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Mortality prediction in patients with acute kidney injury requiring renal replacement therapy after cardiac surgery

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ABSTRACT

Background and objective: Acute kidney injury (AKI) is a common and potentially serious postoperative complication after cardiac surgery, and it remains a cause of major morbidity and mortality. The aim of our study was to assess the prognostic illness severity score and to estimate the significant risk factors for poor outcome of patients with AKI requiring renal replacement therapy (RRT) after cardiac surgery.

Materials and methods: We retrospectively analyzed data of adult (>18 years) patients ($n = 111$) who underwent open heart surgery and had developed AKI with need for RRT. Prognostic illness severity scores were calculated and perioperative risk factors of lethal outcome were assessed at the RRT initiation time. We defined three illness severity scores: Acute Physiology and Chronic Health Evaluation (APACHE II) as a general score, Sequential Organ Failure Assessment (SOFA) as an organ failure score, and Liano score as a kidney-specific disease severity score. Logistic regression was also used for the multivariate analysis of mortality risk factors.

Results: Hospital mortality was 76.5%. More than 7% of patients remained dialysis-dependent after their discharge from the hospital. The prognostic abilities of the scores were assessed for their discriminatory power. The area under the receiver-operating characteristic (ROC) curve of SOFA score was 0.719 (95% CI, 0.598–0.841), of Liano was 0.661 (95% CI, 0.535–0.787) and 0.668 (95% CI, 0.550–0.785) of APACHE II scores. From 16 variables analyzed for model selection, we reached a final logistic regression model, which demonstrated four variables significantly associated with patients' mortality. Glasgow coma score < 14 points (OR = 3.304; 95% CI, 1.130–9.662; $P = 0.003$), mean arterial blood pressure (MAP) < 63.5 mmHg (OR = 3.872; 95% CI, 1.011–13.616; $P = 0.035$), serum creatinine > 108.5 μmol/L (OR = 0.347; 95%

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CI, 0.123–0.998; $P = 0.046$) and platelet count $< 115 \times 10^9$/L (OR = 3.731; 95% CI, 1.259–11.054; $P = 0.018$) were independent risk factors for poor patient outcome.

Conclusions: Our study demonstrated that SOFA score estimation is the most accurate to predict the fatal outcome in patients with AKI requiring RRT after cardiac surgery. Lethal patient outcome is related to Glasgow coma score, mean arterial blood pressure, preoperative serum creatinine and postoperative platelet count.

1. Introduction

Approximately 2 million cardiac surgeries are performed around the world each year [1]. Acute kidney injury (AKI) is a common and potentially serious postoperative complication after cardiac surgery [2]. The common occurrence of AKI is attributed to factors like perioperative hemodynamic alterations, comorbid conditions predisposing renal injury and pharmacological toxins associated with cardiac surgery [3]. The incidence of cardiac surgery associated AKI varies from 5% to 45% depending on the diagnostic AKI criteria, the type of cardiac surgery [4–6]. Frequency of AKI requiring dialysis is generally lower, ranging between less than 1% and 6% [7]. The mortality rate among AKI patients after cardiac surgery is high, with a wide range of 2.4–19.0% [8]. In case of dialysis-dependent AKI, mortality increases significantly in more than 50% of the total count of affected individuals [9]. Because AKI is associated with high mortality, prolonged hospital stay and increased post-hospital morbidity [10–12], the majority of studies focuses on early detection of AKI and prediction of AKI progression [13]. In patients, who have undergone cardiac surgery, damage of renal function is often associated with multiple organ failure. Under these circumstances, it seems that the choice of renal replacement therapy (RRT) should be based on the severity of illness and associated organ dysfunctions. However, the treatment selection is based on subjective criteria. Several prognostic tools have been developed to assess disease severity and the risk of poor outcome, but none of them account for risk factors, specific to patients who have undergone cardiac surgery, such as cardiopulmonary bypass (CPB) duration and surgery type. Both, general illness severity scores and kidney specific disease severity scores, do not identify these risk factors [14].

The aim of our study was to estimate poor outcome risk factors and to determine which clinical prognostic score has the highest predictive values in patients with AKI requiring RRT after cardiac surgery.

