Journal of Medicine in Scientific Research

Volume 4 | Issue 4 Article 17

Subject Area: Cardiothoracic Surgery

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Recommended Citation

A. Kisho, Maged M. (2021) "Prediction of cardiac surgery-associated acute kidney injury using Cleveland and Mehta scores," *Journal of Medicine in Scientific Research*: Vol. 4: Iss. 4, Article 17.
DOI: https://doi.org/10.4103/JMISR.JMISR_53_20

Prediction of cardiac surgery-associated acute kidney injury using Cleveland and Mehta scores

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Abstract

Objective

To detect the clinical accuracy of two models for the prediction of cardiac surgery-associated acute kidney injury (AKI) and severe AKI that need renal replacement therapy according to Cleveland and Mehta scores and using Kidney Disease Improving Global Outcomes (KDIGO) definitions for AKI.

Patients and methods

In total, 742 patients who underwent cardiac surgery in the Department of Cardiac Surgery NHI of Egypt, between January 2016 and December 2018, were enrolled in this research. We evaluate the prediction for cardiac surgery-associated AKI using Cleveland and Mehta scores. We also evaluate the effect of hemofiltration during cardiopulmonary bypass as a preventive measure for postoperative AKI in cardiac surgery.

Results

Depending on KDIGO AKI definition, the incidence of AKI and renal replacement therapy was 35.7% (265/742) and 1.1% (8/742), respectively. The mortality of AKI and renal replacement therapy was 6.4% (17/265) and 62.5% (6/8), respectively, while the total mortality was 3.1% (23/742). For the prediction of renal replacement therapy–AKI, the detection power of Cleveland and Mehta scores was not good. The use of hemofiltration decreases the incidence of developing postoperative acute renal failure requiring replacement therapy as predicted by Cleveland and Mehta scores from 1.7 to 1.3% and 1.4 to 1.2%, respectively.

Conclusion

In a single-center study, depending upon valve surgery dominant and according to KDIGO AKI definition, the predictive power of the two models, Cleveland score and Mehta score, was not accurate enough. The use of hemofiltration decreases the incidence of developing severe renal failure after cardiac surgery.

Keywords: Acute kidney injury, cardiac surgery, mehta score

Introduction

Acute kidney injury (AKI) is one of the most common complications after cardiac surgery with incidences of 30% or more.

Also, mortality increased even with mild renal function changes as reported to influence short-term and long-term survival rates after cardiac surgery [1–3]. Since early detection of the patients at high risk of developing into cardiac surgery-associated AKI may improve prognosis, different predictive models have been developed to forecast cardiac surgery-associated AKI or renal replacement therapy required after cardiac surgery [4,5]; however, there is a big difference in risk scores [6–9]. However, with the new 2012 Kidney Disease Improving Global Outcomes (KDIGO), AKI definition being popularized [10], the predictive value for predicting cardiac surgery-associated AKI or renal replacement therapy has been changed due to the new definition in which some 'subclinical AKI' can be defined. Also, the use of hemofiltration during cardiopulmonary bypass (CPB)

Access this article online	
Quick Response Code:	**Website:** www.jmsr.eg.net
	DOI: 10.4103/JMISR.JMISR_53_20

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Submitted: 13-Apr-2020 **Revised:** 29-Apr-2020 **Accepted:** 08-Jul-2021 **Published:** 11-Dec-2021

How to cite this article: A. Kisho MM. Prediction of cardiac surgery-associated acute kidney injury using Cleveland and Mehta scores. J Med Sci Res 2021;4:380-6.

is a beneficial strategy to decrease the incidence of severe renal failure after cardiac surgery.

Aim

The aim of this study is to validate the predictive value of two predictive kidney injury scores for their respective outcome in Egyptian patients, in which group valve surgeries are dominant and the protective effect of hemofiltration during CPB.

Patients and methods

In our prospective study, we included patients at the Department of Adult's Cardiac Surgery at the National Heart Institute of Egypt between January 2016 and December 2018. Patients (aged >20 years) who underwent cardiac surgical procedures [mitral or aortic valve surgery or coronary artery bypass graft (CABG)] with CPB were enrolled. In addition, due to common exclusion criteria from these two scores, patients who were on dialysis preoperatively and patients who denied access to their medical records for the purpose of research were also excluded. The patient signed on classic NHI high risk consent before cardiac surgery.

Inclusion criteria

All patients referred for adult cardiac surgery for rheumatic and ischemic heart disease (age above 20), including emergency cases and redo cases.

