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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

Readmission to an intensive care unit after cardiac surgery: reasons and outcomes

Radosław Jarząbek[1], Paweł Bugajski[1], Krzysztof Greberski[1], Jerzy Błaszczyński[2], Barbara Słowińska-Jarząbek[3], Ryszard Kalawski[1]

[1]Department of Cardiac Surgery, Jozef Strus City Hospital, Poznan, Poland
[2]Institute of Computing Science, Department of Intelligent Decision Support Systems, Poznan University of Technology, Poznan, Poland
[3]Specialist Mother and Child Hospital, Poznan, Poland

Abstract

Background: Intensive care unit (ICU) readmission after cardiac surgery is believed to be associated with higher in-hospital mortality and may predict poor outcomes. ICU readmissions use resources and increase treatment costs.

Aim: To determine reasons for readmission to ICU, evaluate outcomes in these patients, and identify factors predisposing to the need for readmission to ICU.

Methods: We retrospectively investigated a total of 2076 consecutive adult patients who underwent either isolated coronary artery bypass grafting or a valve procedure or combination of both and were discharged from our ICU between January 2008 and December 2010. To identify the factors that increase the risk of readmission to ICU, we used the dominance-based rough set approach (DRSA) which is a methodology of knowledge discovery from data. The knowledge has the form of "if… then…" decision rules relating patient characteristics to the risk of readmission to ICU.

Results: Of 2076 patients discharged from ICU, 56 (2.7%) required a second stay in the ICU (study group) while 2020 patients needed no readmission to ICU (control group). The main causes of readmission were haemodynamic instability (28.6%, n = 16), respiratory failure (23.2%, n = 13), and cardiac tamponade or bleeding (23.2%, n = 13). The mean length of stay (LOS) in the general cardiac ward after primary discharge from ICU until readmission was 3.5 ± 4.2 days. The mean LOS in ICU after readmission was 12.5 ± 21.2 days. Postoperative complications occurred more frequently in readmitted patients (10.2% vs. 48.2%, $p < 0.0001$). In-hospital mortality was significantly higher in the study group (15 [26.8%] vs. 23 [1.1%] patients, $p < 0.0001$). As a result of applying the DRSA methodology, the algorithm generated decision rules categorising patients into high and low ICU readmission risk. Advanced age, non-elective surgery and the length of initial ICU stay after the surgery were the factors of greatest importance for the correct categorisation of patients in the study group.

Conclusions: The most common cause of readmission to ICU is haemodynamic instability. Postoperative complication and in-hospital mortality rates are significantly higher in patients readmitted to ICU. Factors most commonly predisposing to readmission to ICU after cardiac surgery included advanced patient age, non-elective surgery, and longer initial stay in ICU after the surgery.

Key words: readmission, cardiac surgery, ICU, dominance-based rough set approach (DRSA)

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INTRODUCTION

Due to complexity and extent of cardiac surgery, nearly all patients require postoperative care in an intensive care unit (ICU). A certain subset of patients, however, is discharged from ICU but later requires readmission to ICU due to significant worsening of their clinical condition during the same hospitalisation. It was shown that patients in this group are characterised by much worse outcomes and more frequent complications. Their treatment is costly, and by reducing the number of available ICU beds, these patients limit the ability

Address for correspondence:
Radosław Jarząbek, MD, PhD, Department of Cardiac Surgery, Jozef Strus City Hospital, ul. Szwajcarska 3, 61–289 Poznań, Poland, e-mail: radoslawj@hotmail.com
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to admit new patients for surgical treatment. In cardiac surgical practice, the proportion of patients readmitted to ICU after cardiac surgery ranges from 2.3% to 7.8% [1–6].

Until now, no approach has been developed that would allow effective prediction which patients will require readmission to ICU, which would justify prolonging their initial stay in ICU after the surgery, or providing some other form of careful surveillance. This issue has been rarely studied in the Polish literature, and as far as we know, the methodology of dominance-based rough set approach (DRSA) has not been used so far.

The purpose of this study was to determine factors that necessitated readmission of cardiac surgical patients to the ICU of a city hospital in Poznan, evaluate outcomes in comparison to those patients who did not require readmission to ICU, and identify factors predisposing to the need for readmission to ICU compared to the control group.

