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ORIGINAL ARTICLE

Predictors of Worsening Renal Function in Patients Hospitalized with Acute Heart Failure

H M Mohiuddin Alamgir[1*], K B M Hadiuzzaman[2], Mohammad Kamrul Hasan[3], Kabir Hossain[4], Anjuman Ara Daisy[5], Mamun Chowdhury Raju[6]

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*Corresponding Author

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ABSTRACT

Background*: Worsening renal function (WRF) is a frequent and clinically important complication among patients hospitalized with acute heart failure (AHF), leading to increased morbidity, prolonged hospitalization, and poor clinical outcomes. Early identification of patients at high risk of WRF may facilitate timely intervention and improve prognosis. Aim of the study: To identify the predictors of worsening renal function in patients hospitalized with acute heart failure and evaluate its association with in-hospital clinical outcomes.* ***Methods & Materials****: This prospective observational study was conducted in the Departments of Nephrology and Cardiology at Bangladesh Medical University, Dhaka, Bangladesh, from June 2023 to March 2025. A total of 58 adult patients admitted with acute heart failure and baseline serum creatinine <1.3 mg/dL were enrolled. Worsening renal function was defined as an increase in serum creatinine of ≥0.3 mg/dL within 48 hours or ≥1.5 times the baseline value within seven days. Demographic, clinical, laboratory, echocardiographic, and biomarker data, including urinary TIMP-2×IGFBP-7, were collected. Independent predictors of WRF were identified using multivariable logistic regression analysis.* ***Result****: Worsening renal function developed in 23 (39.7%) patients. Patients with WRF more frequently had diabetes mellitus (60.9% vs. 31.4%, p=0.027), previous heart failure admission (65.2% vs. 37.1%, p=0.034), NYHA class IV symptoms (69.6% vs. 51.4%, p=0.048), lower estimated glomerular filtration rate, lower serum albumin, higher inflammatory markers, elevated NT-proBNP, and markedly increased urinary TIMP-2×IGFBP-7 levels (all p<0.05). Hospital stay was significantly longer (9.2±3.1 vs. 6.4±2.3 days, p<0.001), and ICU admission was more frequent among patients with WRF (43.5% vs. 17.1%, p=0.030). Multivariable logistic regression identified diabetes mellitus (adjusted OR=2.74, p=0.048), previous heart failure admission (adjusted OR=2.96, p=0.044), serum albumin <3.5 g/dL (adjusted OR=3.41, p=0.046), eGFR <70 mL/min (adjusted OR=3.84, p=0.026), NT-proBNP >5000 pg/mL (adjusted OR=3.67, p=0.032), and urinary TIMP-2×IGFBP-7 >0.312 (adjusted OR=13.94, p<0.001) as independent predictors of WRF.* ***Conclusion****: Worsening renal function occurred in nearly two-fifths of hospitalized patients with acute heart failure and was associated with adverse in-hospital outcomes. Diabetes mellitus, previous heart failure admission, impaired renal function, hypoalbuminemia, elevated NT-proBNP, and particularly increased urinary TIMP-2×IGFBP-7 independently predicted WRF. Early risk stratification using these clinical and biomarker-based predictors may improve patient monitoring and optimize management strategies.*

Keywords: *Acute heart failure; worsening renal function; cardiorenal syndrome; urinary TIMP-2×IGFBP-7; NT-proBNP; predictors*

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1. *Registrar, Department of Nephrology, Dhaka Medical College, Dhaka, Bangladesh (ORCID: 0009-0004-4691-3232)*
2. *Professor, Department of Nephrology, Bangladesh Medical University, Dhaka, Bangladesh*
3. *Assistant Professor, Department of Nephrology, Holy Family Red Crescent Medical College and Hospital, Dhaka, Bangladesh*
4. *Associate Professor, Department of Nephrology, Bangladesh Medical University, Dhaka, Bangladesh*
5. *Medical Officer, National Institute of Kidney Diseases and Urology, Dhaka, Bangladesh*
6. *Medical Officer, Kishoreganj 250-Bed District Sadar Hospital, Kishoreganj, Bangladesh*

