Prevalence of acute kidney injury in cardiac patients in the Intensive Care Unit

Tarek A. Ghonemy[a], Hala M. Allam[a], Amir M. Elokely[a], Esam Lotfy[a], Sayed Elnahal[a], Amal F. Gharib[b]

[a]Department of Internal Medicine, Nephrology Unit, [b]Department of Medical Biochemistry, Zagazig University Hospital, Zagazig, Egypt

Correspondence to Tarek A. Ghonemy, MBBCh, MSc, MD, Department of Internal Medicine, Nephrology Unit, Zagazig University Hospital, PO Box 44519, Zagazig, Egypt
e-mail: tarekghonemy@hotmail.com

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Background
Acute kidney injury (AKI) has consistently been associated with adverse clinical outcome after acute myocardial infarction (MI). In addition, AKI is well-known as a potent predictor of the clinical course in heart failure patients. The aim of this study was to assess the prevalence and risk factors of AKI in patients with acute MI and congestive heart failure (CHF) in the ICU at Zagazig University Hospitals, Egypt.
Patients and methods
This study included 100 patients with acute MI and 100 patients with CHF admitted to the ICU. They were subjected to careful history taking, thorough clinical examination, ECG and echocardiographic evaluation, and laboratory investigations, including cardiac enzyme evaluation, renal profile, and fasting blood glucose. Definitions of AKI depend on the measurement of serum creatinine as a surrogate marker for the glomerular filtration rate, in addition to the calculation of estimated glomerular filtration rate.
Results
The proportion of patients who experienced AKI was 47% in patients with CHF and 45% in patients with acute MI. They were significantly older in age (P=0.013 and 0.004, respectively). In CHF, patients with AKI had significantly higher fasting blood sugar (P=0.011), abnormal ECG changes (P=0.001), lower ejection fraction (P=0.034), and lower diastolic dysfunction (P=0.027). However, in acute MI, patients with AKI had significantly higher fasting blood sugar (P=0.013) and higher troponin I level (P=0.015).
Conclusion
The most important risk factors for AKI in patients with CHF are older age, higher frequency of diabetes mellitus, abnormal ECG changes, lower ejection fraction, and diastolic dysfunction. However, high troponin I and older age are the most important risk factors for AKI in patients with acute MI. Careful monitoring of susceptible patients in the ICU is recommended for early detection and management of AKI in those patients.

Keywords:
acute kidney injury, congestive heart failure, myocardial infarction

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Introduction

The heart and kidneys are the organs that are richly vascular (the kidneys are more vascular compared with the heart). In addition, both organs are supplied by sympathetic and parasympathetic innervations. These two organs act in tandem to regulate blood pressure, vascular tone, diuresis, natriuresis, intravascular volume homeostasis, peripheral tissue perfusion, and oxygenation [1]. They have endocrine functions with interdependent physiological hormonal actions regulated by natriuretic peptides, especially atrial natriuretic peptide, a vasodilator secreted from the heart, and rennin–angiotensin–aldosterone system [2]. Moreover, active vitamin D_3 (calcitriol), erythropoietin, and renin are all secreted from the kidneys and are capable of cellular and humoral signaling. Dysfunction of either of the two organs can cause dysfunction of the other [3]. Cardiorenal syndrome (CRS) includes a variety of acute or chronic conditions, in which the primary failing organ can be either the heart or the kidney. Acute CRS is a syndrome of worsening renal function that frequently complicates acute decompensated heart failure (ADHF) and acute coronary syndrome (ACS). Seven observational studies have reported on the frequency and outcomes of CRS type 1 in the setting of ADHF and five have reported on ACS [4]. Depending on the population, 27–40% of patients hospitalized for ADHF develop acute kidney injury (AKI) as defined by an increase in serum creatinine of 0.3 mg/dl or greater [5].

A diseased heart has numerous negative effects on kidney function, and, at the same time, renal insufficiency can significantly impair cardiac function. Thus, direct and indirect effects of each organ that is dysfunctional can initiate and perpetuate the combined disorder of the two organs through a complex combination of neurohormonal feedback mechanisms [6].