METHODS

Studied patients

We evaluated 2223 consecutive adult patients operated using cardiopulmonary bypass in the Department of Cardiac Surgery at the Jozef Strus City Hospital in Poznan, Poland, from January 2008 till December 2010. Among those patients, we identified 2152 patients who underwent coronary artery bypass grafting (CABG), cardiac valve replacement or repair, or a combination of these procedures, hereafter referred to as combined surgery. We excluded patients operated due to an aortic aneurysm or acute aortic dissection, cardiac aneurysm, or other rarer diseases of the heart or great vessels.

In the selected population, 76 (3.5%) patients did not survive the surgery or initial stay in ICU. The remaining 2076 patients were subject to further analysis. Patients who survived the surgery and were discharged from ICU were divided into two groups. The study group consisted of 56 (2.7%) who required readmission to ICU. The control group included 2020 patients who did not require readmission to ICU and awaited discharge from the cardiac surgery unit.

The most important pre- and intraoperative data are shown in Table 1.

Data were collected retrospectively from medical records and our local computer database that contributed data to the National Cardiac Surgery Register (KROK, *Krajowy Rejestr Operacji Kardiochirurgicznych*) [7]. For some parameters, data were missing for some patients as indicated in Table 1. Reasons for missing data included lack of information in available medical records, not performing a given test, and the fact that the KROK database was extended to included additional parameters since 2009. Definitions of complications and conditional attributes were taken from the EuroSCORE and the KROK registry. All operations were performed under normothermic conditions using antegrade cold crystalloid or blood cardioplegia. The surgical approach was median sternotomy in all cases.

Table 1. Pre- and postoperative demographic data

Age [years]	63.2 ± 8.85
Logistic EuroSCORE	4.0 ± 7.9
Body mass index [kg/m^2]	27.9 ± 4.1
GFR [mL/min]	89.3 ± 30.7
Ejection fraction [%]	46.9 ± 8.5
Percentage of predicted VC [%]	87.1 ± 18.3
Men	1493 (71.9%)
Women	583 (28.1%)
Diabetes	679 (32.7%)
NYHA class ≥ III	380 (18.3%)
Neurological dysfunction	92 (4.4%)
COPD	130 (6.3%)
Extracardiac arteriopathy	14 (0.7%)
missing data	758 (36.5%)
Unstable CAD	171 (8.2%)
missing data	758 (36.5%)
Previous cardiac surgery	19 (0.9%)
Status of surgery:	
Elective	1926 (92.8%)
Non-elective	150 (7.2%)
Valvular/combined surgery	398 (19.2%)
Duration of aortic clamping [min]	41.2 ± 19.5
Duration of cardiopulmonary bypass [min]	76.7 ± 29.4

GFR — glomerular filtration rate (Cockcroft-Gault formula); VC — vital capacity; NYHA — New York Heart Association; COPD — chronic obstructive pulmonary disease; CAD — coronary artery disease

Statistical analysis

For data comparisons between the study and control groups, the χ^2 test was used for descriptive data, and the nonparametric Mann-Whitney test for quantitative data (see Tables 8 and 10). Significance was set at an alpha of 5%. Statistical calculations were performed using the Graph Pad In Stat 3 software.

To identify factors increasing the likelihood of readmission to ICU, we used the DRSA methodology. The theory of rough sets was first described by Pawlak [8] and become an important tool for knowledge discovery from data. This approach shows associations of interest between causes and effects (i.e. patient characteristics and the risk of complications) in the form of "if… [conjunction of defined conditions] then… [decision]" decision rules. Advantages of this approach include no assumptions regarding data (which at the same time may be nominal, symbolic, numerical, and ordinal), tolerance of incoherencies in the dataset and missing values, rapid algorithms of data analysis, mathematical simplicity and easy interpretation of the generated decision rules. The theory of rough sets plays an important role in the analysis of decision problems, and particularly to support multicriteria

