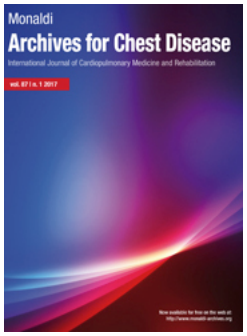

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Impact of percutaneous coronary intervention on renal function in patients with coronary heart disease

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Abstract

The relationship between cardiac and renal function is complicated. The impact of percutaneous coronary intervention (PCI) on renal function in patients with coronary artery disease is still unclear. The current study sought to assess renal function change, including the time course of renal function, after elective PCI in patients with improved renal function and to identify renal function predictors of major adverse cardiovascular events. We examined data from 1572 CHD patients who had coronary angiography

(CAG) or PCI in this retrospective cohort study. Patients receiving elective PCI (n=1240) and CAG (n=332) between January 2013 and December 2018 were included. Pre-PCI and procedural variables associated with post-PCI eGFR, change in renal function after post-PCI follow-up, and post-PCI eGFR association with major adverse cardiovascular events were investigated. Following the procedure, 88.7 percent of PCI group patients had unchanged or improved renal function. The treatment of PCI was found to independently correlate with IRF following coronary angiography in an analysis of patients undergoing PCI [OR 4.561 (95% CI:2 .556-8.139); p<0.001]. The area under the receiver operating characteristic (ROC) curve is 0.763 (model with the treatment of PCI). Improved renal function (IRF) and stable renal function were both associated with a lower risk of a major cardiovascular event.

Key words: percutaneous coronary intervention; renal function.

Introduction

Coronary angiography (CAG) and percutaneous coronary intervention (PCI) are valuable diagnostic and therapeutic tools in cardiovascular medicine. With expanded use in intermediate- and low-risk patients and widening access, PCI is increasingly performed for patients with coronary heart disease (CHD). Previous studies have shown that renal dysfunction at baseline, unstable hemodynamics and the use of large amounts of contrast media have been associated with the deterioration of renal function [1,2]. Contrast-induced nephropathy (CIN) is characterized by a decline in renal function within the first 48-72 h following contrast administration, in the absence of alternative etiologies [3]. CIN occurs in up to 10% of cardiac catheterizations and coronary interventions, resulting in increased morbidity, mortality, and cost. Further, more clearly established is that baseline and post-operative renal function are risk factors for in-hospital and short- and intermediate-term mortality following PCI. Renal dysfunction may be related to coronary microvascular dysfunction and obstruction [4]. Different clinical trials have confirmed that renal dysfunction, including reduced glomerular filtration rate (GFR) and albuminuria, is associated with increased risk for cardiovascular (CV) outcomes.

However, improved renal function (IRF) after PCI has also been reported, even in patients with renal dysfunction at baseline [5,6]. IRF was associated with favorable renal outcomes. Hemodynamic stabilization may be important for improving the short-term and long-term renal outcomes of high-risk patients [7]. Obviously, data about the renal function changes in patients with CHD after elective PCI are inconsistent. This led to the hypothesis that although several clinical and procedural variables contribute to change in renal function, some patients may have cardiorenal syndrome that is alleviated with improved hemodynamics post-PCI.

In this study, the prognostic significance of renal function is evaluated with regard to among patients with CHD who were treated with elective PCI. Therefore, the current study was designed to generate evidence regarding the effect of PCI on renal function, as a guide to clinicians.

Materials and Methods

Study design and patient population

Between January 2013 and December 2018, 1,872 consecutive patients suspected of coronary heart disease with underwent coronary angiography in Shanghai Dongfang and Tongji Hospitals were enrolled in this study, of which 1,731 completed the follow-up of coronary angiography. One hundred and fifty-nine patients were excluded from analysis as per predefined exclusion criteria. The exclusion criteria included chronic peritoneal or hemodialysis treatment, malignant tumors or malignant hematological diseases, refractory heart failure, exposure to radiographic contrast within the previous two days, any allergies to radiographic contrast medium and/or coronary anatomy not suitable for PCI. There were 87 patients with GFRs of <15 mL/ (min 1.73 m^2), 26 with urinary system tumors, 32 with other malignant tumors and malignant hematological diseases, and 14 with non-ischemic cardiomyopathy and refractory heart failure (EF ≤25%). The study included 1,572 people (Figure 1).

