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Predictors of Complications After Pectoralis Major Transposition for Sternum Dehiscence

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Objectives: Mediastinitis and sternum dehiscence are serious complications after open heart surgery, causing an increase in hospital stay, utilization of health care resources, and mortality. The defect that results after sternal wound debridement frequently necessitates tissue-flap coverage, for which pectoralis major transposition currently is the preferred method. In this study, the postoperative outcome and individual characteristics of patients undergoing pectoralis major transposition were analyzed to identify predictors of complications after wound closure.

Methods: A retrospective chart review was conducted, covering a 7-year period, focusing on patient and operation characteristics. All patients with sternum dehiscence, who underwent pectoralis major transposition, were included. All postoperative wound complications were graded according to the Clavien-Dindo classification of surgical complications. Complications were further divided in major and minor. Mortality was defined as death within 30 days after sternal wound repair or during hospital stay.

Results: In total, 77 patients underwent a pectoralis major transposition repair of the sternum. Thirty-eight patients (49%) developed a wound complication of which 21 (27%) had a major wound complication. Mortality was 9%. Further analyses of our data showed that smoking and length of operation time were predictors of wound complications ($P = 0.018$ and $P = 0.01$). Female sex showed a relation with wound dehiscence ($P = 0.014$). Postoperative bleeding, for which reoperation was necessary, occurred more often when the humeral insertion of the pectoralis major flap was divided ($P = 0.004$).

Conclusions: Tissue-flap coverage of the sternum using pectoralis major advancement flaps is a procedure that is still hampered by a high postoperative complication incidence. Female sex, smoking, detachment of the humeral insertion and operation time are associated with postoperative wound complications. These results may contribute in improving operative strategy. Also the use of the Clavien-Dindo classification makes underestimation of the complication rate unlikely in this study. The classification can easily be used in future studies, which will enhance comparability of results.

Key Words: mediastinal infection, sternum, chest wall reconstruction, pectoralis major transposition, complications

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Poststernotomy mediastinitis (PSM), followed by sternum dehiscence, is a life-threatening complication after open heart surgery. It usually starts with an infection of the sternotomy wound that can subsequently spread to the underlying tissues and mediastinal structures.¹ It requires additional surgical procedures and is associated with prolonged hospitalization and increased morbidity and mortality. The reported incidence ranges between 1% and 3%, but 30-day mortality rises to 50% when the infection is not treated adequately.^{2–4} Successful recovery has been found to depend on early diagnosis and treatment. Besides

systemic antibiotic treatment, surgical intervention is cornerstone of treatment. The optimal surgical strategy remains to be defined, but treatment has improved enough to significantly lower morbidity and mortality in patients.⁵

The first step in surgical treatment of PSM is radical debridement of infected and necrotic soft tissue, bone, and cartilage. The defect that remains after this intervention can be closed in multiple ways, depending on size and location.^{6,7} Due to the aggressiveness of the debridement, the defect is often too large for primary closure. This makes it necessary to mobilize adjacent tissues or harvest more distant flaps for coverage of the sternal defect. The flaps generally used for reconstruction of the chest wall are the pectoralis major muscle, rectus abdominis muscle, latissimus dorsi muscle, and the greater omentum.^{5,8} Currently, pectoralis major flap transfer is the preferred method. The muscles are located close to the wound, have good blood supply, excellent rotability, and can be used in different ways.⁴ The proximity to the wound and ease of dissection reduce additional trauma. Besides that, the muscle has the advantage of being versatile. It can be used unilateral as well as bilateral, and it can be transferred as an advancement flap based on the thoracoacromial pedicle or as a turnover flap based on the internal mammary perforators.^{4,9,10}

The introduction of muscle and omentum flaps has lowered morbidity and mortality in patients with PSM. Nevertheless, tissue-flap coverage of the sternum is still hampered by a high incidence of postoperative complications.^{5,11} Common wound complications associated with pectoralis major flap transfer for sternal defects include hematomas, seromas, skin or flap necrosis, wound infection, recurrent or nonresolved infection, and partial or full wound dehiscence.^{5,8} Besides early postoperative complications, there are some long-term complications that have been described, such as functional disability and donor-site deformity.^{6,10,11} The aim of this study was to identify factors that play a significant role in the occurrence of postoperative wound complications after pectoralis major flap transfer.

PATIENTS AND METHODS

A retrospective chart analysis of all patients who underwent secondary closure of sternal wounds with pectoralis major flap transfer of at the University Medical Center in Groningen was performed. All patients older than 18 years with PSM who were subjected to such a procedure, during a period of 7 years, were included in this retrospective analysis.

