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NEPHROLOGY - ORIGINAL PAPER

Association of the blood urea nitrogen-to-left ventricular ejection fraction ratio with contrast-induced nephropathy in patients with acute coronary syndrome who underwent percutaneous coronary intervention

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Abstract

Aim We investigated the predictive value of the blood urea nitrogen-to-left ventricular ejection fraction ratio (BUNEFr) to evaluate the risk of contrast-induced nephropathy (CIN) in acute coronary syndrome (ACS) patients who were treated with percutaneous coronary intervention (PCI).

Methods A total of 1010 ACS patients undergoing PCI were included in this study. The serum creatinine level was measured before and within 48–72 h of contrast medium administration. Contrast-induced nephropathy was defined as an absolute increase of 0.3 mg/dL or a relative increase of 25% from baseline serum creatinine within 48–72 h of contrast medium exposure. To evaluate the relation between BUNEFr and CIN, the patients were divided into a CIN group and a no-CIN group.

Results A total of 74 patients developed CIN (7.3%). Patients with CIN were older and had a higher BUNEFr than those without. Multivariate analysis showed that age, hypotension or positive inotrope support, history of stroke, contrast volume, and BUNEFr (OR 10.59, 95% CI 2.803–40.070, $p=0.001$) were independent predictors of CIN. For the development of CIN, the AUC of a multivariable model that included hypotension or positive inotrope support, history of stroke, and contrast volume was 0.813 (95% CI 0.758–0.857, $p<0.001$). When BUNEFr was added to a multivariable model, the AUC was 0.859 (95% CI 0.814–0.894, $z=3.204$, difference $p=0.0014$). Moreover, the addition of BUNEFr to a multivariable model was associated with a significant net reclassification improvement estimated at 49.4% ($p<0.001$) and an integrated discrimination improvement of 0.044 ($p=0.0138$).

Conclusion The BUNEFr may be a useful new predictor of CIN in ACS patients treated with PCI. The inclusion of BUNEFr in a multivariable model could allow improved risk classification in these patients regarding the development of CIN.

Keywords Acute coronary syndrome · Contrast-induced nephropathy · Blood urea nitrogen to left ventricular ejection fraction

Introduction

Contrast-induced nephropathy (CIN) is a common and potentially severe complication in patients with acute coronary syndrome (ACS) who were undergoing percutaneous coronary intervention (PCI) [1]. The presence of CIN is also associated with increased morbidity and mortality [2]. The incidence of CIN ranges from 2 to 30% due to variations in study populations, clinical settings, and CIN definitions [3–6]. The exact pathogenesis of CIN is not known; multiple mechanisms, such as continuous intrarenal vasoconstriction, the direct toxic effect of the contrast agent, hypoxia in the renal medulla, ischemic damage, oxidative stress, and inflammation, may be responsible for the development of CIN [7].

Blood urea nitrogen (BUN) is one of the markers of kidney function [8]. Blood urea nitrogen may also serve as a comprehensive marker reflecting impaired cardiology function and neurohormonal activation [8]. It has been shown

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that BUN was associated with mortality in patients with acute myocardial infarction [9]. Because BUN reflects both glomerular filtration rate (GFR) and neurohormonal activations, it may serve as a marker of CIN compared with creatinine. The left ventricular ejection fraction (LVEF) was found to be a predictor for CIN in other risk models [10].

In this study, we investigated the role of the BUN-to-LVEF ratio in predicting CIN in patients with ACS who were undergoing PCI. We also evaluated the predictive value of a model incorporating BUNEFr, along with established clinical risk factors, and evaluated its diagnostic performance.

Methods

Study population

We retrospectively evaluated 1140 consecutive patients with ACS who were treated with PCI between January 2008 and July 2015. We excluded those patients who died during coronary angiography/PCI, were on chronic dialysis, had a GFR < 30 (mL/minute/1.73 m^2), had a recent history of gastrointestinal bleeding, did not have serum creatinine within 48–72 h of contrast medium exposure, were using a diuretic before admission, were taking intravenous fluid replacement, did not have a measurement of contrast volume, did not have an echocardiogram during admission, or lacked follow-up. The remaining 1010 patients made up the final study population. To evaluate the association of BUNEFr with CIN, the patients were divided into a CIN group and a no-CIN group. This study was approved by the Institutional Research and Ethics Committee.

