Clinical Interventions in Aging

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ORIGINAL RESEARCH

The Association of Intraindividual Difference Between Cystatin- and Creatinine-Based Estimated GFR and Contrast-Associated Acute Kidney Injury

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Purpose: The estimated glomerular filtration rate (eGFR) based on creatinine is crucial for the risk assessment of contrast-associated acute kidney injury (CA-AKI). In recent, the difference between cystatin C-based eGFR (eGFRcys) and creatinine-based eGFR (eGFRcr) has been widely documented. We aimed to explore whether intraindividual differences between eGFRcys and eGFRcr had potential value for CA-AKI risk assessment in patients undergoing elective percutaneous coronary intervention (PCI).

Patients and Methods: From January 2012 to December 2018, we retrospectively observed 5049 patients receiving elective PCI. To determine eGFR, serum creatinine and cystatin C levels were measured. CA-AKI was defined as serum creatinine being increased ≥ 50% or 0.3 mg/dL within 48 h after contrast agents exposure. Chronic kidney disease (CKD) was defined as the eGFR < 60 mL/min/1.73 m^2.

Results: Approximately half of the participants (2479, 49.1%) had a baseline eGFRdiff (eGFRcys-eGFRcr) between −15 and 15 mL/min/1.73 m^2. Restricted cubic splines analysis revealed a nonlinear relationship between eGFRdiff and CA-AKI. Multivariable logistic regression analysis indicated that compared with the reference group (−15 to 15 mL/min/1.73 m^2), the negative-eGFRdiff group (less than −15 mL/min/1.73 m^2) had a higher risk of CA-AKI (OR, 3.44; 95% CI, 2.57–4.64). Furthermore, patients were divided into four groups based on CKD identified by eGFRcys or eGFRcr. Multivariable logistic analysis revealed that patients with either CKDcys (OR, 2.94; 95% CI, 2.19–3.95, $P < 0.001$) or CKDcr (OR, 2.44; 95% CI, 1.19–4.63, $P < 0.001$) had an elevated risk of CA-AKI compared to those without CKDcys and CKDcr.

Conclusion: There are frequent intraindividual differences between eGFRcys and eGFRcr, and these differences can be used to forecast the risk of CA-AKI.

Keywords: estimated glomerular filtration rate, contrast-associated acute kidney injury, cystatin C, percutaneous coronary intervention

Introduction

In patients with coronary heart disease, percutaneous coronary intervention (PCI) is one technique for revascularization that restores coronary blood flow. During the procedure, contrast agent is used to make the coronary arteries visible. As one of the major postoperative complications in patients undergoing elective PCI, contrast-associated acute kidney injury (CA-AKI) closely related to dialysis risk,[1] an extended hospital stay, increased costs, and even a poor prognosis.[2,3] Additionally, the population of individuals at CA-AKI risk is particularly vast due to the substantial burden of coronary heart disease.[4] It's

Received: 28 October 2023
Accepted: 27 February 2024
Published: 8 March 2024

important to find predictors to forecast the CA-AKI occurrences. One of the most well-known risk factors in clinical practice currently is lower creatinine-based eGFR (eGFRcr),[5] which is usually adopted in risk-scoring systems for CA-AKI prediction.[6] However, it is possible that people with extremes of protein intake, or muscle mass may have creatinine values that do not necessarily reflect the true GFR.[7] Therefore, when eGFR is solely assessed by creatinine, the number of patients at risk for CA-AKI may be ambiguous. Nevertheless, eGFRcr remains the most widely utilized indicator in the clinical context due to its low price and availability. In comparison, cystatin C is less sensitive to muscle mass and independent of dietary protein intake.[8] Some scholars have proposed cystatin C as a diagnostic and evaluable index of CA-AKI.[9] With the increasing clinical application of cystatin C-based eGFR (eGFRcys), it has been extensively noted that there are often differences between eGFRcys and eGFRcr. This difference contains expected information that has been linked to frailty,[10] heart failure,[11] and poor outcomes.[12] One study[13] showed that this difference is common in patients with heart failure, is considered a manifestation of frailty, and is associated with a poor short-term prognosis.