The Ethics Committee of our institution approved the present study, and all patients provided their written informed consent.

According to the results of coronary angiography, patients were divided into four groups: Group A: coronary artery stenosis ≤50% (including normal coronary blood flow, and

previously implanted stent that there was no restenosis); Group B: 50% coronary artery stenosis ≤70% (no PCI treatment and previously implanted stent, there was no restenosis); Group C: coronary artery stenosis >70% undergoing PCI treatment, but residual stenosis > 50%; Group D: coronary artery stenosis >70% undergoing PCI treatment and residual stenosis ≤50% (all included analysis of blood vessel diameters are ≥2.0 mm). Group A and B were seemed as CAG group, while group C and D were viewed as PCI group. A nonionic, low-osmolality contrast agent, iopamiron (755 mg iopamidol per milliliter, SINE, Shanghai, China), was used exclusively. The selection of the arterial access site, guide catheters, balloons and stents, contrast dose and supportive pharmacological therapies applied during the procedure was left to the discretion of the interventional cardiologist. The decision to perform PCI was made at the discretion of the operating cardiologist based on the patient's clinical profile, lesion characteristics, and patient preference. If a patient underwent multiple planned PCI during the time frame, only the last procedure was included in the analyses.

Each center's medical records were reviewed and patients' demographic, clinical, and procedural data were obtained. All enrolled patients undergoing PCI were either not initiated or if already taken, were discontinued the following drugs [angiotensin converting enzyme inhibitor (ACEI)/angiotensin receptor blocker (ARB)/diuretic/statins]. All patients underwent an echocardiographic evaluation within hospital admission. The SCr concentration was routinely measured, and the eGFR level was calculated before coronary angiography or PCI, 24 hours and follow-up. Relevant baseline and follow-up laboratory data [plasma glucose, hemoglobin A1c (HbA1c]), LDL, uric acid] and all adverse clinical events were recorded during hospitalization. Those who were diagnosed with new-onset diabetes were defined as fasting plasma glucose (FPG] of 7.0 mmol/l and 2-h postoral glucose load plasma glucose [2-h PG] of 11.1 mmol/l and no history of diabetes [10]. Uncontrolled LDL was defined as the follow-up LDL ≥70 mg/dl and uncontrolled blood glucose was defined as follow-up HbA1c ≥7 mmol/L.

Endpoints and definitions

The primary endpoint for this study was a change in renal variation from baseline to follow-up following CAG or PCI. Renal function was evaluated at 3-time points; baseline, 24 hours after PCI, and at the latest follow-up (>6 months).

The eGFR was calculated using the four-variable MDRD study equation of renal function was calculated as 175 × plasma creatinine$^{-1.154}$ × age$^{-0.203}$ (× 0.742 if patient is female) [11].

According to Uemura *et al.*, improved renal function (IRF) after PCI was defined as a 20% increase in eGFR 7 or 30 days after baseline [7]. Since prior studies have demonstrated that a 20% increase in eGFR is associated with favorable renal outcomes, especially in patients with renal dysfunction at baseline [12]. Changes in renal function were easier to understand in terms of eGFR instead of creatinine levels. Similarly, this study defined the improvement in renal function as a 20% increase in follow-up eGFR after baseline.

According to the 2016 ESC Heart Failure Guidelines, worsening renal function (WRF) was defined as a decrease in eGFR by ≥ 20% from baseline to follow-up [13]. Stable renal function was regarded as neither increase nor decrease 20% from baseline to follow-up. The IRF and WRF was calculated as follows:

IRF= (follow-up eGFR- baseline eGFR) / baseline eGFR >20%.

WRF= (baseline eGFR-follow-up eGFR) / baseline eGFR ≥20%.

Contrast-induced nephropathy was defined as either a 25% increase in baseline creatinine levels or a 0.5 mg/dL (44 μmol/L) increase in absolute serum creatinine levels within 72 h after the PCI according to the criteria of the main study[3].

Secondary endpoints were major cardiovascular adverse events including heart failure readmission, recurrent myocardial infarction and in-stent restenosis.