In our study, transposition of the pectoralis muscle as advancement flap was the standard procedure. First, the muscles were detached from their sternal origin and dissected from subcutis and thorax as far as needed to sufficiently cover the defect. If necessary, the surgeon decided to divide the humeral insertion of the pectoralis muscle in order to create more freedom of movement. Then the flaps were transposed medially to cover the sternal defect, based on the thoracoacromial pedicle. After this, the overlying skin was closed primarily.¹²

Patient files were reviewed for the following patient characteristics: age, sex, body mass index, nutritional state, hypertension, congestive heart failure (CHF), diabetes mellitus, renal insufficiency, chronic obstructive pulmonary disease (COPD), history of smoking, ASA-score and use anticoagulants during operation. Comorbidities were included when present before the initial cardiac operation. Obesity was

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TABLE 1. Clavien-Dindo Classification of Surgical Complications

Grade	Definition
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions Allowed therapeutic regimens are: drugs as antiemetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. This grade also includes wound infections opened at the bedside
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications. Blood transfusions and total parenteral nutrition are also included
Grade III	Requiring surgical, endoscopic or radiological intervention
Grade IIIa	Intervention not under general anesthesia
Grade IIIb	Intervention under general anesthesia
Grade IV	Life-threatening complication (including CNS complications)* requiring ICU management
Grade IVa	Single organ dysfunction (including dialysis)
Grade IVb	Multiorgan dysfunction
Grade V	Death of patient

* Brain hemorrhage, ischemic stroke, subarachnoid bleeding, but excluding transient ischemic attacks.

CNS indicates central nervous system; ICU, intensive care unit.

defined as body mass index of 30 kg/m² or greater. Nutritional state was scored based on serum albumin. Serum albumin less than 30 g/L was classified as a poor nutritional state and 30 g/L or greater as an acceptable nutritional state.¹³ Congestive heart failure was defined as New York Heart Association (NYHA) score of III or greater. All patients on oral or insulin therapy for their blood glucose were identified as diabetic. Patients with a baseline serum creatinine of 110 mmol/L or greater were defined as having renal insufficiency. Operation reports were reviewed for the following operation details: use of (bilateral) internal mammary artery (IMA) for coronary artery bypass grafting (CABG), unilateral/bilateral use of the pectoralis major, detachment of the humeral insertion, use of the rectus abdominis muscle/fascia, difficulty closing the most caudal part of the sternum (if mentioned in the operation report), time between first debridement and pectoralis major transposition, and duration of the procedure. These variables were analyzed to determine if their presence correlated with postoperative complications after tissue flap repair of complex sternal wounds.

To report consistent and reproducible results, all postoperative wound complications were defined according to the Clavien-Dindo classification of surgical complications (Table 1). This classification grades complications based on the therapy necessary to treat the complication, hereby preventing downrating of negative postoperative outcomes.¹⁴ When patients had more than 1 complication, only the highest-graded complication was counted for the analysis. A distinction was made between minor and major complications. A complication with grade III or higher was defined as major. Mortality was defined as death within 30 days after sternal wound repair or during hospital stay.

All data analyses were performed using IBM SPSS statistics version 20.0 (New York, USA). Univariate analysis of each variable was performed by using Pearson χ^2 test for dichotomous or categorical variables. When the expected value in any cell was less than 5, Fisher exact test was used. Continuous independent variables were analyzed with univariate logistic regression. Significance was set at *P* less than 0.05. Stepdown multivariate logistic regression analysis was conducted to determine the strongest independent predictors of postoperative complications. All variables with a *P* value less than 0.1 were included in

this model together with age and sex. The least significant variable was dropped at each step until only those variables with a *P* value less than 0.05 remained in the final model.

RESULTS

During a 7-year period, 5804 median sternotomies were performed at the department of cardiothoracic surgery. In 53% of these cases, the initial cardiothoracic procedure was a CABG. In 23%, the initial procedure was valve surgery; in 12%, it was a combination of CABG and valve surgery; and in 12%, the initial cardiothoracic operation was performed for another reason than CABG or valve-surgery. Seventy-seven (1.3%) patients who underwent muscle flap coverage of the sternum using pectoralis major flaps met our inclusion criteria. Of these patients, 75% underwent CABG, 9% underwent valve surgery, 10% underwent a combination of CABG and valve surgery, and 6% underwent cardiothoracic surgery other than CABG or valve surgery.

