MEDICAL UNIVERSITY "PROF. DR. PARASKEV STOYANOV" – VARNA
DEPARTMENT OF CARDIOVASCULAR SURGERY AND ANGIOLOGY
CARDIAC SURGERY CLINIC

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EPIDEMIOLOGY, RISK FACTORS, AND CLINICAL PRESENTATION OF WOUND INFECTIONS AFTER STERNOTOMY. PREVENTION AND TREATMENT TRENDS AT THE CARDIAC SURGERY CLINIC

THESIS SUMMARY

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Chairman: Prof. Nikola Yordanov Kolev, MD, DSc

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The defence documentation is published on the website of Medical University "Prof. Dr. Paraskev Stoyanov" – Varna and is available at the Scientific Department of the University.

CONTENTS

ABBREVIATIONS

WHO – World Health Organization;

NPWT – Negative Pressure Wound Therapy;

ci NPWT – Closed Incision Negative Pressure Wound Therapy;

BMI – Body Mass Index;

CABG – Coronary Artery Bypass Grafting;

CHF – Chronic Heart Failure;

CRP – C-Reactive Protein;

MPV – Mechanical Pulmonary Ventilation;

ECC – Extracorporeal Circulation;

CDC – The Centers for Disease Control and Prevention, USA;

SD – Standard Deviation;

OPCAB – Off-Pump Coronary Artery Bypass;

MRSA – Methicillin-Resistant Staphylococcus Aureus;

COPD – Chronic Obstructive Pulmonary Disease;

HbA1c – Glycated Hemoglobin;

VAC – Vacuum-Assisted Closure

1. Introduction

Infection is the most common and expensive postoperative complication – it is the Damoclean sword in surgery[1]. Mediastinitis is one of the most distressing complications in patients undergoing cardiac surgery. Cardiac surgical procedures are aggressive, can often be prolonged, and are usually applied to patients who are mostly with increased comorbidity, which determines the particularly high risk of postoperative infection.

Severe infectious complications after cardiac surgery increase postoperative mortality more than twofold and extend the duration of the recovery period. For these patients, hospital stay is significantly longer compared to patients without wound infection [2], [3].

In recent years, studies focused on patient safety have been receiving increasing attention. Cardiothoracic surgeons encounter the challenge that many clinical questions in the daily practice do not have universally accepted answers, while patients increasingly demand the "best practice" from their physicians.

Seventy percent of the patients with mediastinitis require at least one additional surgical procedure for processing and drainage of the infected wound[4]. This scenario validates the increasing concern about this postoperative complication, which extends hospital stay, and increases hospital costs, as well as the number of procedures and performed examinations. It has a negative impact on the quality of life of the affected patients[5], [6].

In 2016, the World Health Organization (WHO) identified surgical site infections as the most common and studied type of infection in low- and middle-income countries and the second most prevalent in high-income countries[7].

After conducting an extensive meta-analysis covering twenty-four studies and over 407 000 patients, the authors indicate that deep sternal wound infection after cardiac surgery is associated with higher overall mortality, in-hospital mortality, subsequent mortality, and major adverse cardiovascular events compared to patients without infection[8]. It has been pointed out that compared to patients who did not develop a deep sternal wound infection, patients with this complication after cardiac surgery have an increased risk of death, as well as short-term and long-term adverse clinical outcomes[8].

A decline in infection rates naturally leads to a reduction in the use of antibiotics. Consequently, strategies are developed to decrease the potential of resistant bacteria reproduction and thus reduce antibiotic resistance[9].

A mediastinitis frequency above 2% is considered an indicator of insufficient care standards in a cardiac surgery center[59], [60].

In this context, precise knowledge of the frequency and causes of surgical wound infections after cardiac surgery, as well as the risk factors for their occurrence, is crucial. Knowledge in this area is directly associated with creating and implementing measures that would contribute to improving treatment and care and preventing this serious postoperative complication.

2. Aim and Tasks

Aim

The thesis aims to minimise the risk of sternal wound infections after cardiac surgery by applying evidence-based practices and strategies.

Tasks

1. To investigate the epidemiology of postoperative wound infections in the Cardiac Surgery Clinic – Varna by identifying risk factors and analysing the clinic's results.
2. To present a Prevention of Wound Infections Protocol introduced in the Cardiac Surgery Clinic – Varna.
3. To evaluate the effectiveness of the Prevention of Wound Infections Protocol with regard to assessing the existing risk factors and undertaking preventive measures during patient preparation for surgical treatment, behaviour in the operating room, and in the postoperative period.
4. To illustrate the financial impact of sternal wound infections after cardiac surgery in the Cardiac Surgery Clinic – Varna.
5. To present the frequency of wound infections in the Cardiac Surgery Clinic, Varna over a nine-year period.
6. To present results from the prophylactic application of Negative Pressure Wound Therapy (NPWT) on a closed wound of the chest after cardiac surgery (ci NPWT).

7. To present modern methodologies and trends for the prevention and treatment of wound infections after median sternotomy.

3. Materials and Methods

Cohort studies with a control group were conducted to study equivalent, exposed, and unexposed groups from the population (cohorts) over a specific period, to compare the frequency of risk factors for the development of wound infection after cardiac surgery in both groups and to evaluate the results of implementing a Prevention of Wound Infections Protocol.

The studies included only patients over 18 years of age and only patients after median sternotomy (full or upper partial sternotomy).

Wound infection data were collected during hospitalisation after cardiac surgery, as well as during readmission, using medical records, examination results, and infection control observations. Data were extracted from patient documentation and departmental records by independent auditors. Standard descriptive statistics were used. To compare dichotomous variables, the odds ratio was calculated to represent the risk factor and the P-value to represent the significance level. The P-value was determined using Fisher's exact test. Logistic regression through quantitative variables was used to compare the target and control groups. All statistical analyses were performed using Stata 10.

Two studies were conducted: a three-year period and a one-year period study, to compare their results after introducing a Prevention of Wound Infections Protocol. During both periods, identical variables were studied and the same statistical methods were applied.

In line with the publications and global research, data were collected on 17 potential risk factors for sternal wound infection after cardiac surgery: gender, age, BMI, diabetes and its treatment type, type of surgery (CABG, valve or combined), chronic heart failure (CHF), immunosuppressive therapy, peripheral vascular disease, laboratory data: C-reactive protein (CRP), creatinine, albumin, operation conditions (planned or emergency), preoperative stay, blood transfusion and its quantity, hours of mechanical pulmonary ventilation (MPV), duration of extracorporeal circulation (ECC), total surgical time. Additionally, data were accumulated on variable depths of infection, wound infection detection time and associated readmission need, and treatment outcome.

The presence of significant wound infection (superficial or deep) was defined as a requirement for subsequent surgical procedures.

For diagnosis, we adhered to the criteria and definitions of the Centers for Disease Control and Prevention (CDC)[60].

To determine the type of infection (superficial or deep), we followed the classification by Friberg et al.[61].

