Original Contribution

WOUND INFECTIONS AFTER TOTAL MEDIAN STERNOTOMY – RISK FACTORS, MICROBIOLOGICAL ANALYSIS, PROPHYLAXIS AND TREATMENT METHODS

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ABSTRACT

Introduction. Median sternotomy represents a standard surgical access in cardiac surgery, despite the growing popularity of minimally invasive access. Posternotomy infections are a serious complication and are directly related to patients' survival in the short and long term. Despite prevention, their expression is still significant - from 0.5% to 6.8%, and associated hospital mortality rates range from 7% to 35%.

Aims. Analysis of frequency, risk factors, microbiological agents, prevention options and surgical techniques for deep wound infections after open heart surgery for a 17 - year period.

Materials and methods. For the period from October 2002 to June 2019, 146 (1.42% of 10,307 operated) patients were treated at the Cardiac Surgery Clinic at the University Hospital "St. George" diagnosed with deep sternal infection. The study is a retrospective using data from medical records and hospital records. The Center of Disease Control (CDC) criteria were used to define deep sternal infections.

Results. The sex ratio is 2.04: 1 – men: women. The average age for both sexes is 65.4 years. The average stay of patients in the intensive care unit was 5 days (from 0 to 46 days), and the average total hospital stay was 15.6 days (from 5 to 55 days). Early postoperative mortality was 13.7%. The most common risk factors were diabetes mellitus, obesity and emergency surgery.

Conclusion. Cardiac surgery with total midline sternotomy is associated with a risk of developing mediastinitis. Despite the advances in cardiac surgery and the use of mini-invasive techniques, the rate of development of deep wound infections remains relatively high.

Key words: total median sternotomy, deep wound infections, risk factors.

INTRODUCTION

Deep sternal wound infections (DSWI) represent a serious complication after open heart surgery and are directly related to patient survival in both the short and long term. (1, 2) Moreover, mediastinitis leads to extreme increase in financial costs. Despite prophylaxis, the incidence remains significant, ranging from 0.5% to 6.8% and the associated in-hospital mortality ranges from 7% to 35%. (3, 4) During her time, Florence Nightingale faced the problem of wound infections and on this occasion he wrote in his book "Notes on nursing: what it is, and what it is not": "The first requirement in the hospital is that the patient should not be harmed." (5) Median

sternotomy remains the standard surgical approach in cardiac surgery, despite the growing popularity of minimally invasive surgical access (6, 7). The technique has many advantages: it is fast and easy to perform and provides wide access to almost all mediastinal structures. The main disadvantage of total median sternotomy is the risk of developing chest instability, superficial and deep wound infections (mediastinitis), sterno-cutaneous fistulas. (8, 9)

MATERIALS AND METHODS

This retrospective study is conducted at "St. George" University Hospital - Clinic of Cardiac Surgery. For the period October 2002 to June 2019, 10307 open heart surgeries with total median sternotomy are performed in the institution. Cardiopulmonary bypass (CPB) is used in 10 100 of them.

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Preoperative preparation of the patient and the surgical team

All 10307 open heart operations are performed in 3 operating rooms (OR), equipped with a standard ventilation and air conditioning system. The air exchange is 25 times/hour. The temperature in the OR is kept constant - 18-20°C. The operative team consists of 8 ± 1 people - an operator, one or two assistant-surgeons, an anesthesiologist and a *nurse anesthetist*, two Scrub nurses, a perfusionist (*cardiovascular technician*). The passage of persons indirectly connected with the surgical intervention through the OR is minimized. Each member of the team changes clothes and shoes before entering the OR of the clinic, puts on a hat and face mask, which he wears all the time until he leaves. Watches, rings, bracelets are left in the locker room. Preoperative preparation of planned patients includes

bathing at the clinic, shaving the whole body in the evening before surgery and applying an antiseptic solution to the skin. Emergency patients admitted to the intensive care unit are shaved and smeared with an antiseptic solution immediately before surgery. Antibiotic prophylaxis includes intravenous administration of cefuroxime 1.5g. 30 minutes before skin incision. A second dose is given if the intervention lasts for more than 6 hours. In emergency patients, a second antibiotic is added - vancomycin or ciprofloxacin. Prophylaxis continues until the removal of the mediastinal drains.

Within the studied period 146 (1.42%) of 10307 operated patients were diagnosed and treated for deep sternal infection in the Clinic of Cardiac Surgery.

Diagram 1. Dynamics of the incidence (in %) of deep sternal wound infections (2002-2019)

We observe a statistically significant upward trend for the studied seventeen-year period of the relative frequency in% of deep wound infections in terms of the number of open heart operations (**Diagram 1**).

