Hs-CRP to albumin ratio predicts mortality of acute myocardial infarction patients with chronic kidney disease undergoing coronary angiography

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Research

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Abstract

Background

The diagnosis and treatment of acute myocardial infarction (AMI) patients with chronic kidney disease (CKD) is still a challenging problem. The high sensitivity C-reactive protein (hs-CRP) to albumin ratio (HCAR) was proved to be a sensitive biomarker in predicting the prognosis of many diseases. The purpose of this study was to investigate the prognostic value of HCAR in postoperative 2-year mortality of AMI patients with CKD undergoing coronary angiography(CAG).

Methods

A total of 11933 patients undergoing CAG were collected in this retrospective study. Finally, 466 AMI patients with CKD undergoing CAG were enrolled. HCAR was calculated by dividing hs-CRP by albumin obtained from blood biochemical examination. Patients were divided into two groups according to the HCAR cutoff value in predicting 2-year mortality by Receiver operating characteristic (ROC) curve analysis. The primary endpoint was all-cause mortality at a 2-year follow-up. The Kaplan-Meier method and Cox regression analyses were used to analyze the survival of patients.

Results

A significant correlation was found between HCAR and NT-proBNP, LVEF, CK-MB, TnI and eGFR ($P < 0.05$). A cut-off value of 0.24 of HCAR predicted 2-year mortality, with a sensitivity of 66.18% and specificity of 52.21% (ROC area under the curve: 0.60, 95% CI: 0.53–0.68, $P < 0.001$). A higher HCAR was significantly associated with a higher 2-year mortality rate (45/236 (19%) vs. 23/230 (10%), $P = 0.006$). The Kaplan-Meier curve showed that the group with a higher HCAR had a worse prognosis (log-rank $P < 0.001$). HCAR was an independent risk factor for 2-year mortality (OR: 1.779, 95% CI: 1.017–3.112, $P = 0.043$).

Conclusion

HCAR might be a potential prognostic indicator of AMI patients with CKD undergoing CAG.

Introduction

Acute myocardial infarction (AMI), a localized necrosis of the myocardium caused by myocardial ischemia, is still a major contributor to mortality worldwide. Early-onset, more severe diseases and complications such as cardiac failure, arrhythmia, cardiogenic and shock are features of AMI. Percutaneous coronary intervention (PCI) is the main treatment for AMI patients. It can definitely promote the recovery of cardiac function, effectively increase the coronary blood flow and cardiac function reserve by 10%-30%, and significantly improve the prognosis and postoperative survival rate of AMI patients[1].

However, the treatment of AMI patients with chronic kidney disease (CKD) still poses a challenge. Low glomerular filtration rate, poor renal tubular function and lipid metabolism disorder may lead to complications such as contrast nephropathy and negative outcomes such as sudden cardiac death, arrhythmias, arterial calcification, valve calcification and hemorrhagic stroke, thus the postoperative survival rate and prognosis are less satisfactory[2, 3]. Literature has shown that as a common inflammatory biomarker in clinics, high sensitivity C-reactive protein (hs-CRP), mainly produced in hepatocytes, is of great value in rehabilitation assessment and associated with atherosclerosis progression and cardiovascular events. Besides, several studies have shown that it is also an independent risk factor for renal function injury[4–6]. In contrast, serum albumin (Alb), a negative phase agent, is preferable to reduce in inflammation. The decrease of Alb usually indicates the aggravation of inflammation, malnutrition and cachexia[7]. Moreover, studies have shown a significant association of low Alb with adverse cardiovascular outcomes in AMI patients, and the level of Alb is also one of the best predictors of mortality in patients with terminal renal failure[8, 9]. Studies have shown the CRP to Alb ratio could be used as a sensitive marker of inflammatory process and predicting the prognosis of patients with AMI, critical illness, malignant tumor and severe septicemia[10–13]. Thus, the hs-CRP to Alb ratio (HCAR), calculated by dividing hs-CRP by Alb obtained from clinical blood biochemical examination, may be more valuable in indicating higher residual inflammation with malnutrition status than either alone[14–16].

However, to the knowledge of the authors, no data have been reported on the comparable relationship between the HCAR and the risk of subsequent death in AMI patients with CKD. Therefore, this retrospective study was performed to investigate the relationship between HCAR and postoperative 2-year mortality of AMI patients with CKD undergoing CAG.