In addition to heart failure, cardiovascular specialists are highly worried about renal function in patients undergoing percutaneous coronary intervention (PCI), since it is directly associated with CA-AKI. Additionally, the Chronic kidney disease (CKD) stage determined by eGFR may differ according to the use of various markers, increasing the uncertainty surrounding the risk of CA-AKI. This study aimed to explore the predictive value of intraindividual differences between eGFRcys and eGFRcr for CA-AKI in patients undergoing elective percutaneous coronary intervention (PCI).

Methods

Study Population

This study included all patients who received elective PCI and detected creatinine as well as cystatin C in Fujian Provincial Hospital from 2012 to 2018. The exclusion criteria were as follows: (1). concomitant diseases (thyroid disease, malignant tumors with life expectancy less than 1 year, eGFR less than 15 mL/min/1.73m^2 or dialysis (n=30); (2). use of steroid hormones (n=3); (3). died within 72 hours after admission (n=4). Finally, 5049 patients were enrolled in this analysis (Figure 1).

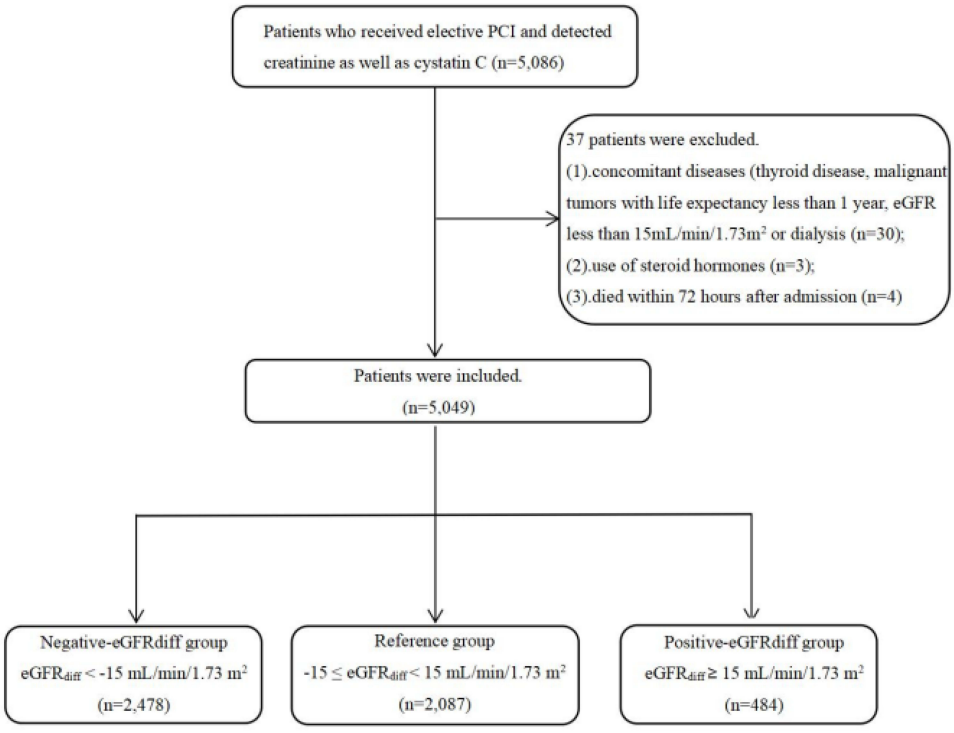

Figure 1 Information on the selection of study participants.

Percutaneous Coronary Intervention

PCI is performed by experienced interventional cardiologists according to ACC/AHA/SCAI guidelines for coronary artery revascularization. A nonionic and low-osmolarity contrast medium (CM) was administered to all the patients during all procedures (either ultravist or iopamiron, both 370 mgI/mL). Hydration is one of the effective methods to preventing CA-AKI in revascularization guidelines. In addition, intravenous infusion of 0.9% normal saline at a rate of 1 mL/kg/h (or 0.5 mL/kg/h for those who were intolerant) for 12 hours constituted hydration treatment.

