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The Use of Vacuum-Assisted Closure in Purulent Complications and Difficult-To-Heal Wounds in Cardiac Surgery

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A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article; **G** – other

Abstract

Background. Sternal wound infections are a serious and potentially fatal complication of cardiac surgery.
Objectives. The aim of the study was to analyze the results of using the vacuum-assisted closure (VAC) system over a 4-year period.
Material and Methods. Quantitative VAC performance data from a retrospective review of a consecutive cohort of 47 patients treated with VAC for post-cardiac surgery wound complications were collected and statistically analyzed. In the study group 35 patients developed infections of the post-operative chest wound. In 12 other patients wound dehiscence was observed, but repeated cultures did not reveal the presence of any bacteria.
Results. The statistical analysis identified the following as significant risk factors: age, female sex, being overweight, a high total logistic EuroScore, the use of both internal thoracic arteries for bypass grafting, and diabetes. In the wound negative culture group the total length of hospital stay was significantly shorter than in the wound positive culture group. Mortality in this group was 0.0% vs. 5.7% in the wound positive culture group. In the study material, Gram-negative bacteria were responsible for 77% of the post-operative wound infections, with only 14% Gram-positive wound cultures. No complications were related to VAC use.
Conclusions. The use of negative-pressure wound therapy with other concomitant surgical procedures is a good method of treating infected wounds as well as non-contaminated dehiscence of the wound and sternum. Considering that most of the infections within the authors' department are caused by Gram-negative bacteria, it would be beneficial to consider modifying the model of preventive antibiotic treatment to cover the Gram-negative spectrum in addition to the Gram-positive bacteria currently targeted (**Adv Clin Exp Med 2015, 24, 4, 643–650**).

Key words: cardiac surgery, vacuum assisted therapy, wound infection.

Chest wound infections are a serious and potentially fatal complication of cardiac surgery. They occur in 0.5% to 10% of operations [1, 2]. Complications may affect the superficial part of the wound, the sternum or the mediastinum [3]. Classical techniques such as irrigation drainage, secondary closure or surgical reconstruction do not always produce the desired effect, and the infected wound remains a source of further complications [4]. Vacuum-assisted closure (VAC) is a new technique that was originally developed for the needs of plastic and reconstructive surgery in the late 1990s. After a few years it found its place in the treatment of chest wound infections [5]. The vacuum-assisted closure system was introduced in Poland a little later, but currently the procedure is becoming more and more widespread as one of the elements of wound infection therapy [6]. The aim of the current study was to analyze the results after 4 years of using the system.

Material and Methods

Between 2008 and 2011, 47 patients (1.2%) out of 4057 who underwent surgery in the Department of Cardiac Surgery at Pomeranian Medical University (Szczecin, Poland) developed a significant infection or wound dehiscence requiring drug therapy, surgical treatment and vacuum-assisted closure. This group was comprised of 22 women and 25 men, aged 48–79 (mean 66.6 years). Among them, 35 patients (0.86%) developed an infection of the post-operative chest wound; 34 (0.86%) following a sternotomy, and one (0.09%) following a thoracotomy. In the other 12 patients (10 sternotomies and one thoracotomy), wound dehiscence was observed, but repeated cultures did not reveal the presence of any bacteria. The classification of the affected wounds is presented in Table 1.

In both of these groups of patients, the VAC system (Kinetic Concepts, Inc., TX, USA; Paul Hartmann AG, Germany) was used to treat the complications of post-operative chest wounds. Data from the patients who had undergone cardiosurgical procedures were prospectively collected and retrospectively analyzed. The main procedures and coronary revascularization procedures are presented in Tables 2 and 3.

The treatment involved a combination of debridement, packing, delayed closure, plastic reconstruction, re-wiring and irrigation, depending on the occurrence of infection and its severity.