Blood sampling and echocardiographic analysis

Blood samples were taken before PCI. Creatinine was measured at admission and 48–72 h post-procedure. Blood urea nitrogen was measured at admission. Echocardiographic examinations were performed soon after ACS diagnosis using transthoracic echocardiography in all patients. Both echocardiography and BUN measurements were performed on the same day before PCI. The LVEF was calculated after measuring the end-diastolic and end-systolic left ventricular (LV) volumes in the apical four-chamber and two-chamber views using the modified Simpson's method. Baseline estimated glomerular filtration rate (eGFR) was calculated using the modification of diet in renal disease (MDRD-4) equation.

Definitions

According to the criteria of the universal definition of myocardial infarction, diagnosis was established through the detection of an increasing or decreasing pattern in cardiac troponin I values, with at least one measurement above the 99th percentile of the upper reference limit together with evidence of myocardial ischemia [11]. A diagnosis of ACS was established and classified as unstable angina (UA), non-ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI) based on clinical findings, ischemic electrocardiographic changes, and elevated cardiac markers according to current guidelines [12, 13]. Cardiovascular risk factors (arterial hypertension, diabetes mellitus, hypercholesterolemia, and smoking) were defined according to the accepted current criteria.

CIN was defined as a rise of 0.3 mg/dL or 25% in post-procedure (48–72 h) creatinine from baseline using the modified Acute Kidney Injury Network (AKIN) classification [14]. The BUNEFr was defined as the BUN-to-LVEF ratio. Hypotension was defined as systolic blood pressure < 80 mmHg for at least 1 h requiring inotropic support with medications within 24 h periprocedurally.

Treatment

All coronary angiography and PCI procedures were performed via the transfemoral approach by experienced interventional cardiologists. Coronary angiography with subsequent PCI was performed in both the UA and NSTEMI patients within the first 48 h. Primary PCI for STEMI was made according to the current guidelines [13]. The diagnosis of CAD was established by coronary angiography in all patients and consisted of the documentation of significant disease (defined as coronary stenoses ≥ 50%, luminal narrowing in at least one of the major coronary arteries, or an infarct-related artery). Multivessel disease was defined as at least 50% diameter stenosis of two or more epicardial coronary arteries or the left main artery by visual estimation. The angiographic data of the patients were evaluated from catheter laboratory records. All patients were treated according to good clinical practice and the current guidelines [12, 13]. The type of stent and the use of thrombectomy devices, predilation, poststenting adjunctive balloon inflation, intravascular ultrasound, intra-aortic balloon counterpulsation (IABP), or glycoprotein IIb/IIIa inhibitors were all left to the operators' discretion. Both aspirin (100 mg/day) and clopidogrel (75 mg/day) or prasugrel (10 mg/day) or ticagrelor (90 mg twice daily) were maintained for at least 12 months, followed by indefinite single antiplatelet therapy in our study. Beta-blockers, angiotensin-converting enzyme inhibitors, and statins were administered according to the European Society of Cardiology guidelines [12, 13].

Statistical analysis

Continuous variables were presented as mean ± standard deviation, and categorical variables were displayed as counts

and percentages. The comparison of parametric values between the two groups was performed using the Student's *t* test when distribution was normal or the Mann–Whitney *U* test as appropriate. A chi-squared test was used to compare the categorical variables between the groups. A multivariate logistic regression analysis was performed to evaluate whether a high BUNEFr was an independent predictor for CIN. Factors with a *p* value of <0.1 by univariate analysis were included in multivariate regression analysis. The predictive values of BUN, LVEF, creatinine, BUNEFr, and a combination of BUNEFr and a multivariable model were estimated by comparing the areas under the receivers operating characteristic (ROC) curve. We used DeLong's test to compare the AUC from each of the models [15], which were evaluated using the NCSS 12 software program. Moreover, the increased discriminative value after the addition of BUNEFr to a multivariable model was also estimated using net reclassification improvement (NRI) and integrated discrimination improvement [16]. Differences were considered significant at the two-sided $p<0.05$ level. All statistical analyses were performed using SPSS version 16 (SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics

A total of 74 patients developed CIN (7.3%). The patients with CIN were older than those in the no-CIN group. The rate of female gender was higher in the CIN group than the no-CIN group. The baseline characteristics of the study patients are presented Table 1.