Exposure

Serum creatinine (Scr) was detected at baseline and 2 consecutive days after the operation, and cystatin was only detected before the operation by using the COBAS automatic biochemical analyser (Roche Diagnostics, Basel, Switzerland). The eGFRcys and eGFRcr were calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) cystatin C equation (2012)[14] and CKD-EPI creatinine equation (2012),[15] respectively (Table S1). The eGFRdiff was defined as eGFRcys - eGFRcr, and categorized as < −15 mL/min/1.73 m^2 (negative-eGFRdiff group), −15 to 15 mL/min/1.73 m^2 (reference group), and ≥ 15 mL/min/1.73 m^2 (positive-eGFRdiff group). A difference of 15 mL/min/1.73 m^2 in eGFR was chosen to be the cut-point because it is clinically meaningful and capable of distinguishing CKD stages.[15] CKDcys and CKDcr were defined as the eGFRcys < 60 mL/min/1.73 m^2 and eGFRcr < 60 mL/min/1.73 m^2, respectively. This definition has clinical value, and is widely used by many studies.[15,16]

Outcomes

The primary outcome was CA-AKI which was diagnosed as an absolute SCr increase ≥ 26.4 μmol/L or a relative increase in SCr ≥ 50% within 48 h after CM exposure.

Covariates

All covariate data were obtained, including demographic characteristics, medical history, medical therapy during hospitalization, laboratory measurements, clinical presentation and procedure details. Biochemical tests including blood routine, coagulation function, liver function, kidney function, electrolytes, blood lipid profile, glycated hemoglobin, etc. were obtained on admission or after overnight fasting of 8–12 h.

Statistical Analysis

We summarized baseline characteristics according to three eGFRdiff (mL/min/1.73 m^2) groups. Numbers and percentages were shown for categorical variables, while means and standard deviations (normally distributed) or median and interquartile range (nonnormally distributed) were shown for continuous variables. By using the Wilcoxon rank-sum test or Student's *t*-test, the difference between the groups was determined.

For the evaluation of the linear or nonlinear association between eGFRdiff and CA-AKI, restricted cubic splines (RCS) were used. Multivariable logistic regression analyses were conducted on the factors that were significant in the univariable analysis ($P < 0.05$) or were of great clinical significance. Adjusted logistic regression models were constructed in the following ways: Model 1 adjusted for age, sex; Model 2 included adjustments for Model 1 variables as well as smoking and morbidities (hypertension, diabetes, atrial fibrillation, anemia, eGFRcr < 60 mL/min/1.73m^2); Model 3 further adjusted for acute myocardial infarction, congestive heart failure and contrast volume > 150mL. A fully adjusted logistic regression model was used for the subgroup and interaction analyses, subgroup ORs and 95% confidence intervals were calculated along with interactions *P* values. The results were presented in the form of forest plots. Another manifestation of the intraindividual difference between eGFRcys and eGFRcr is the different CKD definitions derived from them. To further evaluate the effects of different CKD definitions on predicting CA-AKI, patients were categorized into four groups according to with or without CKDcys and CKDcr. Statistical analyses were performed by R (version 4.1.2; R Foundation, Vienna, Austria). A value of $P < 0.05$ (two-tailed) was considered statistically significant.

Results

Baseline Characteristics

Of 5049 eligible patients, 324 (6.42%) patients developed CA-AKI. Approximately half of the participants had eGFRdiff between −15 and 15 mL/min/1.73 m^2 (2478, 49.1%). Basic demographic and procedural characteristics were presented in Table 1. Since we choose patients with elective PCI, the great majority of patients had stable hemodynamics and patients requiring intra-aortic balloon pump (IABP) support were very few in our study (only 2 patients). Compared with the other two eGFRdiff groups, participants in the negative-eGFRdiff group were generally older and tended to have higher cystatin C and D-dimer levels while having lower serum creatinine and hemoglobin levels. They presented with a higher rate of acute myocardial infarction incidence, had elevated levels of N-terminal pro-brain natriuretic peptide, and were more frequently treated with diuretics. There were no significant differences in sex, body mass index, hypertension and atrial fibrillation among the three groups. The baseline characteristics of patients with and without CA-AKI were shown in Table S2.

Predictive Value of the eGFRdiff on CA-AKI

RCS in logistic regression analysis revealed a nonlinear relationship between eGFRdiff and CA-AKI risk (*P* for non-linearity < 0.001, Figure 2). Univariable logistic regression analysis indicated that compared with reference group, negative-eGFRdiff group had a higher risk of CA-AKI (odds ratio [OR], 3.43; 95% CI, 2.66–4.46, Table 2). These differences persisted after adjustment for potential confounding factors (Model 1: OR, 3.35; 95% CI, 2.60–4.36; Model 2: OR, 3.53; 95% CI, 2.67–4.70; Model 3: OR, 3.44; 95% CI, 2.57–4.64). Subgroup analysis showed that none of the different subgroups had any discernible interaction effects (Figure 3). Negative eGFRdiff was associated with an increased CA-AKI risk irrespective of with or without CKDcr (*P* for interaction = 0.528).