Methods

Study population and data collection

The present study was a single-center, observational, and retrospective study carried out between January 2013 and August 2019. All the data and follow-up records were derived from Cardiovascular Center of Beijing Friendship Hospital Bank(CCB Bank). A total of 11933 patients undergoing CAG were collected. This study included 558 patients with CKD, which was defined as an estimated glomerular filtration rate (eGFR) of less than 60 mL/minute/1.73 m², as calculated by the MDRD equation, and modified with a Japanese coefficient using baseline serum creatinine. Patients with severe infection or malignancies, lacking complete medical records or lost follow-up were excluded (Fig. 1). A total of 466 patients met the eligibility criteria and were enrolled in the study. Subsequently, the patients were divided into two groups according to the HCAR cutoff value in predicting 2-year mortality by the Receiver operating characteristic (ROC) curve analysis. This study was approved by the ethics committee of Beijing Friendship Hospital, Capital Medical University and written informed consent was obtained from all patients

Laboratory analysis

The blood samples were collected on the morning of the second day after hospitalization. Blood parameters including serum hs-CRP and albumin levels were detected. The HCAR was determined by dividing serum hs-CRP by serum albumin. Left ventricular ejection fraction (LVEF) was calculated using Simpson's method.

Statistical analysis

SPSS 21.0 was used for statistical analysis. Normally distributed continuous variables were presented as mean $\pm$ standard deviation, and those with non-normal distribution were presented as median (25th–75th), while continuous variables were analyzed using Student's t-test or non-parametric test. Categorical variables were described as absolute values and percentages, and analyzed by the chi-square test. The ROC curve analysis was performed, and Youden index was used to determine the best cut-off value for the HCAR. The Kaplan-Meier method was conducted using the log-rank test. The Cox proportional hazards regression model was used to analyze the independent predictor of mortality. The results with a *P*-value < 0.05 were considered statistically significant.

Results

The baseline demographic and biochemical characteristics of all 466 patients are listed in Table 1. Among the 466 patients enrolled in the study, the mean age was 72.98 ± 10.12 years old. 257 were male, 76 were of CKD 5 Stage and 390 were of CKD 3–4 Stage. The median HCAR was 0.25(0.08–0.65).

Table 1
Baseline Characteristics of the Study Population based on HCAR Level

Characteristics	Total (n = 466)	Lower HCAR (n = 230)	Higher HCAR (n = 236)	P
Demographic				
Age(years)	72.98 ± 10.12	73.60 ± 9.17	72.37 ± 10.95	0.191
Male, n (%)	257(55%)	121(52%)	136(58%)	0.276
BMI (kg/m ²)	25.34 ± 3.75	25.21 ± 3.57	25.47 ± 3.92	0.458
SBP (mmHg)	135.09 ± 24.99	137.50 ± 24.54	132.73 ± 25.25	0.039
DBP (mmHg)	73.09 ± 12.85	74.02 ± 12.80	72.18 ± 12.87	0.122
Medical history				
HT, n (%)	394(85%)	198(86%)	196(83%)	0.365
DM, n (%)	206(44%)	107(47%)	99(42%)	0.32
Family history, n (%)	110(24%)	56(24%)	54(24%)	0.709
Previous CAG, n (%)	116(24%)	75(33%)	38(16%)	< 0.001
Stroke	110(24%)	55(24%)	55(23%)	0.877
Smoke, n (%)	224(48%)	104(45%)	120(51%)	0.244
Alcohol drink, n (%)	113(24%)	53(23%)	81(34%)	0.008
CKD 5 Stage, n (%)	76(16%)	30(13%)	46(19%)	0.06
Laboratory test				
eGFR(mL/min/1.73 m ²)	43.96 ± 15.30	45.51 ± 14.90	42.44 ± 15.56	0.03
BUN (μmol/L)	7.79 (5.83–10.74)	7.43 (5.91–10.14)	8.09 (5.74–11.27)	0.209
Serum K(mmol/L)	4.27 ± 0.48	4.22 ± 0.43	4.32 ± 0.52	0.23
Serum Na(mmol/L)	139.48 ± 6.84	140.38 ± 3.48	138.63 ± 8.88	0.006
TG(mmol/L)	1.40(1.03–1.95)	1.41(1.03–2.07)	1.39(1.03–1.92)	0.718

