Original Manuscript

Association of Serum Uric Acid and CRP/Albumin Ratio With Contrast-Induced Nephropathy in Acute Myocardial Infarction Patients

Angiology
1–9

DOI: 10.1177/00033197251376082
journals.sagepub.com/home/ang
Sage

Arzu Akgül, MD[1], Çağatay Tunca, MD[2], Alperen Taş, MD[3], and Mehmet Deniz Aylı[1]

Abstract

Contrast-induced nephropathy (CIN) significantly increases morbidity and mortality among acute myocardial infarction (MI) patients undergoing coronary angiography (CAG). This study evaluated the predictive value of serum uric acid (SUA) and C-reactive protein/albumin ratio (CAR) for CIN development. A retrospective analysis included 1326 acute MI patients who underwent CAG between November 2022 and January 2024. CIN occurred in 119 patients (9.0%). Higher SUA (5.60 vs 4.60 mg/dL, $P < .001$) and CAR (2.79 vs 2.15, $P = .004$) were significantly associated with CIN. Multivariate analysis confirmed SUA (Odds Ratio [OR]: 1.577, $P < .001$) and contrast volume (OR: 1.014, $P < .001$) as independent predictors. Receiver Operating Characteristic (ROC) analysis identified optimal SUA cutoff at 4.9 mg/dL (sensitivity 67.7%, specificity 68.1%). The predictive value of SUA was stronger among diabetic patients. Additionally, SUA positively correlated with CAR ($r = .41$, $P < .001$). A simplified risk score incorporating SUA, CAR, contrast volume, diabetes, and age effectively stratified CIN risk. Elevated SUA levels and high CAR independently predict CIN in acute MI patients, enhancing clinical risk stratification and guiding preventive strategies.

Keywords

inflammation, uric acid, contrast induced nephropathy, C-reactive protein/albumin ratio, acute myocardial infarction

Introduction

Contrast-induced nephropathy (CIN), a form of acute kidney injury characterized by a significant increase in serum creatinine levels within 48 to 72 hours post-contrast exposure, remains a critical complication following coronary angiography, especially in acute myocardial infarction (MI) patients.[1,2] CIN development is associated with morbidity, mortality, prolonged hospitalization, and increased healthcare costs.[3] Identification of high-risk individuals is crucial for preventive strategies and effective management.

Risk factors traditionally associated with CIN include chronic kidney disease, diabetes mellitus, hypotension, congestive heart failure, anemia, advanced age, and use of high-volume contrast media.[4,5] Mechanistically, CIN involves direct renal tubular toxicity by contrast media, micro atherothrombotic embolization, intrarenal vasoconstriction due to endothelial dysfunction, oxidative stress, and inflammatory responses.[5-7] Recently, additional biomarkers have been investigated to enhance the accuracy of CIN prediction models.

Elevated serum uric acid (SUA) levels are increasingly recognized as a potent risk factor for cardiovascular events, endothelial dysfunction, and inflammatory states.[8,9] SUA mediates inflammation and oxidative stress, contributing to endothelial dysfunction and potential renal injury.[10] Several large-scale studies and meta-analyses confirmed that elevated SUA levels independently predict CIN in patients undergoing coronary angiography and percutaneous coronary interventions (PCI), emphasizing SUA as a practical biomarker for early risk stratification.[11,12]

Inflammation also significantly influences CIN pathogenesis, with various markers such as neutrophil-to-lymphocyte ratio (NLR), systemic immune-inflammation index (SII), and

[1]Department of Nephrology, Ministry of Health Ankara Etlik City Hospital, Turkey
[2]Department of Cardiology, Ministry of Health Ankara Etlik City Hospital, Turkey
[3]Department of Cardiology, Ahi Evran University Training and Research Hospital, Kırşehir, Turkey

Corresponding Author:
Arzu Akgül, Department of Nephrology, Ministry of Health Ankara Etlik City Hospital, Ankara Etlik City Hospital Etlik, Kecioren, Ankara 06010, Turkey.
Email: arzuakgul@gmail.com

C-reactive protein (CRP) levels demonstrating predictive value for CIN development.[13-15] Recently, the CRP/Albumin ratio (CAR), a marker combining acute-phase inflammation and nutritional status, emerged as a robust indicator of inflammation and prognosis in cardiovascular disease. Several studies have shown CAR to be independently associated with CIN occurrence, suggesting its potential clinical utility in risk assessment.[16,17]

In addition to individual biomarkers, combined clinical and anatomical scoring systems have also been used for CIN risk prediction. For example, the Syntax Score II (SSII), which incorporates both anatomical and clinical variables, has been shown to predict CIN development and long-term mortality in ST-Elevation Myocardial Infarction (STEMI) patients undergoing primary PCI.[18] While such scoring systems provide valuable prognostic information, the calculation of SSII requires detailed angiographic and clinical assessment. Therefore, there is a continuing need for simpler, readily available, and cost-effective biomarkers to facilitate early CIN risk stratification, especially in acute settings.

Acute MI patients represent a particularly high-risk population for CIN due to systemic inflammatory responses, hemodynamic instability, and the urgent need for contrast-enhanced revascularization procedures.[19] However, few studies have simultaneously investigated the predictive value of combining inflammatory markers with hyperuricemia specifically within this group. We hypothesized that elevated SUA levels and an increased CAR independently predict CIN development in acute MI patients undergoing coronary angiography. The present study aims to evaluate the clinical relevance of these biomarkers, assessing their potential utility in risk stratification and management optimization.