The target group in Study No. 1 consisted of 101 patients who developed wound complications, and in Study No. 2 – 17 patients who developed wound complications. The control (reference) group consisted of 101 consecutive patients treated in the same clinic under the same conditions, with similar characteristics and health status, who underwent the same type of surgical intervention and were examined following the same indicators.

The control group of patients after cardiac surgery without wound infection was compared with the cases of patients with wound infection. The following matching criteria were applied:

1. Median age:

Table 12.

Value	Target group	Control group
Median age	64,42 yrs	65,13 yrs

2. Gender distribution:

Table 13.

Value	Target group	Control group
Male	52	66
Female	39	35

3. BMI:

Table 14.

Value	Target group	Control group

Mean BMI	29,72	26,94
BMI > 25	79	64

4. Diabetes mellitus:

Table 15.

Value	Target group	Control group
Diabetes mellitus	63	31
On insulin treatment	31	11
Oral therapy	28	18
On diet	4	2

5. Blood transfusion:

Table 16.

Value	Target group	Control group
Blood transfusion	79	81
Blood transfusion of 4 units and more	29	25

6. Immunosuppressive therapy:

Table 17.

Target group	Control group
1	3

7.Peripheral vascular disease:

Table 18.

Target group	Control group
13	9

8. Type of surgery (emergency/planned):

Table 19.

Value	Target group	Control group
Emergency	39	41
Planned	62	60

9. Preoperative stay (days):

Table 20.

Target group	Control group
5,52	2,73

10. Type of surgery:

Table 21.

Type of surgery	Target group	Control group
CABG	72	52
Combined	19	22
Valve	9	15
Others	1	12

11. Chronic heart failure:

Table 22.

Value	Target group	Control group
CHF	47	38

12. Average duration of ECC (min):

Table 23.

Value	Target group	Control group
Average duration of ECC	113.77 min	117.81
OPCAB	25	21

13. Average operating time (hour):

Table 24.

Value	Target group	Control group
Average operating time	5.83 hrs	5.50 hrs

14. Apparatus ventilation (hour):

Table 25.

Value	Target group	Control group
Apparatus ventilation hours	25.03 hrs	10.18 hrs

15. Creatinine >130 mcmol/L:

Table 26.

Value	Target group	Control group
Creatinine >130 mcmol/L	11 patients	10 patients

16. Albumin < 35g/L

Table 27.

Value	Target group	Control group

Number of patients examined	85	93
Albumin < 35g/L	22	24

17. CRP > 5 mg/L

Table 28.

Value	Target group	Control group
Number of patients examined	60	51
CRP > 5mg/L	49	27

4. Results

4.1. Study No. 1

A retrospective study of 1 354 consecutive patients after cardiac surgeries, was performed in the Cardiac Surgery Clinic at St. Marina University Hospital over a three-year period.

Out of 1 354 patients treated in our clinic during the period, 101 patients (7.45%) have developed a superficial or deep sternal wound infection after cardiac surgery (Table 29).

In 18 patients (1.32% of the admitted patients), a deep wound infection was developed. In 83 patients (6.13% of the admitted patients), a superficial infection was developed.

In 19 cases (1.4% of the admitted patients), the wound infection was identified after discharge and led to readmission.

7 patients died.

Table 29.

Patients	N = 1354	100%
Wound infections	101	7.45%
Superficial infections	83	6.13%
Deep infections	18	1.32%
Infections detected and treated before discharge	82	6.06%
Infections detected and treated after discharge (readmission)	19	1.4%
Died	7	0.51%

The main demographic and perioperative data included in the study of patients with wound complications and the control group are presented in Table 30.

Table 30.

Variables	Target group n =101	Control group n = 101	odds ratio	P-value
Gender			1.777	0.063
Male	52	66		
Female	49	35		
Mean age (standard deviation, SD)	64.4 (8.49)	65.1 (11.52)	0.992	0.615
Mean BMI (standard deviation, SD)	29.2 (4.59)	26.84 (4.8)	1.119	0.001
Diabetes mellitus			3.444	0.000

No	40	70		
Yes	61	31		
Blood transfusion (number of units) (standard deviation, SD)	3.43 (4.8)	2.44 (2.77)	1.082	0.074
Blood transfusion > 4U blood products			2.044	0.074
No	76	87		
Yes	25	14		
Peripheral vascular disease			1.510	0.499
No	88	92		
Yes	13	9		
Type of surgery			0.921	0.886
Planned	62	60		
Emergency	39	41		
Average preoperative stay (days) (standard deviation, SD)	2.45 (2.48)	2.73 (2.89)	0.961	0.465
Chronic heart failure			1.443	0.254
No	54	63		
Yes	47	38		
ECC duration (hour) (standard deviation, SD)	91.46 (61.7)	92 (62.6)	0.999	0.952
Average operative time (hour) (standard deviation, SD)	5.64 (1.19)	5.45 (1.59)	1.047	0.646

Duration of artificial pulmonary ventilation (hour) (standard deviation, SD)	25 (50)	10 (15.8)	1.017	0. 030
Creatinine* >130 mcmol/l			1.227	0.822
No	89	91		
yes	12	10		
Albumin* < 35 g/L			1.231	0.630
No	24	28		
Yes	77	73		
CRP* > 5 mg/L			1.896	0. 165
No	11	19		
yes	90	82		

**The values of the clinical indicators are at the patient's admission and reflect the patient's underlying disease and comorbidity*

Based on the results presented in Table 30, it was found that the presence of "diabetes mellitus", "BMI>25" and "duration of artificial pulmonary ventilation" had a significant influence on the occurrence of postoperative wound infection in the settings of the Cardiac Surgery Clinic - Varna.

The highest odds ratio was "diabetes mellitus" (3.444), followed by the odds ratio of "BMI >25" (1.119) and "duration of artificial pulmonary ventilation" (1.017) (Table 31).

Table 31.

Variable	Target group n =101	Control group n = 101	odds ratio	P-value
Diabetes mellitus			3.444	0.000

No	40	70		
Yes	61	31		
Mean BMI (standard deviation, SD)	29.2 (4.59)	26.84 (4.8)	1.119	0,001
Artificial pulmonary ventilation (hour) (standard deviation, SD)	25 (50)	10 (15.8)	1.017	0,030

A separate logistic model was run between 'group' and 'diabetes' to estimate the contribution of each stage of diabetes on the likelihood of infection (Table 32):

Table 32.

Categories	exp(B)	P-value
No, 0	Reference	Reference
Yes, diet, 1	1.750	0.583
Yes, per-oral, 2	2.722	0.006
Yes, insulin, 3	4.932	0.000

It was found that the indicators "per-oral treatment of diabetes" and "insulin treatment in diabetes" are significant. The "diet treatment" category is not statistically significant, probably due to the small number of cases. The "exp(B)" coefficients show how many times the probability of infection increases in diabetic patients compared to patients without diabetes. In this context, patients with diabetes treated per-orally have about three times greater likelihood of developing a postoperative infection compared to patients without diabetes. Likewise, patients with diabetes using insulin have about five times greater likelihood of developing a postoperative wound infection compared to patients without diabetes.

Preventive measures: Introduction of a Protocol for Prevention of Postoperative Sternal Wound Infections after Cardiac Surgery in the Cardiac Surgery Clinic – Varna.