Table 2. Conditional attributes used to generate decision rules

Attribute name	Sorted set of values
Body mass index (BMI)	[1, 2, 3, 4, 5]
	1 if BMI < 18.5; 2 if BMI 18.5 to 24.9; 3 if BMI 25 to 29.9; 4 if BMI 30 to 39.9; 5 if BMI ≥ 40
Platelet count (Plt)	[1, 2, 3]
	1 if Plt 150,000/mL to 450,000/mL; 2 if Plt < 150,000/mL; 3 if Plt > 450,000/mL
Reduced glomerular filtration rate (GFR)	[Not reduced, Mild, Moderate, Severe]
	Not reduced if GFR > 90 mL/min; Mild if GFR 60–89 mL/min;
	Moderate if GFR 30–59 mL/min; Severe if GFR < 29 mL/min
Ejection fraction (EF)	[Poor, Moderate, Good]
	Poor if EF < 30%; Moderate if EF 31% to 50%; Good if EF > 50%
Number of previous MI	[0, 1, 2, 3, 4, 5]
CCS class	[1, 2, 3, 4]
NYHA class	[No heart failure, I, II, III, IV]
Smoking	[Never, Not smoking for more than 1 month, Current]
Treatment of diabetes	[No, Diet, Oral, Insulin, Untreated]
Arterial hypertension	[No, Treated, Untreated]
Asthma	[No, Treated, Steroids]
Cardiac rhythm	[Sinus rhythm, Other abnormal, Atrial fibrillation/flutter]
COPD	[No, Treated, Untreated]

MI — myocardial infarctions; CCS — Canadian Cardiovascular Society; NYHA — New York Heart Association; COPD — chronic obstructive pulmonary disease

categorisation, making choices or sorting. This methodology has been extensively used in medicine, pharmacology, technical diagnostics, and many other areas [9, 10]. Due to the nature of this publication, no detailed description of the use of DRSA methodology for knowledge discovery from data and decision support has been included, as this information is available in the literature [9, 10]. To generate decision rules by induction from approximations of two decision classes (readmission to ICU = study group, no readmission to ICU = control group), we used the jMAF software developed in the Department of Intelligent Decision Support Systems at the Institute of Computing Science of the Poznan University of Technology (http://idss.cs.put.poznan.pl/site/139.html). In our study, the generated decision rules had the following syntax: if "conditional attribute A = x" and "conditional attribute C ≥ y" than "decision = need for readmission to ICU". Each rule was provided with its support, or the number of cases confirming a given rule. As an example, one of the rules presented in the Results section reads as follows: If (Hyperlipidaemia = N) and (Cardiac rhythm = Sinus rhythm) and (Status of surgery = Non-elective) and (Length of ICU stay ≥ 3) then (Readmission to ICU) W: 4 (7.1%), and it should be interpreted as related to patients without hyperlipidaemia, with sinus rhythm, undergoing non-elective surgery and staying in ICU for at least 3 days, and then requiring readmission to ICU. This rule was confirmed in 4 of 56 (7.1%) patients in the study group.

Table 2 shows conditional attributes considered during induction of decision rule and their sorted sets of values. In addition, we analysed the following binary attributes: anaemia (as per the World Health Organisation definition), previous percutaneous transluminal coronary angioplasty, hyperlipidaemia, extracardiac arteriopathy, neurological dysfunction, endocarditis, critical patient condition before surgery, unstable coronary artery disease, acute myocardial infarction, pulmonary hypertension, valvular/combined surgery, stenosis of the left main coronary artery, 3-vessel disease, intravenous nitrate or heparin treatment, intravenous inotropic drug treatment, mechanical ventilation, cardiogenic shock, intraaortic balloon pump, clopidogrel treatment interrupted 5 days before surgery, clopidogrel treatment continued during 5 days before surgery, acetylsalicylic acid (ASA) treatment interrupted 5 days before surgery, ASA treatment continued during 5 days before surgery, previous cardiac surgery, status of surgery, procedure involving coronary arteries, procedure involving the aortic valve, procedure involving the mitral valve, procedure involving the tricuspid aortic valve, low cardiac output syndrome, postoperative dialysis therapy, and chest reopening. We also analysed the following continuous attributes: age [years], aortic valve gradient [mm Hg], percentage of predicted vital capacity, duration of cardiopulmonary bypass [min], duration of aortic clamping [min], duration of mechanical ventilation [h], and length of ICU stay [days].