Patients in the CIN group had a higher prevalence of stroke/TIA than those in the no-CIN group. Histories of heart failure and a higher Killip class were more frequent in patients in the CIN group than the no-CIN group. The use of IABP and inotropic support or hypotension were more common in the CIN group than the no-CIN group (Table 1). Patients with CIN had higher rates of anemia and renal dysfunction.

Table 1 Baseline characteristics of the study population

Variable	No CIN ($n=936$)	CIN ($n=74$)	*p* value
Age (year)	60.3 ± 11.8	70.7 ± 10.6	<0.001
Age > 75 years *n* (%)	119 (13)	28 (38)	<0.001
Female *n* (%)	230 (25)	30 (41)	0.002
History of HF *n* (%)	8 (1)	8 (11)	<0.001
Hypertension *n* (%)	453 (48)	44 (60)	0.067
Diabetes mellitus *n* (%)	228 (24)	24 (32)	0.122
Hyperlipidemia *n* (%)	216 (23)	13 (18)	0.276
Current smoking *n* (%)	398 (43)	18 (24)	0.002
Previous CAD *n* (%)	227 (24)	23 (31)	0.190
Prior stroke/TIA *n* (%)	27 (3)	10 (14)	<0.001
Killip class ≥ 2 *n* (%)	53 (6)	20 (27)	<0.001
IABP usage *n* (%)	22 (2)	9 (12)	<0.001
Hypotension or positive inotrope *n* (%)	18 (2)	14 (19)	<0.001
Anemia *n* (%)	206 (22)	30 (41)	<0.001
Type of ACS			0.976
STEMI *n* (%)	550 (59)	45 (61)	
NSTEMI *n* (%)	274 (29)	21 (28)	
USAP *n* (%)	112 (12)	8 (11)	
Angiographic findings			
IRA			0.833
LAD *n* (%)	393 (42)	34(46)	
CX *n* (%)	160 (17)	15 (20)	
RCA *n* (%)	313 (34)	20 (27)	
Others *n* (%)	66 (7)	9 (7)	
Multivessel disease *n* (%)	304 (33)	38 (52)	0.001
Furosemide usage *n* (%)	74 (9)	23 (32)	<0.001
Tirofiban usage *n* (%)	244 (26)	19 (26)	0.941

BUNEFr blood urea nitrogen-to-left ventricular ejection fraction ratio, *HF* heart failure, *CAD* coronary artery disease, *TIA* transient ischemic attack, *IABP* intra-aortic balloon counterpulsation, *IRA* the infarct-related artery, *LAD* left anterior descending artery, *CX* left circumflex artery, *RCA* right coronary artery, *CIN* contrast-induced nephropathy

*Comparison was made using Mann–Whitney *U* test at $p < 0.05$, and these values were described by median with inter-quartile range (25th and 75th percentile)

Laboratory findings

The laboratory variables of the groups are shown in Table 2. The LVEF was significantly lower in the CIN group than the no-CIN group ($42\pm11\%$ vs $50\pm10\%$, $p<0.001$). Patients in the CIN group had higher levels of BUN than those in the no-CIN group (22.0 ± 6.2 vs 16.9 ± 6.7, $p<0.001$). Moreover, BUNEFr was higher in the CIN group than the no-CIN group (Table 2).

Angiographic and procedural characteristics

The angiographic and procedural characteristics of the patients are provided in Tables 1 and 2. Tirofiban use did not differ significantly between the two groups, whereas the rate of multivessel disease and in-hospital furosemide usage were higher in the CIN group than the no-CIN group (52% vs 33%, $p=0.001$; 32% vs 9%, $p<0.001$, respectively). The contrast volume was also higher in patients in the CIN group than those in the no-CIN group (187 ± 74 cc vs 160 ± 55 cc, $p<0.001$) (Table 2).