Table 1 Baseline Variables Among Different $eGFR_{diff}$ Groups (mL/Min/1.73 m^2)

	$-15 \le eGFR_{diff} < 15$	$eGFR_{diff} < -15$	$eGFR_{diff} \ge 15$	*P* value
	n=2478	n=2087	n=484	
Demographics				
Age, median [IQR], years	65.0 (58.0–72.0)	67.0 (60.0–74.0)	65.0 (57.0–73.0)	<0.001
Sex, male, n (%)	1932 (78.0)	1630 (78.1)	397 (82.0)	0.126
Body mass index, median [IQR], kg/m^2	24.4 (22.5–26.3)	24.1 (22.2–26.2)	24.0 (22.1–26.4)	0.177
Medical history, n (%)				
Smoking	962 (46.0)	937 (50.7)	229 (50.0)	0.009
Diabetes	899 (36.3)	704 (33.7)	197 (40.7)	0.010
Hypertension	1690 (68.2)	1410 (67.6)	323 (66.7)	0.784
Atrial fibrillation	155 (6.26)	148 (7.09)	32 (6.61)	0.527
Congestive heart failure	95 (3.83)	106 (5.08)	19 (3.93)	0.108
Acute myocardial infarction	700 (28.2)	698 (33.4)	133 (27.5)	<0.001
Laboratory measurements				
WBC, median [IQR], 10^9/L	6.96 (5.82–8.32)	6.97 (5.80–8.52)	6.93 (5.66–8.24)	0.396
HGB, median [IQR], g/L	139 (128–149)	137 (126–147)	138 (128–148)	<0.001
TC, median [IQR], mmol/L	4.05 (3.43–4.89)	4.06 (3.42–4.91)	4.06 (3.40–4.92)	0.783
HDL-C, median [IQR], mmol/L	1.00 (0.84–1.20)	1.00 (0.85–1.19)	1.00 (0.83–1.21)	0.900
LDL-C, median [IQR], mmol/L	2.57 (2.01–3.29)	2.58 (1.98–3.28)	2.51 (2.01–3.26)	0.625
Cystatin C, median [IQR], mg/L	0.88 (0.80–1.01)	1.18 (1.04–1.41)	0.72 (0.62–0.82)	<0.001
Serum creatinine, median [IQR], mg/dL	0.88 (0.76–1.03)	0.85 (0.74–0.96)	1.01 (0.86–1.15)	<0.001
NT-proBNP, median [IQR], pg/mL	160 (60.6–594)	261 (86.9–1055)	182 (60.3–514)	<0.001
HbA1c, median [IQR], %	6.20 (5.80–7.00)	6.20 (5.80–6.90)	6.40 (5.90–7.50)	<0.001
LVEF<40, n (%)	53 (2.25)	62 (3.14)	13 (2.87)	0.189

(*Continued*)

Table 1 (Continued).

	$-15 \leq eGFR_{diff} < 15$	$eGFR_{diff} < -15$	$eGFR_{diff} \geq 15$	*P* value
	n=2478	n=2087	n=484	
PCI procedures				
No. of diseased vessels, n (%)				0.085
1	410 (17.1)	302 (15.3)	67 (14.2)	
2	611 (25.5)	469 (23.8)	129 (27.4)	
3	1373 (57.4)	1201 (60.9)	275 (58.4)	
Lesion, n (%)				
Left main coronary artery	214 (8.89)	173 (8.71)	38 (8.02)	0.825
Left anterior descending artery	2148 (89.1)	1800 (90.4)	434 (91.6)	0.176
Circumflex artery	1660 (68.9)	1416 (71.1)	330 (69.6)	0.282
Right coronary artery	1665 (69.1)	1422 (71.4)	332 (70.0)	0.253
Medical therapy during hospitalization				
Antiplatelet, n (%)	2474 (99.8)	2084 (99.9)	484 (100)	1.000
Statin, n (%)	2456 (99.1)	2069 (99.1)	483 (99.8)	0.333
ACEI/ARB, n (%)	2062 (83.2)	1743 (83.5)	396 (81.8)	0.666
β-blocker, n (%)	2050 (82.7)	1757 (84.2)	404 (83.5)	0.418
CCB, n (%)	884 (35.7)	742 (35.6)	168 (34.7)	0.921
Diuretic, n (%)	524 (21.1)	591 (28.3)	119 (24.6)	<0.001