The decision attribute was readmission to ICU.

Table 3. Reasons for readmission to intensive care unit

Haemodynamic instability	16 (28.6%)
Respiratory failure	13 (23.2%)
Cardiac tamponade/bleeding	13 (23.2%)
Sternal dehiscence/infection	7 (12.5%)
Gastrointestinal complications	3 (5.4%)
Neurological complications	1 (1.8%)
Renal complications	1 (1.8%)
Other	2 (3.6%)

Table 4. Type of surgery in the study and control groups

	Study group (n = 56)	Control group (n = 2020)
Isolated coronary artery bypass grafting	37 (66.1%)	1641 (81.2%)
Valvular	5 (8.9%)	240 (11.9%)
Combined	14 (25%)	139 (6.9%)

Table 6. Complications in the study group

Reoperation	15 (26.8%)
Respiratory failure (including pneumonia)	13 (23.2%)
Mediastinal infection	11 (19.6%)
Heart failure	10 (17.9%)
Sternal dehiscence	8 (14.3%)
Sepsis	7 (12.5%)
Renal failure	6 (10.7%)
Mental disturbances	4 (7.1%)
Multiorgan failure	3 (5.4%)
Coma	3 (5.4%)
Stroke with hemiparesis	2 (3.6%)
Bedsores	2 (3.6%)
Pulmonary embolism	1 (1.8%)
Heparin-induced thrombocytopenia	1 (1.8%)
Sustained arrhythmia requiring pacemaker implantation	1 (1.8%)
Gastrointestinal problems	1 (1.8%)
In-hospital death	15 (26.8%)

RESULTS

Among 2076 (100%) patients initially discharged from ICU in 2008–2010, subsequent readmission to ICU during the same hospitalisation was required in 56 (2.7%) patients. The most common reason for readmission to ICU was haemodynamic instability (in 28.6% of patients in the study group, Table 3). This category included patients with cardiac arrest due to ventricular fibrillation or asystole, and patients with other sustained arrhythmia or heart failure leading to hypotension that was unresponsive to treatment.

Second most prevalent causes were equally respiratory failure and cardiac tamponade or bleeding (each in 23.2% of patients). The category of respiratory failure included all cases of respiratory insufficiency due to various causes requiring mechanical ventilation. The other group (cardiac tamponade/bleeding) included cases of delayed postoperative bleeding with or without signs of cardiac tamponade. The fourth most prevalent cause (12.5% of patients) was sternal dehiscence with or without mediastinal infection in patients at risk who required mechanical ventilation and intensive care after sternal restabilisation surgery. Numbers and proportions of various types of surgery are shown in Table 4.

The mean length of stay in the general cardiac ward since discharge from ICU to readmission to ICU was 3.5 ± 4.2 days (range from ≤ 1 day to 18 days). Table 5 shows the most important time characteristics of various stages of care in both patient groups.

The mean length of ICU stay after readmission was 12.5 ± 21.2 days (range from ≤ 1 day to 97 days). Complications that occurred during treatment are summarised in Table 6.

Compared to the control group, deaths and complications were significantly more frequent in the study group (Table 7). Overall mortality after operations using cardiopulmonary bypass was 5.3%.

Table 5. Treatment duration in both groups

	Study group (n = 56)	Control group (n = 2020)	P
Initial ICU stay [days]	3.0 ± 5.3 [1–40]	1.5 ± 1.5 [1–28]	< 0.0001
Mechanical ventilation [h]	10.0 ± 9.6 [1–63]	8.0 ± 10.5 [1–251]	0.2795
Length of stay in the general cardiac ward before readmission to ICU [days]	3.5 ± 4.2 [1–18]		
ICU stay after readmission [days]	12.5 ± 21.2 [1–97]		
Total length of hospitalisation after the operation [days]	23.1 ± 20.6 [2–99]	8.0 ± 3.3 [2–47]	< 0.0001

Ranges given in square brackets; ICU — intensive care unit

Table 7. Complications in the two groups according to the KROK registry

	Study group (n = 56)	Control group (n = 2020)	P
Complications	27 (48.2%)	207 (10.2%)	< 0.0001
Death	15 (26.8%)	23 (1.1)%	< 0.0001