Aim of the study

The aim of this work was to assess the prevalence and risk factors of AKI in cardiac patients with acute myocardial infarction (MI) and congestive heart failure (CHF) in the Coronary Care Unit, Zagazig University Hospitals, Egypt.

Patients and methods

This cross-sectional study was carried out in the ICU, Zagazig University Hospitals, Egypt, during the period from January 2014 to January 2015. A total of 200 patients were included in this study. Informed consent was obtained from patients or their relatives to participate in this study. They were divided into two groups. Group 1 included 100 patients with CHF, of whom 48 were male and 52 were female, with age ranging from 30 to 60 years and a mean of 51.8±7.8 years. Group 2 included 100 patients with acute MI, of whom 58 were male and 42 were female, with age ranging from 36 to 60 years and a mean of 52.4±6.2 years. The study protocol was reviewed and approved by our Local Institutional Human Research Ethical Committee as it conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as revised in 2002.

Inclusion criteria: Patients diagnosed as having acute MI or CHF admitted to the ICU were included in the study.

Exclusion criteria: Pregnant women and patients with pre-existing CKD were excluded from the study.

Methods

All patients included in the study were subjected to careful history taking and thorough clinical examination. They were also subjected to different laboratory and nonlaboratory investigations, which included ECG, echocardiography, and cardiac enzyme evaluation (total creatine phosphokinase, CK-MB, and lactate dehydrogenase) [7–9], troponin I [8], urea, and creatinine levels were evaluated. Serum urea and creatinine concentrations were measured using the Jaffé method (alkaline picrate reaction) [10], and urine albumin was evaluated by measuring albumin/creatinine ratio [11]. Estimated glomerular filtration rate (eGFR) was calculated using Modification of Diet in Renal Disease equation. AKI was considered when eGFR was less than 60 ml/min/1.73 m^2 [12] or serum creatinine was 0.3 mg/dl greater from the baseline [5]. Urine microscopy was carried out and fasting blood sugar was determined [13]. Abnormal ECG changes in group 1 included the following: right bundle branch block, atrial fibrillation, sinus tachycardia, left bundle branch block, right ventricular hypertrophy, left ventricular hypertrophy, and ischemia. However, abnormal ECG changes in group 2 included the following: anterior wall MI, inferior wall MI, and non-ST-segment elevation myocardial infarction (NSTEMI).

Statistical analysis

Data obtained from the present study were computed using SPSS versions 15.0 (SPSS Inc., http://www.SPSS.com) under the platform of Microsoft Windows XP, Professional Edition. Continuous data were expressed in the form of mean±SD, whereas categorical data were expressed in the form of count and percent. Comparison of continuous data was made using Student's *t*-test, whereas categorical data were compared using the χ^2-test. A *P* value less than 0.05 was considered statistically significant.

Results

The study included 100 patients with CHF. Their ages ranged from 30 to 60 years, with a mean of 51.8±7.8 years. A total of 48 patients were male and 52 patients were female; 31 (31%) patients had diabetes. Fifty-three (53%) patients had normal ECG changes, whereas 47 (47%) patients had abnormal ECG changes. A total of 85 (85%) patients had left ventricular systolic dysfunction, whereas 15 patients had diastolic dysfunction. Eleven (11%) patients were found to have mild pulmonary hypertension, 20 (20%) patients had moderate pulmonary hypertension, and 16 (16%) patients had severe pulmonary hypertension. A total of 47 (47%) patients had AKI. The study included 100 patients with acute MI. Their ages ranged from 36 to 60 years, with a mean of 52.4±6.2 years. A total of 58 patients were male and 42 (42%) patients were female. A total of 45 patients (45%) were found to have AKI. Fifty-eight (58%) patients had anterior wall MI, 26 (26%) patients had NSTEMI, and 16 (16%) patients had inferior wall MI. For demographic, clinical, and laboratory parameters of the studied groups, see Tables 1 and 2.