When a superficial wound complication was diagnosed, after surgical debridement the VAC system was installed and started with a continuous pressure level of – 125 mm Hg. The standard time interval between changes of dressings was 3 days. In most patients, a wound culture was taken each time the dressing was changed; in cases of long-term VAC therapy, cultures were taken at every second change of dressing. Wounds with negative cultures in 2 consecutive tests were closed with single interrupted stitches. When sternal instability occurred, stabilization was performed prior the installation of VAC, by tightening the wires or rewiring, along with surgical debridement of the wound. Wounds sterilized with targeted antibiotic therapy supported by VAC that had negative cultures in 2 consecutive tests were closed. Patients with mediastinitis and/or sternal destruction were treated with surgical debridement and the removing of all sternal wires and soft-tissue sutures. Mediastinal irrigation was performed at 100 mL/h with 5% povidone-iodine for 2 days. Then the VAC system was installed and targeted antibiotic therapy was started. When the wound was sterilized, re-wiring of the sternum or surgical reconstruction with use of a pectoral muscle flap was carried out. Regardless of the time needed for wound healing, antibiotic therapy was continued for at least 2 weeks. Dressings were changed and wounds were assessed every 3 days under aseptic conditions. The surgical procedures were performed under general anesthesia, but most patients tolerated dressing changes with intravenous opiates combined with oral analgesia.

The infections were monitored by means of repeated culture taking, transthoracic echocardiography, chest X-ray examinations and C-reactive protein measurement. No CT examinations were done.

All the patients were continuously hospitalized between the surgery and the occurrence of the complications.

Table 1. Classification of wounds

Clasification of wounds	Treated with VAC with negative wound culture	Treated with VAC with positive wound culture	P
	12	35	
Wound dehiscence alone	7	16	ns.
Sternum instability or dehiscence	5	16	ns.
Mediastinitis	0	3	ns.

Table 2. Main procedures

Main procedures	Coronary	Aortic valve	Mitral valve	Aortic & mitral valve	Tricuspidal valve	Aortic aneurysm	Other	Total
VAC-treated group	39	2	3	2	–	–	1	47
Other patients	2702	523	368	99	38	236	44	4010
Total	2741	525	371	101	38	236	45	4057
p	> 0.035	ns.	ns.	ns.	–	–	ns.	–

Statistical Analysis

The statistical analysis was carried out with a licensed Statistica PL software package using the unpaired *t* test for continuous variables, and the Mann-Whitney *U* test, the χ^2 test and Fisher's exact test for the non-continuous variables. A value of $p < 0.05$ was considered statistically significant.

Prevention Protocols

Standard infection prevention protocols were used on all the patients during the peri-operative period. In patients scheduled for elective surgery, a nasal smear was taken before the admission to the ward. If potentially resistant strains (MRSA, MRSE) were detected in the culture, a 7-day treatment with ointment containing 2% mupirocin (Bactroban®, GlaxoSmithKline, UK), was introduced, followed by another culture. Patients from whom no nasal swab was taken for some reason and those admitted to the ward as urgent cases were treated with mupirocin for at least 5 days. In accordance with the standard protocol, patients were admitted to the hospital on the day of surgery or on the day preceding surgery, to shorten the time of exposure to the hospital bacterial flora. During the period analyzed in this paper, all the patients underwent preventive antibiotic treatment with cefuroxime 4 × 1.0 g/d *i.v.* (Biofazolin®, Bioton, Pl) starting 30 min before surgery and continuing for the first 2 days after it. Patients suffering from diabetes, regardless of the type of preceding treatment, received a continuous infusion of insulin and glucose during the first 2 days after the operation and their blood glucose level was constantly monitored; this was followed by the administration of 4 doses of insulin (3 daily doses of short-acting insulin R and a night dose of long-acting insulin N) throughout their hospital stay, and their blood glucose level was monitored 6 times a day.

Epidemiological Data

In the VAC-treated group, the percentage of women was significantly higher than in the study group as a whole. Also, the average age of the patients in the group suffering from complications was significantly higher than in the other group, but there was no significant age difference between the two sexes. The average values of the logistic EuroSCORE among those treated with VAC were significantly higher than the average for the whole group and the average among men. Also, the mean body mass index (BMI) was significantly higher in the group of VAC-treated patients and in women.

The prevalence of diabetes was significantly higher in the VAC-treated group as compared to the other patients, and this was observed in both sexes.

The percentage of patients who had undergone emergency surgery was slightly higher in the VAC-treated group. Their stay in the hospital prior to surgery was longer as well.