The CDC criteria are used to define deep sternal wound infections. The diagnosis is based on standard physical examination - wound status, fever, intoxication syndrome; laboratory tests (complete blood count, standard biochemical tests, ESR, CRP, procalcitonin); microbiological cultures; imaging studies - transthoracic echocardiography, chest radiography and computed tomography with contrast

enhancement (CT). Echocardiography allows assessment of the function of the left ventricle and the valvular apparatus of the heart, the condition of the pericardium, the presence of pericardial and/or pleural effusion. The method is easy to perform and is non-invasive. However, echocardiography is not informative enough to diagnose DSWI. Chest X-rays and contrast-enhanced CT scans are much more informative methods. X-rays may reveal mediastinal enlargement, pneumomediastinum, presence of pleural effusions. In case of total sterna dehiscence, displacement of the osteosynthetic wires is indicative, which is known in the literature as a phenomenon of

"dancing wires" (**Figure 1**). CT scans assess the pre- and retrosternal space, the presence of gas and fluid collections in the mediastinum, sternum dehiscence and wire integrity, the

presence of bone sequestrs and fistulas. Pleural effusions, encapsulations (if any) and soft tissues of the chest wall are also evaluated. (**Figure 2**)

Figure 1. Phenomenon of "dancing wires" in total sternal dehiscence (male, 62 years, after mitral valve replacement)

Figure 2. CT - patient after CABG – total sternal dehiscence with large retrosternal fluid collection, bilateral pleural effusions

The most common cardiac surgical interventions performed in our institution are coronary artery bypass grafting and off-pump coronary artery bypass grafting procedures (CABG, OPCAB). Combined interventions follow – CABG + aortic/mitral valve reconstruction (CABG + MVR, CABG + AVR). (**Diagram 2**) CABG is considered to be one of the main risk factors for the development of post sternotomy mediastinitis. (4)

Risk factors were identified and analysed using the Society of Thoracic Surgeons (STS) model developed in 2005, which assesses pre- and intraoperative risk of wound infections. 13

factors were included: age, body mass index (BMI), diabetes mellitus, renal failure, congestive heart failure, peripheral artery disease, female gender, COPD, cardiogenic shock, myocardial infarction, complexity of surgery, duration of CPB, use of IABP. (9) Some of the presented risk factors are modified and other is added in the present study. Anemia, thrombocytopenia, dual antiplatelet therapy preoperatively are included due to the fact that these conditions lead to an increased risk of re-exploration of the surgical wound due to bleeding. Diabetes mellitus, smoking and obesity predominate in the study group. (**Table 1**)

Diagram 2. Most frequently performed surgical interventions by years

Table 1. Risk factors in patients with DSWI

Risk factors	N	%
Emergency operation	40	27,4
Diabetes mellitus	54	37
Obesity	29	19,9
COPD	20	13,7
Heart failure	37	25,3
Prolonged mechanical ventilation	7	4,8
Smoking	13	8,9
Re-exploration due to bleeding	11	7,5
Renal failure	17	11,6
Osteoarthritis	4	4,7
Others	55	37,7

The column "Others" includes peripheral artery disease, cerebrovascular disease, status post mastectomy, IABP, osteoporosis, reoperation, shock, cardiac massage, anemia, delirium, ethylism, chronic ulcerohemorrhagic colitis, infectious endocarditis.

Most often, deep sternal infections develop in patients after CABG. (Table 2) There are two cases with DSWI which develop after reoperation for prosthetic valve endocarditis.

Table 2. Distribution of patients with DSWI by type of cardiac intervention

Cardiac intervention	N	%
CABG	65	44,5
CABG + MVR	16	10,9
CABG + Left ventricular repair	4	2,7
CABG + AVR + MVR	6	4,1
CABG + AVR	18	12,4
CABG + TVP	2	1,4
CABG + MVR + TVP	4	2,7
Bent all procedure	2	1,4
OPCAB	1	0,7
AVR	10	6,8
MVR	8	5,5
ReAVR	2	1,4
TVR	1	0,7
Aortic resection - aortic dissection+aortic aneurism	6	4,1
Myxoma extirpation	1	0,7

In all 146 patients who develop deep wound infections after open heart surgery, microbiological samples are taken from the wound for cultural examination using a sterile dry swab with a viscous tip, a plastic handle and Amies transport medium. The results of

the microbiological tests are presented in **Table 3**. In 18 (12.3%) of the patients no microbiological agent is isolated. Gram (+) bacteria is predominant. More than 1 microbiological agent was isolated in 7 (4.8%) patients.

Table 3. Isolated microorganisms in patients with DSWI

Isolated microorganism	N	%
CoNS	23	15,8
S. Aureus	21	14,4
E. coli	14	9,6
Kl. pneumoniae	12	8,2
A. baumannii	16	10,5
Ps. auruginosa	9	6,3
S. marcescens	2	1,4
E. faecalis	7	4,8
P. mirabilis	9	6,3
P. vulgaris	2	1,4
E. cloacae	6	4,1
Kl. Pneumonia + A. baumannii	2	1,4
S. marcescens + Ps. auruginosa	1	0,7
S. aureus + E. coli	2	1,4
E. coli + P. vulgaris	1	0,7
E. cloacae + A. baumannii	1	0,7
No microorganisms isolated	18	12,3

Polyresistant microorganisms are therapeutically problematic. 10 of the isolated S. aureus were MRSA, 8 of E.coli - ESBL(+), Kl. Pneumoniae - 4 of the isolates are meropenem-resistant. There are 2 isolated VREs (vancomycin-resistant enterococci) and 1 colistin-resistant A. baumannii isolate.