Table 2 The laboratory findings of study population

Variable	No CIN ($n=936$)	CIN ($n=74$)	p value
Total cholesterol (mg/dl)	179 ± 44	171 ± 39	0.302
SCr* $_{adm}$ (mg/dl)	0.86 (0.76–1.02)	0.99 (0.84–1.34)	< 0.001
Cr > 1.5 mg/dl *n* (%)	30 (3)	11 (15)	< 0.001
eGFR (mL/minute/1.73 m^2)	85.2 ± 20.3	65.9 ± 20.4	< 0.001
eGFR < 60 mL/minute/1.73 m^2	133 (14)	34 (46)	< 0.001
BUN (mg/dl)	16.9 ± 6.7	22.0 ± 6.2	< 0.001
Hemoglobin (g/dl)	13.9 ± 1.9	12.9 ± 2.0	< 0.001
LVEF (%)	50 ± 10	42 ± 11	< 0.001
Contrast volume (cc)	160 ± 55	187 ± 74	< 0.001
BUNEFr	0.36 ± 0.16	0.58 ± 0.28	< 0.001

LVEF left ventricular ejection fraction, *SCr* serum creatinine at admission, *eGFR* estimated glomerular filtration rate, *BUNEFr* blood urea nitrogen-to-left ventricular ejection fraction ratio

*Comparison was made using Mann–Whitney *U* test at $P < 0.05$, and these values were described by median with inter-quartile range (25th and 75th percentile)

BUNEFr and CIN

Independent risk factors for CIN were age, history of stroke/TIA, contrast volume, hypotension or positive inotropic support, and BUNEFr (OR 10.599, 95% CI 2.803–40.070, $p=0.001$) (Table 3). The performance of BUNEFr for predicting CIN in these patients (Fig. 1) was better than BUN alone (BUNEFr vs BUN: AUC 0.786 vs 0.747, $z=2.299$, $p=0.0215$), LVEF alone (BUNEFr vs LVEF: AUC 0.786 vs 0.685, $z=3.657$, $p=0.0003$), and creatinine alone (BUNEFr vs creatinine: AUC 0.786 vs 0.674, $z=3.639$, $p=0.0003$). Using ROC curve analysis (Fig. 2), the resulting model, which included hypotension or positive inotrope support, history of stroke, contrast volume, age, and BUNEFr, showed good accuracy in predicting the development of CIN (AUC 0.859 [95% CI 0.814–0.894], $p < 0.001$). Compared to a model incorporating only age, hypotension or positive inotrope support, history of stroke, and contrast volume

Table 3 Univariate and Multivariate logistic regression analysis for CIN

Variables	Univariate		Multivariate	
	OR (95% CI)	p value	OR (95% CI)	p value
Age (year)	1.081 (1.056–1.106)	< 0.001	1.049 (1.017–1.082)	0.003
Killip class ≥ 2	6.171 (3.444–11.055)	< 0.001		
BUN* (mg/dl)	1.084 (1.053–1.115)	< 0.001		
Hemoglobin levels (mg/dl)	0.787 (0.700–0.886)	< 0.001		
Admission creatinine levels (mg/dl)*	5.995 (2.952–12.174)	< 0.001		
GFR (mL/minute/1.73 m^2)	0.960 (0.949–0.971)	< 0.001		
LVEF* (%)	0.932 (0.910–0.954)	< 0.001		
BUNEFr	76.797 (26.662–221.204)	< 0.001	10.599 (2.803–40.070)	0.001
In-hospital furosemide usage	4.992 (2.877–8.664)	< 0.001		
Hypotension /positive inotrop	11.900 (5.646–25.083)	< 0.001	3.543 (1.128–11.126)	0.030
Multivessel disease	2.229 (1.380–3.599)	0.001		
IABP	5.752 (2.545–13.000)	< 0.001		
Stroke/TIA	5.260 (2.439–11.345)	< 0.001	3.075 (1.210–7.815)	0.018
Hypertension	1.564 (0.966–2.531)	0.069		
History of CHF*	14.061 (5.115–38.655)	< 0.001		
Contrast volume (cc)	1.005 (1.002–1.008)	< 0.001	1.004 (1.001–1.007)	0.033
Male gender	0.478 (0.293–0.778)	0.003		