Statistical analysis

Demographic data was described across the four groups as mean ± SD for continuous variables and number (%) for categorical variables. The Student's *t*-test and Mann-Whitney U test were used to compare continuous variables, as appropriate and the chi-squared and Fisher exact tests were used to compare categorical variables, as appropriate. Profile plots were drawn for pictorial comparison of pre- and post-

procedural creatinine change. The p-value of 0.05 was taken as statistically significant. Kaplan-Meier analysis with the log-rank test was used to assess the cumulative incidences of heart failure and myocardial infarction. Multiple imputation and survival analyses were performed in R Version 3.1.0 (R Foundation for Statistical Computing, Vienna, Austria). Statistical analyses were performed using IBM SPSS® statistical software (SPSS version 23.0, Chicago, IL, USA) and R software (http://www.R-project.org/).

Results

Baseline characteristics

The baseline characteristics and procedure characteristics in the 1,572 patients are summarized in Table 1. Between January 2013 and December 2018, a total of 1,572 patients were enrolled in the trial. Of these patients, 151 (group A) had coronary angiography and a previously implanted stent with no restenosis, while 181 (group B) had boundary lesions with no stent implantation; 634 patients (group C) undergoing PCI treatment, but residual stenosis is more than 50%; 606 patients (group D) undergoing PCI treatment and residual stenosis is less than 50%. Most risk factors profiles and sex distribution were similar between patients with CAG and patients with PCI. The prevalence of diabetes tended to be higher in patients with elective PCI. The proportion of patients with elective PCI and stenosis is mostly male, had a higher prevalence of current smoking, had higher blood glucose, uric acid, BNP and LDL levels than patients with CAG ($p<0.05$).

Change in eGFR variation

The more severe coronary artery, the greater the amount of medium used during the operation, whereas the proportion of contrast medium nephropathy between the groups after the operation was not significantly different. The incidence of CIN was 0.6% in patients with CAG and 2.4% in patients with PCI. There was no signifcant diference in the incidence of CIN between patients with CAG and those with PCI. Patients with PCI had a lower rate of renal function deterioration, and the proportion of patients with improved renal function was higher (Table 2).The time course of renal function is shown in Table 2, which shows that worsening of follow-up renal function occurred in 220/1572

(14.0%) patients in the study cohort as a whole, 35/151 (23.2%) in group A, 45/181 (24.9%) in group B, 74/634 (11.7%) in group C and 66/606 (10.9%) in group D. Improvement in eGFR was seen in 201/1572 (12.8%) patients in study cohort as a whole, 7/46 (4.6%) in group A, 6/181 (3.3%) in group B, 94/634 (14.8%) in group C and 94/606 (15.5%) in group D. Table 3 shows the profile plot of eGFR values pre and post-CAG or PCI in the individual patients of the four study groups separately. There was a nonsignificant decreasing trend in mean eGFR from 87.98±17.41 mL/(min × 1.73 m^2) to 87.96±15.91 mL/(min × 1.73 m^2) in PCI group. At baseline, eGFR≥60 mL/(min × 1.73 m^2) was present in 88.9% of patients.

In the study cohort as a whole, following coronary angiography, there was a nonsignificant decreasing trend in mean eGFR (Figure 2A). Figure 2 B-D shows eGFR values pre- and post-PCI, in the individual patients of the four study groups separately. During the follow-up period, Figure 2 shows the number of patients having worsening, no change or improvement in baseline and follow-up eGFR in the four groups. Follow-up renal function was unchanged or improved in 88.7% of patients with PCI.

Variables associated with improved or worsening renal function

Of the 1,572 CHD patients in whom follow-up events including heart failure readmission, recurrent myocardial infarction, in-stent restenosis and renal function were recorded as a post-procedure. Among them, there are 220 patients in worsening eGFR group, 201 patients in improved eGFR group and 1151 patients with stable eGFR in which we compared the cardiovascular adverse events including heart failure and myocardial infarction. During the follow-up time, it was found that the incidence of cardiovascular adverse events gradually increased in worsening eGFR group. Cardiovascular adverse events during follow-up of patients with improved renal function will be significantly reduced (Figure 3).