Table 8. Attributes with highest confirmation measures

Attribute name	Number of rules with a given attribute
Length of ICU stay	11
Patient age	9
Status of surgery	5
Anaemia	3
Body mass index	2
Pulmonary hypertension	1
Clopidogrel treatment continued	1
LMCA stenosis	1

ICU — intensive care unit; LMCA — left main coronary artery

In multiattribute data analysis, generation of decision rules was limited to maximum 5 conditional attributes. With this assumption, more than one thousand of decision rules were generated. The large number of the generated decision rules indicates high heterogeneity of cases in the study group and makes interpretation difficult. Thus, the set of conditional attributes was subjected to further processing. We used a method to determine the importance of various conditional attributes using Bayesian confirmation [11]. In this method, the measure of importance of a given conditional attribute increases with the number of decision rules including this attribute which suggest correct decision, or with the number of rules not including this attribute which suggest wrong decision in the qualifying test. If the opposite is the case, the measure of importance of a given attribute decreases. Table 8 includes conditional attributes that were most commonly included in decision rules and were characterised by highest confirmation values.

Using these attributes, we generated 5 decision rules with a support of 4 which indicated assignment to the study group (readmission to ICU). The search was then extended to decision rules with a support of 3 (i.e., 5.4% of patients in the study group), yielding additional 14 rules. The decision rules generated this way (overall 19 rules) covered 26 (46%) cases in the study group. Table 9 includes the generated decision rules. All rules are accurate, i.e. they correctly indicate patient categorisation to the group requiring readmission to ICU.

DISCUSSION

In light of data reported in other studies, the proportion of 2.7% patients requiring readmission to ICU may be considered a very good outcome. In papers dealing exclusively with cardiac surgical patients, this proportion ranges from 2.3% to 7.8% [1–6]. We believe that our criteria of discharging patients from ICU are likely so strict that they limit the likelihood of readmission to a minimum. Our centre is not a typical teaching academic hospital with new residents coming each year. The relatively constant anaesthesiologic team might have a positive effect on the low proportion of patients readmitted to ICU [12]. Another explanation may be related to the profile of performed operations. Centres in Western countries perform more valvular and combined procedures which translates to a higher proportion of patients readmitted to ICU.

In our study group, haemodynamic instability was identified as the most common cause of readmission to ICU (28.6%). This finding is inconsistent with most previous studies in which the most predominant were respiratory complications, reported in more than 50% of patients [1, 2, 13]. Perhaps this may be explained by effective postooperative care that prevented respiratory complications and thus limited readmissions to ICU in our centre. Only in a Lithuanian study [5] that included 2673 patients after CABG, heart failure (including myocardial infarction, arrhythmia, and hypotension) was identified as the most common cause of readmissions to ICU (in 52.8% of patients).

A high proportion of postoperative bleeding as one of the two second most common causes might have been related to common use of antiplatelet drugs, in particular clopidogrel [14–17]. Patients in the study group were characterised by significantly worse outcomes compared to those who did not require readmission to ICU, including nearly 3 times higher total length of hospital stay after the surgery and very high in-hospital mortality (26.8% vs. 1.1%). Overall mortality after operations using cardiopulmonary bypass in 2007–2010 was 5.3%, mostly in high-risk patients undergoing combined surgery. These observations regarding increased complication and mortality rates are consistent with the above cited publications [1–6, 13]. In multiattribute analysis, we included 52 conditional attributes in a relatively small (56 patients) and very heterogeneous sample, which resulted in computational difficulties and yielded in small support of the generated decision rules (maximum of 4, i.e. 7.1% of cases). Patient age was reported as an important factor in virtually all studies evaluating cardiac surgical treatment outcomes. The effect of age has been particularly evident in newer studies, in which the operated patient populations were older [1, 2, 18]. Non-elective status of surgery has also been reported as a risk factor of readmission to ICU [1, 13]. Among postoperative factors, the length of initial ICU stay was the most common attribute included in the strongest rules. Heimrath et al. [19] in a study on CABG patients who stayed in ICU for longer than 48 h found an association of prolonged ICU stay with increased early and late mortality and a higher risk of recurrent hospitalisation for cardiac reasons. In a large study of 7105 cardiac surgical patients (including 554 readmitted