LVEF left ventricular ejection fraction, *BUN* blood urea nitrogen, *BUNEFr* blood urea nitrogen-to-left ventricular ejection fraction ratio, *IABP* intra-aortic balloon counterpulsation, *TIA* transient ischemic attack, *CHF* congestive heart failure

*These parameters are not entered to the model in order to prevent multicollinearity

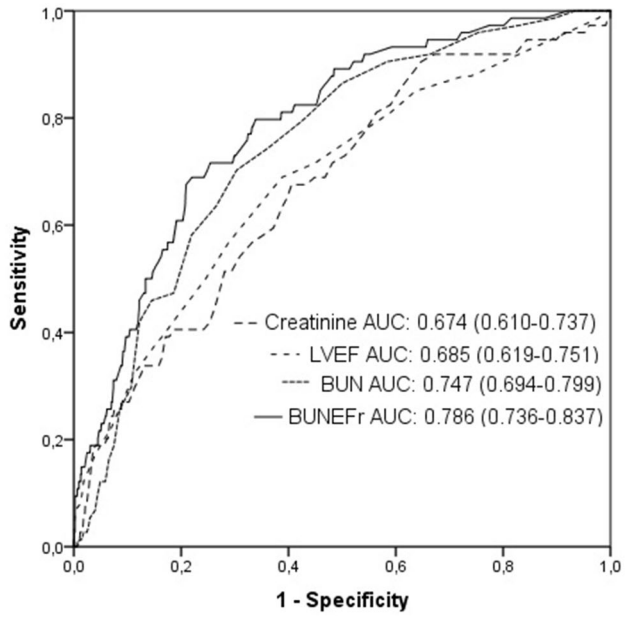

Fig. 1 Receiver operating characteristic (ROC) curves for BUN, LVEF, creatinine, and the BUNEFr for predicting CIN

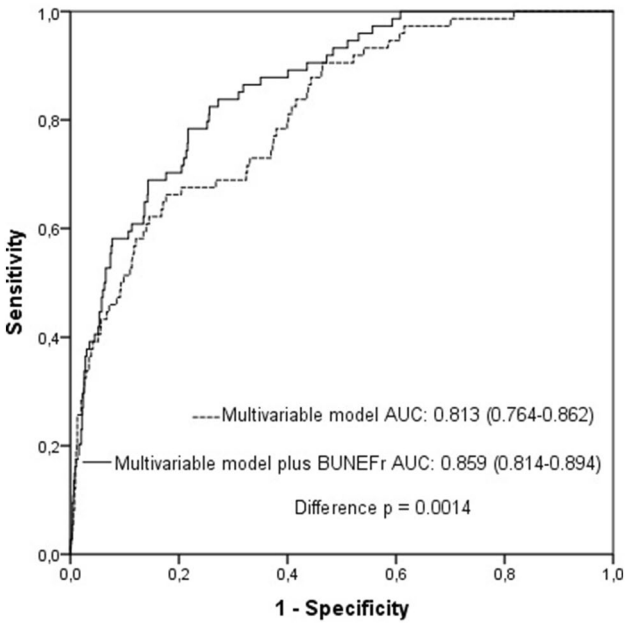

Fig. 2 Receiver operating characteristic (ROC) curves for a multivariable model and BUNEFr plus a multivariable model for predicting CIN

(AUC 0.813 [95% CI 0.758–0.857], $p < 0.001$), the model with the addition of BUNEFr demonstrated a significantly improved accuracy ($p = 0.0014$). Moreover, the addition of BUNEFr to a multivariable model was associated with a significant net reclassification improvement estimated at 49.4% ($p < 0.001$) and an integrated discrimination improvement of 0.044 ($p = 0.0138$). Also, we calculated the predictive values of both model including age, hypotension or positive inotrope support, history of stroke, and contrast volume plus LVEF and BUN plus model for CIN. AUCs of these combinations were 0.841 and 0.819, respectively. Compared with these combinations, BUNEFr plus model was higher predictive value for CIN (AUC 0.859 vs 0.841, $z = 2.117$, $p = 0.0343$ for BUNEFr plus model vs LVEF plus model; AUC 0.859 vs 0.819, $z = 2.317$, $p = 0.0205$ for BUNEFr plus model vs BUN plus model, Fig. 3).