Exclusion criteria

(1) Patients with preoperative renal replacement therapy.
(2) Preoperative mechanical ventilation.
(3) Patients with acute aortic dissection.
(4) Patients with sepsis.

Preoperative data collection

All patients will be subjected to the following:
(1) History taking:
A thorough and detailed history was taken, as regards the age, sex, functional class according to New York Heart Association classification, diabetes mellitus, hypertension, and chronic obstructive pulmonary disease.

(2) Clinical examination:
Complete clinical general and local cardiologic and abdominal examinations were performed.

(3) Investigations.

Laboratory investigations

(1) Complete blood count.
(2) Liver function tests.
(3) Coagulation profile.
(4) Renal function tests: creatinine, blood urea nitrogen, potassium, sodium, calcium, phosphate, magnesium, urine analysis, and renal ultrasound and estimated glomerular filtration rate (eGFR) for those who developed postoperative acute renal failure.
(5) Glycated hemoglobin.
(6) Hepatitis markers.

ECG

Radiological examination

(1) Plain chest radiograph pastor–anterior view in the erect position.
(2) Echocardiography.
(3) Pelvi-abdominal ultrasound.
(4) Coronary angiography for Ischemic Heart Disease (IHD) and those over 40 years in valvular heart disease.
(5) Carotid duplex if age more than 60 years or previous stroke/ Transiant ischemic attack (TIA).
(6) Duplex upper limb if radial artery harvest is required

The following data will be recorded for statistical analysis:
(1) Demographic data and clinical characteristics.
(2) Diabetic patients.
(3) Operation timing.
(4) Preoperative serum creatinine.
(5) Echocardiography finding (valve lesion, poor ejection fraction).

Surgical pprocedures and operative techniques

(1) Conventional median sternotomy incision, left internal mammary (LIMA) synchronous to long saphenous vein harvesting in CABG patients, standard aorto-atrial cannulation, and intermittent antegrade cardioplegia will be the standard myocardial protection technique.
(2) CPB time and cross-clamp time and number of grafts will be documented.

CPB was performed with a Sorin polysulfone membrane hemofilter, the hemofilter was positioned in the standard CPB circuit so that its inlet was connected to the arterial line and its outlet connected to the venous cardiotomy reservoir. Hemofiltration was performed throughout CPB. Pump flow was maintained at a rate of 2.2–2.4 l/min/m during CPB.

The following data will be conducted through ICU evaluation:
(1) Postoperative blood loss during the ICU stay.
(2) Mean blood units transfused.
(3) Mechanical ventilation duration (h/days).
(4) Total ICU stay.
(5) ICU morbidities (low cardiac output, arrhythmias, Intraortic Ballon Pump (IABP) insertion, and respiratory, renal, and infective complication).
(6) Hospital mortality.

Postoperative evaluation

Patients will be evaluated after surgery by the following:
(1) Chest radiograph.
(2) ECG.
(3) Complete blood count.
(4) Cardiac enzymes (Creatine Kinase (CK), Creatine kinase-MB (CKMB)).
(5) Liver function tests.
(6) Coagulation profile.
(7) Renal function tests.
(8) Follow-up of trans-thoracic echocardiography before discharge.

The two acute kidney disease predicting scores

Renal replacement therapy, defined as initiation of dialysis in the postoperative period, this is the outcome for validation of Cleveland and Mehta scores. The dialysis was started based on the indications, including uremia, acidosis, hyperkalemia, or severe fluid overload (Tables 1–3).

Kidney Disease Improving Global Outcomes acute kidney injury definition

An increase in serum creatinine by more than or equal to 0.3 mg/dl (≥26.5 µmol/l) within 48 h, or an increase in serum creatinine to more than or equal to 1.5-times baseline, which is known or presumed to have occurred within the prior 7 days, or urine volume less than 0.5 ml/kg/h for 6 h.

Protocol of starting hemofiltration and early renal replacement therapy

According to our protocol of the study, we calculate the risk of developing AKI postoperatively using the two scores: Cleveland and Mehta.

If the patient score is high (i.e. high-risk patient) above the critical value of

(1) Cleveland score more than 8.
(2) Mehta score more than 42.

We take our precautions by starting hemofiltration during CPB and start early renal replacement therapy (dialysis) postoperatively.

We also put critical values to help us answer the question when to start renal replacement therapy (dialysis) postoperatively in high-risk patients to avoid the possible complications.