2. Materials and methods

We performed a retrospective analysis of patients older than 18 years who underwent heart surgery and were admitted to the Intensive Care Unit (ICU) of cardiac surgery in the Hospital of Lithuanian University of Health Sciences Kauno Klinikos within a 5-year period. All patients receiving RRT due to AKI (AKI Network (AKIN) stage 3) after cardiac surgery were assessed for inclusion to the study. Exclusion criteria were preoperative need for RRT, including those with chronic renal failure requiring dialysis and those with non-renal indications for RRT. The indications to start dialysis treatment in the cases of severe AKI were clinical symptoms of uremia, hypervolemia, hyperkalemia, metabolic acidosis, high levels of serum creatinine (>600 μmol/L) and urea (>30 mmol/L). The indications for slow continuous RRT were refractory arterial hypotension and pronounced hyperhydration and/or hypercatabolism.

We examined four groups (16 variables) of possible risk factors for poor outcome: (1) demographic data (age, gender), (2) preoperative serum creatinine level and estimated glomerular filtration rate (eGFR) using MDRD on the day before surgery, (3) surgical data (CPB duration, types of cardiac surgery) and (4) postoperative variables (temperature, mean arterial pressure (MAP), oliguria, Glasgow coma score, sepsis, serum creatinine level before initiation of RRT, white blood cell (WBC) and platelet count, mechanical lung ventilation, vasopressors administration) on the day of the initiation of RRT.

Severity scores were calculated at the time of the initiation of RRT. We estimated the predictive ability of three well-known severity scores: Acute Physiology and Chronic Health Evaluation (APACHE) II as a general score, Sequential Organ Failure Assessment (SOFA) as an organ failure score and Liano score as a kidney-specific disease severity score.

2.1. Definitions

AKI was diagnosed if serum creatinine increased to ≥26.5 μmol/L within 48 h or 1.5-fold from the baseline, which was known or presumed to have occurred in the preceding 7 days. AKIN stage 3 was diagnosed, if RRT in patients with AKI was started [15].

Patient survival was defined as survival 30 days after cardiac surgery. Moreover, the hospital mortality rate for the study population was assessed

Microbiologically documented sepsis was defined as a combination of positive blood culture and two of following four criteria: (1) core body temperature > 38.3 °C or <36 °C, (2) heart rate >90 beats/min, (3) respiratory rate >20 breaths/min or $PaCO_2 < 32$ mmHg, (4) WBC >12,000/mm^3 or <4000/mm^3 or normal WBC count with >10% immature forms [16].

Risk factor of AKI was defined such as history of chronic kidney disease, arterial hypotension without inotropic drugs, sepsis, X-ray contrast media, administration of nephrotoxic medications and vasopressors.

Liano score was determined using the formula: probability of death = 0.032 (age in decades) − 0.086 (sex) − 0.109 (nephrotoxicity) + 0.109 (oliguria) + 0.116 (hypotension) + 0.122

(jaundice) + 0.150 (coma) − 0.154 (consciousness) + 0.182 (assisted respiration) + 0.210. A score of 1 was ascribed to the presence, and a score of 0 to the absence of the following non-numerical clinical parameters in the Liano score: (1) sex: male; (2) nephrotoxicity: use of nephrotoxic drugs, presence of pigmenturia, hemoglobinuria or rhabdomyolysis; (3) oliguria: 24-h urine volume < 400 mL; (4) hypotension: systolic blood pressure < 100 mmHg for 8 h with or without inotropes; (5) jaundice: clinically jaundiced or total plasma bilirubin level higher than 20 μmol/L; (6) coma: glasgow coma score less than or equal to 5.

2.2. *Statistical analysis*

Data of the study were processed using SPSS 20.0.0 software. Mean parametric values ($x \pm SD$) were calculated. By employing the Kolmogorov–Smirnov test the distribution of quantitative values was established. Comparing the quantitative values which do not satisfy the laws of the normal distribution the tests of comparison of non-parametric values were applied. The difference between two independent groups was established by employing the Mann–Whitney-Wilcoxon test. The relation between the qualitative values has been evaluated following the criterion of Pearson chi-square. The difference between the compared groups was statistically significant when $P < 0.05$.

In the univariate analysis, all 16 variables and three severity scores were tested for their association with lethal outcome using regression analysis. A cut-off *P*-value for inclusion into multivariable model was 0.05.