DM, diabetes mellitus; FBG, fasting blood-glucose; HDL, high-density lipoprotein; HGB, Hemoglobin; HT, hypertension; LDL, low-density lipoprotein; TC, total cholesterol; TG, triglyceride; UA, uric acid. eGFR, Estimated Glomerular Filtration Rate; CKD, chronic kidney disease; CAG, Coronary angiography; BUN, blood urea nitrogen; HbA1C, Hemoglobin A1C; WBC, WBC: white blood cell; ALT, alanine aminotransferase; AST, Aspartate Aminotransferase; CK-MB, Aspartate Aminotransferase; Tnl, troponin I; LVEF, left ventricular ejection fraction; HCAR, hs-CRP /albumin ratio.

Characteristics	Total (n = 466)	Lower HCAR (n = 230)	Higher HCAR (n = 236)	P
TC(mmol/L)	4.28 ± 1.07	4.28 ± 1.14	4.29 ± 1.00	0.963
LDL-C(mmol/L)	2.45 ± 0.78	2.44 ± 0.82	2.47 ± 0.75	0.713
HDL-C(mmol/L)	1.03 ± 0.24	1.04 ± 0.24	1.02 ± 0.24	0.67
HbA1C(%)	6.30 (5.78–7.30)	6.30 (5.80–7.20)	6.30 (5.75–7.45)	0.789
FBG(mmol/L)	5.98 (5.03–8.36)	5.77 (4.80–7.84)	6.42 (5.25–8.59)	< 0.001
WBC(10 ⁹ /L)	7.83(5.97–9.63)	6.80 (5.40–8.60)	8.40 (6.91–10.75)	< 0.001
HGB (g/L)	123.86 ± 19.58	124.42 ± 19.62	123.31 ± 19.57	0.539
PLT (10 ⁹ /L)	215.47 ± 72.12	206.94 ± 63.79	223.78 ± 78.65	0.012
UA (μmol/L)	403.63 ± 104.42	397.06 ± 92.78	410.08 ± 114.55	0.188
ALT(U/L)	18.00(12.00–31.00)	17.00 (12.00–26.00)	20.00 (13.00–40.50)	0.003
AST(U/L)	30.00(18.00–71.00)	24.00(17.00–44.00)	40.00(19.30–113.50)	< 0.001
CK-MB(U/L)	4.00 (1.80 -15.05)	3.10 (1.60–7.70)	5.60 (2.20 -25.25)	< 0.001
Tnl(ng/ml)	0.87(0.11–3.66)	0.52(0.08–1.73)	1.72(0.17–6.90)	< 0.001
LVEF	0.56 ± 0.12	0.57 ± 0.11	0.55 ± 0.12	0.073
NT-proBNP(pg/ml)	6066(1990–15840)	3619(1406–10400)	9611(2859–22277)	< 0.001
Drug use after admission				
Antiplatelet, n (%)	436(94%)	221(96%)	215(91%)	0.04
ACEI/ARB, n (%)	316(68%)	160(70%)	156(66%)	0.503
β-blocker, n (%)	344(74%)	172(75%)	172(73%)	0.753
Statins, n (%)	410(88%)	207(90%)	203(86%)	0.178

DM, diabetes mellitus; FBG, fasting blood-glucose; HDL, high-density lipoprotein; HGB, Hemoglobin; HT, hypertension; LDL, low-density lipoprotein; TC, total cholesterol; TG, triglyceride; UA, uric acid. eGFR, Estimated Glomerular Filtration Rate; CKD, chronic kidney disease; CAG, Coronary angiography; BUN, blood urea nitrogen; HbA1C, Hemoglobin A1C; WBC, WBC: white blood cell; ALT, alanine aminotransferase; AST, Aspartate Aminotransferase; CK-MB, Aspartate Aminotransferase; Tnl, troponin I; LVEF, left ventricular ejection fraction; HCAR, hs-CRP /albumin ratio.