The Protocol was introduced with the joint and kind assistance of Paul Vogt, Department of Cardiovascular Surgery, Klinik Im Park, Zurich, Switzerland, following his visit and active participation in our clinic's activities. After discussions with Paul Vogt and researching data on wound infections in cardiac surgery in Bulgarian literature, we believe our institution is the first in Bulgaria to introduce this Protocol. Therefore, we decided to proceed with a one-year prospective study of patients in the Cardiac Surgery Clinic, aimed at determining the Protocol's influence on the known risk factors and direct assessment of its application. The assessment was conveyed using statistically processed data on wound infection rates during the two periods.

4.2. Study No. 2

To evaluate the results of the introduced Protocol, a prospective study was conducted on patients in the Cardiac Surgery Clinic over one year, covering 505 patients after cardiac surgery who underwent median sternotomy.

Out of 505 patients treated in our clinic during the period, 17 patients (3.36%) developed a superficial or deep sternal wound infection after cardiac surgery (Table 33).

In 6 patients (1.18% of the admitted patients), a deep wound infection was developed, and in 11 patients (2.17% of the admitted patients), a superficial wound infection was developed.

In 2 cases (0.39% of the admitted patients), the wound infection was identified after discharge and led to readmission.

Table 33.

Patients	N = 505	100%
Wound infections	17	3.36%
Superficial infections	11	2.17%
Deep infections	6	1.18%

Infections detected and treated before discharge	15	2.97%
Infections detected and treated after discharge (readmission)	2	0.39%
Died	1	0.19%

The data in Table 34. are calculated in the same way and using the same methods as in Table 30.

Table 34.

Variables	odds ratio	P-value
Gender	1.55730	0.3484
Age	0.990285	0.6777
BMI > 25	1.0865	0.0887
Diabetes mellitus	1.8452	0.1971
Blood transfusion >4U blood products	1.6868	0.2650
Peripheral vascular disease	0.7158	0.7367
Type of surgery: planned/emergency	0.21067	0.0572
Average preoperative stay (days)	1.08759	0.2650
Chronic heart failure	3.058	0.0499
ECC duration (hour)	1.00122	0.7051
Average operating time (hour)	1.00392	0.1010

Duration of artificial pulmonary ventilation (hour)	1.0029	0.0141
Креатинин* >130 mcmol/L	1.1818	0.8303
Albumin* < 35 g/L	2.198	0.0310
CRP* >5 mg/L	0.91198	0.7859

**The values of the clinical indicators are at the patient's admission and reflect the patient's underlying disease and comorbidity*

Based on the results presented in Table 34, "chronic heart failure (CHF)", "duration of artificial pulmonary ventilation (APV)" and "low albumin levels (Table 35)" were identified as significant risk factors in the settings of the Cardiac Surgery Clinic –Varna.

Table 35.

Variables	odds ratio	P-value
Chronic heart failure	3.058	0.0499
Artificial pulmonary ventilation	1.0029	0.0141
Albumin* < 35 g/L	2.198	0.0310

At the borderline of statistical significance were "BMI > 25" and "type of surgery: planned/emergency" (0.05 < P-value < 0.10). Noteworthy is the lack of significant correlation between wound infections and diabetes mellitus. This might be a result of the database being too limited in scope. However, Table 36 shows that the findings are correct and that the diabetic cases are distributed proportionally between wound infections and non-wound infections.

Table 36.

Group/diabetes	0	1

0	326	159
1	10	9

4.3. Evaluation of the effectiveness of the implementation of the Prevention of Wound Infections Protocol

A comparison of the relative share of wound infections before and after implementation of the Protocol was performed using a classical two-independent samples comparison test (Student t-test). A one-sided critical region test was applied, i.e., to test whether the relative share of wound infections in the control group was statistically greater than the relative share of wound infections in the treatment group. The calculations were performed with Stata (Table 37.).

Evidence of a significant difference

Table 37.

Value	Control group, n	Target group, n	z	P-value (Z>z)	
Wound infection	1354	505	3.21	**0.0007**	
Yes	101	17			
No	1253	488			

The test strongly supports the assumption that the relative share of wound infections in the control group (Study No 1) is greater than the relative share of wound infections in the treatment group (Study No 2). This is based on the fact that P-value < 0.05 (in this case P-value = 0.0007).

4. 4. Incidence of wound infections in the Cardiac Surgery Clinic - Varna over a nine-year period

2011 – 2013

Table 38.

Patients	N =1354	100%
Wound infections	101	**7.45%**
Superficial infections	83	6.13%
Deep infections	18	1.32%
Infections detected and treated before discharge	82	6.06%
Infections detected and treated after discharge (readmission)	19	1.4%
Died	7	**0.51%**

2014

Table 39.

Patients	N = 505	100%
Wound infections	17	**3.36%**
Superficial infections	11	2.17%
Deep infections	6	1.18%
Infections detected and treated before discharge	15	2.97%
Infections detected and treated after discharge (readmission)	2	0.39%
Died	1	**0.19%**

2015

Table 40.

Patients	N = 483	100%
Wound infections	9	**1.86%**
Superficial infections	4	0,83%
Deep infections	5	1.04%
Infections detected and treated before discharge	**7**	1.45%
Infections detected and treated after discharge (readmission)	2	0.41%
Died	0	**0%**

2016

Table 41.

Patients	N = 474	100%
Wound infections	11	**2.32%**
Superficial infections	9	1.9%
Deep infections	2	0.42%
Infections detected and treated before discharge	7	1.48%
Infections detected and treated after discharge (readmission)	4	0.84%
Died	0	**0%**

2017

Table 42.

Patients	N = 459	100%
Wound infections	14	**3.05**
Superficial infections	9	1.96
Deep infections	5	1.09
Infections detected and treated before discharge	6	1.30
Infections detected and treated after discharge (readmission)	8	1.74
Died	3	**0.65%**

2018

Table 43.

Patients	N = 426	100%
Wound infections	9	**2.11%**
Superficial infections	3	0.7%
Deep infections	6	1.4%
Infections detected and treated before discharge	5	1.17%
Infections detected and treated after discharge (readmission)	4	0.93%
Died	0	**0%**

2019

Table 44.

Patients	n = 340	100%
Wound infections	5	**1.47%**
Superficial infections	2	0.59%
Deep infections	3	0.88%
Infections detected and treated before discharge	4	1.18%
Infections detected and treated after discharge (readmission)	1	0.29%
Died	0	**0%**

2011 – 2019

Table 45.

Year	Frequency in % of patients with wound infections of the total number of patients undergoing sternotomy	Patients with wound infections died (%) of the total number of patients undergoing sternotomy
2011 – 2013	7.45%	0.51%
2014	3.36%	0.19%
2015	1.86%	0%
2016	2.32%	0%
2017	3.05%	0.65%
2018	2.11%	0%
2019	1.47%	0%

5. Discussion

5.1. Discussion of the results

The patients examined in the Cardiac Surgery Clinic – Varna, had varying severity of overall condition, comorbidity, severity of primary disease, type, and kind of surgical intervention.