The discrimination of each severity score (Liano, SOFA, APACHE II) was determined and compared by receiver operating characteristic (ROC) curves for 30-day mortality. Area under the ROC curve of 1.0 indicates perfect discrimination, whereas an area less than 0.5 means that it is no better than chance. Area from 0.5 to 0.7 suggest a low predictive discrimination, and value greater than 0.7 confirms the usefulness of the model as a risk predictor.

3. Results

In total, 111 (94.9%) patients (women 29 (26.1%), men 82 (73.9%)) were considered eligible for this study. Six (5.1%) patients were excluded because RRT was performed before cardiac surgery. The mean age of the patients was 67.15 ± 1.06 years; the mean preoperative serum creatinine level and mean eGFR were 145.38 ± 8.61 μmol/L and 60.18 ± 2.88 mL/min/1.73 m^2, respectively. Clinical characteristics of study patients before cardiac surgery: 4 (3.6%) had chronic obstructive pulmonary disease, 26 (2.4%) patients had anamnesis of myocardial infarction, 19 (17.1%) were with diabetes mellitus, 29 (26.1%) had chronic kidney disease. 62 (55.9%) study patients underwent an emergency cardiac operation. Valve operation was done for 11 (9.9%) patients; coronary artery bypass grafting (CABG), for 45 (40.5%); valve and CABG, for 18 (16.2%); aorta reconstructive operation, for 18 (16.2%); and other operations, for 19 (17.1%) patients. CPB was used in 90 (81.1%) patients, and mean duration was 156.72 ± 9.28 min. Some variables were estimated at the time of the first RRT procedure: mean serum creatinine was 400 ± 14.5 μmol/L; serum potassium, 5.31 ± 0.09 mmol/L; and blood urea, 27.91 ± 1.35 mmol/L. Expressed oliguria and signs of sepsis was observed in 65 (58.6%) and 30 (27.0%) study patients respectively. Vasopressors were prescribed to 86 (77.5%) patients, and 91 (82.0%) patients had risk factors of AKI. The prognostic scores were applied on the first RRT day and their averages were as follows: APACHE II, 24.77 ± 6.16; SOFA, 14.59 ± 0.44; and Liano score, 0.63 ± 0.17. The mean length of hospital stay was 35.5 ± 3.24 days; hospitalization duration before the ICU, 7.66 ± 1.08 days; and hospitalization in the ICU to RRT initiation, 6.61 ± 0.70 days.

In total, 111 patients underwent 803 RRT procedures during study period. The mean number of RRT procedures for each patient was 7.23 ± 1.02. The mean duration of the RRT period was 10.32 ± 1.74 days for each study patient. A total of 49 patients (44.1%) received treatment with intermittent hemodialysis (IHD) (total number of IHD procedures was 583), 43 (38.7%) received continuous venovenous hemofiltration (CVVH) or continuous venovenous hemodiafiltration (CVVHDF) (total number of CVVH and CVVHDF procedures was 93 of which 38 CVVHDF procedures), and 19 (17.2%), combination of IHD and CVVH or CVVHDF (total number of IHD and CVVH or CVVHDF was 127 procedures).

Death during the hospitalization period occurred in 85 (76.6%) patients. Improvement of renal function was observed in 18 (16.2%) patients, and 8 (7.2%) study patients remained dialysis-dependent after their discharge from the hospital.

Details of patient characteristics and data of the preoperative and postoperative factors in survived and non-survived patients groups are presented in Table 1. Not surprisingly, there were significant differences in poor outcome predictive clinical scores and length of the hospital stay between groups. The mean APACHE II, SOFA, and Liano scores (25.56 ± 0.66, 15.38 ± 0.49, and 0.650 ± 0.194 respectively) of non-survivors were significantly higher than in the survivors' group (22.19 ± 1.11, 11.27 ± 0.981, and 0.556 ± 0.341, respectively). The mean length of the hospital stay of survived patients was very long (65.69 ± 7.93 days) and was longer than that of non-survived patients (26.26 ± 2.80 days, $P < 0.0001$). However, there was no significant difference between the two patient groups (survived and non-survived) in the matter of age and gender, preoperative serum creatinine level and eGFR, underlying chronic kidney disease before cardiac surgery (eGFR < 90 mL/min/1.73 m^2), surgical factors (emergency of operation, surgery type, presence of CPB and CPB duration), postoperative factors (inotropes and diuretics administration, presence of risk factors for AKI, sepsis, oliguria, level of blood urea and serum creatinine before initiation of RRT). Moreover, the mean number of RRT procedures for survived and for non-survived patients did not differ significantly (9.38 ± 2.88 and 6.58 ± 1.01, respectively; $P = 0.261$). The duration of the RRT period for survivors and non-survivors was 15.19 ± 5.2 and 8.82 ± 1.6 days, respectively ($P = 0.059$).