Materials and Methods

This retrospective observational study was conducted at Ankara Etlik City Hospital, involving 1326 consecutive patients admitted through the emergency department and undergoing coronary angiography due to acute MI, between November 2022 and January 2024. Ethical approval was obtained from the hospital ethics committee.

Patients with end-stage renal disease (estimated glomerular filtration rate, eGFR <15 mL/min), kidney transplants, chronic liver disease, malignancy, autoimmune disease, congestive heart failure with reduced ejection fraction (EF $<40\%$), chronic obstructive pulmonary disease, chronic hematologic diseases (including anemia), alcohol consumption, active inflammatory conditions, or those receiving allopurinol therapy were excluded to reduce confounding effects.

Data collection included demographic characteristics (age, sex), chronic diseases (diabetes mellitus, hypertension, dyslipidemia, smoking status), family history, medications (beta-blockers, statins, angiotensin-converting enzyme inhibitors), and clinical parameters (blood pressure, echocardiographic ejection fraction assessed by Simpson method). Peripheral venous blood was obtained on admission to the emergency department before PCI. Serum creatinine concentration was measured in all patients upon hospital admission and daily for the 3 days after contrast exposure. Laboratory parameters were collected following including fasting glucose, serum creatinine, SUA, lipid profile (low density lipoprotein cholesterol [LDL-C], high density lipoprotein cholesterol [HDL-C], triglycerides), lymphocyte count, hemoglobin, CRP, and serum albumin levels. CIN was defined according to standard criteria[17] as an increase in serum creatinine by >0.5 mg/dL or $>25\%$ from baseline within 72 hours after PCI.

Coronary angiography and subsequent PCI were performed using the Judkins technique with femoral or radial access, determined at the operator's discretion, and low osmolality, nonionic contrast media (iohexol, Omnipaque 350 mg/mL; GE Healthcare, Chicago, IL, USA).

Statistical Analysis

Patients were stratified into 2 groups based on CIN development (CIN vs no-CIN), and SUA was further categorized into quartiles for additional comparative analysis. Primary statistical analyses, including normality tests, group comparisons, and initial logistic regression modeling, were performed using SPSS software (version 15.0; SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was applied to assess normality. Continuous variables were analyzed using Student's *t*-test or Mann-Whitney *U* test, and categorical variables were analyzed using the chi-square test. Logistic regression analysis (univariable and multivariable) was conducted to identify independent predictors of CIN.

Receiver operating characteristic (ROC) analysis was performed to determine optimal cutoff values for predictive parameters, and sensitivity, specificity, and area under the curve (AUC) values were reported. Linearity between continuous predictors and the logit was evaluated using the Box-Tidwell procedure, with no significant deviations detected. Multicollinearity was assessed through variance inflation factor (VIF) analysis, confirming values below 5 for all variables. Independence and distribution of residuals were examined using standardized residual plots, with no concerning patterns identified. Goodness-of-fit was tested using the Hosmer-Lemeshow test, confirming adequate model fit. Additionally, a nomogram was created to visually represent model predictions. The nomogram's predictive performance was validated using Brier scores, which indicated good agreement between predicted probabilities and observed outcomes. All these additional analyses were performed using R software version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria) and provided as Supplemental Materials. Statistical significance was set at a 2-sided P value of $<.05$.

Results

Out of 1326 patients analyzed, CIN developed in 119 patients (9.0%). Detailed baseline characteristics comparing CIN and

Table 1. Baseline Clinical Characteristics.

Variables	CIN		P
	Absent (n = 1207)	Present (n = 119)	
Gender, female n (%)	216 (17.9)	29 (24.4)	.083
DM, n (%)	240 (19.9)	35 (29.4)	.014
HT, n (%)	462 (38.3)	63 (52.9)	.002
Smoking, n (%)	693 (57.4)	51 (42.9)	.002
Dyslipidemia, n (%)	510 (42.3)	46 (38.7)	.448
Family history of heart disease, n (%)	274 (22.7)	30 (25.2)	.534
History of myocardial infarction, n (%)	11 (0.9)	3 (2.5)	.101
Beta-blocker use, n (%)	79 (6.5)	10 (8.4)	.440
Statin use, n (%)	234 (19.4)	15 (12.6)	.071
ACE inhibitor use, n (%)	230 (19.1)	22 (18.5)	.880
Age, y	55 (27-88)	62 (27-91)	<.001
SBP, mmHg	130 (80-236)	137 (94-267)	<.001
DBP, mmHg	79 (45-145)	80 (54-156)	.009
MAP, mmHg	95.3 (56.7-180)	99 (70-193)	.001
CRP, mg/L	8.7 (1.0-84.3)	9.85 (1.4-47.6)	.005
Albumin, g/L	37.9 (23.0-57.0)	36.0 (24.0-57.0)	.010
CRP/Albumin	2.15 (0.20-19.46)	2.79 (0.33-14.42)	.004
SII	1138.18 (127.38-18848.0)	1249.90 (234.67-8166.36)	.029
Lymphocyte count, $10^3/mm^3$	1.8 (0.1-12.3)	1.6 (0.2-4.6)	<.001
Hemoglobin, g/dL	14.0 (7.0-18.4)	13.4 (8.8-19.0)	<.001
Urea, mg/dL	32 (3-127)	34 (16-160)	.001
Creatinine, mg/dL	0.86 (0.40-2.29)	0.88 (0.47-2.30)	.285
Uric acid, mg/dL	4.6 (1.8-9.3)	5.60 (1.7-10.6)	<.001
Glucose, mg/dL	122 (44-577)	131 (54-484)	.006
LDL-C, mg/dL	115 ± 38	116 ± 39	.875
Triglycerides, mg/dL	144 ± 98	132 ± 90	.223
HDL-C, mg/dL	39 ± 12	40 ± 14	.222
Ejection fraction, %	50 (40-65)	48 (40-65)	.001
Contrast volume, mL	260 (120-550)	320 (200-510)	<.001

Normally distributed data are presented as mean ± standard deviation, non-normally distributed data as median (minimum-maximum), and categorical data as n (%).