Patients with DSWI are divided into three groups, according to the type of surgical technique used in treatment (**Table 4**):

- Group I - wound debridement and refixation with subsequent irrigation of the mediastinum with antiseptic solution (Braunol) is performed;
- Group II - debridement of the wound was performed and vacuum-assisted closure therapy (VAC) was applied and the sternum is fixed in the second stage;
- Group III - soft tissue flap (omentoplasty, rectus abdominis muscle) is applied.

Table 4. Distribution of patients by groups according to the operative technique

Group I - refixation with irrigation		Group II - VAC with refixation		Group III - Soft tissue flap	
N	%	N	%	N	%
61	41,8	68	46,6	17	11,6

The operative technique is chosen according to the patient's condition, the onset of the infection, the isolated microorganism and the surgical experience of the team. In Group III, omental flap is used for chest wall reconstruction, except in 1, in which a rectus abdominis muscle flap is interposed. In 1 of the patients, in addition to omentoplasty, a

titanium plate is implanted (**Figure 3**). Empiric antibiotic treatment is initiated in all patients and then changed as needed according to the antibiogram data. In three of the patients who had a clinical manifestation of severe sepsis, an innovative approach in cardiac surgery was used to remove the mediators of inflammation (cytokines, endotoxins) - oXiris filter (Baxter).

Figure 3. Surgical techniques in DSWI: **A** - Fixation with irrigation; **B** - VAC; **C** – Omentoplasty

DISCUSSION AND RESULTS

The average length of stay of patients in the intensive care unit is 5 days (from 0 to 46 days), and the average total in-hospital stay is 15.6 days (from 5 to 55 days). There was no significant difference in these parameters in the three groups of patients. Therapy failed in 5 patients from Group I, which required re-

intervention - VAC and rerefixation. In Group II, re-intervention is required in 7 of the patients. In 3 - VAC and rerefixation, in 4 - omentoplasty (in 2 and titanium plate implantation). The most common complications are acute kidney injury, requiring hemofiltration and septic shock. They are the main cause of death. In Group III

no cases of reinfection is reported. In 1 patient in this group, herniorrhaphy was performed using a polypropylene mesh (Ethicon) 4 months after the sterna reconstruction due to an epigastric postoperative hernia. Readmission within 1 year is required in 21 patients (14.4%). In 2 of them rehospitalization is not associated with complications of the surgical wound.

No intraoperative mortality is reported. Perioperative mortality occurred in 1 of patients in group II, who developed *disseminated intravascular coagulation (DIC)* and died 12 hours after refixation from hemorrhagic shock. Early postoperative mortality was 8.9% (13 patients). 1 patient died of stroke, 2 - of pulmonary thromboembolism, 1 - of heart failure (cardiogenic shock), 1 - hemorrhagic shock (due to rupture of the right ventricle from the edge of the sternum - Group I). The others presented with severe sepsis and *multiple organ dysfunction syndrome (MODS)*. 7 of the patients (4.8%) died during the second month after the reconstruction. The cause of death is severe gastrointestinal hemorrhage (hemorrhagic shock) – 1 patient, mesenteric thrombosis - 1, stroke - 1, rupture of a graft to the right coronary artery - 1 (Group I), severe sepsis with MODS - 4. The total postoperative mortality in patients with DSWI is 13.7%. The reports by other authors concerning this surgical field reveal similar results (10, 11).

The definitions of chest wound infections are not yet standardized. Post-sternotomy wound infections, post sternotomy mediastinitis and deep sternal wound infections are used to denote infections involving the sternum and mediastinal structures. (12) However, it is important to distinguish between superficial wound infections and deep wound infections. Superficial wound infections, with an incidence of 0.5 to 8% according to the literature, include only the layers between the skin and the sternum, leaving the sternum intact. Deep wound infections involving the sternum are rare. Their incidence depends on the classification used and varies between 0.4% and 5% and results in higher in-hospital mortality.(3) The problem of deep wound infections is becoming increasingly important for several reasons:

- The number of cardiac surgical centers and catheterization laboratories in Bulgaria is constantly increasing;

- Much of the domain of cardiac surgeons is already "taken over" by the work of interventional cardiologists, which means that patients in cardiac surgery clinics are mostly severely disabled, patients with terminal heart failure (FI <35%), patients on dual antiplatelet therapy (with an increased risk of postoperative haemorrhage and chest re-exploitation), elderly patients with limited physical capacity. All this dramatically increases the likelihood of developing superficial and deep wound infections;
- The number of re-operated patients is increasing, which is currently over 10% in most centers.

There is currently no standardized regimen for the treatment of wound infections after open heart surgery and there are no developed prophylactic programs - microbiological analysis, detection of predictive biomarkers, and surgical techniques to reduce the occurrence of these life-threatening complications. (13,14)

CONCLUSION

Open heart surgery using extracorporeal circulation is associated with it risk of developing mediastinitis. Improving surgical techniques and analyzing risk factors and microbiological agents could reduce the rate of development of this life-threatening complication.

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