In all 77 patients, a radical debridement of infected and necrotic tissue was performed as first step, followed by topical negative pressure therapy. In a second procedure, the defect was covered with pectoralis major muscle flaps. Seventy-four patients underwent bilateral pectoralis major flap transfers, and 3 patients underwent unilateral pectoralis major flap transfers (151 flaps in total). According to the Clavien-Dindo classification of surgical complications, 38 patients suffered from a complication at the surgical site (49%), 21 wound complications were classified as major (27%) (Table 2). Seven patients (9%) died within 30 days or during hospital stay. Three patients died because of heart failure, 3 because of sepsis with multiorgan failure, and 1 because of respiratory failure. Hospital stay after pectoralis major transposition was significantly longer in patients who experienced a complication, especially in patients who developed major complications (37 vs 14 days (*P* < 0.01)).

Analysis of all patient and procedure specific factors showed that current smokers were more likely to develop a wound complication (*P* = 0.028). Average operative time of the procedure was not significant at the *P* less than 0.05 level in the univariate analysis (*P* = 0.051) (Table 3). Multivariate regression analysis showed that smoking and operative time were independent predictors of complications at the surgical site (Table 4). Smoking also showed a relationship when looking at major wound complications alone (*P* = 0.014). Furthermore, patients in whom it was difficult to close the most caudal part of the sternal wound (as described in the operation report) were more likely to develop a major wound complication (*P* = 0.047). Detachment of the humeral insertion was not significant at the *P* less than 0.05 level in the univariate analysis (*P* = 0.053) (Table 3). Multivariate regression analysis showed that smoking and detachment of the humeral insertion were independent predictors of major surgical-site complications (Table 5).

In the group of patients with a major complication of the surgical wound, 9 patients had recurrent dehiscence. Furthermore, 7 pectoralis major flap transfers were complicated by severe bleeding, 6 by infection, 6 by skin/flap necrosis, and 4 by seroma. Some patients suffered from

TABLE 2. Postoperative Complications Classified by Severity (Clavien-Dindo)

	n
Total	38
Grade I	11
Grade II	6
Grade IIIa	—
Grade IIIb	21
Grade IV	—
Grade V	—

TABLE 3. Predictors of Postoperative Wound Complications

	Overall (n = 77)	Total Wound Complication (n = 38)	P	Major Wound Complication (n = 21)	P
Patient characteristics	n (%)	n (%)		n (%)	
Age, mean ± SD	66 ± 10	66 ± 9	0.782	67 ± 10	0.438
Female	22 (29)	11 (29)	0.943	9 (43)	0.089
BMI	39 (51)	21 (55)	0.424	11 (52)	0.852
Poor nutritional state*	44 (79)	21 (78)	0.889	13 (76)	0.800
Hypertension	57 (74)	28 (74)	0.946	15 (71)	0.750
CHF (NYHA ≥ 3)*	45 (67)	22 (67)	0.932	13 (72)	0.593
Diabetes	30 (39)	14 (37)	0.707	10 (48)	0.340
Renal insufficiency	23 (30)	11 (29)	0.861	7 (29)	0.879
COPD	20 (26)	12 (32)	0.268	8 (36)	0.137
Current smoker*	27 (38)	18 (50)	0.028	12 (60)	0.014
ASA-score (≥3)*	69 (92)	33 (92)	1	17 (85)	0.333
Anticoagulants during operation*	35 (51)	17 (50)	0.808	10 (53)	0.905
Operation details					
PM (bilateral)	74 (96)	37 (97)	0.571	21 (100)	—
LIMA	56 (73)	27 (71)	0.681	16 (76)	0.803
BIMA	9 (12)	6 (16)	0.262	2 (10)	0.882
RA muscle/fascia used*	22 (31)	13 (34)	0.477	8 (36)	0.743
Difficulty closing caudal third*	8 (11)	6 (16)	0.275	5 (23)	0.047
Detachment humeral insertion*	15 (21)	10 (26)	0.278	8 (36)	0.053
Average time between procedures, mean ± SD	26 ± 12	24 ± 9	0.209	23 ± 10	0.176
Average operative time (min), mean ± SD	158 ± 46	172 ± 54	0.051	175 ± 61	0.072

* Missing values.

PM indicates pectoralis major; LIMA, left internal mammary artery; BIMA, bilateral internal mammary arteries; RA, rectus abdominis; BMI, body mass index.

more than 1 complication. Patients who developed recurrent dehiscence or postoperative bleeding always needed reoperation in our population. It was therefore of interest to investigate if specific variables were related to these complications. Univariate analysis showed that women were more likely to develop recurrent dehiscence ($P = 0.014$), current smokers were also more at risk of developing this complication ($P = 0.004$) (Table 6). The same analysis was conducted with postoperative bleeding as primary outcome measure. Patients in whom the humeral insertion was detached were more likely to experience postoperative bleeding ($P = 0.004$). Furthermore, a relation was found with prolonged operation time ($P = 0.011$) (Table 6).