Data processing in Study No. 1 found that "diabetes", "BMI > 25", and "duration of artificial pulmonary ventilation" significantly influence the occurrence of postoperative wound infection in the settings of Cardiac Surgery Clinic – Varna (Table 30). The highest probability of wound infection is with the presence of "diabetes", followed by "BMI > 25" and "duration of artificial pulmonary ventilation" (Table 31). Data processing in Study No. 2, conducted under the introduced Prevention Protocol, showed that "chronic heart failure (CHF)", "duration of artificial pulmonary ventilation", and "low albumin levels" are significant risk factors (Table 35.). In the second study, "BMI > 25" remains on the borderline of statistical significance, but statistical processing shows an even distribution of cases in the control and target groups.

The statistical results undeniably show a reduction in wound infection rates after introducing the Prevention Protocol in the Cardiac Surgery Clinic – Varna, in the compared periods (Table 37).

A comparison of sternal wound infections rates over a nine-year period in our clinic unambiguously shows a downward trend: from 7.45% to 1.47% (Table 45).

Statistical data processing showed that we cannot establish other indicators as significant risk factors with the available information and conditions in our clinic. The results in both groups regarding gender, age, immunosuppressive therapy, preoperative stay, presence of peripheral vascular disease, type of surgery, elevated CRP and creatinine levels, duration of extracorporeal circulation, and total operative time did not show significant differences. One likely explanation is the relatively small database for individual indicators, study periods, and patient characteristics. However, the findings align closely with those observed in international standards.

One limitation of our study is that it is single-center and as such may not be sufficiently representative. Another limitation is that our results were measured only during admission or readmission and did not allow long-term patient follow-up after discharge. We also

acknowledge the challenges, changes in patient profile, and the activity of medical facilities during the COVID-19 conditions, which imposed a limitation on the study period.

5.2. Financial and social implications of sternal wound infections after cardiac surgery

Financial implications of wound complications in the Cardiac Surgery Clinic (based on data from St. Marina University Hospital)

Table 46.

№ History of disease/Year	Hospital stay/days	Revenue BGN	Expense BGN	Difference BGN	Status
19948/2011	92	10100	40402	-30 302	Died
37957/2011	55	10100	23680	-13 580	Discharge
38552/2011	133	10100	48047	-37 947	Discharge
23929/2012	44	10100	24326	-14 226	Discharge
746/2013 (re-admission)	15	660	8797	-8 137	Discharge
1568/2013 (re-admission)	3	660	4118	-3 458	Discharge
2788/2013 (re-admission)	43	660	18812	-18 152	Discharge
25054/2013	87	15450	48447	-32 997	Died
6724/2014 (re-admission)	14	660	7125	-6 465	Discharge
7073/2014 (re-admission)	13	660	6477	-5 817	Discharge

42817/2014 (re-admission)	4	660	3391	-2 731	Discharge

The data reveals a significant imbalance between the revenue received by the medical institution and the expenses incurred for patients with this complication, as well as the need for rehospitalisation in cases where the complication is diagnosed after discharge.

A certain number of hospitals in the United States have adopted or are considering legislation that would impose public reporting of surgical site infection rates. This new culture of transparency could have an adverse effect on hospitals with high levels of such complications, leading to a loss of reputation and a decrease in related revenues. The actual costs of providing additional care, extended hospital stays, and additional surgical procedures also contribute to reduced revenues.

5.3. Preventive measures in the Cardiac Surgery Clinic – Varna

Various effective measures for preventing sternal wound infections post-cardiac surgery are highlighted and analysed in the sources addressing the issue. The main ones include preoperative screening to prevent the transmission of multi-resistant microorganisms, such as MRSA, antimicrobial prophylaxis based on current guidelines and consensus, preoperative skin and surgical field preparation with appropriate antiseptics, proficient surgical technique, as well as timely wound management in case of infection, in accordance with good surgical practices and evidence-based approach.

We consider it important to emphasize that the development of a sternal wound infection as a process involves a range of factors, as various conditions contribute to its effects, both independently and in combination. These can include patient-related factors – lifestyle habits, health culture, gender, age, comorbidity; environmental factors – hygiene conditions, conditions in the medical facility, operating room conditions such as temperature, adequate work process and environmental control, which are also of crucial importance. The factors related to the surgical team should not be forgotten – management of surgical site infection prevention measures, effective communication, hand hygiene and proper dressing techniques, adequate surgical technique, safe application of medical products. In this context, we aim to

define three separate categories of circumstances defining the likelihood of wound infection or its prevention, as well as the possibilities for its effective treatment:

1. Patient characteristics that cannot be changed before surgery or have very low probability of change. For patients with chronic diseases – such as COPD and diabetes, these risk factors cannot be reduced or eliminated. Similarly, the patient's age, gender, presence of previous cardiac surgery or the emergency of the surgery also place patients in conditions of higher wound infection risk. These factors cannot be changed preoperatively. Although it could be argued that risk factors like obesity and smoking are modifiable behaviours, it is evident that the moment to address these problems was long before the patient was admitted to the hospital. Therefore, patient care plans must be developed to reduce the impact of these risk factors preoperatively, during hospitalisation, and after discharge.
2. Implementing monitoring for compliance with the established standards.

Medical care standards are considered essential for wound infection prevention and continuous compliance must be controlled. The standards require work processes to be exercised in accordance with evidence-based practice and executed in a manner that maintains the standard for each patient. The medical staff must assess the infection prevention practices introduced in their institution to determine the extent to which these best practice standards are followed. A multidisciplinary team can be created to improve each stage of the treatment process if necessary.

3. Implementing new programs and products based on new studies, following medical standards and good practices, or utilising improvement opportunities unique to each hospital setting[317].

The preventive measures we implement to avoid wound infections begin with patient hospitalisation planning. Among routine preoperative examinations, testing the nasopharyngeal secretions for multi-resistant microorganism carriage (e.g., MRSA) and applying the corresponding preparation is of great importance. Genotype analyses of S. aureus isolated from patients' sternal wounds with mediastinitis have shown a match with S. aureus isolated from the patient's nostrils[184]. Examining staff is also a good preventive measure. Upon admission to the department, risk factors for postoperative infection are individually assessed for each patient.

We aim to strictly monitor blood sugar levels in diabetic patients throughout the treatment period, with control also performed for patients without medical history or accompanying

medical documentation indicating diabetes but with elevated blood sugar levels. This includes HbA1c testing; perhaps introducing this test as routine for non-diabetics would lead to more accurate accounting of such a critical risk factor. A widely accepted practice is examining and recording inflammatory indicators, as well as preoperative protein and albumin levels. After careful patient examination, the presence of vascular diseases, associated complications, chronic wounds, and infections are recorded and documented. When extrathoracic infections are detected, appropriate measures are taken to treat and limit the spread of infection, which is, of course, related to the patient's underlying disease and the critical necessity of their surgical treatment. For all other patients, the need to reduce the preoperative stay in the surgical department to the possible minimum is considered. Efforts are taken to compensate, to the maximum possible extent, the accompanying somatic diseases (heart failure, anaemia, kidney diseases, lung diseases, systemic diseases, etc.). The preoperative stay is often dependent on the severity of the patient's disease, their comorbidity, and the requirement for proper planning ahead of surgery. The patient participates in a discussion about the planned surgical treatment, the expected results, behaviour and procedures in the Intensive Care Unit, as well as the rules that must be followed by the patient to ensure a smooth postoperative period. The risk of using both thoracic arteries is assessed against the risk of infection according to the presence of risk factors, such as obesity and diabetes, for each individual patient. In accordance with the established standards and protocols of the Cardiac Surgery Clinic – Varna, patient preoperative preparation is carried out: antiseptic bathing, using shaving machines instead of razor shaving. A crucial element is the prescription of prophylactic antibiotic therapy – preoperative and intraoperative, in line with established standards and the hospital's medication policy.