INTRODUCTION

Acute heart failure (AHF) is a clinical syndrome characterized by the rapid onset or worsening of signs and symptoms of heart failure requiring urgent hospitalization and prompt medical treatment [1,2]. WRF represents a manifestation of cardio-renal syndrome, in which dysfunction of the heart adversely affects kidney function through complex hemodynamic and neurohormonal mechanisms [3,4]. Worldwide, heart failure affects more than 64 million people, and approximately 20-30% of patients hospitalized with AHF develop WRF [1,4]. The prevalence of heart failure in Bangladesh is approximately 0.26-0.28% of the population, although comprehensive nationwide data on hospitalized acute heart failure and worsening renal function are still lacking [5]. The development of WRF in AHF is multifactorial. Reduced cardiac output leads to inadequate renal perfusion, while elevated central venous pressure causes renal venous congestion, both of which impair glomerular filtration [6,7]. In addition, activation of the renin-angiotensin-aldosterone system and sympathetic nervous system, systemic inflammatory responses, oxidative stress, and endothelial dysfunction further aggravate renal injury [3,8]. Although diuretics are essential for relieving congestion,

excessive diuresis or intravascular volume depletion may also contribute to deterioration of renal function in susceptible patients [9,10]. Consequently, the interaction between cardiac dysfunction, renal hypoperfusion, congestion, and therapeutic interventions creates a complex clinical scenario that often complicates the management of hospitalized patients with AHF. The occurrence of WRF importance have demonstrated that patients who develop WRF experience prolonged hospital stays, increased healthcare costs, higher rates of rehospitalization, and greater short- and long-term mortality than those with preserved renal function [4,11]. Early recognition of patients at risk provides an opportunity for careful hemodynamic assessment, individualized fluid and diuretic management, timely monitoring of renal function, and implementation of appropriate preventive strategies [10,12]. Accurate prediction of WRF may also support risk stratification, optimize resource utilization, and improve overall patient outcomes. However, prediction remains challenging because renal function is influenced by multiple interacting clinical, laboratory, and treatment-related factors, and transient increases in serum creatinine do not always reflect irreversible kidney injury [3,13]. Advanced age, diabetes mellitus, pre-existing renal dysfunction, impaired left ventricular systolic function and severe congestion have been recognized as major risk factors of worsening renal function in patients hospitalized with acute heart failure. Elevated natriuretic peptide levels, hypotension and high-dose loop diuretic therapy have also been associated with an increased risk of worsening renal function. However, these associations have not been consistently demonstrated because of differences in study populations, study design, diagnostic criteria and treatment strategies across studies [10,12,14]. Furthermore, evidence from low- and middle-income countries, particularly Bangladesh, is scarce, limiting the applicability of international findings to the local population. Therefore, identifying reliable predictors of worsening renal function among patients hospitalized with acute heart failure is essential to facilitate early diagnosis, optimize therapeutic decision-making, and reduce preventable renal complications. The study aimed to identify the predictors of worsening renal function in patients hospitalized with acute heart failure and to evaluate their association with in-hospital clinical outcomes.

METHODS & MATERIALS

This prospective observational study was conducted in the Departments of Nephrology and Cardiology at Bangladesh Medical University (BMU), Dhaka, Bangladesh, between June 2023 and March 2025. Adult patients admitted with a diagnosis of acute heart failure, including acute de novo heart failure and acute decompensated chronic heart failure, were consecutively screened for eligibility. A total of 58 patients completed the study and were included in the final analysis. Participants were classified into two groups according to the development of worsening renal function during hospitalization:

WRF group (n=23): Patients with baseline serum creatinine <1.3 mg/dL who developed an increase in serum creatinine ≥0.3 mg/dL within 48 hours or ≥1.5 times the baseline value within seven days.

No WRF group (n=35): Patients with baseline serum creatinine <1.3 mg/dL who did not meet the above criteria during hospitalization.

Urine output criteria were not used for diagnosing WRF because diuretic therapy in acute heart failure may substantially influence urine volume and reduce the diagnostic reliability of this parameter.

Inclusion Criteria:

- Age ≥18 years.
- Hospitalization with acute heart failure (acute de novo heart failure or acute decompensated chronic heart failure) diagnosed based on clinical presentation, physical examination, echocardiography, and laboratory findings.
- Baseline serum creatinine <1.3 mg/dL on admission.

Exclusion Criteria:

- Coronary angiography or percutaneous coronary intervention within ±7 days of admission.
- Planned coronary artery bypass grafting or valvular heart surgery during the study period.
- Known thyroid dysfunction.
- Current treatment with anticancer medications.
- End-stage renal disease or dialysis dependence.
- Active systemic infection or sepsis.
- Conditions likely to interfere with renal biomarker interpretation.