All patients of KDIGO stage 3 with AKI need to early start the renal replacement therapy if:

(1) eGFR less than 30 (eGFR is calculated by the abbreviated Modification of Diet in Renal Disease (MDRD) equation: 186×(creatinine/88.4)−1.154× (age)−0.203×(0.742 if female)×(1.210 if black).
(2) Blood urea nitrogen more than 100 mg/dl.
(3) Potassium more than 5.5 mmol/l (despite correction) or new onset of related ECG changes.
(4) Ph less than 7.15 with either $PaCO_2$ less than 35 mmHg or $PaCO_2$ more than 50 mm Hg.
(5) Acute pulmonary edema due to hypervolemia resulting in hypoxia requiring oxygen supply.
(6) Oliguria persisted longer than 48 h.

Earlier initiation of renal replacement therapy has a lot of benefits, including:

Table 1: The two prediction scores analyzed in this study were Cleveland score, Mehta score. The brief description and characteristics of the scores are shown in below

The two prediction scores				
Prediction	**Cleveland score**		**Mehta score**	
	RRT-AKI		**RRT-AKI**	
Variables	**Definition**	**Score**	**Definition**	**Score**
Age	NA	NA	55-100	0-10
Race	NA	NA	Nonwhite	2
Sex	Female	1	NA	NA
Preoperative kidney function	SCr 1.2-2.1 mg/dl	2	SCr 0.5	5
	SCr>2.1 mg/dl	5	SCr<40	40
Insulin-dependent diabetes	Yes	1	Yes	5
Non-insulin-dependent diabetes	Yes	0	Yes	2
CHF	Yes	1	NA	NA
COPD	Yes	1	Yes	3
Recent MI (<21 days)	NA	NA	Yes	3
LVEF	<35%	1	NA	NA
Previous surgery	Yes	1	Yes	3
Preoperative IABP	Yes	2	NA	NA
Cardiogenic shock	NA	NA	Yes	7
NYHA	NA	NA	IV	4
Timing of surgery	Emergency	2	NA	NA
Type of surgery	CABG only	0	CABG only	0
	Valve only	1	Aortic valve only	2
	CABG+valve	2	Aortic valve+CABG	5
			Mitral valve only	4
			Mitral valve CABG	7
Score range	0-17		0-85	

AKI, acute kidney injury; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; NYHA, New York Heart Association; RRT, renal replacement therapy; SCr, serum creatinine.

Table 2: Original Mehta risk scoring model for prediction of incidence of renal dialysis after cardiac surgery

Last creatinine	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4 or high						Score
Points	5	10	15	20	25	30	35	40						
Age	<55	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	+100			Score
Points	0	1	2	3	4	5	6	7	8	9	10			
Surgery	CABG		AV only		AV+ CABG		MV			Only MV +CABG				Score
Points	0		2		5		4			7				
Diabetes	No diabetes			Controlled orally					Insulin dependent					Score
Points	0			2					5					
Recent MI	No recent MI						Within last 3 weeks							Score
Points	0						3							
Race	White						Nonwhite							Score
Points	0						2							
Chronic lung disease	No						Yes							Score
Points	0						3							
Reoperation	No prior CV surgery						Prior CABG or CV surgery							Score
Points	0						3							
NYHA class	I, II, III						V							Score
Points	0						3							
Cardiogenic Shock	No						Yes							Score
Points	0						7							
Total score	2-7	8-11	12	20	25	30	35	40	45	50	55	60	65	68+
Risk of dialysis %	0.1	0.2	0.3	1.1	2.5	5.4	10	16	20	28	40	56	70	80

CABG, coronary artery bypass graft; NYHA, New York Heart Association.

(1) Avoid hypervolemia.
(2) Get rid of toxins.
(3) Correct acid–base.
(4) Preventing other complications attributable to AKI.

Statistical analysis

The results are expressed as number (percent) or mean ± SD. Comparison between mean values of clinical scores in both renal failure and nonrenal failure groups was performed using unpaired *t* test. Receiver-operating curve test was used to discriminate between diseased (acute renal failure) and undiseased groups and to calculate the sensitivity and specificity of the clinical score. Statistical Package for Social Sciences (SPSS) computer program (version 20 Windows) was used for data analysis. *P* value less than or equal to 0.05 was considered significant.

Results

A total of 226 patients had cardiac surgery performed between January 2015 and December 2018 and the incidence of renal replacement therapy was 2.6% (*N* = 6), female sex, poor cardiac contractility (ejection fraction (EF) <35%), operation type, creatinine on admission, and insulin-dependent diabetes mellitus as well as intraoperative risk factors (long clamp and pump time) were associated with renal replacement therapy.

The youngest patient was 20 years old and the oldest was 66 years old, the group study contained 102 (45.1%) males, 124 (54.9%) females, and type of operation was between 124 isolated CABG that represents 54.8%, 91 valve surgeries that represent 40.2%, and 11 (combined CABG + valve), which represents 4.8%.