5.4. Protocol for preventing wound infections after cardiac surgery

5.4.1. Prevention Protocol

One of the key moments in our efforts to reduce the frequency of postoperative infections was the adoption of a Protocol for Prevention of Wound Complications. The implementation of the Protocol enhanced and supplemented the existing rules in our clinic. As noted above, the Protocol was introduced with the assistance of Paul Vogt from Zurich, Switzerland during his visit to the Cardiac Surgery Clinic in Varna and after familiarising and discussing the research results of his team. Our research indicates that the implementation of this initiative resulted in beneficial outcomes (Table 37).

Main highlights and new elements in the Protocol[44, 318, 319] :

Table 47.

Period	Preventive measures
I. Preoperative	1. Reducing bacterial load in the nasal mucosa by applying nasal Mupirocin, starting the day before surgery and continuing for four days after surgery. 2. On the day of surgery, patients are required to thoroughly wash themselves using a 4% Chlorhexidine gluconate or Octenidine dihydrochloride 0.1% before being taken to the operating room. 3. Disinfection of the surgical incision site at least twice with 70% Isopropyl alcohol – Chlorhexidine gluconate 2%. The patient's skin must be allowed to dry completely before the patient is covered with surgical sheets. 4. Systemic intravenous antibiotic prophylaxis with a second-generation cephalosporin is applied at least 30 minutes before the start of the surgery. 5. A second intravenous antibiotic dose is applied if the surgery lasts more than six hours.
II. Intraoperative	1. No or very limited precise use of electrocautery skin incision in the subcutaneous tissue. 2. Preserving the caudal bifurcation of the left and right mammary arteries at the epigastrium level during coronary revascularization. 3. Three grams of Vancomycin are mixed with 4 ml of 0.9% NaCl, resulting in a wax-like material that is rubbed into the spongiosa of the sternal edges.

	4. Use of 6 to 8 "figure of eight" osteosynthesis wires, reinforcing especially the lower part of the sternum. 5. Irrigation of the sternum and osteosynthesis wires after sternal fixation with 80 mg of Gentamicin. 6. No suturing of the subcutaneous fat layer, even in obese patients. 7. Intradermal skin sutures or interrupted single sutures. 8. No episternal drainage tubes or drains. 9. Routine glove change after sternotomy and placement of the sternal retractor, every two hours and before metal sternal osteosynthesis.
III. Postoperative	1. Wound dressings after sternotomy are changed after 48 hours or if the dressing is wet. 2. No external thoracic stabilisation with chest jackets.

In a comprehensive study of 8168 patients after complete median sternotomy, P. Vogt et al. present results from implementing this protocol in three cardiac surgery centers – in Switzerland, Russia, and Austria, for the period from 2006 to 2014. For the purposes of the study, patients were divided into two groups: control and target, with the aforementioned measures applied to the target group. After conducting statistical analyses, the authors report a reduction in sternal wound infections from 5.1% to 1% both at the average level for the three cardiac surgery centers and at the national level. Moreover, the analysis of wound healing type, differentiating between the absence of infection, superficial wound infection, and deep sternal wound infection, revealed a significant protective effect of the protocol for preventing infections. Regarding concerns about the emergence of multi-resistant microorganisms, the authors declare that during the first three days after surgery, serum Vancomycin concentrations were below any clinically significant level in their studied population.

5.4.2. Expanded and adapted Prevention Protocol in the Cardiac Surgery Clinic – Varna

Along with the above-mentioned measures, we apply additional preventive measures in our practice, as follows:

I. Regarding preparation of the operating field:

1. One-time cleaning of the entire patient's body using water-based antiseptics – performed by the second operating nurse or the assisting surgeon.

2. Triple application of 2% Chlorhexidine alcohol-based; the operating field should dry after each treatment. The soft tissue incision area of the chest should be treated for no less than 30 seconds.

II. Regarding soft tissue incision:

1. All soft tissues, including the periosteum, are cut only with a scalpel.

2. Electrocoagulation is used only to stop point-like bleeding.

III. During sternotomy:

1. The sword-shaped outgrowth is not cut with the blade to prevent unnecessary mobility and to remain surrounded by its soft tissues.

2. Use of wax for hemostasis – not routinely, but after assessing the benefit/risk balance.

IV. Regarding internal mammary artery harvesting:

1. Internal mammary arteries are skeletonized;

2. Use of harmonic device for harvesting both mammary arteries when possible.

V. Regarding wound closure:

1. After stopping the artificial circulation apparatus and starting hemostasis, the pericardial cavity is washed with 1 L of warm physiological solution;

2. Wound closure is performed after thorough hemostasis.

VI. Regarding sternal fixation using osteosynthesis with metal implants:

1. Single metallic ligatures are applied to the sternum, with the recommended distance between them being 1–1.5 cm; generally, 6–8 metallic bodies are applied (two on the manubrium, one around the joint between the sternal body and manubrium, 4–5 on the sternal body). The first wire is placed as high as possible, and the last one – as low as possible.

2. The cut aponeurosis is sutured with separate or continuous sutures. With this suture line, the pericardial cavity is completely separated from the suprasternal space. For this purpose, a braided suture with an average resorption time of 2/0 is used.

3. After osteosynthesis, the sternum is irrigated with 60–70 ml of a solution containing Gentamicin (3 ampoules of Gentamicin are dissolved in 100 ml of 0.9% NaCl. 2/3 of the quantity is used at this stage, the remaining amount – before applying the skin suture);

4. The fascial-muscular layer is sutured with interrupted U-shaped sutures using braided sutures with average resorption and diameter 0–2/0, to completely separate the sternum from the subcutaneous tissue.

5. Before applying the skin suture, the subcutaneous tissue is re-irrigated with the remaining Gentamicin solution – see Point 4.

6. The skin is sutured with a continuous suture using a monofilament suture with average resorption and diameter of 3/0–4/0.

VII. Regarding the surgical method: Increasing the frequency of OPCAB.

VIII. Regarding anesthesiological measures:

1. Field preparation before placing venous pathways is performed three times using 2% Chlorhexidine alcohol-based.

2. Intravenous lines are located far from the patient.

3. The insertion of the preparations takes place at a distance from the central venous catheter.

4. There should be no three-way stopcocks within the patient's bed area.

IX. Regarding postoperative measures:

1. Early mobilization;

2. Active diuretic application;

3. Patient weight control.

X. Regarding antibacterial therapy: After the surgery and removal of chest drains, prophylactic antibiotics are not routinely applied.