Abbreviations: DM, Diabetes Mellitus; HT, Hypertension; ACE, Angiotensin-Converting Enzyme; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; MAP, Mean Arterial Pressure; CRP, C-reactive protein; SII, Systemic Immune Inflammatory Index; LDL-C, Low-Density Lipoprotein Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol.

non-CIN groups are presented in Table 1. The CIN group was significantly older and exhibited a higher prevalence of diabetes mellitus (29.4 vs 19.9%, $P = .014$), hypertension (52.9 vs 38.3%, $P = .002$), and higher median systolic blood pressure (137 vs 130 mmHg, $P < .001$) and mean arterial pressure (99 vs 95.3 mmHg, $P = .001$).

Laboratory analysis revealed significant differences between groups. Patients developing CIN had notably higher median SUA levels (5.6 vs 4.6 mg/dL, $P < .001$), CRP levels (9.8 vs 8.7 mg/L, $P = .005$), and CAR (2.79 vs 2.15, $P = .004$). Additionally, lower lymphocyte counts ($1.6 \times 10^3/mm^3$ vs $1.8 \times 10^3/mm^3$, $P < .001$) and hemoglobin levels (13.4 vs 14.0 mg/dL, $P < .001$) were observed in CIN patients.

When patients were categorized by SUA quartiles, CIN incidence significantly increased with higher quartiles (3% in lowest vs 17.5% in highest quartile, $P < .001$), as shown in Table 2.

Logistic regression identified SUA (Odds Ratio [OR]: 1.577, 95% CI: 1.287-1.933, $P < .001$) and contrast volume (OR: 1.014, 95% CI: 1.010-1.017, $P < .001$) as independent predictors of CIN (Table 3). ROC analysis provided optimal cutoff values (Table 4, Figure 1), with SUA demonstrating a cutoff of 4.925 mg/dL (AUC: 0.701; sensitivity: 67.7%, specificity: 68.1%) and contrast volume a cutoff of 272.5 mL (AUC: 0.760; sensitivity: 68.4%, specificity: 68.1%).

A subgroup analysis based on diabetic status revealed that the predictive value of SUA for CIN was stronger among diabetic patients (AUC: 0.755, cutoff: 5.2 mg/dL, sensitivity: 72.5%, specificity: 70.4%) compared with non-diabetics (AUC: 0.683, cutoff: 4.85 mg/dL, sensitivity: 64.2%, specificity: 67.9%; P for interaction = .045).

A correlation analysis demonstrated a significant positive correlation between SUA levels and CAR ($r = .41$, $P < .001$),

Table 2. Baseline Characteristics of Patients According to the Serum Uric Acid Quartiles (mg/dL).

Variables	<3.9 (n = 328)	≥3.9-5.7 (n = 655)	≥5.7 (n = 338)	*P*
Baseline creatinine, n (%)				
<1.5 mg/dL	326 (99.4)[a,b]	654 (99.8)[b]	329 (97.3)[a]	<.001
≥1.5 mg/dL	2 (0.6)[a,b]	1 (0.2)[b]	9 (2.7)[a]	
CIN, n (%)	10 (3)[a]	50 (7.6)[b]	59 (17.5)[c]	<.001
Gender, female, n (%)	76 (23.2)[a]	106 (16.2)[b]	61 (18)[a,b]	.028
DM, n (%)	84 (25.6)	128 (19.5)	63 (18.6)	.045
HT, n (%)	138 (42.1)	238 (36.6)	147 (43.5)	.052
Smoking, n (%)	182 (55.5)	386 (58.9)	174 (51.5)	.078
Dyslipidemia, n (%)	114 (34.8)[a]	277 (42.3)[a,b]	163 (48.2)[b]	.002
Family history of heart disease, n (%)	62 (18.9)	158 (24.1)	84 (24.9)	.121
History of myocardial infarction, n (%)	3 (0.9)	6 (0.9)	5 (1.5)	.683
Beta-blocker use, n (%)	23 (7)	41 (6.3)	25 (7.4)	.774
Statin use, n (%)	59 (18)	115 (17.6)	75 (22.2)	.188
ACEI use, n (%)	61 (18.6)	121 (18.5)	69 (20.4)	.744
Age, y	55 (30-83)[a,b]	54 (27-87)[a]	57 (27-91)[b]	.016
SBP, mmHg	130 (90-256)	130 (80-267)	130 (92-235)	.889
DBP, mmHg	78.5 (55-135)	80 (45-156)	79 (49-145)	.488
CRP/Albumin	2.27 (0.24-16.5)	2.2 (0.24-18)	2.24 (0.20-19.5)	.805
SII	1139 (177-18848)	1149 (127-15515)	1186 (176-8166)	.697
Lymphocyte count, $10^3/mm^3$	1.9 (0.1-6.7)[a,b]	1.8 (0.2-6.6)[a]	1.7 (0.2-12.3)[b]	.020
Hemoglobin, g/dL	14 (7-18.3)	14 (7.8-18.4)	13.9 (8.5-19)	.795
Urea, mg/dL	32 (3-94)[a]	31 (11-127)[a,b]	34 (8-160)[c]	<.001
Creatinine, mg/dL	0.8 (0.42-2.05)[a]	0.86 (0.40-1.6)[b]	0.90 (0.46-2.30)[c]	<.001
Albumin, g/L	38 (23-52)	37.5 (26-53.2)	37 (24-57)	.447
CRP, mg/L	9.1 (1-84.3)	8.8 (1-59.4)	8.7 (1-68.1)	.936
Glucose, mg/dL	124 (44-527)	123 (53-577)	125 (49-507)	.888
LDL-C, mg/dL	105 (35-214)[a]	118 (37-228)[b]	112 (35-234)[b,c]	.002
HDL-C, mg/dL	37 (12-90)	37 (9-91)	36.5 (13-83)	.760
Triglycerides, mg/dL	113 (22-654)	120 (25-853)	129 (29-936)	.308
Ejection fraction, %	50 (40-65)	50 (40-65)	50 (40-65)	.553
Contrast volume, mL	260 (140-550)	260 (120-550)	270 (120-510)	.081