One internal thoracic artery was used for bypass grafting in 32 patients (82%) from the VAC-treated group and in 2730 of the remaining patients (72.5%). The difference was not statistically significant. Both thoracic arteries were used in 6 patients from the VAC-treated group and in 184 of the remaining patients. This difference was statistically significant both in comparison to the group in which no arterial grafts were performed

Table 3. Coronary revascularization procedures

Procedure	VAC-treated group	Other patients	Total coronary revascularization
MIDCAB	2	61	63
OPCAB	8	400	408
CABG	29	2241	2270
Aortic valve procedures + CABG	1	224	225
Mitral valve procedures + CABG	0	209	209
Aortic and mitral valve procedures + CABG	2	33	35
Tricuspidal valve procedures + CABG	0	16	16
Aortic aneurysm procedures + CABG	0	47	47
Other procedures + CABG	0	4	4
Total coronary revascularization	42	3235	3277

Table 4. Pre-operative and mid-operative data

Data		VAC-treated group	Other patients	P
Group		**47**	**4010**	
Sex	m	25 (53.2%)	2859 (71.3%)	p < 0.02
	f	22 (46.8%)	1151 (28.7%)	
Age		66.6 ± 10.1	63.5 ± 8.3	p < 0.006
Age	m	64.7 ± 8.8	62.4 ± 9.9	ns.
	f	68.9 ± 7.4	66.2 ± 10.1	ns.
Logistic EuroScore (%)		9.7% ± 13.0%	6.6% ± 8.3%	p < 0.011
LES (%)	m	11.2% ± 16.5%	5.9% ± 7.6%	p < 0.0006
	f	8.0% ± 7.4%	8.3% ± 9.7%	ns.
BMI		30.5 ± 4.1	28.4 ± 4.2	p < 0.0004
BMI	m	29.4 ± 2.7	28.3 ± 3.9	ns.
	f	31.8 ± 5.0	28.6 ± 4.8	p < 0.006
Ejection fraction (%)		49.0 ± 12.0	50.4 ± 11.5	ns.
EF (%)	m	47.4 ± 12.4	49.2 ± 11.6	ns.
	f	50.7 ± 5.0	53.3 ± 5.0	ns.
Diabetics		23 (48.9%)	971 (24.2%)	p < 0.00025
Diabetics	m	11 (44.0%)	661 (22.1%)	p < 0.03
	f	12 (54.5%)	309 (26.9%)	p < 0.009
Admitted as urgent		16 (34.1%	1079 (26.9%).	ns.
Duration of hospital stay before the procedure (days)		1.45 ± 1.7	1.24 ± 1.0	ns.
Use of ITA1		32/39 (82.0%)	2730/3766 (72.5%)	ns.
Bilateral use of ITA vs. non--ITA[1]		6/13 (46.2%)	184/1220 (15.1%)	p < 0.007
Bilateral use of ITA vs. single ITA + non-ITA[1]		6/38 (15.8%)	184/3766 (4.9%)	p < 0.02
Time of	clamping[2]	38.3' ± 19.7'	42.5' ± 21.9'	ns.
	perfusion[2]	64.6' ± 24.8'	67.2' ± 31.1'	ns.

[1] MIDCAB treated patients were excluded
[2] OPCAB & MIDCAB treated patients were excluded

and in the combined group of patients without arterial grafts and those in whom a single internal thoracic artery was used. The results are summarized in Table 4.

Results

The time elapsed between surgery and the onset of complications ranged from 3 to 78 days (mean 16.1 days), while the time from surgery to implementing VAC treatment ranged from 4 to 78 days (mean 22.0 days). The time of effective VAC use ranged from 6 to 111 days (mean 22.1 days), and the number of sets used ranged from 2 to 37 (mean 7.4 sets).

VAC was used in 12 patients with sterile wound cultures. Wound fluid leakage and/or wound dehiscence in this group occurred later than in the group with symptoms of infection and positive cultures. However, these differences were not statistically significant. Other differences, including the

Table 5. Surgical methods complementary to VAC therapy used in patients with or without positive wound culture and details of VAC treatment in both groups

Data	Treated with VAC with negative wound culture	Treated with VAC with positive wound culture	P
	12	35	
Debridement of the wound	12	35	ns.
Sternum instability	5	16	ns.
Flow drainage	0	3	ns.
Tightening of the wires	2	6	ns.
Rewiring of sternum	0	1	ns.
Rewiring of sternum (Martinez method)	0	1	ns.
Rewiring of sternum (Robicsek method)	3	5	ns.
Reconstruction of sternum	0	3	ns.
Time between the surgery date and the onset of symptoms (days)	19.4 ± 7.6	15.0 ± 13.8	ns.
Time between the surgery date and application of VAC (days)	25.7 ± 14.9	20.8 ± 18.1	ns.
Duration of VAC therapy (days)	11.8 ± 5.5	25.6 ± 34.1	ns.
VAC kits used	3.9 ± 1.8	8.5 ± 8.0	ns.
Total length of hospitalization (days)	32.3 ± 10.0	57.3 ± 37.8	$p < 0.03$
Mortality	–	2 (5.7%)	ns.