Abbreviations: WBC, white blood cell; HGB, hemoglobin; PLT, platelet; TC, total cholesterol; HDL-C, high density lipoprotein -cholesterol; LDL-C, low density lipoprotein-cholesterol; NT-proBNP, N-terminal pro-brain natriuretic peptide; HbA1c, glycated haemoglobin; LVEF, left ventricular ejection fraction; ACEI/ARB, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; CCB, calcium channel blockers.

The Effect of Different CKD Definitions on CA-AKI

Multivariable logistic analysis indicated that CKD was an independent risk factor of CA-AKI. Compared to non-CKD patients, patients with either CKDcys (OR, 2.94; 95% CI 2.19–3.95) or CKDcr (OR, 2.44; 95% CI,1.19–4.63) were prone to CA-AKI development (Table 3). Interestingly, the risk of CA-AKI in patients with both CKDcys and CKDcr was similar to those with either CKDcys or CKDcr (CKDcys and CKDcr vs CKDcys and non-CKDcr, OR, 0.999; 95% CI, 0.661–1.491; CKDcys and CKDcr vs non-CKDcys and CKDcr, OR, 1.207; 95% CI, 0.604–2.568).

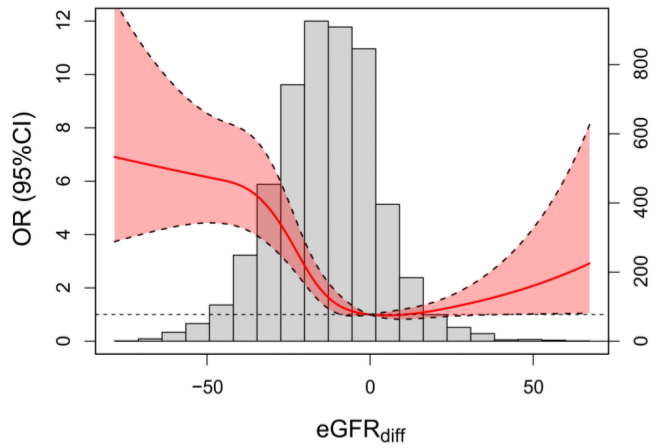

Figure 2 Restricted cubic spline (RCS) of the association between the eGFRdiff and CA-AKI (eGFRdiff was defined as eGFRcys - eGFRcr). The frequency distribution histogram (where the height of each bar represents the frequency of data within that range).

Table 2 Logistic Regression for the Relationship of eGFRdiff and CA-AKI

Models	Negative-eGFR$_{diff}$ Group		Reference Group	Positive-eGFR$_{diff}$ Group	
	OR(95% CI)	*P* value	OR(95% CI)	OR(95% CI)	*P* value
Unadjusted	3.43(2.66–4.46)	< 0.001	1(Ref.)	0.97(0.55–1.63)	0.925
Model 1	3.35(2.60–4.36)	< 0.001	1(Ref.)	0.98(0.55–1.65)	0.945
Model 2	3.53(2.67–4.70)	< 0.001	1(Ref.)	0.78(0.43–1.33)	0.383
Model 3	3.44(2.57–4.64)	< 0.001	1(Ref.)	0.76(0.41–1.34)	0.368

Notes: Model 1: adjusted age > 75 years and sex. Model 2: Model 1 +smoking, diabetes, hypertension, atrial fibrillation, anemia, eGFRcr < 60 mL/min/1.73m^2. Model 3: Model 2 +acute myocardial infarction, congestive heart failure and contrast volume > 150mL.

Abbreviations: CA-AKI, contrast-associated acute kidney injury; negative-eGFR$_{diff}$ group, eGFR$_{diff}$ < −15 mL/min/1.73 m^2; reference group, −15 ≤ eGFR$_{diff}$ < 15 mL/min/1.73 m^2; positive-eGFR$_{diff}$ group, eGFR$_{diff}$ ≥ 15 mL/min/1.73 m^2.