Univariate analysis showed that several characteristics differed significantly between survived and non-survived patients. From 16 variables analyzed for model selection, we implied the final logistic regression model, which demonstrated the four variables, which were significantly associated with patients' mortality (Table 2). We did not find significant relationships between mortality and patients' demographic

Table 1 – Clinical characteristics of study patients ($n = 111$) with dialysis-dependent acute kidney injury after cardiac surgery.

Factors	All ($n = 111$)	Survivors ($n = 26$)	Non-survivors ($n = 85$)	P
Demographic and preoperative				
Age, years	67.15 ± 1.06	67.58 ± 2.56	67.02 ± 1.15	0.826
Female	68.66 ± 2.45	69.75 ± 7.51	68.48 ± 2.64	0.084
Male	66.62 ± 1.15	67.18 ± 2.77	66.42 ± 1.21	
Female/male, *n* (%)	29 (26.1)/82 (73.9)	4 (15.4)/22 (84.6)	25 (29.4)/60 (70.6)	0.154
Diabetes, *n* (%)	19 (17.1)	5 (19.2)	14 (16.5)	0.744
Myocardial infarction, *n* (%)	26 (23.4)	6 (23.1)	20 (23.5)	0.962
Chronic renal failure, *n* (%)	17 (16.22)	2 (7.7)	15 (17.6)	0.093
Serum creatinine, μmol/L	145.38 ± 8.61	142.04 ± 81.03	144.49 ± 88.43	0.900
eGFR using MDRD, mL/min/1.73 m^2	60.18 ± 2.88	66.59 ± 6.56	58.21 ± 3.04	0.331
<30, *n* (%)	12 (10.8)	1 (3.8)	11 (12.9)	0.485
30–59, *n* (%)	43 (38.8)	11 (42.3)	32 (37.6)	
60–89, *n* (%)	39 (35.1)	11 (42.3)	28 (32.9)	
≥90, *n* (%)	17 (15.3)	3 (11.5)	14 (16.5)	
Surgical				
Urgent surgery, *n* (%)	62 (55.9)	13 (50.0)	49 (57.6)	0.492
Cardiac surgery type				
Valve, *n* (%)	11 (9.9)	5 (19.2)	6 (7.1)	0.255
CABG, *n* (%)	45 (40.5)	11 (42.3)	34 (40.0)	
CABG and valve, *n* (%)	18 (16.2)	5 (19.2)	13 (15.3)	
Reconstruction of aorta, *n* (%)	18 (16.2)	2 (7.7)	16 (18.8)	
Others, *n* (%)	19 (17.1)	3 (11.5)	16 (18.8)	
CPB, *n* (%)	90 (81.1)	23 (88.5)	67 (78.8)	0.272
CPB time, min	156.72 ± 9.29	171.00 ± 22.41	151.82 ± 9.86	0.371
APACHE II score	24.77 ± 6.16	22.19 ± 1.11	25.56 ± 0.66	0.014
SOFA score	14.59 ± 0.44	11.27 ± 0.981	15.38 ± 0.49	0.0001
Liano score	0.628 ± 0.17	0.556 ± 0.341	0.650 ± 0.194	0.02
Postoperative				
Administration of inotropes				
None, *n* (%)	25 (22.5)	8 (30.8)	17 (20.0)	0.627
Low dose, *n* (%)	19 (17.1)	5 (19.2)	14 (16.5)	
Moderate dose, *n* (%)	45 (40.5)	9 (34.6)	36 (42.4)	
High dose, *n* (%)	22 (19.8)	4 (15.4)	18 (21.2)	
Hospitalization duration before ICU (days)	7.66 ± 1.08	8.58 ± 1.93	7.38 ± 1.28	0.640
Hospitalization duration in ICU before RRT initiation (days)	6.61 ± 0.70	5.58 ± 0.99	6.93 ± 0.86	0.419
Risk factors of AKI				
0, *n* (%)	20 (18.0)	5 (19.2)	15 (17.6)	0.748
1–3, *n* (%)	83 (74.8)	20 (76.9)	63 (74.1)	
>3, *n* (%)	8 (7.2)	1 (3.8)	7 (8.2)	
Sepsis without septic shock, *n* (%)	7 (7.2)	3 (11.5)	4 (4.7)	0.379
Sepsis with septic shock, *n* (%)	23 (20.7)	4 (15.4)	19 (22.4)	
Oliguria, *n* (%)	65 (58.6)	13 (50.0)	52 (61.2)	0.311
Serum creatinine before RRT, μmol/L	400.37 ± 14.49	449.77 ± 31.83	385.26 ± 15.97	0.059
Blood urea before RRT, mmol/L	27.91 ± 1.35	26.88 ± 2.49	28.22 ± 1.58	0.676
Serum potassium before RRT, mmol/L	5.31 ± 0.09	5.17 ± 0.15	5.34 ± 0.10	0.421
RRT modality, *n* (%)				
IHD	49 (44.1)	17 (65.4)	32 (37.6)	0.240
CVVH or CVVHDF	43 (38.7)	5 (19.2)	38 (44.7)	0.601
IHD + CVVH or CVVHDF	19 (17.2)	4 (15.4)	15 (17.7)	0.165
Other outcomes				
Length of hospital stay, days	35.5 ± 3.24	65.69 ± 7.93	26.26 ± 2.80	0.0001