Different superscript letters (e.g., a, b, c) denote statistically significant differences between groups, whereas identical superscript letters indicate no significant difference.

Normally distributed data are presented as mean ± standard deviation, non-normally distributed data as median (minimum-maximum), and categorical data as n (%).

Abbreviations: CIN, Contrast induced nephropathy; DM, Diabetes Mellitus; HT, Hypertension; ACEI, Angiotensin-Converting Enzyme Inhibitor; DBP, Diastolic Blood Pressure; MAP, Mean Arterial Pressure; CRP, C-reactive protein; SII, Systemic Immune Inflammatory Index; LDL-C, Low-Density Lipoprotein Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol.

suggesting that these markers may jointly indicate an elevated inflammatory and metabolic risk profile.

Based on our multivariate logistic regression results, we developed a simplified clinical risk score to predict CIN, incorporating the most significant variables identified: SUA, CRP/albumin ratio, contrast volume, diabetes mellitus, and age. Each variable was weighted according to its regression coefficient:

- Serum uric acid >4.9 mg/dL: 3 points
- CRP/albumin ratio >2.5: 2 points
- Contrast volume >272.5 mL: 3 points
- Diabetes mellitus (present): 2 points
- Age ≥65 years: 1 point

The total CIN risk score ranges from 0 to 11 points, categorizing patients into low-risk (0-3 points), intermediate-risk (4-7 points), and high-risk (8-11 points) groups. This scoring system enables rapid bedside risk stratification, guiding clinicians to implement preventive strategies proactively.

Discussion

The present study identifies SUA and the CAR as critical independent predictors of CIN, with the predictive value of SUA notably stronger among diabetic patients. Additionally, the positive correlation between SUA and CAR demonstrates an important link between metabolic disturbances and

Table 3. Regression Analysis.

	Univariate logistic regression			Multivariate logistic regression		
Variables	95% CI	OR	*P*	95% CI	OR	*P*
Gender (female)	.434-1.054	.676	.084			
Age	1.027-1.060	1.044	<.001	.994-1.045	1.019	.140
DM	1.104-2.552	1.679	.015	.576-2.635	1.232	.591
HT	1.243-2.648	1.814	.002	.564-2.123	1.094	.791
Smoking	1.229-2.630	1.798	.003	.519-1.613	.915	.758
Statin use	.343-1.050	.600	.073			
SBP	1.010-1.023	1.017	<.001			
DBP	1.011-1.033	1.022	<.001			
MAP	1.012-1.031	1.02	<.001	1.000-1.031	1.015	.054
CRP/Albumin	1.019-1.184	1.098	.014	.982-1.192	1.082	.112
SII	1.000-1.000	1.000	.123			
Lymphocyte	.509-.832	.651	.001	.553-1.009	.747	.057
Hemoglobin	.730-.898	.810	<.001	.775-1.069	.910	.253
Urea	1.023-1.049	1.036	<.001			
Creatinine	1.570-6.832	3.276	.002	.372-3.689	1.171	.788
Uric acid	1.511-1.981	1.730	<.001	1.287-1.933	1.577	**<.001**
Albumin	.286-.754	.465	.002			
CRP	1.005-1.047	1.026	.017			
Glucose	1.003-1.006	1.003	.004	.988-1.006	1.002	.364
Troponin	.997-1.037	1.017	.100			
Ejection fraction	.920-.981	.950	.002	.984-1.075	1.029	.209
Contrast volume	1.011-1.016	1.014	<.001	1.010-1.017	1.014	**<.001**

Abbreviations: DM, Diabetes Mellitus; HT, Hypertension; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; MAP, Mean Arterial Pressure; CRP, C-reactive protein; SII, Systemic Immune Inflammatory Index.

Table 4. ROC Analysis.

Variable	AUC	*P*	Cut off	Sensitivity (%)	Specificity (%)
Uric acid	0.701	<.001	4.9	67.7	68.1
Contrast volume	0.760	<.001	272.5	68.4	68.1

Abbreviations: ROC, Receiver Operating Characteristic; AUC, Area Under the Curve.

systemic inflammation in predicting CIN. These findings highlight the clinical importance of integrating these biomarkers into existing risk stratification tools to better identify high-risk patients.