average time from surgery to implementing VAC treatment, the duration of treatment using VAC and the number of sets used did not reach statistical significance in these groups either. Only the total time of treatment in those without infection was significantly shorter than in the group with positive cultures. It is worth emphasizing that no deaths occurred in this group of patients. The surgical techniques and results are presented in Table 5.

In the group of 35 patients with positive cultures, the most frequently observed infections were caused by Gram-negative rods, in 27 patients (77.1%). Gram-positive flora were cultured from 5 patients (14.3%) and mixed flora from 3 patients (8.6%). In some patients flora conversion occurred during the treatment. In 9 patients (25.7%) it occurred once, in 4 (11.4%) it occurred twice, and in 2 (5.7%) it occurred 3 times. In 9 patients the occurrence of resistant strains was observed. In 5 patients, in the first round of cultures there were MRSA/MRSE Gram-positive and Gram-negative *Enterobacter cloacae* ESBL+/AmpC+ bacteria. In 4 patients alert strains were cultured after the 1st conversion of bacterial flora, and in 1 of them such strains were cultured once more after the 3rd conversion. The only difference that could be observed between the group of those infected with alert pathogens and the other patients with positive cultures was that the time of their hospitalization was slightly longer. These differences were not statistically significant. The culture results are summarized in Table 6.

Two patients (5.7%) in the VAC-treated group died: one of a stroke, and the other as a result of multi-organ complications. In the remaining 45 patients (94.5%), satisfactory wound healing was achieved. No VAC-related complications were observed in the treated group.

The clinic‘s cost for treating patients in whom the VAC technique was used was about 8000 PLN (roughly 1930 EUR) higher per patient than the treatment costs for the remaining patients. The difference is statistically significant.

Discussion

The incidence of in-hospital wound infections depends on many different factors: the organization of work, compliance with procedures, the quality of aseptic techniques and antiseptics, the number of staff, the infrastructure of a unit as well as the pool of microorganisms, especially resistant hospital strains, in the surrounding environment.

Table 6. Bacterial strains cultured from the sternum wounds and their variability

Initial wound culture	Number of patients	First conversion of wound culture	Second conversion of wound culture	Third conversion of wound culture
Pseudomonas aeruginosa	1	*Enterbacter cloacae* ESBL + *Serratia marcescens*		
Pseudomonas aeruginosa	3			
Pseudomonas aeruginosa *Enterococcus faecalis*	1	*Enterococcus faecalis* *Serratia marcescens*		
Pseudomonas aeruginosa *Serratia marcescens*	1	*Pseudomonas aeruginosa* *Serratia marcescens* *Enterococcus faecalis*		
Serratia marcescens	1	*Enterbacter cloacae ESBL + AmpC +*		
Serratia marcescens	1	*Klebsiella oxytoca*	*Serratia marcescens*	*Acinetobacter baumannii*
Serratia marcescens	2			
Escherichia coli	1	*Pseudomonas aeruginosa*		
Escherichia coli	1			
Citrobacter koseri	1			
Corynebacterium stratium	1			
Proteus mirabilis	5			
Proteus vulgaris	2			
Enterobacter cloacae	1	MRSE	*Serratia marcescens*	*Escherichia coli* ESBL +
Enterobacter cloacae	6			
Enterobacter cloacae ESBL +	1	*Candida albicans*	*Escherichia coli*	
Enterobacter cloacae Amp C + MRSE	1			
MSSA	1			
MRSE	1			
Enterococcus faecalis	1			
MRSA	1			
MRSA	1	MRSE		
Total	35	9	3	2