Characteristics	Total (n = 466)	Lower HCAR (n = 230)	Higher HCAR (n = 236)	P
2 year mortality, n (%)	68(15%)	23(10%)	45(19%)	0.006
DM, diabetes mellitus; FBG, fasting blood-glucose; HDL, high-density lipoprotein; HGB, Hemoglobin; HT, hypertension; LDL, low-density lipoprotein; TC, total cholesterol; TG, triglyceride; UA, uric acid. eGFR, Estimated Glomerular Filtration Rate; CKD, chronic kidney disease; CAG, Coronary angiography; BUN, blood urea nitrogen; HbA1C, Hemoglobin A1C; WBC, WBC: white blood cell; ALT, alanine aminotransferase; AST, Aspartate Aminotransferase; CK-MB, Aspartate Aminotransferase; Tnl, troponin I; LVEF, left ventricular ejection fraction; HCAR, hs-CRP /albumin ratio.				

The scatter diagrams and correlation analysis showed the correlation between HCAR and the indices reflecting the cardiac function, the severity of myocardial damage and renal function: NT-proBNP, LVEF, CK-MB, Tnl and eGFR (Fig. 2). Besides, the HCAR was significantly correlated with WBC ($r = 0.331$, $P < 0.001$), hs-CRP ($r = 0.996$, $P < 0.001$) and ALT ($r = 0.139$, $P = 0.003$), which indicated that MLR could also reflect both the degree of inflammation and hepatic function.

The ROC analysis was used to analyze HCAR efficiency in predicting 2-year mortality. A cut-off value of 0.24 of HCAR showed the best efficiency, with a sensitivity of 66.18% and specificity of 52.21% (ROC area under the curve: 0.60, 95% CI: 0.53–0.68, $P < 0.001$; Fig. 3A). The ROC curve was also used to assess HCAR efficiency in predicting the stage of CKD (Stage 3–4 vs. Stage 5), and a cut-off value of 0.15 had a sensitivity of 77.63% and specificity of 39.74% (ROC area under the curve: 0.61, 95% CI: 0.54–0.68, $P = 0.003$; Fig. 3B).

The patients were divided into 2 groups according to the HCAR cutoff value of 0.24 in predicting 2-year mortality. The group with a higher HCAR ($\text{HCAR} \leq 0.24$) included 236 patients (136 males, aged 72.37 ± 10.95 years old) and the group with a lower HCAR ($\text{HCAR} < 0.24$) included 230 patients (121 males, aged 73.60 ± 9.17 years old). Overall, the group with a higher HCAR had lower eGFR and higher FBG, WBC, PLT, ALT, AST, CK-MB, Tnl and NT-proBNP ($P < 0.05$) (Table 1). Besides, the group with a higher HCAR was significantly associated with a higher 2-year mortality (45/236 (19%) vs. 23/230 (10%), $P = 0.006$) (Fig. 4). The Kaplan-Meier curve showed that the group with a higher HCAR had a worse prognosis (log-rank $P < 0.001$, Fig. 5).

As shown in Table 2, compared to survivors, nonsurvivors had lower BMI, eGFR, HBG, and LVEF and older age, AST, NT-proBNP and HCAR ($P < 0.05$). CK-MB tended to be higher in nonsurvivors with a critical P -value of 0.095. The use of antiplatelet agents, ACEI/ARB, β -blocker and statins could reduce mortality significantly ($P < 0.01$). Finally, a Cox regression analysis was used to assess the risk factors for 2-year mortality. Based on the results shown in Table 2, traditional risk factors, including age, gender, CKD stage, BMI, HT, DM, family history of CAD, TG, TC, LDL-C, HDL-C, smoke and FBG, LVEF, NT-proBNP, HCAR, the use of antiplatelet agents, ACEI/ARB, β -blocker and statins were included into the multivariable Cox regression analysis. The regression analysis shown in Table 3 demonstrated that HCAR was an

independent risk factor for 2-year mortality (OR: 1.779, 95% CI: 1.017–3.112, $P = 0.043$), together with NT-proBNP, age and the use of antiplatelet agent and statins.