Predictors of renal replacement therapy: Insulin dependent diabetes mellitus (IDDM) represents 17%, chronic obstructive pulmonary disease 3.7%, those with poor EF 23.9%, creatinine (1.2–2.1) 18.8%, creatinine above 2.1 (0.8%), congestive heart failure 0.9%, and IABP 0.16%.

Mean hemofiltration volume was 3400 ± 1921 ml. The preoperative serum hemoglobin (12.3 ± 2.0 g/dl) was the hematocrit (37.1 ± 5.3%).

However, after surgery, both became higher (14.7 ± 1.6 g/dl and 39.2 ± 4.5%; *P* = 0.0019).

The prediction for the need of dialysis in our study was 1.7% at Cleveland score and 1.4% at Mehta score, which is

Table 3: Original Cleveland risk scoring model for prediction of incidence of renal dialysis after cardiac surgery

Risk factor points	Points
Female sex	1
Congestive heart failure	1
LVEF of<35%	1
Preoperative use of IABP	2
COPD	1
Insulin-requiring diabetes	1
Previous cardiac surgery	1
Emergency surgery	2
Valve surgery only (reference to CABG)	1
CABG+valve	2
Other cardiac surgeries	2
Preoperative creatinine level of 1.2 to<2.1 mg/dl (reference to 1.2 mg/dl)	2
Preoperative creatinine level of<2.1 mg/dl (reference to 1.2 mg/dl)	5
Minimum score, 0; maximum score, 17	

CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease.

Table 4: General characteristics (demographic features) of the studied group

	n (%)
Age (years)	
Minimum-maximum	20.0-66.0
Mean±SD	51.78±11.17
Sex	
Male	102 (45.1)
Female	124 (54.9)
Operation types	
Isolated CABG	124 (54.8)
Valve	91 (40.2)
Combined CABG+valve	11 (4.8)

CABG, coronary artery bypass graft.

overestimation of the actual need for dialysis, which is 1.3 and 1.2%, respectively.

Hemofiltration during CPB attenuates postoperative anemia, thrombocytopenia, and hypoalbuminemia, and decreases inflammatory response during CPB, which may explain the decrease in the need for renal replacement therapy in high-risk patients (Tables 4–8 and Fig. 1).

Discussion

One of the most common complications of cardiac surgery with a major role in worsening prognosis is that the incidence of cardiac surgery-associated AKI varies between 8.9 and 39% [2,3]. Some revealed reasons for the high incidence are the different types of underlying diseases, operation type, comorbidities, and treatment development in global population.

Table 5: Diabetes mellitus and hypertension in the studied group

	n (%)
Diabetes	
Oral therapy	74 (32.7)
Insulin	39 (17.2)
Hypertension	
No	120 (53.1)
Yes	106 (46.9)

Table 6: Operative data of the studied group

	n (%)
Operative priority	
Elective	220 (97.3)
Emergency	6 (2.7)
Operation sequence	
First operation	222 (98.2)
Redo operation	4 (1.8)
Operation types	
Isolated CABG	124 (54.9)
Valve	91 (40.2)
Combined CABG+valve	11 (4.9)
Cumulative bypass time (min)	
Minimum-maximum	57.0-163.0
Mean±SD	92.27±42.02
Cumulative XC time (min)	
Minimum-maximum	46.0-125.0
Mean±SD	75.25±46.91

CABG, coronary artery bypass graft.

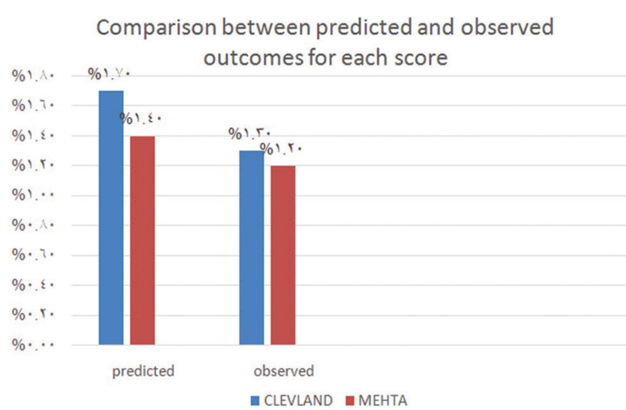

Figure 1: Comparison between predicted and observed outcomes for Cleveland (1.7 and 1.3 respectivly) and Mehta (1.4 and 1.2 respectivly) AKI–RRT. AKI, acute kidney injury; RRT, renal replacement therapy.