In developed countries, coronary artery disease remains the leading cause of death. However, the widespread use of revascularization procedures (such as in acute MI) has significantly reduced mortality rates.[20] Innovations in modern stent technology have enabled more patients to undergo PCI, including many high-risk patients with impaired renal function. The development of CIN is associated with increased morbidity, higher mortality, and substantial financial burden.[21]

The pathophysiology of CIN involves 3 primary components: direct toxic effects of iodinated contrast agents on renal tubular cells, micro-level atheroembolism in the renal circulation, and intrarenal vasoconstriction triggered by contrast agents and emboli.[22] Multivariable analyses of prospective studies have demonstrated that baseline renal dysfunction, diabetes mellitus, chronic heart failure, and the use of high volumes of contrast agent significantly increase the risk of developing CIN.[21] The cornerstone of reducing CIN incidence lies in identifying high-risk patients and providing adequate hydration before the procedure.[23]

In our study, multivariable regression analysis identified contrast volume as an independent predictor of CIN development. ROC analysis revealed a contrast volume cutoff of 272.5 mL, with a sensitivity of 68.4% and a specificity of 68.1% for predicting CIN. The relationship between contrast volume and CIN can be explained by the aforementioned mechanisms linking large contrast loads to renal toxicity and hemodynamic effects.

In the present study, multivariable regression also identified SUA levels as being independently associated with CIN development. ROC analysis determined a SUA cutoff value of 4.9 mg/dL, with a specificity of 68.1% and a sensitivity of

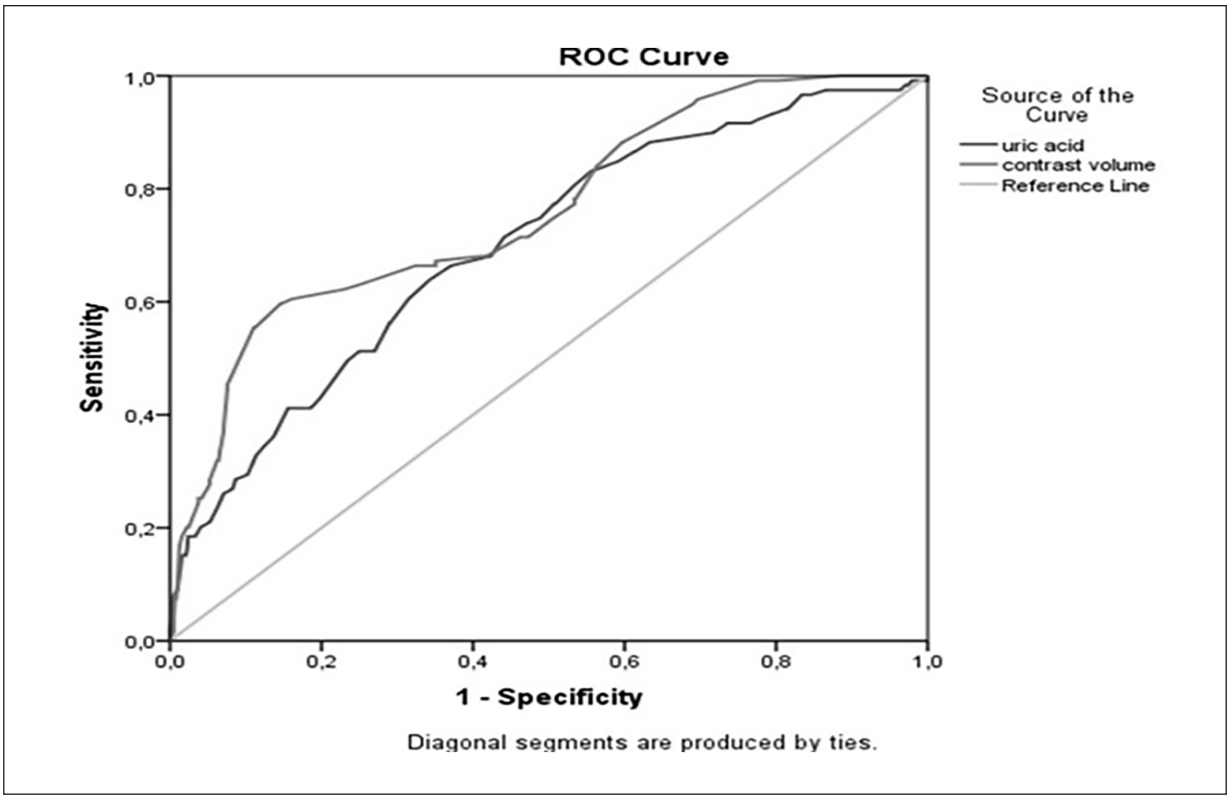

Figure 1. Receiver operating characteristic (ROC) curves illustrating the predictive performance of serum uric acid and contrast volume for the development of contrast-induced nephropathy.