Table 1 Clinical and demographic characteristics of the studied groups

	Group 1 (*N*=100)	Group 2 (*N*=100)
Age	51.8±7.8	52.4±6.2
Sex		
Male/female	48/52	58/42
Diabetes		
Diabetic/nondiabetic patients	31/69	29/71
Renal function		
Normal/abnormal (%)	53/47 (78/22)	55/45 (76/45)
ECG changes (%)	Normal/abnormal: 53/47 (53/47)	AWMI: 58 (58)NSTEMI: 26 (26)IWMI: 16 (16)
Echocardiography		
LVEDD (38–57 mm)	61.3±11.0	55.1±8.5
LVESD (22–40 mm)	44.6±11.2	41.2±7.3
PWTD (7–11 mm)	9.72±2.0	8.6.1±1.4
EF (50–70%)	51.2±10.4	55.3±9.2
FS (25–45%)	26.6±6.6	28.8±6.9
LVF		
Systolic dysfunction/diastolic dysfunction (%)	85/15 (85/15)	
Pulmonary hypertension		
Absent	19.7±4.1	
Mild	36.5±3.2	
Moderate	53.6±12.9	
Severe	74.1±1.9	

AKI, acute kidney injury; AWMI, anterior wall myocardial infarction; EF, ejection fraction; FS, fractional shortening; IWMI. inferior wall myocardial infarction; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricle end-systolic diameter; LVF, left ventricular function; NSTEMI, non-ST-segment elevation myocardial infarction; PWTD, posterior wall thickness at end diastole.

Table 2 Laboratory parameters of the studied groups

	Group 1 (*N*=100)	Group 2 (*N*=100)
CPK (U/l)	177.2±361.6	645.1±842.3
CPK-MB (μ/l)	23.7±71.6	55.6±81.7
LDH (μ/l)	636.1±400.8	872.6±577.2
Troponin I (ng/ml)	0.2±0.6	3.79±5.48
Albumin (g/dl)	3.6±0.64	3.78±0.58
Urea (mg/dl)	59.3±29.0	49.9±38.4
Creatinine (mg/dl)	1.16±1.11	1.27±1.12
A/C ratio (mg/g)	193±155	93±79
eGFR (ml/min/1.73 m^2)	107.5±64.0	90.9±40.5
Fasting blood sugar (mg/dl)	145±63	107.2±43.7

A/C, albumin/creatinine; CPK, creatine phosphokinase; eGFR, estimated glomerular filtration rate; LDH, lactate dehydrogenase.

Analysis of the clinical and demographic data in group 1

On analysis of the clinical and demographic data in patients with CHF (group1), it was found that the incidence of AKI was significantly higher in older patients (*P*=0.013). There was no significant difference between male and female patients (*P*=0.075). The incidence of AKI was statistically higher in diabetic patients than in nondiabetic patients (*P*=0.018). Moreover, it was highly statistically higher in patients with left ventricular diastolic dysfunction (*P*=0.027). Furthermore, in patients with abnormal ECG changes, there was a significantly higher incidence of AKI in comparison with patients without ECG changes (*P*=0.001). In patients with lower ejection fraction the incidence of AKI was more significant (*P*=0.034), whereas no significant difference was found as regards other echocardiographic parameters. Pulmonary hypertension was found to have insignificant effect on the incidence of AKI in patients with CHF (*P*=0.19) (Table 3).

Analysis of laboratory data in group 1

On analysis of the laboratory data in patients with CHF (group 1), it was found that patients with high fasting blood sugar have significantly higher incidence of AKI (*P*=0.011), whereas no significant effect was found as regards other laboratory parameters (Table 4).

Analysis of the clinical and demographic data in group 2

On analysis of clinical and demographic data in patients with MI (group 2), it was found that the incidence of AKI was statistically significantly higher in older age group (*P*=0.004). However, no significant difference was found between male and female groups (*P*=0.21). Moreover, ECG changes were found to have a insignificant effect on renal functions in this group of patients (*P*=0.06) (Table 5).