Table 9. Decision rules

No.	Content of the rule	Supported by patients
1	If (Age ≥ 70) and (Plt = 2) and (Length of ICU stay ≤ 8) and (Length of ICU stay ≥ 4) then (Readmission to ICU)	4 (7.1%)
2	If (Age ≥ 70) and (Plt = 2) and (Length of ICU stay ≥ 4) and (Chest opening = N) then (Readmission to ICU)	
3	If (Hyperlipidaemia = N) and (Cardiac rhythm ≠ Atrial fibrillation/flutter) and (Status of surgery = Non-elective) and (Length of ICU stay ≥ 3) then (Readmission to ICU)	
4	If (Hyperlipidaemia = N) and (Cardiac rhythm = Sinus rhythm) and (Status of surgery = Non-elective) and (Length of ICU stay ≥ 3) then (Readmission to ICU)	
5	If (Age ≥ 76) and (BMI ≠ 2) and (Tricuspid valve surgery = Y) then (Readmission to ICU)	3 (5.4%)
6	If (Anaemia = Y) and (NYHA class = III) and (COPD ≥ Treated) and (LMCA stenosis = No) and (3-vessel disease = Y) then (Readmission to ICU)	
7	If (Age ≥ 69) and (EF = Good) and (Smoking = Current) and (Clopidogrel treatment continued = N) and (Length of ICU stay ≥ 2) then (Readmission to ICU)	
8	If (Anaemia = Y) and (Number of previous MI ≠ 0) and (NYHA class = III) and (COPD ≥ Treated) and (3-vessel disease = Y) then (Readmission to ICU)	
9	If (Anaemia = Y) and (CCS class ≠ 3) and (NYHA class = III) and (COPD ≥ Treated) and (3-vessel disease = Y) then (Readmission to ICU)	
10	If (Aortic valve gradient ≥ 90.0) and (Hyperlipidaemia = Y) and (ASA treatment continued = Y) and (Status of surgery = Non-elective) then (Readmission to ICU)	
11	If (Smoking ≠ Current) and (Hyperlipidaemia = N) and (Status of surgery = Non-elective) and (Length of ICU stay ≥ 3) then (Readmission to ICU)	
12	If (Aortic valve gradient ≥ 90.0) and (ASA treatment continued = Y) and (Duration of cardiopulmonary bypass ≥ 101) and (Status of surgery = Non-elective) then (Readmission to ICU)	
13	If (Arterial hypertension = Treated) and (Length of ICU stay ≥ 3) then (Readmission to ICU)	
14	If (BMI = 3) and (Reduced GFR = Not reduced) and (EF = Good) and (Duration of mechanical ventilation ≤ 9) and (Length of ICU stay ≥ 3) then (Readmission to ICU)	
15	If (Age ≥ 69) and (EF = Good) and (Smoking = Current) and (Pulmonary hypertension = Y) and (Length of ICU stay ≥ 2) then (Readmission to ICU)	
16	If (Age ≥ 69) and (EF = Good) and (Smoking = Current) and (Critically ill before operation = Y) and (Length of ICU stay ≥ 2) then (Readmission to ICU)	
17	If (Age ≥ 78) and (COPD = Treated) and (Extracardiac arteriopathy = Y) then (Readmission to ICU)	
18	If (Age ≥ 76) and (Smoking = Never) and (Tricuspid valve surgery = Y) then (Readmission to ICU)	
19	If (Age ≥ 69) and (Number of previous MI ≠ 1) and (Smoking = Current) and (Length of ICU stay ≥ 2) and (EF = Good) then (Readmission to ICU)	

ASA — acetylsalicylic acid; BMI — body mass index; CCS — Canadian Cardiovascular Society; COPD — chronic obstructive pulmonary disease; EF — ejection fraction; GFR — glomerular filtration rate; ICU — intensive care unit; LMCA — left main coronary artery; MI — myocardial infarctions; N — no; NYHA — New York Heart Association; Plt — platelet count; Y — yes

patients) by Joskowiak et al. [6], combined surgery and prolonged initial ICU stay were indicated as the most important predictors of readmission.