Analyses of the factors affecting the incidence of purulent complications is conducted in many institutions, but the results are often significantly diverse. They depend on the population from which the patients originate, the statistical methods used and the number of patients in the study group. In an analysis of 9136 patients, Abboud et al. showed that the only risk factors are obesity and smoking [7]. Diez et al., in a study of a group of 1700 surgery patients, listed obesity, COPD and the use of both thoracic arteries for bypass grafting as independent predictors of infection [8]. According to Hosseinrezaei et al. (520 patients), risk factors include diabetes, hyperlipidemia, COPD, female sex and drug addiction (opium) [2]. The most comprehensive analysis to date was carried out by Fowler et al. on a group of 331,429 patients who had undergone coronary artery bypass grafting, based on the STS National Cardiac Database. The multi-factor analysis identified the following as significant risk factors: BMI > 40, age > 85 years of age, shock, immunosuppressive therapy, severe renal failure requiring dialysis and diabetes [9]. Among the patients in the current study, significant risk factors included age, female sex, being overweight, a high total logistic EuroScore, the use of both internal thoracic arteries and diabetes.

In the current study, significant purulent sternal wound complications – infection of the subcutaneous tissue of the sternum and mediastinal disorders – occurred in 35 patients (0.86%). The data published by other authors are similar, the rate of infection being from 0.5% up to 10% [1, 2, 4, 7–10]. The proportion of deaths that occurred in patients treated with VAC in this study (4.2%) does not differ from the data presented by other authors, but the spectrum of bacteria in the material is different [1, 4, 7]. Strains of Gram-positive cocci represented only 20% of the infections, while in most authors' reports the percentage of infections exceeds 40%. In the present study, however, over 70% of infections were caused by Gram-negative rods, in contrast to other studies, where these bacteria were responsible for only 20–30% of the complications [1, 2, 4, 10, 11]. According to Gårdlund et al., mediastinum infections can be divided into 3 types. The first, associated with obesity, obstructive pulmonary disease and sternal dehiscence, is usually caused by coagulase-negative staphylococci. The second, associated with peri-operative infection, is often caused by *Staphylococcus aureus*. The third is related to wounds caused by Gram-negative bacteria in the post-operative period [12]. Garey et al. showed that the factors that heighten the risk of infections caused by Gram-positive and Gram-negative strains differ. In the former, significant risk factors included diabetes, age and peripheral vascular disease; while in the latter the risk factors include hospitalization for 48 h or more prior to the surgery, puncture and pleural drainage in the post-operative period, prolonged mechanical ventilation, and diabetes [13]. Ottino et al., on the other hand, showed that prophylactic antibiotic therapy, directed mainly against Gram-positive bacteria, is main reason for the increased number of infections with Gram-negative strains [14]. It appears that excessive concentrations of patients (many beds in a single room) and a lack of possibilities for completely isolating patients with wound infections from others may also be important factors influencing the incidence of infections caused by Gram-negative rods in the post-operative period. To a large extent, this is related to the degree of occupancy of beds. In the analyzed period, the percentage of occupancy of beds in the authors' unit was 80–85%. The average age of patients between 2008 and 2011 increased by 1.5 years, from 62.6 to 64.1, and the length of hospitalization was slightly reduced, from 9 days in 2008–2009 to 8.4 days in 2010–2011, due to the opening of a separate 14-bed post-operative rehabilitation unit in the department in 2010. Under these conditions, the authors believe that in addition to their beneficial effect on wounds, VAC dressings offer an additional advantage: not only do they isolate the wound from the environment, but they also shield the hospital staff and other patients from infected wounds.

Compared to conventional methods of drainage and treatment, the use of VAC significantly enhances patient comfort. The battery-powered system allows for full mobilization and the proper rehabilitation of the patient. It should be noted, however, that the VAC technique cannot be regarded as a universal cure for every problem related to the treatment of purulent complications. A belief in the effectiveness of VAC therapy may reduce the sensitivity of surgeons to the possibility of an infection incident in their unit. It is all too easy to change a dressing, take a smear and postpone the decision to discharge a patient until a few days later. This is perhaps one of the reasons that may explain the lack of any apparent shortening of treatment in the authors' department, despite the implementation of ever more advanced and modern methods. In addition to VAC therapy, classical techniques of surgically treating infected wounds using the network of thoracic muscles should remain an important element of the whole procedure [15].

The authors concluded that the use of negative-pressure wound therapy with other concomitant surgical procedures is a good method of curing infected wounds as well as non-contaminated dehiscense of wounds and the sternum. Considering the fact that most of the infections within the authors' department are caused by Gram-negative bacteria, it would be beneficial to consider modifying the model of preventive antibiotic treatment, which at this time is mostly directed against Gram-positive bacteria, to cover the Gram-negative spectrum as well.

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