In subgroup analysis, we investigated the prognostic role of BUN both in patients with normal renal function [GFR ≥ 60 (mL/minute/1.73 m^2)] and with reduced renal function [GFR < 60 (mL/minute/1.73 m^2)]. We found statistically a relationship between BUNEFr and CIN in both patient groups (OR 12.011, 95% CI 1.450–99.511, $p = 0.021$ in reduced renal function group, OR 15.078, 95% CI 2.523–90.103, $p = 0.003$ in normal function group).

Discussion

This study demonstrated that BUNEFr is an independent predictor of CIN in ACS patients treated with PCI. To the best of our knowledge, this is the first study that investigates the BUNEFr for predicting CIN in these patients. Moreover, the present study showed that the predictive accuracy of a model that included hypotension or positive inotrope support, history of stroke, contrast volume, and BUNEFr was

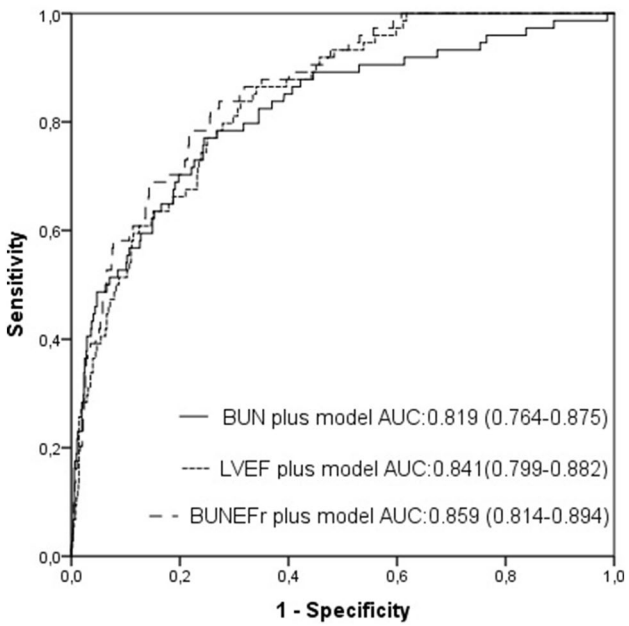

Fig. 3 Receiver operating characteristic (ROC) curves for a multivariable model plus BUNEFr, LVEF plus a multivariable model, and a multivariable model plus BUN for predicting CIN

higher than that of a model incorporating only hypotension or positive inotrope support, history of stroke, and contrast volume in these patients.

Blood urea nitrogen is one of the markers of renal function, and its concentration is determined via balance and absorption in the kidneys. The rate of production and the rate of elimination of urea determine its plasma level in the steady state. Both production and renal elimination of urea vary greatly and are influenced by various factors [17, 18]. Urea is filtered in the glomeruli and reabsorbed along the tubules. When production of urea is not changed, changes in GFR and/or in tubular urea reabsorption, dependent on ADH serum levels as the authors indicate [17], are sources of wide variations in serum urea levels. This is relevant to patients with advanced congestive heart failure, which causes both decrease in GFR and secretion of ADH. It has been shown that Norepinephrine may also lead to an increase in BUN levels [18]. There was a relationship between a high BUN level and activation of the renin-angiotensin-aldosterone and sympathetic nerve systems showing renal hypoperfusion from hypovolemia, renovascular disease, and reduced cardiac output in addition to reduced GFR. Thus, BUN may serve as an indicator of both cardiorenal dysfunction and neurohumoral activation [22]. The LVEF is most commonly used as a tool to assess cardiac function related to hemodynamic instability and ultimately leads to deterioration of renal perfusion. Shacham et al. showed that low LVEF was associated with CIN in patients undergoing PCI [19]. In that study, worsened LVEF was an independent predictor of CIN [19]. The AGEF risk score, which includes age, low LVEF, and reduced GFR, showed there to be a relationship between low EF and risk of CIN [20]. The Chen risk score includes LVEF and other vital risk factors for CIN [21]. Gohbara et al. found that low LVEF was associated with CIN in STEMI patients [22]. A reduced left ventricular ejection fraction may imply diuretic therapy and low output states, which are possible factors involved in CIN.