5. 4. 3. Closed Incision Negative Pressure Wound Therapy (ciNPWT)

After implementing the Prevention of Wound Infections Protocol in our clinic, we observed good results, manifesting in a persistent and stable reduction of this complication's frequency. We are actively pursuing a continuous strategy to lessen the risk of wound infections. we aim to implement advanced strategies for preventing and control of this complication. We believe that an innovative and increasingly popular preventive measure is the use of negative pressure therapy on sutured, clean incisions, such as the incision in sternotomy. The anticipated preventive processes consist of improving local blood flow, reducing oedema, holding the incision edges together, protecting the wound from external contamination, and supporting the healing stages. Patients suitable for this therapy are those with significant risk factors. Since 2017, after training in Düsseldorf, Germany, we have been applying ciNPWT as a preventive measure for patients with significant risk factors for wound infection development.

As early as 2011, Colli and Camara shared their first experience with ciNPWT in cardiac surgery patients with serious postoperative sternal wound infection risk factors. They reported complete primary wound healing in the observed patients without device complications and without patient complications during the 30-day postoperative period. Grauhan et al. believe that applying ciNPWT is associated with reducing surgical wound infection frequency after cardiac surgery, not only for patients with existing risk factors but for all patients. According to clinical evidence and consensus guidelines published by Dohmen et al., ciNPWT appears to be an effective approach when used on sutured, clean incisions, such as the sternotomy incision. The authors also propose a classification of risk factors for deep infection after cardiac surgery, related to the preventive use of ciNPWT[323]:

Table 48.

Significant risk factors	Intermediate risk factors	Small risk factors
1. BMI<18 or ≥40 kg/m2; 2. Insulin-dependent diabetes mellitus; 3. Dialysis in patients with chronic kidney disease	1. BMI: 35–39 kg/m2; 2. Diabetes mellitus (type 1 or 2, on per-oral treatment or diet); 3. Chronic kidney disease; 4. Use of bilateral internal mammary arteries (BIMA); 5. Long-term immunosuppressive treatment; 6. Previous radiotherapy of the chest wall; 7. Chronic lung disease	1. BMI: 30–34 kg/m2; 2. Peripheral vascular disease; 3. Female sex; 4. Age >75 years; 5. Cardiac reoperation for CABG; 6. Left ventricular ejection fraction <30%; 7. Acute myocardial infarction within 90 days prior to surgery; 7. Hospitalised at least 7 days prior to surgery

In their consensus guidelines, Dohmen et al. suggest considering ciNPWT for all high-risk patients after assessment of accompanying risk factors; the patients having one or more primary risk factors are the most indicative for vacuum therapy. Dohmen et al. also recommend using the therapy for patients with two or more intermediate risk factors. The use of ciNPWT is especially recommended for patients after heart or lung or heart/lung transplantation due to the high degree of immunosuppression.

We accept the above classification as sufficiently detailed and applicable to our conditions. Our opinion is that at this stage and in our circumstances, the application of vacuum therapy through a closed incision should be limited to patients with significant existing risk factors to restrict unnecessary expenses. The risk factors we consider as grounds for applying ciNPWT are: BMI > 35, presence of diabetes, female gender, especially in combination with obesity and diabetes, use of sequential coronary artery bypass grafts, previous radiotherapy, and reoperations. We

also believe that applying this therapy does not replace strict adherence to good surgical techniques in cardiac surgery. We did not find published data in Bulgarian literature about the use of ciNPWT after cardiac surgery, but we believe this method will gain increasing popularity. We again emphasize strict glycemic control as a primary preventive measure (Table 49.)

Diabetes mellitus as a risk factor for wound infection in the Cardiac Surgery Clinic – Varna

Table 49.

Year	2016	2017	2018
Number of wound infections	11	14	9
Patients with wound infection and diabetes mellitus	4	9	6
The share of patients with wound infection and diabetes mellitus to the total number of wound infections	36,6%	64,28%	66,66%

From January 2017 to August 2023, we applied negative pressure therapy in 109 cases (44.0% – men, 56.0% – women). In 40 of them (36.7%), NPWT was used on open wounds: 30 (75%) after sternotomy, 6 (15%) after saphenectomy, and 4 (10%) for decubitus ulcers. In 69 cases (63.3%), NPWT was used on primarily closed wounds (ciNPWT) as a preventive measure for patients with wound infection risk factors and to assist primary wound closure: 62 (89.9%) after sternotomy and 7 (10.1%) after saphenectomy. We recorded failure in three cases (4.3%) with ciNPWT: one patient (1.4%) with deep sternal wound infection requiring surgical treatment and two patients (2.9%) with superficial sternal infection treated conservatively with dressings.

Table 50.

Surgical wound	NPWT n=40 (on an open wound)	ciNPWT n=69 (on a closed wound)
After sternotomy	75%	89,9%
After saphenectomy	15%	10,1%
Decubitus ulcers	10%	
Failure	0%	4,3%: 1. 1.4% – deep infection after ciNPWT 2. 2.9% – superficial infection

Clinical discussion and identifying the risk factors and their severity for postoperative infection development is an important and challenging task. Some factors cannot be modified – age and gender, while others can be influenced to a greater or lesser extent. Therefore, we believe that applying negative pressure therapy together with other means from the set of preventive measures and treatment of wound complications after cardiac surgery has its future. Our observations show that NPWT is a highly effective addition in treating wound infections in patients after cardiac surgery and can be successfully used for wound treatment and prevention in various body areas. Our experience so far indicates that ciNPWT may have application in preventing wound infections after cardiac surgeries. More clinical experience and targeted studies are needed to assess the effect of using this type of therapy in wound infection prevention.

6. Diagnosis and treatment of wound infections in the Cardiac Surgery Clinic – Varna

6.1. Diagnosis

Early diagnosis of postoperative infection requires a high degree of control and observation. According to our experience, surgical wound infections during hospitalisation most often appear between the 5th and 8th postoperative days. The patient may present with deterioration of their general condition, anorexia, and temperature. Considering its non-specific nature, temperature is the most common first clinical sign of infection. However, in the postoperative period after cardiac surgery, temperature may occur in the absence of infection and can persist for a long period in certain situations. Adverse drug reactions, phlebitis, atelectasis, and pulmonary embolism in addition to post-pericardiotomy syndrome are the main causes of temperature after the 6th postoperative day[317].

Sternal wound infection manifests in a spectrum ranging from a subacute, stable patient to a fulminant critically ill patient who needs immediate intervention to prevent undesirable consequences. Vital signs typically can indicate tachycardia and temperature. In more advanced sepsis cases, there may be hypotension and the patient might require intensive treatment. Systemic sepsis signs, combined with clinical signs, strongly suggest a deep sternal wound infection. Delay in mediastinitis diagnosis significantly impacts morbidity, mortality, and overall treatment outcome. In our Clinic, the condition is usually recognised early due to the increased attention to this complication, especially in the presence of risk factors.