Figures 4 and 5 compare patients with improved or worsening eGFR in terms of their baseline and procedural data. In our study, numerous other clinical variables were associated with improved eGFR, we followed up the low-density lipoprotein, blood sugar, and the rate of new-onset diabetes in patients with improved or worsening eGFR and found that there was no correlation to the prognosis of renal function. The incidence

of contrast-medium nephropathy has no significant effect on long-term renal function. There were significantly more patients with WRF who occurred major cardiovascular adverse events including heart failure readmission, recurrent myocardial infarction and in-stent restenosis during follow-up time than those with IRF ($p<0.01$). Besides, old age and major adverse cardiovascular events are associated with worsening eGFR. However, on multivariate analysis, the treatment of PCI was found to independently correlate with improved renal function [OR 4.561 (95%CI: 2.556-8.139); $p<0.001$]. The AUC-ROC was 0.763(95% CI: 0.637–0.757) in the model with the treatment of PCI (Figure 6).

Discussion

The findings of the study can be summarised as follows: (1) follow-up renal function was unchanged or improved in 88.7% of patients undergoing PCI and 75.9% of patients undergoing CAG, with a low risk of progression to CKD stage or dialysis; (2) patients with improved renal function significantly reduced long-term major cardiovascular adverse events; (3) in patients with PCI, the proportion of patients with improved renal function was higher.

Previous studies have shown that the deterioration of renal function following cardiac catheterization is closely related to the development or progression of renal dysfunction and dialysis initiation [18,19]. Tsai et al. studied consecutive patients undergoing PCI and found that at least 7% of all patients undergoing a PCI, develop CIN [20]. CIN is associated with a high in-hospital mortality burden, with 1 potential death avoided for every 9 cases of AKI that are prevented [21]. The current analysis focuses on the effect of PCI on renal function and only secondarily, as with other studies, on the effect of renal function on outcomes. The eGFR is the clinical standard for the assessment of risks and complications of renal function and provides risk assessment in diagnostic or therapeutic procedures such as a contrast agent administration [14]. As GFR declines, the prevalence of clinical manifestations of CHD increases, in parallel with the prevalence of large-vessel coronary disease, arteriosclerosis, microvascular disease, LVH, and myocardial fibrosis. Vascular calcification also increases as GFR declines and is associated with mortality in ESKD; calcification of the subintima and media of large vessels are both associated with all-cause and cardiovascular mortality [15,20]. Although patients undergoing PCI are

also at high risk for subsequent renal damage, their long-term renal outcomes have not been fully elucidated.

In our study all included patients, there was a nonsignificant decreasing trend in early eGFR and found that no more than 3% of all patients develop CIN. In this study, for patients with more severe coronary artery, the more the volume of contrast medium used during the operation, while the proportion of CIN between the groups after the operation was not significantly different. Probably, there might be a complex situation or a longer procedure for the achievement of complete revascularization in patients with more contrast media compared to those without. Worsening renal function was seen in only 14.0% of the study cohort. Renal function is sometimes improved or unchanged after PCI. It is noteworthy from our analysis that not only was eGFR ≥60 mL/(min × 1.73m^2) remarkably prevalent (>80%) among patients with CHD, but perhaps most noticeable, a large number of patients, including those with severe coronary artery exhibited improvement in renal function after PCI. As shown in our analysis, nearly 86% of patients showed unchanged or improvement in renal stage following CAG or PCI.

Although several factors may explain this association between renal and cardiovascular disease, there is growing evidence that hyperlipidemia and diabetes contribute not only to cardiovascular disease but also to renal disease progression. Good control of blood glucose levels is critical in diabetic patients to delay the progression of the underlying metabolic dysfunction and to reduce the risk of renal dysfunction and cardiovascular disease [22]. The CREDENCE trial [23] has shown that the cardiovascular and renal protection was observed independently of glycaemic control (as in the EMPA-REG OUTCOME trial) [24]. Studies in a variety of animal models have shown that hypercholesterolemia accelerates the rate of progression of kidney disease [25]. A high-fat diet causes macrophage infiltration and foam cell formation in rats, leading to glomerulosclerosis [26]. Therefore, it is crucial for cardiac patients to control risk factors, including lipids and glycaemic. It is likely that improved lipids and glycaemic control are clearly associated with improved renal function, but in our study we found that improved renal function was independent of these factors and was closely associated with PCI. In our study, many other clinical variables were associated with improvement in eGFR, and we followed up LDL, glucose, and rate of new-onset diabetes in patients with improved

or worsening eGFR and found that there is no correlation between them through multivariate logistic regression analysis. This may be due to the standardised pharmacological treatment of the enrolled patients in this study.