DISCUSSION

Although minimally invasive procedures have entered the stage in the last two decades, median sternotomy still is the standard procedure for open heart surgery. Median sternotomy carries various potential complications of which PSM is most severe, because it necessitates further operation and increases the mortality rate. Consequently, it has a significant economic impact on the health care system.⁴ The introduction of flap coverage in the treatment of sternal wounds

significantly lowered morbidity and mortality.^{5,15} However, tissue-flap coverage of the sternum is still hampered by a relatively high postoperative complication incidence. Generating an overview of possible independent predictors of postoperative complications may contribute in improving this outcome. That was the ultimate goal of this internal audit.

In this 7-year study period we analyzed the results of 77 patients who underwent tissue-flap coverage of the sternum using the pectoralis major flap. Thirty-eight patients suffered from a complication at the surgical site, 21 of these wound complications were classified as major (≥ grade III). Seven patients (9%) died within 30 days after the procedure or during the same hospital admission. This mortality rate falls within the range (7.9–21%) reported in the literature.^{1,5,11,16} Hospital stay was significantly longer in patients who developed a postoperative complication, especially in those with a major surgical site complication. Although not calculated in detail, it is obvious that postoperative complications have a significant economic impact on the healthcare system.

To our knowledge, no previous studies used the Clavien-Dindo classification to grade postoperative complications after pectoralis major transposition for sternal defects. It was therefore difficult to compare our results with the numbers reported in the literature. Because the

TABLE 4. Stepdown Logistic Regression Analysis: Total Wound Complications

	β	P	OR	95% Confidence Interval (OR)
Smoking	1.331	0.018	3.785	1.251–11.452
Operative time (per min)	0.018	0.01	1.018	1.004–1.032
OR, odds ratio.				

TABLE 5. Stepdown Logistic Regression Analysis: Major Wound Complications

	β	P	OR	95% Confidence Interval (OR)
Smoking	1.546	0.017	4.691	1.312–16.769
Detachment humeral insertion	1.680	0.016	5.367	1.375–20.955

TABLE 6. Predictors of Postoperative Wound Complications (Redehiscence and Bleeding)

	Overall (n = 77)	Redehiscence (n = 9)	P	Bleeding (n = 7)	P
Patient characteristics	n (%)	n (%)		n (%)	
Age, mean $\pm$ SD	66 $\pm$ 10	68 $\pm$ 10	0.579	68 $\pm$ 10	0.512
Female	22 (29)	6 (67)	0.014	2 (29)	1
BMI	39 (51)	5 (56)	1	3 (43)	0.711
Poor nutritional state*	44 (79)	5 (71)	0.622	5 (71)	0.622
Hypertension	57 (74)	8 (89)	0.432	4 (57)	0.367
CHF (NYHA $\geq$ 3)*	45 (67)	3 (43)	0.206	6 (100)	0.167
Diabetes	30 (39)	6 (67)	0.142	2 (29)	0.699
Renal insufficiency	23 (30)	3 (33)	1	2 (29)	1
COPD	20 (26)	4 (44)	0.227	2 (29)	1
Current smoker*	27 (38)	7 (88)	0.004	3 (43)	1
ASA-score ($\geq$ 3)*	69 (92)	6 (75)	0.121	7 (100)	—
Anticoagulants during operation*	35 (51)	4 (57)	1	5 (71)	0.429
Operation details					
PM (bilateral)	74 (96)	9 (100)	—	7 (100)	—
LIMA	56 (73)	7 (78)	0.687	4 (57)	0.305
BIMA	9 (12)	1 (11)	0.831	1 (14)	0.720
RA muscle/fascia used*	22 (31)	4 (44)	0.441	3 (43)	0.668
Difficulty closing caudal third*	8 (11)	3 (33)	0.060	1 (14)	1
Detachment humeral insertion*	15 (21)	1 (11)	0.672	5 (71)	0.004
Average time between procedures, mean $\pm$ SD	26 $\pm$ 12	25 $\pm$ 8	0.772	24 $\pm$ 12	0.679
Average operative time: mean $\pm$ SD, min	158 $\pm$ 46	156 $\pm$ 62	0.925	212 $\pm$ 72	0.011

* Missing values.

Clavien-Dindo classification grades complications based on the therapy used to treat the complication, downrating of negative outcomes is prevented.¹⁴ This may explain why our numbers seem fairly high when comparing them with previous studies.^{5,8,11} Because of the use of this classification, we think we have reported a more realistic complication rate. The classification can easily be used in future studies, which will enhance comparability of results.