Analysis of the previous literature on predictors of ICU readmission among cardiac surgical patients indicates a group of complications that are important in this regard, but it is difficult to identify a single most important cause. Lithmathe et al. [1] in a study of 3374 patients indicated preoperative renal failure, complex surgery, prolonged mechanical ventilation (> 24 h), postoperative bleeding, and low cardiac output. In our study, duration of mechanical ventilation had no direct effect on outcomes but the need for prolonged ICU stay was commonly associated with prolonged mechanical ventilation. In our patient population, complex surgery was also much more frequently performed in the study group but this was not reflected in the multiattribute analysis. Postoperative low cardiac output syndrome and bleeding necessitating chest reopening were analysed in our study but not found to be significant. Vohra et al. [2] identified several key factors in a large group of 7717 patients, including postoperative respiratory complications during the initial ICU stay, low cardiac output syndrome, cardiac arrhythmia, renal failure requiring haemofiltration, and postoperative bleeding. In our study group, respiratory complications during the initial ICU stay were not a separate attribute but may have been related to prolonged ICU stay. In the study by Cohn et al. [4] in a group of 2228 patients, significant factors included postoperative heart failure and reduced left ventricular ejection fraction, and among postoperative factors also a larger increase in body mass and a higher duration of mechanical ventilation. The first two factors were not found to be significant in our analysis, and increase in body mass was measured only by Cohn et al. [4]. Bardell et al. [3] analysed 2117 patients who underwent CABG only and again identified preoperative renal failure and postoperative mechanical ventilation for > 24 h. Our observations did not confirm these reports regarding reduced preoperative glomerular filtration rate.

Preoperative anaemia is somewhat different issue as this factor was not considered in studies regarding readmissions to ICU. This observation should not be ignored, however, as recent reports by Kulier et al. [20], van Straten et al. [21], Boening et al. [22], and De Santo et al. [23] indicate that preoperative anaemia is associated with increased postoperative complication and mortality rates among patients undergoing CABG.

In summary, in case of such complex problems as identification of patients at high risk of the studied complication, it is often not possible to identify a single causative factor. Numerous factors that were not reported previously or appeared not to be significant may have a catastrophic effect on treatment outcomes when occurring in a certain configuration. Decision rules generated using the DRSA methodology are a novel research tool to identify causal relationships between the analysed data. At first sight, the set of the generated decision rules, often numerous and including many elementary component, may be poorly comprehensible for the observer. Of note, however, this constitutes a set of ready algorithms for computational systems which can easily process large datasets.

Limitations of the study

The major limitation of the present study was its retrospective nature. Large size imbalance of the study and control groups, and large heterogeneity of the study group have had an adverse effect on the reliability of our conclusions.

CONCLUSIONS

1. The most common cause of readmission to ICU is haemodynamic instability.
2. The length of postoperative hospital stay, number of postoperative complications, and in-hospital mortality among patients readmitted to ICU were significantly higher compared to those patients who did not require readmission to ICU.
3. Factors most commonly predisposing to readmission to ICU after cardiac surgery included advanced patient age, non-elective surgery, and longer initial stay in ICU after the surgery.

Conflict of interest: *none declared*

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Ponowne przyjęcie pacjenta po operacji kardiochirurgicznej na oddział intensywnej terapii: przyczyny, wyniki leczenia

Radosław Jarząbek[1], Paweł Bugajski[1], Krzysztof Greberski[1], Jerzy Błaszczyński[2], Barbara Słowińska-Jarząbek[3], Ryszard Kalawski[1]

[1]Oddział Kardiochirurgii, Wielospecjalistyczny Szpital Miejski im. Józefa Strusia, Poznań
[2]Instytut Informatyki, Zakład Inteligentnych Systemów Wspomagania Decyzji, Politechnika Poznańska, Poznań
[3]SZOZ nad Matką i Dzieckiem, Poznań

Streszczenie

Wstęp: Pacjenci po operacji kardiochirurgicznej ponownie przyjęci w trakcie tej samej hospitalizacji na oddział intensywnej terapii (IT) są obciążeni znacznie gorszym rokowaniem, częściej występują u nich powikłania, co zwiększa koszty leczenia, zmniejsza liczbę wolnych łóżek na oddziale IT, ograniczając możliwości operowania kolejnych pacjentów.