Ethical Considerations

The study protocol was approved by the Ethical Review Committee of Bangladesh Medical University, Dhaka, Bangladesh. Written informed consent was obtained from all participants before enrolment. Confidentiality of participant information was maintained throughout the study, and participants were informed of their right to withdraw from the study at any stage without affecting their medical care.

Study Procedure

Urine samples were obtained within 24 hours of admission for measurement of urinary TIMP-2 and IGFBP-7. Midstream urine samples were collected under aseptic conditions, centrifuged, aliquoted, and stored at −80°C until analysis. Urinary TIMP-2 and IGFBP-7 concentrations were measured using commercially available enzyme-linked immunosorbent assay (ELISA) kits according to the manufacturer's instructions. The combined biomarker, urinary [TIMP-2] × [IGFBP-7], was calculated and expressed as $(ng/mL)^2/1000$.

Venous blood samples were collected at admission and during follow-up (48 hours and day 7). Serum creatinine was measured using the Jaffe kinetic method on the Atellica CH Analyzer (Siemens Healthcare Diagnostics, Germany) according to the manufacturer's instructions. The measured values were used to calculate estimated glomerular filtration rate (eGFR) and to identify worsening renal function.

Data Collection

Baseline demographic characteristics, cardiovascular risk factors, comorbidities, smoking status, previous cardiovascular events, medication history, and clinical findings were collected using a structured data collection form. Heart failure characteristics, including the type of heart failure (acute de novo or acute decompensated chronic heart failure), New York Heart Association (NYHA) functional class, heart failure phenotype (HFrEF, HFmrEF, or HFpEF), and left ventricular ejection fraction (LVEF), were recorded. Laboratory investigations performed at admission included complete blood count, serum creatinine, estimated glomerular filtration rate (eGFR), blood urea, serum sodium, serum albumin, and C-reactive protein (CRP). Cardiac biomarkers, including N-terminal pro-B-type natriuretic peptide (NT-proBNP) and

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high-sensitivity cardiac troponin I (hs-Troponin-I), were measured. Urine samples collected within 24 hours of admission were analysed for tissue inhibitor of metalloproteinase-2 (TIMP-2) and insulin-like growth factor-binding protein-7 (IGFBP-7), and the combined biomarker was expressed as urinary [TIMP-2] × [IGFBP-7]. Serum creatinine was reassessed at 48 hours and on day 7 to determine the development of worsening renal function. Information on in-hospital pharmacological treatment, including angiotensin-converting enzyme inhibitor/angiotensin receptor blocker (ACEI/ARB), loop diuretics, mineralocorticoid receptor antagonists, and sodium-glucose cotransporter-2 (SGLT2) inhibitors, as well as hospital outcomes such as length of hospital stay and intensive care unit (ICU) admission, was also recorded.

Statistical Analysis

Statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequency and percentage. Comparisons between the WRF and No WRF groups were performed using the independent-samples t-test or Mann–Whitney U test for continuous variables, depending on data distribution, and the Chi-square test for categorical variables. Variables associated with worsening renal function in univariate analysis ($p<0.05$) or considered clinically relevant were entered into a multivariable binary logistic regression model to identify independent predictors of worsening renal function. The strength of association was expressed as odds ratios (ORs) or adjusted odds ratios (AORs) with corresponding 95% confidence intervals (CIs). A p-value of <0.05 was considered statistically significant.

RESULT

Patients with WRF had a higher mean age than those without WRF (67.91±8.66 and 55.85±10.79 years), although the difference was not statistically significant (p=0.381). Male participants predominated in both groups (65.22% and 74.29%, p=0.458). Mean BMI was higher in the WRF group (25.86±5.03 and 23.61±4.33 kg/m^2), without statistical significance (p=0.184) *Table I*.

Table I: Socio-demographic characteristics of the study participants (*n*=58)

Variable	WRF (n=23)		No WRF (n=35)		p-value
	n	%	n	%	
Age (years)					
Mean±SD	67.91±8.66		55.85±10.79		0.381
Gender					
Male	15	65.22	26	74.29	0.458
Female	8	34.78	9	25.71	
BMI (kg/m^2)					
Mean±SD	25.86±5.03		23.61±4.33		0.184

Diabetes mellitus (60.87% and 31.43%) and previous heart failure admission (65.22% and 37.14%) were significantly more frequent among patients with WRF. Hypertension was observed in 73.91% of the WRF group compared with 51.43% of the non-WRF group (p=0.087). Current smoking (47.83% and 28.57%), dyslipidaemia (56.52% and 42.86%), previous MI (34.78% and 20.00%), previous stroke (21.74% and 8.57%), and CKD history (26.09% and 8.57%) showed no statistically significant differences between groups (*Table II*).