In this regard, changes in renal function would be an important factor for predicting outcomes. The presence and severity of renal dysfunction at baseline are well-known prognostic predictors for patients with ACS [16]. Renal dysfunction is an established predictor of adverse outcomes in patients with ACS and its negative effect has been reported to increase with the decline in renal function [17]. Previously, Uemura et al. reported that non-dialysis patients with ACS and advanced renal dysfunction have poor prognoses, even after undergoing contemporary PCI [7]. This study was inconsistent with the results of my study, mainly because Uemura et al.'s study investigated the cardiovascular outcomes after PCI in non-dialysis patients with ACS and eGFR <30 mL/min/1.73 m^2). This retrospective observational cohort study is a sub-analysis of those 194 patients with a focus on changes in renal function. The current study aimed to provide a prediction of post-PCI renal function to allow for a more informative patient-physician consultation. Statistical analyses demonstrated that both STEMI and cardiogenic shock were independent predictors for an IRF, and on follow-up, these patients had a lower incidence of initiation of permanent dialysis [20].

In other studies, eGFR is reduced in patients with advanced heart failure (HF), and renal function is a powerful independent predictor of prognosis. Reduction in baseline GFR may be associated with a higher risk of death in HF patients [20,21,27,28]. This may, however, represent a clinically appropriate tendency of using less contrast volume in patients with worse baseline eGFR, as well as other preventive measures to avert renal injury. In addition, the model evaluating factors associated with worsening eGFR in follow-up time included many expected baseline clinical variables, such as in-stent restenosis, myocardial infarction and in-hospital heart failure. Indeed, cardiac and renal functions are closely linked, and CRS has been introduced in recent years to characterize this interaction. Patients with HF may develop different degrees of impaired renal function. The term known as "CRS" includes a broad spectrum of diseases in which the heart and renal are both involved. CRS encompasses a spectrum of disorders involving both the heart and renal in which acute or chronic dysfunction in 1 organ may induce

acute or chronic dysfunction in the other organ. It represents the confluence of heart-renal interactions across several interfaces [8]. Similar to other studies, we found a powerful relationship between worsening eGFR during follow-up and higher MACE. It's well established that variability in the eGFR is greater in patients with HF and associated with mortality [29].

The effect of impaired renal function on outcomes of CHD patients undergoing PCI has been well described, with a worse prognosis. However, In our contemporary analysis, worsening renal function was observed in only 14% of patients. A recent study, the ISCHEMIA-CKD trial showed that intervention in stable CHD patients with advanced renal disease did not increase the need for initiation of dialysis concerning medical management which in a way suggests that all patients with renal dysfunction would not be at higher risk of future renal worsening because of the intervention [30]. In our study, cardiovascular adverse events during follow-up of patients with improved renal function will be significantly reduced. Therefore, we demonstrated that the treatment of PCI is a predictor of IRF. PCI may alleviate the cardiorenal syndrome (CRS) and thus improve renal function.

Currently, there are only limited reports addressing the timing of renal insult and its relation to clinical outcomes. In the FAME 2 trial, PCI that was guided by the fractional flow reserve was associated with a lower risk of the primary composite outcome than medical therapy alone, a difference that was driven by a reduction in urgent revascularization [31]. We similarly observed a lower incidence of MACE for CHD with coronary angiography or invasive strategy, although the event rates were low. During the follow-up, the major cardiovascular adverse events in patients with improved renal function will be significantly reduced. Besides, the event rates were lower than projected, and together with a low incidence of MACE in the improved renal function group and the trial had less power than anticipated to show a benefit for the invasive strategy. The current study provides practical guidance and reassurance to physicians of patients with CHD reluctant to undergo PCI due to concerns for worsening renal function during the procedure. Finally, although provocative, we propose that in patients with PCI, the proportion of patients with improved renal function was higher. Our data suggest that

from the point of view of IRF, there should not necessarily be hesitation to perform PCI based on the level of eGFR at the time of PCI or the concern of causing CIN.