The sex distribution in our study population was consistent with that of other studies.^{1,8,17} Breast size in women was previously found as risk factor for the development of PSM.¹⁸ Jones et al⁵ found that recurrent dehiscence after tissue-flap coverage of the sternum occurs more frequently in obese women with large pendulous breasts. An association between female sex and recurrent wound dehiscence was also found in our study. This might have been caused by traction of large breasts on the wound edges or devascularization of mammary tissue. Due to the retrospective nature of this study, breast size as a cofactor could not be included in the analysis.

Previous studies showed that the presence of COPD was also a predictor of PSM and sternum dehiscence after open heart surgery. Chronic obstructive pulmonary disease might play a role in the development of recurrent dehiscence after sternal reconstruction as well, probably because of frequent and severe coughing.^{5,19} On the contrary, obesity and COPD were no independent predictors of postoperative complications, and more specifically re-dehiscence, according to our data. Several other comorbidities were analyzed because of their negative influence on wound-healing. A relation with hypertension, CHF, diabetes, and complications at the surgical site was found by others.⁸ Our data did not support these findings. Previous studies showed that smoking is a risk factor for developing PSM after median sternotomy.^{20,21} In our study population, patients who smoked at the time of hospital admission were more at risk of developing a complication at the surgical site. This is not surprising because smoking is

associated with adverse outcomes after surgery, including poor or delayed wound healing, wound dehiscence, and surgical site infection.^{22,23}

Among the procedure specific factors, detachment of the humeral insertion was related to postoperative bleeding. When performing a pectoralis major flap transfer, the surgeon often needs to dissect the muscle from the subcuticular fat and rib cage to cover the defect. Sometimes, this includes dividing the humeral insertion of the pectoralis major. As the pectoralis major has an extensive network of blood vessels, dividing it creates an additional risk of post-operative blood loss, especially in patients who use anticoagulants. Operation time was longer in patients who developed postoperative complications. This relation might be explained by desiccation of the wound edges during operation and a higher chance of wound contamination. However, most likely, prolonged operation time is a manifestation of the critical condition of the patient or the complexity of the sternal defect.

Based on the results found in this study, extra care should be given to women with large breasts. Lateral traction on the surgical wound edges can be reduced by suspending the breasts with a well-fitted brassiere in the early postoperative period.⁵ Furthermore, extra attention from the surgeon for hemostasis is demanded, especially in patients in whom the humeral insertion of the pectoralis major is divided. Alternatively, the muscle insertion should not be divided, but the tendon should be released from the humerus through a separate incision.

As mentioned in the Introduction, the pectoralis major can be transferred as advancement or turnover flap. Zahiri et al¹⁰ analyzed the difference in postoperative outcome between both flaps. The use of turnover flaps led to less postoperative complications, which can be attributed to several factors, of which superiority in filling the defect is most important. When only using the lower sternocostal part of the pectoralis major, the turnover flap is very suitable for coverage of the caudal part of the wound. This usually is possible, even if the IMA has been used, whereas vascular supply is guaranteed through the

intercostal and superior epigastric system. Subsequently, the cranial part can be covered with a contralateral advancement flap. In our population, all procedures were performed using (bilateral) advancement flaps. Several times, it was reported to be difficult to close the most caudal part of the defect in our population. Although this was not statistically significant, these patients were more likely to develop recurrent dehiscence. Because in most patients the IMA is only harvested on one side, a combination of turnover and advancement flap would have been a possible option. Especially in large caudal defects, the use of turnover flaps could potentially give better results.

Our study's main limitation was the inability to show reliable results of multivariate regression analyses for the different complications. Our conclusions about the relation between female sex and recurrent dehiscence and detachment the humeral insertion and postoperative bleeding are based on univariate analyses alone. This means we did not correct for possible confounding factors. We did conduct multivariate regression analyses, and they did show that detachment of the humeral insertion was an independent predictor for postoperative bleeding and that female sex was an independent predictor for recurrent dehiscence. They also showed that difficulties closing the caudal third was an independent predictor for recurrent dehiscence. However, due to the small number of events, the odds ratios and confidence intervals were extremely large. We decided not to show these regression analyses in our Results section. The relation of these variables and complications should be further analyzed in a larger population. Another limitation of our study was its retrospective nature. Despite our efforts to analyze both digital and paper charts accurately, several variables were incomplete due to missing data, and some variables were difficult to classify based on the collected data. Also, the retrospective collection of patient and operation characteristics might have led to biased data. However, thanks to the large patient study population during several years, the findings of this study may contribute in improvement of operative strategy and lay the foundation for a more in-depth, prospective study.

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