Values are mean ± standard deviation.
CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; RRT, renal replacement therapy; ICU, intensive care unit; IHD, intermittent hemodialysis; CVVH, continuous venovenous hemofiltration; CVVHDF, continuous venovenous hemodiafiltration.

factors (age, gender), preoperative eGFR, surgical factors (CPB duration, type of cardiac surgery), postoperative variables (temperature, oliguria, sepsis, serum creatinine level before initiation of RRT, WBC count, mechanical lung ventilation, administration of vasopressors). As shown in Table 2, Glasgow coma score < 14 points (OR = 3.304, 95% CI; 1.130–9.662, $P = 0.003$), MAP < 63.5 mmHg (OR = 3.872, 95% CI; 1.011–13.616, $P = 0.035$), preoperative serum creatinine >108.5 μmol/L (OR = 0.347, 95% CI; 0.123–0.998, $P = 0.046$), and postoperative platelet count < 115 × 10^9/L (OR = 3.731, 95% CI; 1.259–11.054, $P = 0.018$) were independent risk factors for lethal patient outcome.

Table 2 – Associations of variables and mortality of patients with dialysis-dependent acute kidney injury after cardiac surgery in the model of multivariable logistic regression analysis.

Variable	Coefficient estimate	Odds ratio (95% CI)	P
Glasgow coma points	0.547	3.304 (1.130–9.662)	0.0029
Mean arterial blood pressure	0.642	3.872 (1.01–13.616)	0.035
Postoperative platelet count	0.554	3.731 (1.259–11.054)	0.018
Preoperative serum creatinine	0.531	0.347 (0.123–0.982)	0.046

Fatal outcome occurred in 85 (76.5%) study patients. There were 6 (7.1%), 34 (40.0%), 13 (15.3%), 16 (18.8%), and 16 (18.8%) deaths in valves, CABG, CABG and valves, aorta reconstructive and other operation groups, respectively.

A total of 33 (29.7%) patients survived 30 days after cardiac surgery. The second aim of our study was to determine which clinical prognostic score has the highest predictive value in patients with AKI requiring RRT after cardiac surgery. The prognostic abilities of the scores were assessed for their discriminatory power (Fig. 1). The value of the area under curve (AUC) was obtained in a close range of 0.661 (Liano) and 0.668 (APACHE II). These values showed that Liano and APACHE II scores had low predictive values. The value of AUC for SOFA was 0.719, which is a good outcome predictor (Table 3). Therefore, SOFA score at the time of the initiation of RRT was found to be the most accurate in prediction of fatal outcome within 30 days after cardiac surgery in this patients' group.