Table II: Baseline comorbidities and cardiovascular risk factors (*n*=58)

Variable	WRF (n=23)		No WRF (n=35)		p-value
	n	%	n	%	
Current smoker	11	47.83	10	28.57	0.132
Hypertension	17	73.91	18	51.43	0.087
Diabetes mellitus	14	60.87	11	31.43	0.027
Dyslipidaemia	13	56.52	15	42.86	0.304
Previous MI	8	34.78	7	20.00	0.213
Previous stroke	5	21.74	3	8.57	0.156
CKD history	6	26.09	3	8.57	0.071
Previous heart failure admission	15	65.22	13	37.14	0.034

Acute decompensated chronic heart failure and HFrEF were the predominant in both groups (65.22% and 60.00%) followed by HFmrEF and HFpEF. NYHA IV was more common among patients with WRF whereas NYHA III predominated in those without WRF (p=0.048). Mean LVEF was lower in the WRF group (37.8±11.5% and 41.6±10.8%), although the difference was not statistically significant (p=0.488) *Table III*.

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Table III: Heart failure characteristics at admission (*n*=58)

Variable	WRF (n=23)		No WRF (n=35)		p-value
	n	%	n	%	
Acute de novo HF	8	34.78	14	40.00	0.692
Acute decompensated chronic HF	15	65.22	21	60.00	
NYHA III	7	30.43	17	48.57	0.048
NYHA IV	16	69.57	18	51.43	
HFrEF	15	65.22	21	60.00	0.661
HFmrEF	6	26.09	7	20.00	
HFpEF	2	8.70	7	20.00	
LVEF (%), Mean±SD	37.8±11.5		41.6±10.8		0.488

Patients with WRF had significantly higher total WBC count (10.8±3.2 and 8.9±2.4×10^9/L), lower eGFR (67.78±4.13 and 79.00±7.12 mL/min), lower serum albumin (3.31±0.42 and 3.71±0.39 g/dL), higher CRP (18.4±8.6 and 11.8±5.7 mg/L), and lower serum sodium (135.30±6.97 and 135.88±4.70 mmol/L). Haemoglobin, serum creatinine, and blood urea were comparable between groups (*Table IV*).

Table IV: Laboratory profile of patients on admission (*n*=58)

Variable	WRF (Mean±SD)	No WRF (Mean±SD)	p-value
Haemoglobin (g/dL)	11.07±2.10	11.92±1.82	0.416
Total WBC (×10^9/L)	10.8±3.2	8.9±2.4	0.016
Serum creatinine (mg/dL)	1.03±0.18	0.97±0.16	0.172
eGFR (ml/min)	67.78±4.13	79.00±7.12	0.036
Blood urea (mg/dL)	18.13±3.23	14.43±3.74	0.247
Sodium (mmol/L)	135.30±6.97	135.88±4.70	0.009
Albumin (g/dL)	3.31±0.42	3.71±0.39	<0.001
CRP (mg/L)	18.4±8.6	11.8±5.7	0.001

Patients with WRF demonstrated significantly higher NT-proBNP (p<0.001), hs-troponin-I (p=0.002), and urinary TIMP-2×IGFBP-7 (p<0.001). Medication use was similar between groups. Hospital stay was longer in patients with WRF (9.2±3.1 and 6.4±2.3 days), and ICU admission was more frequent (43.48% and 17.14%) *Table V*.

Table V: Cardiac biomarkers, medications and hospital outcome among participants (*n*=58)

Variable	WRF (n=23)		No WRF (n=35)		p-value
	n	%	n	%	
Biomarker					
NT-proBNP (pg/mL)	7260±2845		4525±2080		<0.001
hs-Troponin-I (ng/L)	84±39		55±28		0.002
Urinary TIMP-2×IGFBP-7	1.01±0.56		0.24±0.11		<0.001
Medication					
ACEI/ARB use	11	47.83	13	37.14	0.419
Loop diuretic use	18	78.26	28	80.00	0.873
Mineralocorticoid antagonist	14	60.87	18	51.43	0.474
SGLT2 inhibitor	5	21.74	11	31.43	0.417
Hospital Outcome					
Length of stay (days)	9.2±3.1		6.4±2.3		<0.001
ICU admission	10	43.48	6	17.14	0.03

Table VI shows age ≥70 years (OR 2.41, p=0.031), diabetes mellitus (OR 3.39, p=0.027), previous heart failure admission (OR 3.17, p=0.036), NYHA class IV (OR 2.82, p=0.047), albumin <3.5 g/dL (OR 4.25, p=0.009), eGFR <70 mL/min (OR 5.62, p=0.002), NT-proBNP >5000 pg/mL (OR 5.13, p=0.003), and urinary TIMP-2×IGFBP-7 >0.312 (OR 18.62, p<0.001) as factors associated with WRF.