Table 2
Characteristics of the Study Population based on all cause morality

Characteristics	Survivors	Nonsurvivors	P
	(n = 398)	(n = 68)	
Demographic			
Age(years)	72.36 ± 10.05	76.59 ± 9.85	0.001
Male, n (%)	223(56%)	34(50%)	0.355
BMI (kg/m ²)	25.53 ± 3.61	24.24 ± 4.34	0.022
SBP (mmHg)	135.66 ± 24.92	131.71 ± 25.28	0.228
DBP (mmHg)	73.41 ± 12.93	71.21 ± 12.28	0.192
Medical history			
HT, n (%)	333(84%)	61(90%)	0.203
DM, n (%)	176(44%)	30(44%)	0.987
CAD family history	95(24%)	15(22%)	0.745
Previous CAG, n (%)	100(25%)	13(19%)	0.285
Stroke, n (%)	92(23%)	18(26%)	0.547
Smoke, n (%)	190(48%)	34(50%)	0.73
Alcohol drink, n (%)	116(29%)	18(26%)	0.644
CKD 5 Stage, n (%)	58(15%)	18(26%)	0.014
Laboratory test			
eGFR(mL/min/1.73 m ²)	44.88 ± 15.09	38.56 ± 15.52	0.002
BUN (μmol/L)	7.57 (5.83–10.89)	8.67 (5.62–11.51)	0.231
Serum K(mmol/L)	4.26 ± 0.47	4.33 ± 0.54	0.27
Serum Na(mmol/L)	139.53 ± 7.24	139.20 ± 3.87	0.713
TG(mmol/L)	1.43(1.02–1.99)	1.33(1.03–1.82)	0.417
TC(mmol/L)	4.31 ± 1.09	4.13 ± 0.94	0.211
LDL-C(mmol/L)	2.47 ± 0.80	2.37 ± 0.70	0.357
HDL-C(mmol/L)	1.03 ± 0.24	1.04 ± 0.25	0.681
HbA1C(%)	6.30 (5.70–7.30)	6.30 (5.80–7.30)	0.675

Characteristics	Survivors	Nonsurvivors	P
	(n = 398)	(n = 68)	
FBG(mmol/L)	5.94 (5.00 -8.21)	6.87 (5.08–9.21)	0.111
WBC(10^9 /L)	7.83 (6.10–9.56)	7.91(5.54–10.68)	0.96
HBG (g/L)	124.61 ± 19.12	119.46 ± 21.72	0.045
PLT (10^9 /L)	216.47 ± 72.66	209.56 ± 69.09	0.465
UA (μmol/L)	400.90 ± 103.90	419.36 ± 106.83	0.185
ALT(U/L)	18.00 (12.00–31.00)	22.00 (12.00 -47.50)	0.132
AST(U/L)	29.00(18.00–67.00)	39.40(20.00 -146.00)	0.049
CK-MB(U/L)	4.00(1.70–13.90)	4.30(2.50 -21.15)	0.095
TnI(ng/ml)	0.81(0.10–3.45)	1.73(0.17–3.96)	0.168
LVEF	0.57 ± 0.11	0.52 ± 0.12	< 0.001
NT-proBNP(pg/ml)	5316(1834–13030)	20433(5318–30000)	< 0.001
Higher HCAR	191(48%)	45(66%)	0.006
Drug use after admission			
Antiplatelet, n (%)	387(97%)	49(72%)	< 0.001
ACEI /ARB, n (%)	279(70%)	37(54%)	0.009
β-blocker, n (%)	305(77%)	39(57%)	0.001
Statins, n (%)	367(92%)	43(63%)	< 0.001

Table 3
Cox regression analysis in relation to 2-year mortality

Variable	B	Wald	P Value	OR	95% CI
Age	0.046	10.465	0.001	1.048	1.018–1.077
Antiplatelet	-1.398	7.701	0.006	0.247	0.092–0.663
Statins	-0.943	4.520	0.033	0.390	0.163–0.929
NT-proBNP	< 0.001	16.380	< 0.001	1.00005	1.00003-1.00008
Higher HCAR	0.576	4.077	0.043	1.779	1.017–3.112

Discussion

The key role of inflammation in diseases development has attracted more attention, and the studies on inflammatory indices have been highlighted in recent years. At present, hs-CRP and CRP are widely used as indicators of inflammation. Although both the two indices are actually measured with C-reactive protein, the clinical significance of CRP and hs-CRP is not exactly the same[17, 18]. CRP has good performance in the diagnosis of infectious and connective tissue diseases, whereas, hs-CRP, due to its higher sensitivity, precision and reproducibility, seems better for diagnosis of cardio-and cerebrovascular disease[14, 18–20]. Contrary to other specific inflammatory factors or markers, the hs-CRP and serum albumin are easily measured in clinics, and are widely used in many primary hospitals, with a high penetration rate, stable results and easy to observation. Through the combination of the two indicators above, HCAR has the advantages of simplicity, low-cost and high reliability. On the basis of making full use of the existing biochemical examination, HCAR can help to excavate more detailed diagnosis and treatment information, provide reference for clinical diagnosis and treatment, and effectively save costs, which is potentially valuable in clinical application.

