardiac surgery is a very serious complication, as demonstrated by the high morbidity
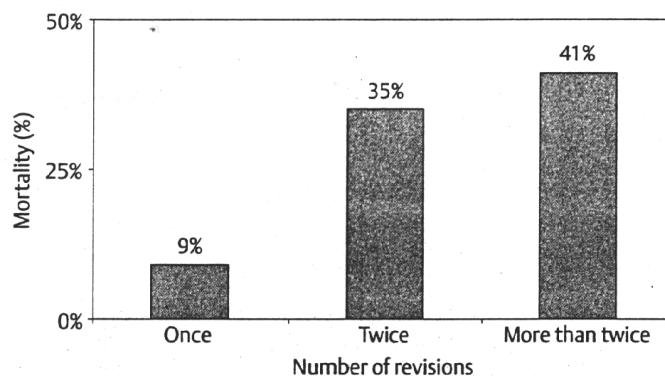

Fig. 2 Increase in hospital mortality in relation to the number of sternal revision required to treat DSWI: The overall hospital mortality rate in the DSWI population was 21.6 % (29 of 134 patients). Out of 134 patients, 74 were treated successfully with a single sternal revision, 31 required two revisions and 27 required more than two revisions due to recurrent infection or sternal instability. The difference in mortality rates amongst the three groups is statistically significant (p = 0.0003).

and mortality rate associated with this problem [1–6]. Postoperative mediastinitis is certainly related to full sternotomy. A minimal invasive approach combined with other interventional methods can be considered in patients at high risk for DSWI where possible.

As expected, we were unable to demonstrate any differences in DSWI rates between patients undergoing conventional coronary bypass and those where beating-heart surgery was performed. This finding supports the conclusion that the heart-lung machine does not substantially add to the risk of developing DSWI. The discussion about risk factors is controversial since the etiology of DSWI is multifactorial and difficult to analyze [8]. Perioperative risk factors such as the need for surgical reexploration, prolonged intensive care unit treatment and prolonged duration of operation have been identified by other groups as well [12]. These factors are difficult to control, but our results underscore that careful attention to hemostasis and meticulous surgical technique remain the basis of avoiding DSWI.

Patients with more than one risk factor have an even higher incidence of DSWI, indicating that a combination of risk factors potentiates the risk. This is particularly true for the combination of diabetes and double IMA. If both risk factors are present, the risk is much higher than for either factor alone. Our findings are consistent with the study published by Grossi who described an odds ratio of 13.9 in diabetics receiving both IMAs [13].

Diabetes is obviously one of the most important risk factors. A selection bias can be ruled out since the mortality rate in the diabetic subgroup is even higher than in the control group. Meticulous control of perioperative serum glucose levels can help to reduce the risk of DSWI in diabetic patients as demonstrated by Furnary and co-workers [14]. Our results advocate the institution of such a protocol. The necessity to use both IMAs is compelling in the era of complete arterial grafting [15]. However, several groups have demonstrated the high incidence of DSWI in patients after double IMA takedown, thus discouraging its use – particularly in diabetic patients [16,17].

Studies on different IMA takedown techniques have revealed that minimizing tissue trauma may lower the incidence of DSWI, thus reducing DSWI to an tolerable incidence below 2% [18,19].

Recently published experimental data on sternal ischemia using different mammarian takedown techniques [20] and clinical data [19] are strong arguments for skeletonizing the IMA, particularly if both arteries are needed. In our institution, we have made a policy change based on the results of these studies. We currently skeletonize the IMA in nearly all patients.

The hospital mortality in patients with DSWI is extremely high, especially in patients requiring more than one operation to treat the infection [4]. In a study analyzing the long-term results of CABG patients with mediastinitis, a mortality of 28.6% was demonstrated at 1.5 years, which is quite comparable to our own results [6]. More efforts are needed to develop effective prophylactic protocols and reliable treatment methods for DSWI.

In conclusion, this study identifies three important preoperative risk factors for DSWI – the use of a pedicled IMA, diabetes mellitus, and obesity. In controlling these factors, the incidence of DSWI may be effectively reduced.

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