Table VI: Factors associated with worsening renal function

Variable	OR	95% CI	p-value
Age ≥70 years	2.41	1.10–5.82	0.031
Diabetes mellitus	3.39	1.15–9.98	0.027
Previous HF admission	3.17	1.08–9.31	0.036
NYHA IV	2.82	1.01–7.89	0.047
Albumin <3.5 g/dL	4.25	1.42–12.69	0.009
eGFR <70	5.62	1.88–16.83	0.002
NT-proBNP >5000	5.13	1.71–15.37	0.003
TIMP-2×IGFBP-7 >0.312	18.62	5.22–66.44	<0.001

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Table VII demonstrated that diabetes mellitus (adjusted OR 2.74, p=0.048), previous HF admission (adjusted OR 2.96, p=0.044), serum albumin <3.5 g/dL (adjusted OR 3.41, p=0.046), eGFR <70 mL/min (adjusted OR 3.84, p=0.026), NT-proBNP >5000 pg/mL (adjusted OR 3.67, p=0.032), and urinary TIMP-2×IGFBP-7 >0.312 (adjusted OR 13.94, p<0.001) remained independent predictors of worsening renal function.

Table VII: Independent predictors of worsening renal function

Variable	Adjusted OR	95%CI	p-value
Diabetes mellitus	2.74	1.01–7.46	0.048
Previous HF admission	2.96	1.03–8.54	0.044
Albumin <3.5 g/dL	3.41	1.02–11.38	0.046
eGFR <70 ml/min	3.84	1.18–12.52	0.026
NT-proBNP >5000 pg/mL	3.67	1.12–12.02	0.032
TIMP-2×IGFBP-7 >0.312	13.94	3.58–54.24	<0.001