Sensitivity Analysis

The eGFRcr derived from other formulae, such as CKD-EPI (2021) and Modification of Diet in Renal Disease (MDRD), may affect the value of eGFRdiff and the population of CKD. To deeper evaluate the robustness of the results, we conducted a series of sensitivity analyses. Overall, the results obtained from sensitivity analyses were consistent with our

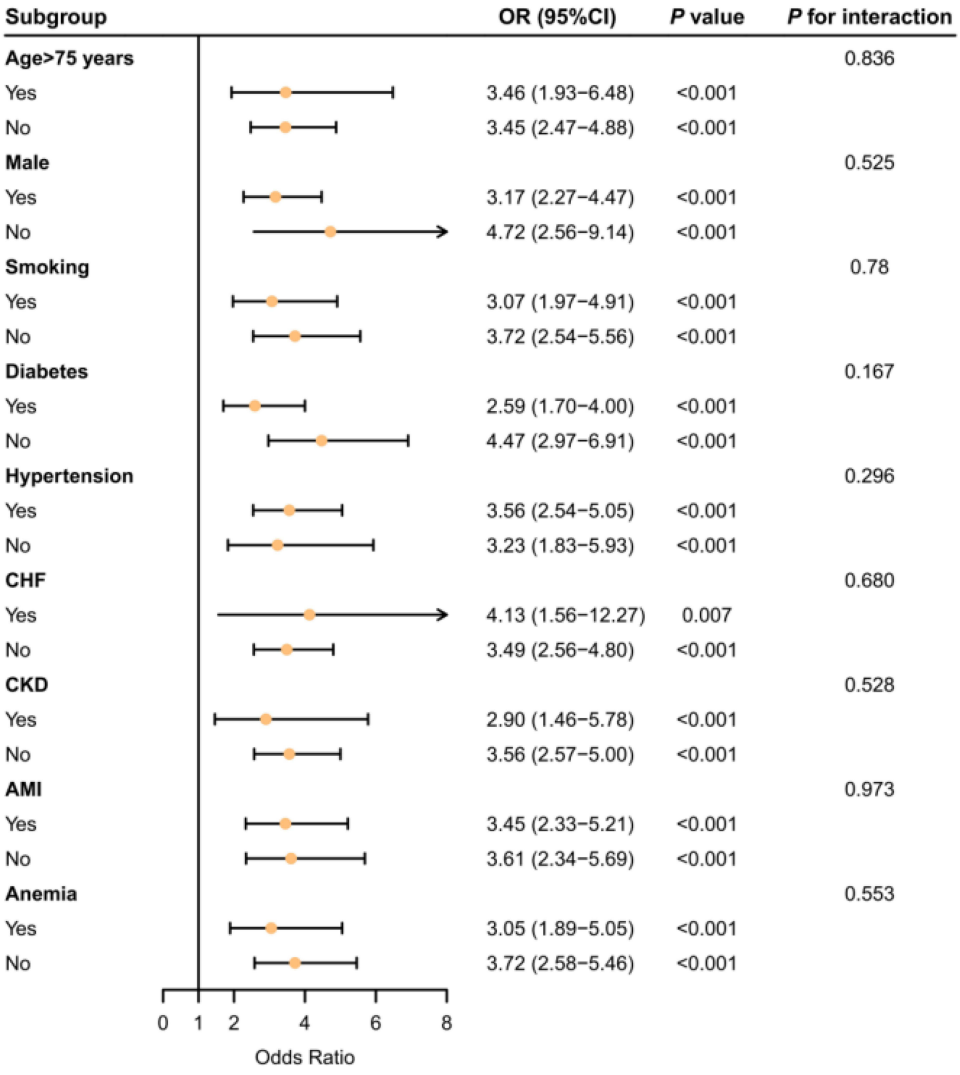

Figure 3 Subgroup analysis stratified by CA-AKI risk factors.