67.7%. Uric acid is the final product of purine metabolism, and its levels are influenced by diet, medications, renal function, and increased purine turnover.[24] Elevated SUA levels are associated with urate crystal deposition, which can lead to conditions such as gouty arthritis and kidney stones.[25] Moreover, elevated SUA has been linked to increased cardiovascular risk through both direct vascular effects and indirect mechanisms.[26,27] Previous studies suggest that contrast agents may exert a uricosuric effect by increasing the secretion of uric acid in renal tubules, potentially contributing to renal injury.[28] Uric acid can enter vascular smooth muscle cells via specific organic anion transporters, activating p38 Mitogen-Activated Protein Kinase (MAPK) and Extracellular Signal-Regulated Kinase 1/2 (Erk1/2) kinases, as well as transcription factors Nuclear Factor kappa-light-chain-enhancer of activated B cells (NF-κB) and Activator Protein-1 (AP-1). This cascade promotes vascular smooth muscle cell proliferation and an inflammatory phenotype. During this process, these cells secrete growth factors, vasoconstrictors (e.g., thromboxane A2), cytokines, and inflammatory proteins such as CRP and Monocyte Chemoattractant Protein-1 (MCP-1).[29] Additionally, uric acid has been observed to upregulate type 1 angiotensin II receptors in endothelial and smooth muscle cells.[30] Elevated SUA amplifies inflammatory responses by triggering the production of Interleukin (IL)-1β, IL-6, and Tumor Necrosis Factor-alpha (TNF-α).[31] Furthermore, by increasing the production of reactive oxygen species, uric acid raises oxidative stress levels and leads to deterioration of renal functions.[31]

Several studies have provided insight into the association between hyperuricemia and the development of CIN. The link between hyperuricemia and acute renal failure has informed our understanding of how elevated uric acid might precipitate CIN. In a study of 1950 patients undergoing coronary angiography and PCI, higher SUA levels were an independent predictor of CIN.[32] Another study of 1372 patients found that elevated SUA was an independent risk factor for acute kidney injury in the setting of primary PCI for STEMI.[33] Similarly, in a study of 450 ST-elevation MI patients, SUA was an independent predictor of CIN; a uric acid cutoff of 5.45 mg/dL yielded 70% sensitivity and 67% specificity for predicting CIN.[34]

Consistent with these reports, our study also identified elevated SUA as a significant risk factor for CIN development. SUA levels may potentially be used to stratify the risk of CIN occurrence and the need for dialysis in vulnerable patients.[34] The well-known Mehran risk score is another tool used to predict CIN risk; this scoring system incorporates 8 variables (hypotension, use of an intra-aortic balloon pump, congestive heart failure, chronic kidney disease, diabetes, age >75 years, anemia, and contrast volume) to estimate CIN likelihood.[35] Our findings suggest that adding markers of hyperuricemia and inflammation might further refine risk

assessment, although measuring SUA and inflammatory parameters only at hospital admission (as in our cross-sectional study) is a limitation. Notably, some studies have indicated that allopurinol (a uric acid-lowering agent) can reduce CIN risk, but larger prospective trials are needed to confirm the benefit of such preventive strategies.[36]

An increase in baseline creatinine is a well-established risk factor for CIN.[37] In our study, higher baseline creatinine was significantly associated with CIN on univariable analysis. Additionally, the systemic immune-inflammation index (SII) was higher in the group that developed CIN; however, SII did not reach statistical significance in our multivariable regression. While previous studies have identified SII as a predictor of CIN,[38,39] our findings did not confirm this association.

In our study, the CAR was also higher in patients who developed CIN compared with those who did not. Inflammation plays a key role in the pathogenesis of CIN,[40] and numerous studies have demonstrated that an elevated CAR is predictive of CIN development.[16,41] The relationship between CAR levels and CIN observed in our cohort aligns with these prior findings. Furthermore, recent studies have highlighted the potential predictive value of the CAR in acute kidney injury (AKI). A study involving 815 consecutive STEMI patients treated with primary PCI found that CAR was an independent predictor of AKI, with higher CAR levels correlating with in-hospital mortality and AKI development.[42] This aligns with our findings, suggesting that CAR, as an inflammation-based biomarker, could play a valuable role in CIN risk stratification, particularly in patients with acute MI. We also observed that diabetes mellitus was more common among patients who developed CIN, and their baseline blood glucose levels were significantly higher. Diabetic patients often have multivessel coronary artery disease with more extensive atherosclerotic lesions.[43] This complexity necessitates the use of larger volumes of contrast during interventions, thereby elevating CIN risk. The higher incidence of CIN in diabetic patients in our study can be attributed to this interplay between diabetes, procedural complexity, and contrast volume.

We synthesized a new CIN risk scoring system based on the key independent predictors from our study to provide a simple bedside tool for risk stratification. This tool integrates metabolic (e.g., SUA) and inflammatory (e.g., CAR) biomarkers alongside traditional risk indicators, thereby capturing dimensions of patient risk that the widely used Mehran score, which relies on 8 clinical and procedural variables, does not incorporate. The resulting nomogram is straightforward and clinically practical, enabling clinicians to quickly estimate an individual's CIN risk using available clinical and laboratory parameters. By accounting for a patient's metabolic and inflammatory status, our risk score may offer incremental predictive value over existing models, improving identification of high-risk patients who could benefit from prophylactic measures. Naturally, this scoring system should undergo prospective validation in more extensive, diverse cohorts to confirm its performance; if successful, it could be integrated into routine practice to guide preventive interventions in at-risk patients, analogous to how the Mehran score is currently applied.[44]

From a clinical perspective, our findings suggest that elevated SUA and CAR levels can help guide personalized CIN prevention strategies. Patients identified as high-risk might benefit from intensified hydration protocols, closer renal monitoring, or prophylactic urate-lowering therapies. Prospective trials are needed to validate such tailored approaches.

Our study has several limitations. Firstly, it was a single-center retrospective study, which limits the ability to establish causality; prospective studies are needed to better elucidate mechanisms. Secondly, patients with heart failure and reduced ejection fraction (EF) were excluded. Some patients presenting with MI may have had reduced EF (e.g., due to acute heart failure) and were thus omitted. Although patients with heart failure and reduced EF are known to be at higher risk for CIN, excluding them means our findings may not generalize to that subgroup; further studies including such patients are necessary.