The interactions and feedback mechanisms involved in heart and renal failure are more complex than previously thought. Future studies will be required to understand the proposed entity of cardiorenal syndrome in patients with CHD. Although our study fails to provide clarity to the intrinsic pathophysiological mechanisms, the hemodynamic surrogate of right atrial pressure supports the concept of renal congestion as a contributing factor to cardiorenal syndrome in patients with chronic congestive heart failure [32,33]. Recent advances in basic science and clinical understanding of organ crosstalk, including the validation of novel preclinical biomarkers of the cardiorenal syndrome may provide insights into the pathophysiology, diagnosis, and management of this disease over time. In terms of clinical implication, PCI intervention in patients with coronary artery disease should not be postponed because of concerns about worsening renal function. It may be more helpful for cardiovascular physicians to perform revascularisation in patients with coronary artery disease.

Conclusions

In patients with CHD undergoing PCI, renal function is more likely to stay the same or improve than worsen. IRF was relatively common in non-dialysis patients with CHD and advanced renal dysfunction who underwent PCI. Further, IRF was associated with favorable cardiovascular outcomes.

Study limitations

This study has several limitations, related to the database used for the research. This analysis of the trials is an analysis of prospectively collected trial data. However, to mitigate this untenable assumption, we incorporated baseline eGFR as a covariate in the analysis of post-PCI eGFR rather than analyzing the change in eGFR. baseline eGFR was defined simply as pre-PCI eGFR; thus, IRF may simply represent the return to the patients' true baseline eGFR before admission. A further limitation in evaluating renal function was that the adjudicated occurrence of post-PCI dialysis was not recorded. Thirdly, data regarding the completeness of revascularization in the study patients were not available

for analysis. the strategies and timing in regard to PCI, as well as peri-procedural management, were left to the discretion of the centers and treating physicians. Therefore, larger multicenter studies with prospective randomized designs are needed to test the hypothesis generated on a larger scale.

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Table 1. Characteristics of the patients at baseline.

Characteristic	Group A (n=151)	Group B (n=181)	Group C (n=634)	Group D (n=606)	p-value
Male	79 (52.3)	109 (60.2)	428 (67.5)	388 (64.0)	0.004
Age (years)	65.23±9.07	66.08±8.56	66.30±9.72	64.47±9.25	0.003
Body mass index (kg/m^2)	24.93±3.95	25.12±3.33	25.48±4.20	25.42±5.03	0.708
Hypertension	92 (60.9)	134 (74.0)	438 (69.1)	402 (66.3)	0.358
Diabetes mellitus	30（19.9）	59（32.6）	180（28.4）	154（25.4）	0.159
Current smoker	34（22.5）	69（38.1）	258（40.7）	245（40.5）	0.015
Prior PCI	60（39.7）	54（29.8）	70（11.0）	85（14.0）	<0.001
Prior CABG	2（1.3）	4（2.2）	6（0.9）	13（2.1）	0.340
Blood glucose	5.59±1.92	5.98±2.29	5.93±1.98	6.0±2.12	0.090
HbA1c (%)	6.30±1.18	6.52±1.15	6.55±1.37	6.43±1.20	0.065
LDL cholesterol	2.59±0.91	2.60±0.82	2.83±0.90	2.79±0.92	0.001
Uric acid	313.73±73.09	319.61±73.46	326.61±69.97	329.50±86.34	0.031
Left ventricle end-diastolic dimension, cm	47.44±4.06	48.84±5.45	47.97±4.94	47.77±4.66	0.163
Mean LVEF, %	63.25±5.25	60.77±8.83	61.71±6.64	62.34±6.50	0.009
TnI	0.0188 (0.010, 0.028)	0.056 (0.0004, 0.112)	0.292(0.194，0.391)	0.309(0.198，0.420)	＜0.001