6.2. Treatment

Surgical treatment of the infected sternal wound goes through various stages: it is generally associated with thorough surgical debridement, widespread use of VAC therapy, sternal refixation, local antibiotic application, and plastic techniques. We believe that the optimal strategy varies to some extent for each case and depends on the infection's duration, mediastinal structure condition, and surgeon's experience.

At the initial phase of treatment, surgical wound debridement is performed with revision and removal of suture material and osteosynthesis wires (in deep infection) and removal of all necrotic areas in both bone structures and soft tissues. We believe that attempts at local and limited wound treatment and preservation of even small bone fragments from sternal osteomyelitis lead to new infection spread and recurrence development. Unsuccessful removal of the devitalized tissues and sanitation of the mediastinum during the first surgical treatment is the most common cause of repeated postoperative mediastinitis. During treatment, materials are taken for microbiological examination. At the end of surgical treatment and after appropriate

indications, we apply the VAC system, which is usually the second stage of infected wound treatment. When applying NPWT for open wound treatment, we adhere to the indications and contraindications cited earlier. The criteria for discontinuing NPWT are: negative bacterial culture, absence of fever, decrease in CRP levels, and clinically healthy granulating wound. When using negative pressure therapy, we follow the established NPWT methodology, taking into account individual wound characteristics, infection elimination stage, underlying tissues and structures, the patient's overall condition and comorbidities, and the time required to achieve expected results. During treatment, antibiotic therapy may be necessary, aligned with microbiological examination results or clinical wound indicators if results are not yet available. The changes of VAC dressing are performed according to the infection process depth, wound condition, existing foci of infection, and the surgeon's clinical experience.

The third treatment stage involves reconstructive surgery, a prerequisite for which is achieving certain clinical and paraclinical results during the first two stages: negative bacteriological examination, presence and growth of granulation tissue, absence of systemic inflammatory reaction, and normoproteinemia. The reconstructive operation options include: secondary suture (for superficial infections) with sternal plasty if there are insufficient soft tissues; sternum refixation with or without plasty using muscle flaps; rectus abdominis muscle plasty or omentum for large bone defects.

In our practice of treating deep sternal infections, we have used omentum major as a plasty material for closing wound defects in three cases, m. rectus abdominis dex. in one case, and in one case we had to place a titanium plate. These cases are from before 2015, after which we did not need to resort to these surgical strategies.

For deep sternal wound infections, it is preferable for the patient to be in an intensive care unit to achieve maximum effective monitoring and treatment correction if necessary.

It is necessary to pay attention to wound care, dressings, and antiseptics. Biofilm formation, especially in polymicrobial infections, reduces the effect of antimicrobial agents and immune response. This can cause failed healing, infection deepening, and the need for surgical treatment. In fighting infection, the approach includes removing nonviable and/or infected tissue from the wound and cleaning with local antiseptics. The most accepted approach is placing a dressing, most often cotton gauze. Ideally, the dressing should function as a temporary barrier against microorganisms through mechanical stability, absorb excessive exudate, not

irritate the wound surface, and be sterile. To contribute more actively to the healing process, some dressings, known as medicinal (or bioactive) wound dressings, have a bioactive agent, most often an antimicrobial agent. They may also include analgesics, anaesthetics, anti-inflammatory drugs, and growth factors. The introduction of antibiotics in the 20th century significantly improved wound infection control, but their widespread use led to the emergence of multi-resistant bacterial strains[324]. Currently, the use of antiseptics with a non-specific mode of action is preferred, i.e., those able to destroy the cell membrane or the bacterial cell itself or block the negative surface charges, since there have been no instances of resistance linked to their typical application[325]. It should be emphasized that antiseptic dressings should not be used routinely, only when there are signs of wound infection or in immunocompromised patients[326]. In our practice, the most frequently used antiseptics are Chlorhexidine, Polyhexanide, Octenidine, and Povidone-iodine.

We consider it important to perform primary surgical treatment overly depending exclusively on conservative therapy. We also believe that surgical treatment should be performed in an operating room under appropriate conditions and with suitable anaesthesia, which often determines the thoroughness of the treatment. Each stage of treatment for these patients must be carried out with normal coagulation indicator values.

6.3. NPWT application in infected extrathoracic wounds

It is acknowledged that NPWT has wide application in many areas of surgical disciplines. In the Cardiac Surgery Clinic – Varna, in cases of infected extrathoracic wounds, negative pressure therapy is most frequently used in infected wounds after saphenectomy and in deeper decubitus ulcers. Fortunately, patients with such complications were relatively few, and we cannot provide sufficient data for statistical processing. Nevertheless, the results encourage us to continue applying this therapy. However, its application was not carried out before thorough surgical treatments, often multiple, especially in decubitus ulcers.

6.4. Microbiology

The most frequently isolated causative agents of postoperative wound infection in our clinic are Staphylococcus Epidermidis, followed by Enterococcus Faecalis and Methicillin-resistant Staphylococcus Aureus (MRSA). In most cases of deep sternal wound infection, more than one causative agent was isolated (Graph 1).

An interesting study and its conclusions were published by a team of researchers from the Medical University – Varna and the Regional Health Inspectorate –Varna (*Infections related to medical service and their outbreaks in the Varna region for 2014 – 2016*, D. Monov, E. Zheleva, A. Baeva, M. Kolarova; publication Varna Medical Forum, vol. 6, 2017, Supplement 2). They reported a trend of increasing the number of treated patients in the region's hospitals during the studied period. The highest number of nosocomial infections in 2015 and 2016 were registered in the two largest medical facilities in the region: St. Marina University Hospital and St. Anna Hospital. The authors concluded that the leading nosological structures were surgical site infections, lower respiratory tract infections that are not pneumonias, intubation-related pneumonias, and urinary tract infections. The main causative agents of nosocomial infections in 2016 were Acinetobacter baumannii, Pseudomonas aeruginosa, Klebsiella pneumoniae, and Staphylococcus aureus. Three outbreaks were registered in 2016 and one outbreak in 2015 with causative agents Pseudomonas aeruginosa, Acinetobacter baumannii, and ESBL Enterobacter cloacae. These results correlate with the most frequent causative agents isolated in our clinic and once again confirm the need for strict control, monitoring, and adherence to medical standards at all levels of the treatment process.

7. Conclusion

7.1. Summary

The thesis results and conclusions can be showcased as solutions to the defined tasks. Our research identified and analysed the risk factors for the development of wound infection in the Cardiac Surgery Clinic – Varna. A Prevention of Wound Infections Protocol was presented, and its effectiveness was statistically evaluated. Clear evidence regarding the economic strain caused by this complication in cardiac surgery was highlighted, proving the need for preventive measures. Data on wound infection epidemiology in the clinic were presented, along with the trend of a reduction in frequency over a nine-year period. We report initial data on the application of ciNPWT as a preventive measure. We believe we are presenting modern methods and trends for the prevention and treatment of wound infections after median sternotomy.