Another limitation is that while CIN was assessed within 48 to 72 hours post-procedure, contrast-induced renal injury can occasionally manifest beyond this window. Due to the retrospective design and the generally short follow-up in our dataset, we lacked information on long-term renal outcomes. Studies with larger cohorts and longer follow-up periods would help clarify the relationship between uric acid, inflammatory markers, and the trajectory of renal function after contrast exposure.

Conclusion

Our study supports that elevated SUA and increased CAR are independently associated with the development of CIN in acute MI patients undergoing coronary angiography. These results suggest that hyperuricemia and inflammation may serve as clinically relevant markers for identifying patients at increased risk. This study provides novel evidence by evaluating the combined predictive value of these biomarkers in a high-risk patient cohort and introduces a simplified, clinically applicable risk score. Integration of SUA and CAR into existing risk assessment tools could enhance the identification of patients who might benefit from targeted preventive measures. Larger prospective trials are needed to validate these biomarkers and to establish their potential utility in routine nephrology and cardiovascular practice.

Author Note

All aspects of the research, including data collection, analysis, and manuscript preparation, were conducted independently by the authors.

ORCID iDs

Arzu Akgül https://orcid.org/0009-0007-8119-3893
Çağatay Tunca https://orcid.org/0000-0001-7111-8450
Alperen Taş https://orcid.org/0000-0002-1696-7449

Ethical Considerations

The authors state that they have obtained appropriate institutional review board approval (Institutional Ethics Committee of Ankara Etlik City Hospital [AEŞH-EKI-2023-548]) and/or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

Author Contributions

All authors contributed to: (1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, and (3) final approval of the version to be published.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

AI

Artificial intelligence (AI) tools were utilized to confirm statistical analyses and assist in the creation of the nomogram; however, the final decisions and interpretations were made exclusively by the authors.

Supplemental Material

Supplemental material for this article is available online.

References

1. McCullough PA. Contrast-induced acute kidney injury. J Am Coll Cardiol. 2008;51(15):1419-1428.
2. Modi K, Padala SA, Gupta M. Contrast-Induced Nephropathy. StatPearls Publishing LLC; 2025.
3. Pucelikova T, Dangas G, Mehran R. Contrast-induced nephropathy. Catheter Cardiovasc Interv. 2008;71(1):62-72.
4. Rudnick MR, Kesselheim A, Goldfarb S. Contrast-induced nephropathy: how it develops, how to prevent it. Cleve Clin J Med. 2006;73(1):75-80, 83-87.
5. Pisani A, Riccio E, Andreucci M, et al. Role of reactive oxygen species in pathogenesis of radiocontrast-induced nephropathy. Biomed Res Int. 2013;2013:868321.
6. Goldenberg I, Matetzky S. Nephropathy induced by contrast media: pathogenesis, risk factors and preventive strategies. CMAJ. 2005;172(11):1461-1471.
7. Zuo T, Jiang L, Mao S, Liu X, Yin X, Guo L. Hyperuricemia and contrast-induced acute kidney injury: a systematic review and meta-analysis. Int J Cardiol. 2016;224:286-294.
8. Kanbay M, Solak Y, Afsar B, et al. Serum uric acid and risk for acute kidney injury following contrast. Angiology. 2017;68(2):132-144.
9. Mercuro G, Vitale C, Cerquetani E, et al. Effect of hyperuricemia upon endothelial function in patients at increased cardiovascular risk. Am J Cardiol. 2004;94(7):932-935.
10. Ruggiero C, Cherubini A, Miller E, et al. Usefulness of uric acid to predict changes in C-reactive protein and interleukin-6 in 3-year period in Italians aged 21 to 98 years. Am J Cardiol. 2007;100(1):115-121.
11. Liu Y, Tan N, Zhou YL, et al. High-sensitivity C-reactive protein predicts contrast-induced nephropathy after primary percutaneous coronary intervention. J Nephrol. 2012;25(3):332-340.
12. Kurtul A, Yarlioglues M, Duran M, Murat SN. Association of neutrophil-to-lymphocyte ratio with contrast-induced nephropathy in patients with non-ST-elevation acute coronary syndrome treated with percutaneous coronary intervention. Heart Lung Circ. 2016;25(7):683-690.
13. Kaya A, Kaya Y, Topçu S, et al. Neutrophil-to-lymphocyte ratio predicts contrast-induced nephropathy in patients undergoing primary percutaneous coronary intervention. Angiology. 2014;65(1):51-56.
14. Huang J, Zhang Q, Wang R, et al. Systemic immune-inflammatory index predicts clinical outcomes for elderly patients with acute myocardial infarction receiving percutaneous coronary intervention. Med Sci Monit. 2019;25:9690-9701.
15. Yang YL, Wu CH, Hsu PF, et al. Systemic immune-inflammation index (SII) predicted clinical outcome in patients with coronary artery disease. Eur J Clin Invest. 2020;50(5):e13230.
16. Kelesoglu S, Yilmaz Y, Elcik D, et al. C-reactive protein to albumin ratio as a predictor of contrast-induced nephropathy after carotid angiography. Angiology. 2024;75(1):90-97.
17. Stacul F, van der Molen AJ, Reimer P, et al. Contrast induced nephropathy: updated ESUR Contrast Media Safety Committee guidelines. Eur Radiol. 2011;21(12):2527-2541.
18. Rencuzogullari I, Çağdaş M, Karakoyun S, et al. Association of syntax score II with contrast-induced nephropathy and hemodialysis requirement in patients with ST segment elevation myocardial infarction undergoing primary percutaneous coronary intervention. Korean Circ J. 2018;48(1):59-70.
19. Wang J, Zhang C, Liu Z, Bai Y. Risk factors of contrast-induced nephropathy after percutaneous coronary intervention: a retrospective analysis. J Int Med Res. 2021;49(4):3000605211005972.
20. De Luca G, Suryapranata H, Marino P. Reperfusion strategies in acute ST-elevation myocardial infarction: an overview of current status. Prog Cardiovasc Dis. 2008;50(5):352-382.
21. McCullough PA, Soman SS. Contrast-induced nephropathy. Crit Care Clin. 2005;21(2):261-280.
22. Margulies K, Schirger J, Burnett J Jr. Radiocontrast-induced nephropathy: current status and future prospects. Int Angiol. 1992;11(1):20-25.
23. Marenzi G, De Metrio M, Rubino M, et al. Acute hyperglycemia and contrast-induced nephropathy in primary percutaneous coronary intervention. Am Heart J. 2010;160(6):1170-1177.
24. Maiuolo J, Oppedisano F, Gratteri S, Muscoli C, Mollace V. Regulation of uric acid metabolism and excretion. Int J Cardiol. 2016;213:8-14.
25. Richette P, Bardin T. Gout. Lancet. 2010;375(9711):318-328.
26. Kanbay A, Inonu H, Solak Y, et al. Uric acid as a potential mediator of cardiovascular morbidity in obstructive sleep apnea syndrome. Eur J Intern Med. 2014;25(5):471-476.
27. Ekici B, Kütük U, Alhan A, Töre HF. The relationship between serum uric acid levels and angiographic severity of coronary heart disease. Kardiol Pol. 2015;73(7):533-538.
28. Mudge GH. Uricosuric action of cholecystographic agents. A possible factor in nephrotoxicity. N Engl J Med. 1971;284(17):929-933.