Cel: Celem pracy było wyodrębnienie przyczyn, które wymuszają powtórne przyjęcie pacjentów na oddział IT, ocena rokowania tej grupy osób w porównaniu z pacjentami, którzy nie wymagają ponownie intensywnego leczenia, oraz wskazanie czynników predysponujących do powtórnej terapii na oddziale IT.

Metody: Retrospektywnie przeanalizowano dane 2076 pacjentów kolejno poddanych operacji pomostowania aortalno-wieńcowego, wszczepienia protezy lub naprawy zastawki lub połączeniu tych procedur — w latach 2008–2010, w krążeniu pozaustrojowym, wypisanych z oddziału IT. Do analizy danych użyto testu χ^2 i testu nieparametrycznego Manna-Whitneya. Do identyfikacji czynników predysponujących do powtórnej hospitalizacji na oddziale IT wykorzystano metodykę zbiorów przybliżonych opartą na relacji dominacji (DRSA, *dominance-based rough set approach*). Metodyka ta pozwala wyindukować z danych wzorce logiczne zwane regułami decyzyjnymi, pokazujące interesujące związki przyczynowo-skutkowe między obrazem stanu pacjenta a ryzykiem wystąpienia powikłań.

Wyniki: Z grupy 2076 (100%) pacjentów, pierwotnie wypisanych z pooperacyjnego oddziału IT, ponownego intensywnego leczenia w ramach tej samej hospitalizacji wymagało 56 (2,7%) osób (grupa badana). Grupę kontrolną stanowiło 2020 (97,3%) pacjentów. Najczęstszymi przyczynami powrotów pacjentów na oddział IT była niestabilność hemodynamiczna (28,6%, n = 16), niewydolność oddechowa (23,2%, n = 13) i tamponada serca lub krwawienie (23,2%, n = 13). Średni czas trwania pobytu na oddziale ogólnym od momentu wypisu z oddziału IT do ponownego przyjęcia wyniósł 3,5 ± 4,2 dnia. Czas trwania ponownego pobytu na oddziale IT wyniósł 12,5 ± 21,2 dnia. W porównaniu z grupą kontrolną powikłania wystąpiły istotnie częściej w grupie badanej (10,2% *vs*. 48,2%; p < 0,0001). Zgon szpitalny miał miejsce u 15 (26,8%) pacjentów z grupy badanej i u 23 (1,1%) pacjentów z grupy kontrolnej (p < 0,0001). W wyniku zastosowania metodyki zbiorów przybliżonych wygenerowano reguły decyzyjne klasyfikujące pacjentów do grupy badanej. Czynnikami o największym znaczeniu dla prawidłowej klasyfikacji osób do grupy badanej były: wiek, nieplanowy tryb operacji oraz wydłużony pierwotny czas leczenia na oddziale IT po zabiegu.

Wnioski: Najczęstszą przyczyną ponownych przyjęć pacjentów na oddział IT jest niestabilność hemodynamiczna. Czas hospitalizacji w okresie pooperacyjnym, liczba powikłań pooperacyjnych i śmiertelność szpitalna w grupie osób ponownie leczonych na oddziale IT są istotnie większe niż w grupie niewymagającej takiej terapii. Wiek pacjenta, nieplanowy tryb operacji i wydłużony czas pierwotnego leczenia na oddziale IT po zabiegu najczęściej predysponowały do ponownego przyjęcia pacjenta na oddział IT po zabiegu kardiochirurgicznym.

Słowa kluczowe: ponowne przyjęcie, kardiochirurgia, intensywna terapia, metodyka zbiorów przybliżonych

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Adres do korespondencji:
dr n. med. Radosław Jarząbek, Oddział Kardiochirurgii, Wielospecjalistyczny Szpital Miejski im. Józefa Strusia, ul. Szwajcarska 3, 61–289 Poznań, e-mail: radoslawj@hotmail.com
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