The use of IABP as a marker of significant hemodynamic disturbances during PCI may be associated with the development of CIN [23]. The use of IABP is generally required to provide hemodynamic support to patients with cardiogenic shock in the event of unexpected hypotension and hemodynamic deterioration during complex and high-risk PCI. It has been shown that hypotension and IABP without hypotension was associated with the development of CIN [23]. In our study, the use of IABP and furosemide were more common in the CIN group than the no-CIN group. The rates of high Killip class, history of heart failure, and hypotension/inotropic support usage were higher in the CIN group than the no-CIN group. These unfavorable hemodynamic settings may lead to activation of the renin-angiotensin-aldosterone and sympathetic nerve systems and cause reabsorption of BUN at distal nephron. Therefore, an increased BUNEFr at admission may be mark of impaired cardiorenal functions and negative neurohormonal activation. Moreover, the frequencies of hypertension and anemia, which are known risk factors for CIN, were more common in the CIN group than the no-CIN group. The CIN group was also older than the no-CIN group. All of them may cause the development of CIN in these patients.

As the treatment of CIN is rather limited, and CIN always leads to a prolonged hospital stay, and worse in-hospital and long-term clinical outcomes, a practical and effective solution to this complication is its prevention. Therefore, the prediction of CIN has a pivotal role in ACS patients treated with PCI. The BUNEFr, as a reflection of both kidney and non-kidney pathophysiological pathways, may help the interventional team to prevent the development of CIN via various procedures, such as a reduced dose of contrast volume followed by sufficient hydration or combined with pharmacological prophylaxis. Moreover, by incorporating BUNEFr into a prognostic model with other easily obtainable parameters, its predictive value is improved.

The current study has several limitations. First, this analysis was a retrospective study, and it is possible that identified or unidentified cofounders were not fully adjusted and influenced the result of this study. Second, several factors that can affect the BUN level, such as diet and muscle mass before the assessment of BUN, were not recorded. Moreover, in the most of the patients, we do not have data about clinical estimation of fluid status of patients such as mentation capillary refill, skin turgor/dryness, urine output. Also, there are missing data regarding inferior vena cava diameter in the most of the patients. Third, we did not study the use of baseline medications, which may impact the incidence of CIN.

Conclusion

The BUNEFr could be a useful early predictor for CI-AKI in patients with ACS who were treated PCI. Moreover, the inclusion of BUNEFr into a multivariable model could allow improved risk classification for these patients in terms of the development of CIN.