DISCUSSION

Worsening renal function (WRF) remains a frequent and prognostically important complication of acute heart failure, highlighting the need for early identification of patients at high risk for adverse clinical outcomes [15]. Patients with WRF were older than those without WRF, although the difference was not statistically significant. Similarly, male predominance was observed in both groups and body mass index (BMI) was slightly higher among patients with WRF. It is consistent with Forman et al., who evaluated 1,004 patients hospitalized with heart failure and patients who developed WRF tended to be older; however, age and sex were not independent predictors [16]. Similarly, Jones et al., demonstrated that advanced age and male sex were associated with adverse heart failure outcomes [17]. The significant association between diabetes mellitus and WRF in our study is consistent with Forman et al., who identified diabetes as an independent predictor of WRF in hospitalized HF patients [16]. Our observation that previous HF admission was significantly associated with WRF also agrees with Butler et al., who found that patients with recurrent HF admissions experienced a substantially higher incidence of WRF during hospitalization, independent of the intensity of diuretic therapy or ACE inhibitor use [18]. Although hypertension (73.9% and 51.4%) and previous CKD (26.1% and 8.6%) were more common among patients with WRF, statistical significance was not achieved. A study by Damman et al. confirmed that baseline CKD substantially increases the risk of WRF and mortality in HF populations, although its predictive value may vary according to study size and patient characteristics [4]. In the present study, acute decompensated chronic heart failure (ADCHF) was the predominant presentation in both groups, with no significant difference (65.22% and 60.00%, p=0.692). Our findings are consistent with the study by Forman et al., who reported that patients presenting with more advanced HF symptoms and previous HF episodes had a significantly greater risk of developing WRF during hospitalization [16]. The significant association between NYHA class IV and WRF in our study is also supported by the KorAHF Registry, which demonstrated that worsening renal function occurred more frequently among patients with advanced HF and was associated with poorer in-hospital and long-term outcomes [19]. Similarly, Breidthardt et al. found that WRF was associated with increased mortality and prolonged hospitalization [20]. The significantly lower eGFR observed in the WRF group (p=0.036). Similarly, Kawase et al. found that reduced admission eGFR independently predicted WRF in patients with acute decompensated HF [21]. Our finding of significantly lower serum albumin among patients with WRF (p<0.001). Clarke et al. demonstrated that baseline albumin ≤3.0 g/dL was the only independent predictor of WRF among patients with acute decompensated HF receiving continuous loop diuretic therapy [22]. The higher WBC count and CRP levels observed in the WRF group also supported by Garofalo et al., who showed that inflammatory activation contributes to endothelial dysfunction and renal injury [23]. Patients with WRF had lower serum sodium despite comparable admission serum creatinine levels. Aronson et al. demonstrated that hyponatraemia is an independent predictor of WRF in acute heart failure [24]. The significantly higher NT-proBNP levels in the WRF group are consistent with the findings of Ibrahim et al. reported that combining IGFBP-7 with NT-proBNP improves diagnostic and prognostic assessment in acute heart failure [25]. The markedly higher urinary TIMP-2×IGFBP-7 concentrations in patients with WRF support by Schanz et al., who demonstrated that urinary [TIMP-2]×[IGFBP-7] accurately predicts AKI in acute decompensated heart failure [26]. The significantly higher hs-troponin I levels in patients with WRF indicate greater myocardial injury. Peacock et al. demonstrated that elevated troponin in acute heart failure is associated with adverse clinical outcomes [27]. The comparable use of ACEI/ARB, loop diuretics, mineralocorticoid receptor antagonists, and SGLT2 inhibitors between groups is consistent with the Meunier-McVey N (2021), which emphasize that mild worsening renal function alone should not prompt discontinuation of guideline-directed medical therapy unless accompanied by significant acute kidney injury or haemodynamic instability [28]. Patients with WRF experienced longer hospitalization and more frequent ICU admission, consistent with the findings of Wettersten et al., who reported that WRF in acute heart failure is associated with prolonged hospital stay and worse clinical outcomes [29]. The significant associations of advanced age, diabetes mellitus, previous HF admission, and NYHA class IV with WRF are consistent with the findings of Forman et al., who identified diabetes, prior HF, and greater clinical severity as major predictors of in-hospital WRF [16]. Baseline renal dysfunction (eGFR <70 mL/min) was strongly associated with WRF, consistent with Damman et al., who demonstrated that impaired baseline renal function is a powerful predictor of WRF and adverse outcomes in heart failure [4]. The significant association between NT-proBNP >5000 pg/mL and WRF is consistent with the findings of Wettersten et al., who demonstrated that persistently elevated natriuretic peptide levels identify patients with persistent congestion in whom WRF is associated with adverse clinical outcomes [29]. Urinary TIMP-2×IGFBP-7 >0.312 was the strongest predictor of WRF in our study. Schanz et al. showed that urinary [TIMP-2]×[IGFBP-7] accurately predicts acute kidney injury in acute decompensated heart failure [26]. Diabetes mellitus, previous HF admission, reduced eGFR, hypoalbuminaemia, elevated NT-proBNP, and urinary TIMP-2×IGFBP-7 are key predictors of WRF. Forman et al. demonstrated that diabetes and prior HF independently increase WRF risk, while Damman et al. identified impaired baseline eGFR as a major determinant of renal deterioration

[4,16]. Wettersten et al. reported that elevated NT-proBNP reflects persistent congestion and predicts adverse outcomes [29].

LIMITATIONS

- Only hospitalized patients with baseline serum creatinine <1.3 mg/dL were included; therefore, the results may not be applicable to patients with pre-existing chronic kidney disease or advanced renal dysfunction.
- Worsening renal function was assessed only during hospitalization, and long-term renal recovery, rehospitalization, and mortality outcomes were not evaluated.

CONCLUSION

Worsening renal function is a common complication among patients hospitalized with acute heart failure and is associated with prolonged hospitalization and increased need for intensive care. Diabetes mellitus, previous heart failure admission, reduced baseline eGFR, hypoalbuminemia, elevated NT-proBNP, and urinary TIMP-2×IGFBP-7 were identified as independent predictors of worsening renal function. Among these, urinary TIMP-2×IGFBP-7 demonstrated the strongest predictive association, highlighting its potential role as an early biomarker for renal injury in acute heart failure. Incorporating clinical risk factors together with novel renal biomarkers may facilitate early identification of high-risk patients, guide individualized therapeutic strategies, and potentially improve short-term clinical outcomes. Larger multicenter studies with long-term follow-up are warranted to validate these findings and determine their impact on clinical practice.

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CONFLICT OF INTEREST

None declared

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee.

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