Leveraging international expertise in alignment with our resources, our efforts are focused on improving the methodologies for the prevention and treatment of postoperative wounds applied

in our clinic. The primary goal of our thesis research was to reduce the risk of sternal wound infections after cardiac surgery in the Cardiac Surgery Clinic as much as feasible.

7.2. Conclusions

1. Wound infection incidents after cardiac surgery in our clinic do not exceed the good surgical practices described in the literature.

2. Risk factors for developing wound infection that we find significant under our Clinic's conditions are comparable to those cited in international publications.

3. Recognition of wound infection risk factors is crucial for limiting its frequency and spread.

4. The introduction of the Prevention of Wound Infections Protocol reduced these complications in the Cardiac Surgery Clinic – Varna.

5. Strict adherence to the Prevention of Wound Infections Protocol could lead to a stable trend of decreasing wound infection frequency.

6. Strict control of medical standards compliance and monitoring patients from admission to discharge, are important elements in preventing and treating wound infections after cardiac surgery.

7. NPWT application in sternal wound infection treatment is a significant stage of surgical strategy. Negative pressure therapy may offer valuable benefits in treating extrathoracic infected wounds.

8. The application of ciNPWT as a preventive measure for patients with significant risk factors appears as a favourable option in the conditions of the Cardiac Surgery Clinic –Varna. There is a necessity for more comprehensive research at the local level, as well as adherence to contemporary guidance and standards.

9. Introduction of new programs, products, and technologies based on new research could contribute to reducing wound complication frequency.

10. Body weight reduction and strict glycemic control would reduce the risk of wound complications.

11. Decreasing wound infection frequency after cardiac surgery leads to improved patient quality of life, reduced hospital stay, and optimisation of financial expenses.

7.3. Thesis contributions

1. Conducting a study to identify risk factors for wound infection in the Cardiac Surgery Clinic – Varna and analysing the epidemiology of postoperative wound infections in this clinic over a 9-year period.

2. Information about the initial implementation of a Prevention of Wound Infections Protocol in Bulgaria, which details patient preparation for surgical treatment, behaviour in the operating room and postoperative period aimed at reducing the frequency of postoperative sternal wound infections. Statistical results on the effectiveness of its implementation in the Cardiac Surgery Clinic – Varna are presented.

3. Presenting data from the initial implementation of ciNPWT (closed incisional negative-pressure wound therapy) in Bulgaria as a preventive measure for wound infection in patients with significant risk factors.

8. Participation and Publications

8.1. Participation

1. Heart Tumors and Cysts; Manoilov P., Panayotov Pl., Panayotova D.; XX Anniversary Session of the Heart – Lung Association, Second Scientific Meeting "Varna – Augsburg", Varna, 30.05 – 31.05.2014;

2. Risk factors for wound infection in cardiac surgery – Brief literature review, own experience, risk models; P. Manoilov, Pl. Panayotov, V. Petrov, V. Hadjiev; XIV National Congress of Surgery with international participation, Sofia, 23.10 – 26.10.2014;

3. Prevention of wound infections in the Cardiac Surgery Clinic, St. Marina University Hospital – Varna; Study, Experience, Results – P. Manoilov, P. Panayotov, V. Hadjiev, V. Petrov, H.

Cherkezov – Sixth National Congress of Thoracic, Cardiac and Vascular Surgery, Sandanski, 14.05 – 16.05.2015;

4. Analysis of results after introducing a Protocol for Prevention of Wound Complications after cardiac surgery – P. Manoilov, P. Panayotov, V. Hadjiev, H. Cherkezov, Vl. Kornovski, M. Slavov, B. Bogdanov, V. Petrov – XV National Congress of Surgery with international participation, Albena Resort, 29.09 – 02.10.2016;

5. Epidemiology and prevention of wound complications after cardiac surgery in the Cardiac Surgery Clinic at St. Marina University Hospital – Varna; P. Manoilov – XXV Heart –Lung Conference, Golden Sands Resort, 31.05 – 01.06.2019;

6. Application of NPWT in patients after cardiac surgery – P. Manoilov – XXVI Heart –Lung Conference, Albena Resort, 11.11 – 13.11.2022;

7. Application of NPWT in patients after cardiac surgery – P. Manoilov – Cardiac Surgery Forum Varna; October 26 – 28, 2023;

8. Haemodialysis catheter placement directly in the right atrium due to exhausted vascular access options – P. Manoilov – XXVII Heart-Lung Conference, Albena Resort, 10.11 – 12.11.2023;

9. Results of prevention and treatment of sternal wound infections after sternotomy over a 9-year period – P. Manoilov – XXVIII Heart – Lung Conference, Albena Resort, 01 – 03.11.2024.

8.2. Publications

1. Heart Tumors and Cysts – P. Manoilov, Pl. Panayotov, D. Panayotova – Scripta Scientifica Medica, vol. 46 (2014) Abstract; DOI: http://dx.doi.org/10.14748/ssm.v46i1.2392

2. Risk factors for wound infection in cardiac surgery – brief literature review, risk models. P. Manoilov, P. Panayotov, H. Cherkezov, A. Georgiev; Heart – Lung, Year 20, Issue 1–2, 2014, ISSN 1310-6341;

3. Risk Factors for wound infection in cardiac surgery – literature review, own experience, risk models. P. Manoilov, Pl. Panayotov, V. Hadjiev, V. Petrov, H. Cherkezov, A. Georgiev – Bulgarian Thoracic, Cardiac and Vascular Surgery, 2015, issue 1, ISSN 1313 - 9339

4. Analysis of the results of the Protocol for Prevention of Wound Complications after Cardiac Surgery. P. Manoilov, Pl. Panayotov, V. Hadzhiev, H. Cherkezov, V. Kornovski, M. Slavov, B. Bogdanov, V. Petrov – Scripta Scientifica Medica, vol. 48 (2016) Abstract; DOI: http://dx.doi.org/10.14748/ssm.v48i0.2293

5. Implantation of a hemodialysis catheter directly in the right atrium due to exhaustion of vascular access. P. Manoilov, P. Panayotov, V. Petrov, G. Todorov, M. Slavov; Scripta Scientifica Medica, vol. 52 (2020); DOI: http://dx.doi.org/10.14748/ssm.v52i3.6642

6. Surgical access for haemodialysis. Haemodialysis catheter placement directly in the right atrium due to exhausted vascular access options. P. Manoilov, P. Panayotov, V. Petrov; ISBN 978-619-241-156-5

7. Application of NPWT in patients after cardiac surgery. Literature review and own experience. Pavlin Manoilov, Martina Sapundzhieva, Emil Yordanov; Heart-Lung (Varna), 29, 2023, Online first, Medical University of Varna

9. Guidelines for future research

9.1. We consider it valuable to develop an in-depth application of ciNPWT for the cardiac surgical patients' target group as a preventive measure. A comprehensive review assessing the clinical and financial viability of this therapy needs to be established.

9.2. We consider the introduction of gentamicin-collagen implants in our clinical practice for patients with significant risk factors a beneficial step forward. An assessment of their effectiveness is required.

9.3. Initiatives may focus on the application of platelet-rich plasma and its assessment as a preventive measure in cardiac surgery.

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