4. Discussion

Up to now AKI is one of the most serious and often complications after cardiac surgery. It is associated with an increased postoperative mortality, a higher incidence of complications, a longer stay in ICU and hospital, and increased health care costs [17–20]. Despite ongoing efforts to decrease occurrence of AKI, it remains a frequent complication of cardiac surgery [2,7,21,22]. Mortality of the patients with AKI after cardiac surgery is high compared to those in whom AKI do not develop (2.4–19% versus 1–8%) [23]. AKI after cardiac surgery is associated with a >4-fold increase in the odds of death [5,18,24].

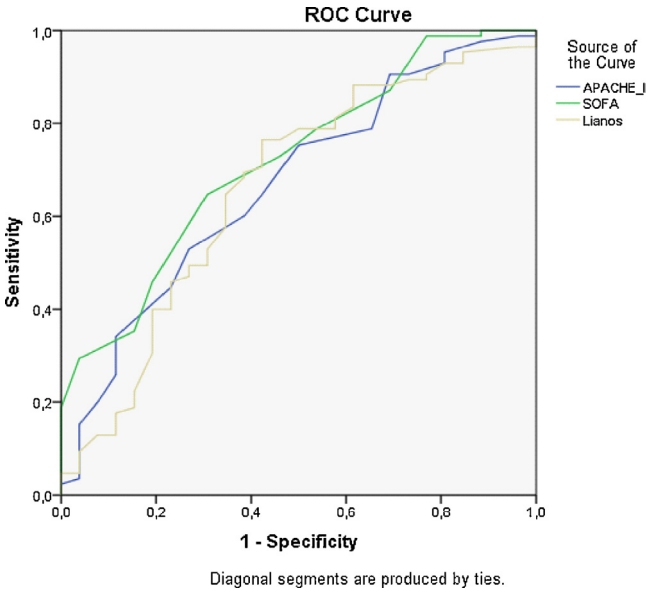

Fig. 1 – The discriminatory power of three disease severity scores (APACHE II, SOFA, Liano) (values for the curves are shown in Table 3).

Mortality is still strongly dependent upon the severity of AKI. The most studies have focused on AKI without the need for RRT. We studied severe AKI requiring RRT. In our hospital mortality rate of patients with AKI requiring RRT during 5 years period was very high–76.5%. This may be due to the fact, that our patients were older (average age of patients was 67.15 ± 1.06 years), about 26% of patients had chronic kidney disease before cardiac surgery (mean preoperative serum creatinine and eGFR were 145.38 ± 8.61 μmol/L and 60.18 ± 2.88 ml/min/1.73 m^2, respectively), more than 50% of patients underwent an emergency cardiac operation, about 77% of our patients received vasopressors and more than 80% had risk factors of AKI before surgery. According to the literature, the mortality rate of patients with AKI requiring RRT exceeds 40–50% [25,26]. Investigators from Brazil [17] studied patients with AKI after cardiac surgery (CABG or cardiac valves surgery) to evaluate the incidence, morbidity and mortality associated with AKI and to determine the value of this feature as a predictor of hospital mortality (30 days). In their study, the patients without AKI had a hospital mortality rate of 7.1%, while patients with AKI at stage 3 (97 patients, 3%) – 55% and their risk of death was 24.5 times greater than that of patients with no AKI. The KDIGO stage 3 patients who did not require dialysis had a mortality rate of 41%, while the mortality of dialysis patients was 62% (less than that of ours). Sheridan et al. [27] investigated the dependence of mortality rate and the type of cardiac surgery and found that aortic valve replacement, CABG and aortic valve replacement plus CABG are associated with higher mortality. Our data showed that the highest mortality was in CABG surgery patients group.

Since the mortality rate was notably high, in the present study we tried to estimate risk factors for poor outcomes in patients with AKI requiring RRT after cardiac surgery. We tested 16 variables for their association with lethal patient outcome. Our univariate analysis showed that several characteristics differed significantly between the survived and non-survived patients (length of hospital stay and the mean of

Table 3 – AUC values for severity scores (APACHE II, SOFA, Liano).