Compliance with ethical standards

Conflict of interest Tuncay Kiris, Eyup Avci, and Aykan Celik declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Marenzi G, Lauri G, Assanelli E, Campodonico J, De Metrio M, Marana I, Grazi M, Veglia F, Bartorelli AL (2004) Contrastinduced nephropathy in patients undergoing primary angioplasty for acute myocardial infarction. J Am Coll Cardiol 44:1780–1785
2. Abe M, Morimoto T, Akao M et al (2014) Relation of contrast-induced nephropathy to long-term mortality after percutaneous coronary intervention. Am J Cardiol 114(3):362–368
3. Rihal CS, Textor SC, Grill DE et al (2002) Incidence and prognostic importance of acute renal failure after percutaneous coronary intervention. Circulation 105:2259–2264
4. McCullough PA, Wolyn R, Rocher LL, Levin RN, O'Neill WW (1997) Acute renal failure after coronary intervention: incidence, risk factors, and relationship to mortality. Am J Med 103:368–375
5. Xu H, Li W, Yang J et al (2016) The China Acute Myocardial Infarction (CAMI) Registry: a national long-term registryresearch- education integrated platform for exploring acute myocardial infarction in China. Am Heart J 175:193–201.e3
6. Silvain J, Nguyen LS, Spagnoli V, Kerneis M, Guedeney P, Vignolles N, Cosker K, Barthelemy O, Le Feuvre C, Helft G, Collet JP, Montalescot G. Contrast-induced acute kidney injury and mortality in ST elevation myocardial infarction treated with primary percutaneous coronary intervention. Heart. 2017
7. McCullough PA (2008) Contrast-induced acute kidney injury. J Am Coll ardiol 51:1419–1428
8. Schrier RW (2008) Blood urea nitrogen and serum creatinine: not married in heart failure. Circulation 1(1):2–5
9. Horiuchi Y, Aoki J, Tanabe K, Nakao K, Ozaki Y, Kimura K, Ako J, Yasuda S, Noguchi T, Suwa S, Fujimoto K, Nakama Y, Morita T, Shimizu W, Saito Y, Hirohata A, Morita Y, Inoue T, Okamura A, Uematsu M, Hirata K, Shibata Y, Nakai M, Nishimura K, Miyamoto Y, Ishihara M; J-MINUET investigators (2018) A high level of blood urea nitrogen is a significant predictor for in-hospital mortality in patients with acute myocardial infarction. Int Heart J 59(2):263–271
10. Lazaros G, Zografos T, Oikonomou E, Siasos G, Georgiopoulos G, Vavuranakis M, Antonopoulos A, Kalogeras K, Tsalamandris S, Tousoulis D (2016) Usefulness of C-reactive protein as a predictor of contrast-induced nephropathy after percutaneous coronary interventions in patients with acute myocardial infarction and presentation of a new risk score (Athens CIN Score). Am J Cardiol 118(9):1329–1333
11. Thygesen K, Alpert JS, Jaffe AS et al (2012) Third universal definition of myocardial infarction. Circulation 126(16):2020–2035
12. Steg PG, James SK, Atar D et al (2012) ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Task force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC). Eur Heart J 33(20):2569–2619
13. Hamm CW, Bassand JP, Agewall S et al (2011) ESC committee for practice guidelines. ESC guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: the task force for the management of acute coronary syndromes (ACS) in patients presenting without persistent ST-segment elevation of the European Society of Cardiology (ESC). Eur Heart J 32(23):2999–3054
14. Lakhal K, Ehrmann S, Chaari A, Laissy JP, Re´gnier B, Wolff M et al (2011) Acute kidney injury network definition of contrast-induced nephropathy in the critically ill: incidence and outcome. J Crit Care 26:593–599
15. DeLong ER, DeLong DM, Clarke-Pearson DL (1988) Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 44(3):837–845
16. Pencina MJ, D'Agostino Sr RB, Steyerberg EW (2011) Extensions of net reclassification improvement calculations to measure usefulness of new biomarkers. Stat Med 30:11–21
17. Conte G, Dal Canton A, Terribile M et al (1987) Renal handling of urea in subjects with persistent azotemia and normal renal function. Kidney Int 32:721–727
18. Cohn JN, Levine TB, Olivari MT et al (1984) Plasma norepinephrine as a guide to prognosis in patients with chronic congestive heart failure. N Eng J Med 311:819–823
19. Shacham Y, Leshem-Rubinow E, Gal-Oz A et al (2015) Association of left ventricular function and acute kidney injury among ST-elevation myocardial infarction patients treated by primary percutaneous intervention. Am J Cardiol 115(3):293–297
20. Andò G, Morabito G, de Gregorio C, Trio O, Saporito F, Oreto G (2013) Age, glomerular filtration rate, ejection fraction, and the AGEF score predict contrast-induced nephropathy in patients with acute myocardial infarction undergoing primary percutaneous coronary intervention. Catheter Cardiovasc Interv 82(6):878–885
21. Lin KY, Zheng WP, Bei WJ, Chen SQ, Islam SM, Liu Y, Xue L, Tan N, Chen JY (2017 Mar) A novel risk score model for prediction of contrast-induced nephropathy after emergent percutaneous coronary intervention. Int J Cardiol 1:230:402–412
22. Gohbara M, Hayakawa A, Akazawa Y, Furihata S, Kondo A, Fukushima Y, Tomari S, Endo T, Kimura K, Tamura K. Association between acidosis soon after reperfusion and contrast-induced nephropathy in patients with a first-time st-segment elevation myocardial infarction. J Am Heart Assoc. 2017 Aug 23;6(8)
23. Mehran R, Aymong ED, Nikolsky E, Lasic Z, Iakovou I, Fahy M, Mintz GS, Lansky AJ, Moses JW, Stone GW, Leon MB, Dangas G (2004) A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: de- velopment and initial validation. J Am Coll Cardiol 44:1393–1399