Previous studies have suggested that coronary atherosclerosis is a multistep and chronic inflammatory process. Inflammation plays a key role in the formation, development and rupture of atherosclerotic plaques. In 2019, Zhuang conducted a randomized clinical trial, enrolling 3802 subjects followed up for 5.01 years, and it was found that hs-CRP was positively associated with the incidence of coronary heart disease in the general population[16]. In 2014, Daniel's study identified hs-CRP as an independent predictive factor of 30-day mortality in STEMI patients[21]. Serum albumin level can reflect the nutritional status of patients and predict prognosis of cancer, infection and critical patients. A low albumin level indicates poor prognosis of patients. Therefore, by combining hs-CRP and albumin, the predictive value of HCAR has gained increasing attention of researchers. Wang et al. have shown that HCAR is closely related to the incidence of short-term adverse cardiovascular events in patients with acute coronary syndrome, and could provide help to risk stratification[22]. However, the clinical value of HCAR in AMI patients has not been reported, especially in patients with chronic kidney disease.

Using scatter diagrams and correlation analysis, this study showed that HCAR was significantly and positively correlated with inflammatory indices, leukocyte count and hs-CRP, in AMI patients with CKD undergoing CAG. Thus, HCAR is a useful indicator closely related to hs-CRP, which could also reflect inflammation. Besides, HCAR was positively correlated with NT proBNP, CK MB, TnI, AST and ALT, and negatively correlated with LVEF and eGFR ($P < 0.05$). These findings indicate that HCAR is significantly associated with cardiac, renal and hepatic functions. Thus, in patients with AMI combined with CKD, HCAR may reflect the severity of myocardial infarction, as well as cardiac and renal function.

The current study also showed that in AMI patients with CKD undergoing CAG, HCAR has a good value in predicting mortality. The diagnostic efficiency is the highest when HCAR is 0.24, with a sensitivity of 66.2% and specificity of 52.0%. Therefore, in this study, the patients were divided into two groups with the HCAR value of 0.24 as the cut-off value. Consistent with the above correlation analysis, the group with a higher HCAR was negatively correlated with eGFR, and positively correlated with NT-proBNP, CK MB, TnI, ALT and AST, which further confirmed that HCAR has certain advantages in reflecting the severity of

myocardial infarction, as well as cardiac and renal function. Especially, a negative correlation between HCAR level and mortality was observed, suggesting that HCAR may predict prognosis of the patients. Further analysis of survival rates of patients showed that the survival time of patients in the group with a lower HCAR was significantly longer than that in the group with a higher HCAR. Hence, a comprehensive analysis of mortality risk factors was conducted. The Cox survival analysis indicated that higher HCAR level, older age and higher NT-proBNP were independent predictors of 2-year mortality of AMI patients with CKD undergoing CAG.

Also, there was a negative correlation between HCAR and eGFR ($P < 0.05$). The predictive value of HCAR in CKD patients was also investigated. The results showed that HCAR had a good diagnostic value in predicting the severity of CKD. HCAR was most efficient in the diagnosis of CKD staging when HCAR was 0.17, with a sensitivity of 77.6% and specificity of 39.7%. These results indicate that HCAR is clinically valuable in evaluating the renal function of AMI patients with CKD undergoing CAG.

However, this study also has some limitations. Firstly, this was a retrospective and single-center study with a limited sample size. Thus, a prospective, multicenter and randomized controlled trial is required to corroborate our findings. Secondly, this study only focused on value of HCAR in predicting the 2-year mortality of AMI patients with CKD undergoing CAG. Further studies need to be conducted on MACE, CKD progression and mortality in 5 years or even longer time. Thirdly, this study only evaluated the association of HCAR level with prognosis of the patients upon admission, lacking the data reflecting changes over time. In the future, more information should be collected to gain more insight into the diagnostic value of HCAR.