So early prediction of high-risk patients for cardiac surgery-associated AKI may contribute to prevention of complications; different predictive models are developed to detect cardiac surgery-associated AKI or renal replacement therapy after cardiac surgery. One of the most important of those risk scores, adequate predictive power published by Palomaba *et al*. [7], the Cleveland Clinic score [8], and the

Table 7: Postoperative data of the studied group

	Mean±SD
Hours ventilated	
Minimum-maximum	3.0-128.0
Mean±SD	16.92±14.23
Stay on ICU (days)	
Minimum-maximum	1.0-12.0
Mean±SD	2.41±1.32
Postoperative stay (days)	
Minimum-maximum	5.0-16.0
Mean±SD	9.42±7.26

Table 8: Comparison between predicted and observed outcomes for each score

Score	Renal replacement therapy (dialysis) (%)	
	Cleveland	Mehta
Predicted	1.7	1.4
Observed	1.3	1.2

classification system published by Mehta *et al.*[6] compared with the present score-derivation groups, the incidence of cardiac surgery-associated AKI is far higher in developing countries [11–14]. So, it is important to detect whether or not these existing scores are able to predict the respective outcome in patients in developing countries.

In 2008, Palomaba *et al.*[7] administered a single-center study to come up with a risk score to predict cardiac surgery-associated AKI with 605 patients. In this study, the results of internal validation were good with (area under the receiver-operating curve 0.84), which meant an honest predictive power of AKI after cardiac surgery. By that point, the authors had recognized the more serious prognosis and long-term chronic kidney disease devolvement may well be resulted from even slightly AKI. They also evaluate the effect of intraoperative and postoperative risk factors, leading to cardiac surgery-associated AKI. However, the validation in our study is not nearly as good as that. Potential reasons may include that the definition of AKI within the primary study was a rise of serum creatinine levels above 2.0 mg/dl in patients with baseline serum creatinine below 1.5 mg/dl. In patients with baseline creatinine between 1.5 and 3.0 mg/dl, AKI was defined as a creatinine increase of 50 over the baseline value. This urine output-lacking definition may lead to the missing diagnosis of cardiac surgery-associated AKI compared with the KDIGO definition.

However, the predictive power in our study was not accurate, and that we tried to search out the explanation.

First, the endpoint event of the Cleveland and Mehta score is renal replacement therapy. Up till now, the whether the early start of renal replacement therapy is helpful or not remains debatable [15]. Some studies have shown that the early start of renal replacement therapy can decrease mortality [16]. The renal replacement therapy incidence in our group is 1.3%, slightly below that in those two scores (Cleveland 1.7%, Mehta 1.4%). This could be one among the explanations that lead to the insufficient predictive power in our study.

We evaluated the efficacy of conventional hemofiltration during CPB in high-risk adult patients with a high predicted postoperative AKI risk. We focused on postoperative need for renal replacement therapy in high-risk patients according to Cleveland and Mehta scores.

The use of hemofiltration decreases the incidence of developing postoperative acute renal failure requiring replacement therapy, as predicted by Cleveland and Mehta scores from 1.7 to 1.3% and 1.4 to 1.2%, respectively.

Hemofiltration during CPB attenuates postoperative anemia, thrombocytopenia, and hypoalbuminemia and decreases the effect of the inflammatory response during CPB, which may explain the decrease in need for renal replacement therapy in high-risk patients [17,18].

Second, in spite of strict similar inclusion or exclusion criteria being utilized, there remained much difference among our group and also the derivation groups. The ratio of valve surgery is higher in developing countries like Egypt than the previous risk-score developing centers, within which coronary surgery is the most common. Compared with coronary surgery, the pathophysiology and pathological impairment are clear. Patients who undergo valve surgery typically demonstrate low stroke volume associated with regurgitation, which increases the vulnerability of the kidney to injury during cardiac surgery [19].

Meanwhile, some limitations of our study must be noted, our validation may be a single-center study, with a relatively lower sample amount.

Conclusion

In this study, we validate two models of risk scores predicting cardiac surgery-associated AKI and the need for renal replacement therapy after cardiac surgery. Although the scores presented good calibration in our group, their predictions were barely satisfactory with an overestimated renal replacement therapy incidence by Cleveland and Mehta scores. However, the chance factors within the scores will be further analyzed to come up with reliable new risk scores.

The use of hemofiltration during CPB decreases the incidence of acute renal failure and the postoperative need for renal replacement therapy.

However, the risk factors in the scores can be further analyzed to generate reliable new risk scores.

Conflicts of interest

None.

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