Analysis of laboratory data for group 2

On analysis of the laboratory parameters in patients with MI (group 2), it was found that there was a statistically higher incidence of AKI in patients with

Table 3 Comparison between patients with normal kidney function and those with AKI as regards clinical and demographic characteristics in group 1

	No AKI (*N*=53)	AKI (*N*=47)	*P*
Age	50.0±8.0	53.8±7.1	0.013
Sex			
Male/female	21/32	27/20	0.075
Diabetes			
Diabetic/nondiabetic patients	11/42	20/27	0.018
ECG changes			
Normal/abnormal	36/17	17/30	0.001
Echocardiographic changes			
LVEDD (mm)	60.6±12.4	62.0±9.3	0.54
LVESD (mm)	43.9±12.8	45.2±9.1	0.56
EF%	53.3±9.5	48.8±11.0	0.034
FS%	27.3±6.0	25.8±7.2	0.26
PWTD (mm)	9.6±2.1	9.8±1.9	0.61
Left ventricular function			
Systolic dysfunction/diastolic dysfunction	94/4	36/11	0.027
Pulmonary hypertension			
Absent	28	25	
Mild	7	4	0.19
Moderate	13	7	
Severe	5	11	

AKI, acute kidney injury; EF, ejection fraction; FS, fractional shortening; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricle end-systolic diameter; PWTD, posterior wall thickness at end diastole.

Table 4 Comparison between patients with normal kidney function and those with AKI as regards laboratory parameters in group 1

	No AKI (*N*=53)	AKI (*N*=47)	Student *t*-test	
			t	*P*
CPK (U/l)	217.5±397.9	131.8±313.7	−1.18	0.23
CPK-MB (μ/l)	35.8±88.3	10.2±43.1	−1.87	0.064
LDH (μ/l)	592.9±176.4	684.8±553.1	1.0	0.28
Troponin I (ng/ml)	0.24±0.77	0.15±0.5	−0.7	0.48
Albumin (g/dl)	3.7±0.7	3.5±0.5	−1.32	0.18
Urea (mg/dl)	50.3±22.2	69.6±32.5	3.48	0.0007
Creatinine (mg/dl)	0.72±0.16	1.65±1.47	4.26	0.00009
A/C ratio (mg/g)	210±160	173±142	−1.25	0.21
Fasting blood sugar (mg/dl)	89.4±19.9	133.6±24.2	2.4	0.011

A/C, albumin/creatinine; AKI, acute kidney injury; CPK, creatine phosphokinase; LDH, lactate dehydrogenase.

Table 5 Comparison between patients with normal kidney function and those with AKI as regards clinical and demographic characteristics in group 2

	No AKI (*N*=55)	AKI (*N*=45)	*P*
Age	50.8±6.3	54.4±5.6	0.004
Sex			
Male/female	35/20	23/22	0.21
ECG changes			
AWMI	28	30	
NSTEMI	14	12	0.06
IWMI	13	3	

AKI, acute kidney injury; AWMI, anterior wall myocardial infarction; IWMI. inferior wall myocardial infarction; NSTEMI, non-ST-segment elevation myocardial infarction.

higher troponin I and in those with higher fasting blood sugar (P=0.015 and 0.013, respectively). However, no significant effect was found on renal function as regards other laboratory parameters (Table 6).

Discussion

AKI is well-known as a potent predictor of the clinical course in heart failure (HF) patients. Large epidemiological studies reveal that 30 to 67% of patients hospitalized for decompensated HF have a glomerular filtration rate (GFR) less than 60 ml/min/1.73 m^2 [14]. In addition, AKI has consistently been associated with adverse clinical outcome after acute MI. The risk for mortality, HF, malignant arrhythmia, and reinfarction increases with only mildly impaired renal function and continues in a curvy-linear manner with progressive renal impairment [15]. In the present

Table 6 Comparison between patients with normal kidney function and those with AKI as regards laboratory parameters in group 2

	No AKI (*N*=55)	AKI (*N*=45)	Student *t*-test	
			t	*P*
CPK (μ/l)	680.8±871.9	601.5±869.7	–0.45	0.65
CPK-MB (ng/ml)	65.3±85.1	43.8±76.5	–1.31	0.19
LDH (μ/l)	779.8±495.6	986.0±651.4	1.79	0.075
Troponin I (ng/ml)	2.5±3.5	5.34±6.9	2.48	0.015
Albumin (g/dl)	3.8±0.5	3.6±0.5	–1.73	0.086
Urea (mg/dl)	34.0±12.3	69.4±49.2	4.7	0.00002*
Creatinine (mg/dl)	0.75±0.12	1.9±1.44	5.3	0.000003*
A/C ratio (mg/g)	83±58	100.5±98	1.39	0.16
Fasting blood glucose (mg/dl)	95.6±32.1	144.9±39.8	2.9	0.013*

A/C, albumin/creatinine; AKI, acute kidney injury; CPK, creatine phosphokinase; LDH, lactate dehydrogenase. *, highly significant

study, we aimed to assess the prevalence and risk factors for AKI in patients with MI and CHF in the ICU at Zagazig University Hospitals.