Table 3 CA-AKI Risk Among Different CKD Groups

Models	CKDcys (-) CKDcr (-)	CKDcys (+) CKDcr (-)	CKDcys (-) CKDcr (+)	CKDcys (+) CKDcr (+)
Unadjusted	1 (Ref.)	3.55(2.76–4.58)	3.69(1.92–6.54)	4.20(2.96–5.88)
Model 1	1 (Ref.)	3.39(2.61–4.39)	3.44(1.79–6.14)	3.80(2.64–5.42)
Model 2	1 (Ref.)	2.65(2.00–3.50)	2.45(1.25–4.45)	2.97(2.00–4.34)
Model 3	1 (Ref.)	2.94(2.19–3.95)	2.44(1.19–4.63)	2.94(1.93–4.41)

Notes: Model 1: adjusted age > 75 years and sex. Model 2: Model 1 +smoking, diabetes, hypertension, atrial fibrillation, anemia, eGFRcr < 60 mL/min/1.73m^2. Model 3: Model 2 +acute myocardial infarction, congestive heart failure and contrast volume > 150mL.

Abbreviations: CA-AKI, contrast-associated acute kidney injury; CKDcys, eGFRcys < 60 mL/min/1.73 m$^{2;}$ CKDcr, eGFRcr < 60 mL/min/1.73 m$^{2.}$

main findings and were presented in Tables S3 and S4. Negative-eGFRdiff maintained a strong association with CA-AKI regardless of the use of eGFR equations. After excluding patients with eGFR < 30mL/min/1.73m^2 (n=36), the results remained consistent with the main analysis (Table S5).

Discussion

As far as we are aware, this is the first study to investigate the association of intraindividual differences between eGFRcys and eGFRcr and CA-AKI in patients undergoing elective PCI. The main finding of this study was that not only the differences in the absolute value of eGFRcys versus eGFRcr but also the differences in CKD status were associated with the risk of CA-AKI. Despite being a retrospective study conducted at a single institution, our investigation included a large sample size and thorough available factors.

Although creatinine is currently the most commonly used biomarker to estimate GFR, its susceptibility to non-glomerular filtration rate has been concerned. Therefore, cystatin C as an alternative predictor was discussed in previous studies.[17] In recent years, the National Kidney Foundation (NKF) and the American Society of Nephrology (ASN) have strongly recommended the promotion of routine and dynamic detection of cystatin C, especially to confirm eGFR in those who are at risk of or with chronic kidney disease.[18] Individual differences between eGFRcys and eGFRcr have not received attention for a long time before. At present, it is the mainstream trend to comprehensively evaluate renal function and the risk of kidney disease by using both indicators simultaneously.[12,13,19] A close relationship between eGFRdiff and heart failure was observed in previous studies. A Cohort Analysis of Chronic Renal Insufficiency Cohort (CRIC) Study found that patients in the eGFRdiff < −15 group had a 2-fold increased risk of heart failure hospitalization,[11] a 1.37-fold increased risk of developing into end-stage Kidney Disease (ESKD), and a 2.73-fold increased risk of death[12] compared with patients in the eGFRdiff ≥ 15 group. Besides, eGFRdiff is also closely associated with frailty and poor prognosis. In the Systolic Blood Pressure Intervention Trial (SPRINT), fully adjusted model showed that each unit standard deviation decrease in eGFRdiff was associated with 24% increased odds of prevalent frailty (OR,1.32; 95% CI,1.23–1.41), with a higher incidence rate of injurious falls (HR, 1.19; 95% CI, 1.09–1.30), cardiovascular events (HR, 1.12; 95% CI, 1.03–1.23), and all-cause mortality (HR, 1.41; 95% CI, 1.22–1.59).[10] Our research expands the clinical applications of eGFRdiff and highlights its significance in the prediction of CA-AKI.

As a potential substitute for creatinine, cystatin C has been proved to be a biomarker in the prevention[20,21] and diagnostic criterion of CA-AKI.[9,22,23] Since cystatin C and creatinine were often analysed separately, the roles they played concurrently in CA-AKI have been still unclear. What's more, the significance of eGFRdiff for CA-AKI is still a blank. This study is the first to observe a relationship between eGFRdiff and CA-AKI. Our study showed that patients with eGFRdiff less than −15 mL/min/1.73 m^2 had a more than 3-fold higher risk of CA-AKI than those without, which was proved to be independent of eGFRcr. There are some reasons for this result. Firstly, one of the main contributing factors to the onset of frailty is sarcopenia, which is defined as the loss of skeletal muscle mass and decrease in muscle strength that is directly linked to aging.[24] eGFRdiff is associated with sarcopenia and frailty,[10,25] which have proved to be the risk factors for CA-AKI.[26] Non-GFR factors such as sarcopenia and malnutrition can interfere with the estimation of eGFRcr, resulting in an overestimation of that and a lower eGFRdiff. Negative eGFRdiff may be a bridge between frailty