	SOFA	APACHE II	Liano
Area under curve (AUC)	0.719	0.668	0.661
Standard error	0.062	0.060	0.064
95% CI	0.598–0.841	0.550–0.785	0.535–0.787

APACHE II, SOFA and Liano scores). Unlike other studies, we did not find significant relationships between mortality and patients demographic factors (age, gender), preoperative eGFR, surgical factors (CPB duration, type of cardiac surgery), postoperative variables (temperature, oliguria, sepsis, serum creatinine level before initiation of RRT, WBC count, mechanical lung ventilation, administration of vasopressors). We found, that Glasgow coma score < 14 points, MAP < 63.5 mmHg, preoperative serum creatinine >108.5 μmol/L and postoperative platelet count $< 115 \times 10^9$/L were independent risk factors for poor patient outcome and were significantly associated with patient mortality. In literature there are only few studies on estimating the risk factors for poor outcome in patients with AKI requiring RRT after cardiac surgery. Mukhoedova et al. [28] assessed 18 preoperative, perioperative, and postoperative risk factors in cardiosurgical patients with AKI and revealed different significant predictors of fatal outcomes as we did. They found the following predictors of fatal outcomes: the severity according to the APACHE II scale (25 ± 1 scores), the number of organ dysfunctions, large-dose inotropic support, artificial ventilation, oliguria, severe concomitant hepatic failure, moderate-to-severe concomitant posthypoxic encephalopathy.

In our study we also tried to determine the clinical prognostic score that has the highest predictive value. Our data confirmed that SOFA scale has good mortality-risk-predicting ability in patients with AKI requiring RRT after cardiac surgery, while Liano and APACHE II scores have low predictive values. Malov et al. [23] performed a single-center retrospective cohort study to determine the demographic and clinical parameters for risk of poor outcome in patients requiring RRT after cardiac surgery with CPB. Their study provided a clinical score to predict AKI after open-heart surgery and validated that score in a comparable population. The value of the AUC of the three scales was obtained in a close range of 0.821 (APACHE II) to 0.855 (SOFA), 0.842 (Liano) which is a very good indicator. This makes their study results different from ours.

It is important to acknowledge some limitations of our study. Since we have provided a small-sample, single-center study, the data may not accurately represent the problem of AKI after cardiac surgery. The developed mortality prediction model is applicable only to the patient group for which it was designed. It is applicable to the patients older than 18 years who have undergone a cardiac surgery and have developed an AKI requiring RRT. Because of the retrospective nature of the study, we had no possibility to evaluate some parameters while they were not investigated routinely. There was not enough data to estimate the valuable characteristics of heart failure, the left ventricular ejection fraction. On the other hand, this parameter is not universal because it can be changed with sympathomimetic stimulation. Furthermore, we did not assess the level of lactate in the blood plasma, which is an important indicator of metabolic disorders in multiple organ failure. Postoperative risk factors and severity scores were estimated only at the time point of RRT initiation. Because of these limitations some mortality-rate-influencing data were not included in the multivariate analysis.

The majority of other studies focus on early detection of AKI and prediction of its progression. These studies have identified risk factors associated with development of AKI. They include diabetes mellitus, urgent surgery, preoperative renal impairment, anemia, etc. [7,18,25]. In our study we also estimated risk factors for early development of AKI and found that even 82.0% of our patients had risk factors for AKI (history of chronic kidney disease, arterial hypotension, sepsis, X-ray contrast media, and administration of nephrotoxic medications).

However, the advantage of our study is the estimation of risk factors not only for early development of AKI, but also for poor outcomes in special patient groups which developed the most severe AKI requiring RRT.

5. Conclusions

Our study demonstrated that the Glasgow coma score less than 14 points, mean arterial blood pressure less than 63.5 mmHg, preoperative serum creatinine more than 108.5 μmol/L, and postoperative platelet count less than 115×10^9/L were related to lethal outcome in patients with AKI requiring RRT after cardiac surgery. There were no significant relationships between mortality and patient's demographic factors, preoperative eGFR, surgical factors, postoperative variables. SOFA score at the time of the initiation of RRT was found to be the most accurate in prediction of fatal outcome within 30 days after cardiac surgery in this patient group.

Conflict of interest

None declared.

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Authors' contribution

I.S. and D.A. conceived the study, participated in its design and drafted the initial manuscript. J.K. and L.R. collected the data. V.B., E.Z. and A.A. performed statistics, interpretation of data and drafted the last version of manuscript. V.K., D.P. and I.A.B. coordinated data interpretation, participated in the design of study, helped to draft the manuscript. All authors read and approved the final manuscript.

Ethical approval

The study was approved and study permission was received from the Kaunas Regional Biomedical Research Ethics Committee. Informed consent was waived due to retrospective nature of the study.

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