In conclusion, this study indicates that HCAR may comprehensively reflect the condition of AMI patients with CKD undergoing CAG. HCAR could not only reflect the degree of inflammation, but also predict the severity of myocardial infarction, renal function, liver function and prognosis. With its advantages of simplicity, cost-effectiveness, and reliability, HCAR is potentially applied clinically in the future.

Abbreviations

AMI: Acute myocardial infarction; CKD: Chronic kidney disease; Hs-CRP: High sensitivity C-reactive protein; Alb: albumin; HCAR: High sensitivity C-reactive protein to albumin ratio; CAG: Coronary angiography; ROC: Receiver operating characteristic; PCI: Percutaneous coronary intervention (PCI); eGFR: Estimated glomerular filtration rate; LVEF: Left ventricular ejection fraction

Declarations

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Authors' contributions

Bo Zuo and Jiayu Li were devoted to the analysis and interpretation of the data and writing for this article. Hui Chen designed this research. All authors reviewed and approved the manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the ethics committee of Beijing Friendship Hospital, Capital Medical University and written informed consent was obtained from all patients

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

1. Falsoleiman H, Fatehi GH, Dehghani M, Shakeri MT, Bayani B, Ahmadi M, Rohani A: **Clinical outcome, and survival between primary percutaneous coronary intervention versus fibrinolysis in patients older than 60 years with acute myocardial infarction.** *Heart Views* 2012, **13**(4):129-131.
2. Nyman U, Bjork J, Aspelin P, Marenzi G: **Contrast medium dose-to-GFR ratio: a measure of systemic exposure to predict contrast-induced nephropathy after percutaneous coronary intervention.** *Acta Radiol* 2008, **49**(6):658-667.
3. Sarnak MJ, Amann K, Bangalore S, Cavalcante JL, Charytan DM, Craig JC, Gill JS, Hlatky MA, Jardine AG, Landmesser U *et al.*: **Chronic Kidney Disease and Coronary Artery Disease: JACC State-of-the-Art Review.** *J Am Coll Cardiol* 2019, **74**(14):1823-1838.
4. Newsome P, Francque S, Harrison S, Ratzu V, Van Gaal L, Calanna S, Hansen M, Linder M, Sanyal A: **Effect of semaglutide on liver enzymes and markers of inflammation in subjects with type 2 diabetes and/or obesity.** *Aliment Pharmacol Ther* 2019, **50**(2):193-203.