and CA-AKI. Furthermore, negative eGFRdiff may be a novel and particular type of renal dysfunction and result in susceptibility to CA-AKI. Previous studies have shown that a significantly lower eGFRcys than eGFRcr may also be a manifestation of kidney disease,[27–29] which is mainly manifested in glomerular filtration dysfunction of medium-sized molecules,[27,30] such as cystatin C. And, eGFRdiff is negatively correlated with the severity of this novel kidney disease.[31] Moreover, this disease may cause the decline of the resistance and defense of the kidneys[32] and lead to a tendency of CA-AKI when hit by the contrast agent.

Besides, patients with either CKDcys or CKDcr were found to be associated with CA-AKI development in this study. Current ACC/AHA/SCAI guidelines only recommended routine hydration in patients with CKD defined by eGFRcr. However, we have found that the differences between eGFRcys and eGFRcr were very common and about 20% of the patients (1031 / 5049) had CKDcys but not CKDcr. These patients may be underestimated in the initial CA-AKI risk assessment and were likely to miss the only prevention measure due to the insufficient clinical use of cystatin C. Therefore, we suggest that it is necessary to detect cystatin C routinely and even evaluate eGFRdiff and CKDcys in patients undergoing PCI to enhance the sensitivity of CA-AKI risk assessment during current clinical practice. Combining other risk factors such as age, gender, diabetes mellitus to promote the precision of risk assessment of CA-AKI.[33] The categorization based on eGFRcr and eGFRcys makes it feasible to correctly identify the groups at risk for CA-AKI, and clinicians may then apply more aggressive intervention methods in response, including active hydration, reduced contrast use and active adoption of acute kidney injury care bundles.[34]

Limitations

There are several limitations in our study. First of all, the design of this study is a single-center, observational study, which has inherent limitations. It is thus necessary to confirm these results in a multicenter, large-scale, international study. The presence of residual confounding cannot be included despite adjusting for potential confounders as far as possible. In addition, GFR was estimated from serum biomarkers and not able to be compared with the real situation.

Conclusion

Our study demonstrated that intraindividual differences between eGFRcys and eGFRcr could provide more predictive utility on the risk stratification of CA-AKI in patients undergoing elective PCI. First, eGFRdiff less than −15 mL/min/1.73 m^2 is associated with a higher risk of CA-AKI. Second, both CKD determined by eGFRcys or eGFRcr can markedly predict the occurrence of CA-AKI. Future research is required to investigate the underlying mechanisms of eGFRdiff and to determine whether it is associated with other disorders. It is also necessary to raise public awareness of eGFRdiff.

Abbreviations

PCI, percutaneous coronary intervention; CA-AKI, contrast-associated acute kidney injury; eGFRcr, creatinine-based eGFR; eGFR, estimated glomerular filtration rate; eGFRcys, cystatin C-based eGFR; CM, contrast medium; CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration; MDRD, Modification of Diet in Renal Disease.

Data Sharing Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Informed Consent

A review and approval of the study were performed by the Fujian Provincial Hospital Ethics Committee (Ethical approval number: K2019-07-011). Our research conformed to the Declaration of Helsinki. Due to the retrospective nature of the study, informed written consent was waived. Personal information and data remained confidential and anonymous.

Author Contributions

LW Z, MQ L and JL Z contributed equally to this work. All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these

areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was funded by a grant from the National Natural Science Foundation of China General Program (Grant number: 81873495, 82171569), Heart Failure Center Research Foundation of Fujian Provincial Hospital (supported by Fujian Provincial Department of Finance), National Key Clinical Specialty Construction Project of China (Cardiovascular Medicine 2021). The grants played no roles in the design of the study, collection of data, follow-up of the patients, interpretation of data and writing the manuscript.

Disclosure

The authors report no conflicts of interest in this work.

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