In the present study, 47 patients with CHF (47%) were found to have AKI. This figure is close to that found by Stanojević *et al.* [15], who investigated the prevalence and influence of AKI on functional capacity in the elderly CHF patients. In their study, 42.2% of patients had AKI. Moreover, Waldum *et al.* [16] found that AKI (eGFR<60 ml/min) was present in 44.9% of patients. In addition, Kim *et al.* [17] revealed that 1154 patients (41.7%) with CHF patients had AKI. In a meta-analysis study, McAlister *et al.* [18] found that 10 589 patients (51%) and 11 422 patients (55%) had an eGFR less than 60 ml/min using the Modification of Diet in Renal Disease and Chronic Kidney Disease Epidemiology Collaboration equations, respectively.

As regards the relation of AKI with the demographic data in CHF patients, we found that CHF patients with AKI were significantly older when compared with patients without AKI. This is in agreement with the study by Roik *et al.* [19], who evaluated the prognostic value of AKI in patients with CHF in 12-month follow-up. In their study, patients with AKI were significantly older. In another study, Petretta *et al.* [20] also reported that HF patients with reduced renal functions were significantly older than those with preserved renal functions. In the present study, it was found that patients with AKI had significantly higher frequency of diabetes mellitus (DM) when compared with patients without AKI. This is in agreement with the study by Kim *et al.* [17], who noted that, in CHF patients, DM is a risk factor for AKI. As regards ECG changes and their effects on renal function, it was found in this study that patients with AKI had significantly higher frequency of cases with abnormal ECG. This is in agreement with the study by Cohen *et al.* [21], who found that patients with abnormal renal function had more frequent cardiac arrhythmias and cardiac conduction disturbances when compared with patients with normal kidney function. In addition, Bruch *et al.* [22] found that patients with AKI had longer PR and QRS intervals. Considering the relation of AKI with the echocardiographic parameters, it was noted that patients with AKI had significantly lower ejection fraction when compared with patients without AKI. In addition, it was found that patients with AKI had significantly higher frequency of diastolic dysfunction when compared with patients with normal renal function. This is in accordance with the study by Yang *et al.* [23], who analyzed the impact of impaired kidney function on survival rate of hospitalized chronic heart failure (CHF) patients. In their study, patients with abnormal kidney function had significantly worse cardiac function.

In the present study, 45 patients (45%) had MI AKI. In comparison with our study, Langston *et al.* [24] reported that renal insufficiency was found in 60.0% of patients with acute MI. Moreover, Schiele *et al.* [25] aimed to determine the extent to which a reduction in GFR influences 1-year mortality in MI patients. They reported that 72.0% of patients had renal insufficiency. In the current study, patients with acute MI who developed AKI were older in age than patients with normal kidney function. This result is in agreement with the study by Ersbøll *et al.* [26], who prospectively included 1054 patients with acute MI (mean age 63 years, 73% male) and performed echocardiographic assessment of systolic and diastolic function within 48 h of admission as well as eGFR. In their study, patients with reduced GFR were significantly older than patients with normal GFR. As regards the effect of laboratory parameters on renal function in patients with acute MI, troponin I was found to be significantly

higher in patients with AKI, and this result is shown to be in agreement with the study by Ersbøll *et al.* [24].

Conclusion

The most important risk factors for AKI in patients with CHF are older age, higher frequency of diabetes (DM), abnormal ECG changes, lower ejection fraction, and diastolic dysfunction. However, high troponin I and older age are the most important risk factors for AKI in patients with acute MI. Careful monitoring of susciptible patients in ICU is recommended for early detection and mangement of AKI in those patients.

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Conflicts of interest

There are no conflicts of interest.

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