5. Kubo S, Kitamura A, Imano H, Cui R, Yamagishi K, Umesawa M, Muraki I, Kiyama M, Okada T, Iso H: **Serum Albumin and High-Sensitivity C-reactive Protein are Independent Risk Factors of Chronic Kidney Disease in Middle-Aged Japanese Individuals: the Circulatory Risk in Communities Study.** *J Atheroscler Thromb* 2016, **23**(9):1089-1098.
6. Wang J, Tang B, Liu X, Wu X, Wang H, Xu D, Guo Y: **Increased monomeric CRP levels in acute myocardial infarction: a possible new and specific biomarker for diagnosis and severity assessment of disease.** *Atherosclerosis* 2015, **239**(2):343-349.
7. Calik AN, Inan D, Karatas MB, Akdeniz E, Genc D, Canga Y, Cinar T, Emre A: **The association of preprocedural C-reactive protein/albumin ratio with in-stent restenosis in patients undergoing iliac artery stenting.** *J Cardiovasc Thorac Res* 2020, **12**(3):179-184.
8. Oduncu V, Erkol A, Karabay CY, Kurt M, Akgun T, Bulut M, Pala S, Kirma C: **The prognostic value of serum albumin levels on admission in patients with acute ST-segment elevation myocardial infarction undergoing a primary percutaneous coronary intervention.** *Coron Artery Dis* 2013, **24**(2):88-94.
9. Bergstrom J: **Nutrition and mortality in hemodialysis.** *J Am Soc Nephrol* 1995, **6**(5):1329-1341.
10. Duman H, Cinier G, Bakirci EM, Simsek Z, Hamur H, Degirmenci H, Emlek N: **Relationship Between C-Reactive Protein to Albumin Ratio and Thrombus Burden in Patients With Acute Coronary Syndrome.** *Clin Appl Thromb Hemost* 2019, **25**:1076029618824418.
11. Karabag Y, Cagdas M, Rencuzogullari I, Karakoyun S, Artac I, Ilis D, Yesin M, Ciftci H, Erdogdu HI, Tanboga IH: **The C-Reactive Protein to Albumin Ratio Predicts Acute Kidney Injury in Patients With ST-Segment Elevation Myocardial Infarction Undergoing Primary Percutaneous Coronary Intervention.** *Heart Lung Circ* 2019, **28**(11):1638-1645.
12. He S, Wang Y, Chen H, Yang L, Liang S, Lu L, Chen Y: **C-Reactive Protein/Albumin Ratio (CAR) as a Prognostic Factor in Patients with Non-Metastatic Nasopharyngeal Carcinoma.** *J Cancer* 2016, **7**(15):2360-2366.
13. Oh TK, Ji E, Na HS, Min B, Jeon YT, Do SH, Song IA, Park HP, Hwang JW: **C-Reactive Protein to Albumin Ratio Predicts 30-Day and 1-Year Mortality in Postoperative Patients after Admission to the Intensive Care Unit.** *J Clin Med* 2018, **7**(3).
14. Xu H, Hu L, Wei X, Niu J, Gao Y, He J, Hou J: **The Predictive Value of Preoperative High-Sensitive C-Reactive Protein/Albumin Ratio in Systemic Inflammatory Response Syndrome After Percutaneous Nephrolithotomy.** *J Endourol* 2019, **33**(1):1-8.
15. Oh TK, Choi YR, Cho JY, Yoon YS, Han HS, Park IS, Ryu JH: **The High-Sensitivity C-Reactive Protein/Albumin Ratio Predicts Long-Term Oncologic Outcomes after Curative Resection for Hepatocellular Carcinoma.** *J Clin Med* 2018, **7**(6).
16. Zhuang Q, Shen C, Chen Y, Zhao X, Wei P, Sun J, Ji Y, Chen X, Yang S: **Association of high sensitive C-reactive protein with coronary heart disease: a Mendelian randomization study.** *BMC Med Genet* 2019, **20**(1):170.

17. Moutachakkir M, Lamrani Hanchi A, Baraou A, Boukhira A, Chellak S: **Immunoanalytical characteristics of C-reactive protein and high sensitivity C-reactive protein.** *Ann Biol Clin (Paris)* 2017, **75**(2):225-229.
18. Pathak A, Agrawal A: **Evolution of C-Reactive Protein.** *Front Immunol* 2019, **10**:943.
19. Castro AR, Silva SO, Soares SC: **The Use of High Sensitivity C-Reactive Protein in Cardiovascular Disease Detection.** *J Pharm Pharm Sci* 2018, **21**(1):496-503.
20. Zhou Y, Han W, Gong D, Man C, Fan Y: **Hs-CRP in stroke: A meta-analysis.** *Clin Chim Acta* 2016, **453**:21-27.
21. Ribeiro DR, Ramos AM, Vieira PL, Menti E, Bordin OL, Jr., Souza PA, Quadros AS, Portal VL: **High-sensitivity C-reactive protein as a predictor of cardiovascular events after ST-elevation myocardial infarction.** *Arq Bras Cardiol* 2014, **103**(1):69-75.
22. Wang W, Ren D, Wang CS, Li T, Yao HC, Ma SJ: **Prognostic efficacy of high-sensitivity C-reactive protein to albumin ratio in patients with acute coronary syndrome.** *Biomark Med* 2019, **13**(10):811-820.

Figures

Figure 1

Flow chart of patient selection. AMI, acute myocardial infarction; CKD, chronic kidney disease; CAG, coronary angiography.

Figure 2

The scatter diagrams and correlation analysis of HCAR. A: The scatter diagram of HCAR and NT-proBNP. B: The scatter diagram of HCAR and EF. C: The scatter diagram of HCAR and CK-MB. D: The scatter diagram of HCAR and TnI. E: The scatter diagram of HCAR and eGFR. F: The correlation analysis of HCAR.

Figure 3

ROC curve of HCAR in predicting 2-year mortality and the stage of CKD. A: ROC curve of HCAR in predicting 2-year mortality. B: ROC curve of HCAR in predicting the stage of CKD.

Figure 4

The comparison of 2-year mortality based on HCAR level.

Figure 5

The Kaplan-Meier curve analysis of 2-year mortality based on the HCAR level.