29. Jung YD, Fan F, McConkey DJ, et al. Role of P38 MAPK, AP-1, and NF-κB in interleukin-1β-induced IL-8 expression in human vascular smooth muscle cells. Cytokine. 2002;18(4):206-213.
30. Corry DB, Eslami P, Yamamoto K, Nyby MD, Makino H, Tuck ML. Uric acid stimulates vascular smooth muscle cell proliferation and oxidative stress via the vascular renin-angiotensin system. J Hypertens. 2008;26(2):269-275.
31. Filiopoulos V, Hadjiyannakos D, Vlassopoulos D. New insights into uric acid effects on the progression and prognosis of chronic kidney disease. Ren Fail. 2012;34(4):510-520.
32. Barbieri L, Verdoia M, Schaffer A, et al. Uric acid levels and the risk of contrast induced nephropathy in patients undergoing coronary angiography or PCI. Nutr Metab Cardiovasc Dis. 2015;25(2):181-186.
33. Shacham Y, Gal-Oz A, Flint N, Keren G, Arbel Y. Serum uric acid levels and renal impairment among ST-segment elevation myocardial infarction patients undergoing primary percutaneous intervention. Cardiorenal Med. 2016;6(3):191-197.
34. Mendi MA, Afsar B, Oksuz F, et al. Uric Acid is a useful tool to predict contrast-induced nephropathy. Angiology. 2017;68(7):627-632.
35. Mehran R, Aymong ED, Nikolsky E, et al. A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: development and initial validation. J Am Coll Cardiol. 2004;44(7):1393-1399.
36. Erol T, Tekin A, Katırcıbaşı MT, et al. Efficacy of allopurinol pretreatment for prevention of contrast-induced nephropathy: a randomized controlled trial. Int J Cardiol. 2013;167(4):1396-1399.
37. Toprak O. Risk markers for contrast-induced nephropathy. Am J Med Sci. 2007;334(4):283-290.
38. Gucun M, Akyuz O, Bayram E, Cakmak EO. Systemic immune-inflammation index is a novel marker to predict contrast-induced acute kidney injury. Eurasian J Med Investig. 2021;5(4):435-440.
39. Kelesoglu S, Yilmaz Y, Elcık D, et al. Systemic immune inflammation index: a novel predictor of contrast-induced nephropathy in patients with non-ST segment elevation myocardial infarction. Angiology. 2021;72(9):889-895.
40. Kan WC, Huang YT, Wu VC, Shiao CC. Predictive ability of procalcitonin for acute kidney injury: a narrative review focusing on the interference of infection. Int J Mol Sci. 2021;22(13):6903.
41. Satilmis S, Karabulut A. Value of C-reactive protein/albumin ratio in predicting the development of contrast-induced nephropathy in patients with non-ST elevation myocardial infarction. Angiology. 2020;71(4):366-371.
42. Karabağ Y, Çağdaş M, Rencuzogullari I, et al. 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.
43. Toprak O, Cirit M, Yesil M, et al. Impact of diabetic and pre-diabetic state on development of contrast-induced nephropathy in patients with chronic kidney disease. Nephrol Dial Transplant. 2007;22(3):819-826.
44. Çetin M, Acehan F, Kundi H, et al. A novel risk prediction tool for contrast-induced nephropathy in patients with chronic kidney disease who underwent diagnostic coronary angiography. Eur Rev Med Pharmacol Sci. 2023;27(8):3430-3437.