BNP, pg/mL	406.76 (172.88, 640.64)	498.42 (355.23, 641.61)	487.67 (402.19，573.16)	441.98 (376.27, 516.68)	0.004
hs-CRP	2.16 (1.00, 3.32)	3.56 (1.78,5.34)	5.00 (3.79,6.22)	4.17 (3.00, 5.35)	0.001
Hemoglobin (g/L)	133.60±14.13	135.68±15.84	135.96±15.09	136.43±14.51	0.292
Atrial fibrillation, (%)	1 (0.7)	4 (2.3)	14 (2.3)	7 (1.2)	0.682
STEMI （%）	89 (58.9)	125 (69.1)	443 (69.9)	411 (67.8)	0.078
Number of stents	-	-	1.6±0.8	1.7±1.0	-
Contrast volume (mL)	62.25±9.39	69.45±24.14	164.63±36.54	161.93±44.57	<0.001
Contrast-induced nephropathy, (%)	0	2 (1.1)	13 (2.1)	17 (2.8)	0.123
Culprit lesion					
Left main	-	-	28 (4.4)	26(4.3)	-
Right coronary artery	-	-	175 (27.6)	90 (14.9)	-
Left circumflex artery	-	-	101 (15.9)	41 (6.8)	-
Left anterior descending artery	-	-	328 (51.7)	441 (72.8)	-
Medications					
Diuretic	22 (11.9)	29 (17.1)	65 (10.3)	177 (11.3)	0.060
Statins	138 (91.4)	177 (97.8)	631 (99.5)	606 (100.0)	<0.001
ACEI or ARB	75 (49.7)	114 (63.0)	438 (69.1)	380 (62.7)	<0.001

Data are presented as mean ± SD, median (interquartile range), or n (%); eGFR, estimated glomerular filtration rate; LDL, low-density lipoprotein; HDL, high-density lipoprotein; HbA1c, glycated hemoglobin; LVEF, left ventricular ejection fraction; STEMI, ST-elevation myocardial infarction; ACEI, angiotensin–converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass graft; TnI ,troponin I; BNP, brain natriuretic peptide; hs-CRP high-sensitivity C-reactive protein.

Table 2. Follow-up events of enrolled patients

	Group A (n=151)	Group B (n=181)	Group C (n=634)	Group D (n=606)	p-value
Follow-up time (months)	28.95±12.10	22.81±14.61	13.85±10.76	17±10.77	<0.001
HbA1c(%)	6.28±0.97	6.83±4.22	6.50±1.11	6.42±0.99	0.065
LDL	2.05±0.76	1.92±0.63	1.9±0.63	1.84±0.58	0.060
Uric acid	316.35±63.14	322.74±66.30	322.83±64.52	322.19±69.11	0.263
Heart failure readmission (%)	11 (7.3)	20 (11.0)	32 (5.1)	37 (6.1)	0.083
Recurrent myocardial infarction	5 (3.3)	8 (4.4)	24 (3.8)	17 (2.8)	0.836
In-stent restenosis	11（7.3）	15（8.3）	55（8.7）	73（12.0）	0.116
eGFR function					
worsening eGFR	35（23.2）	45（24.9）	74（11.7）	66（10.9）	<0.001
improved eGFR	7（4.6）	6（3.3）	94（14.8）	94（15.5）	<0.001
Stable eGFR	109（72.2）	130（71.8）	466（73.5）	446（73.6）	0.953

Data are presented as mean ± SD, median (interquartile range), or n (%); eGFR, estimated glomerular filtration rate; LDL, low-density lipoprotein; HbA1c, glycated hemoglobin.

Table 3. eGFR changes from baseline to follow-up.

(Mean±SD)	Group A (n=151)	Group B (n=181)	Group C (n=634)	Group D (n=606)
Baseline eGFR	66.31±19.76	72.63±17.54	81.35±16.74	94.92±15.26
Early eGFR	66.84±20.70	71.89±17.46	82.80±17.45	95.60±16.00
Follow-up eGFR	54.47±14.58	63.25±11.00	77.30±11.40	99.12±11.76

Table 4. Proportion in eGFR variation from baseline to follow-up.

Baseline eGFR	Group A(n=151)	Group B(n=181)	Group C (n=634)	Group D (n=606)
＞90（n=644）	19	29	202	394
60-89(n=754)	69	107	376	202
45-59(n=138)	40	376	49	10
30-44(n=34)	21	49	7	0
15-30(n=2)	2	0	0	0

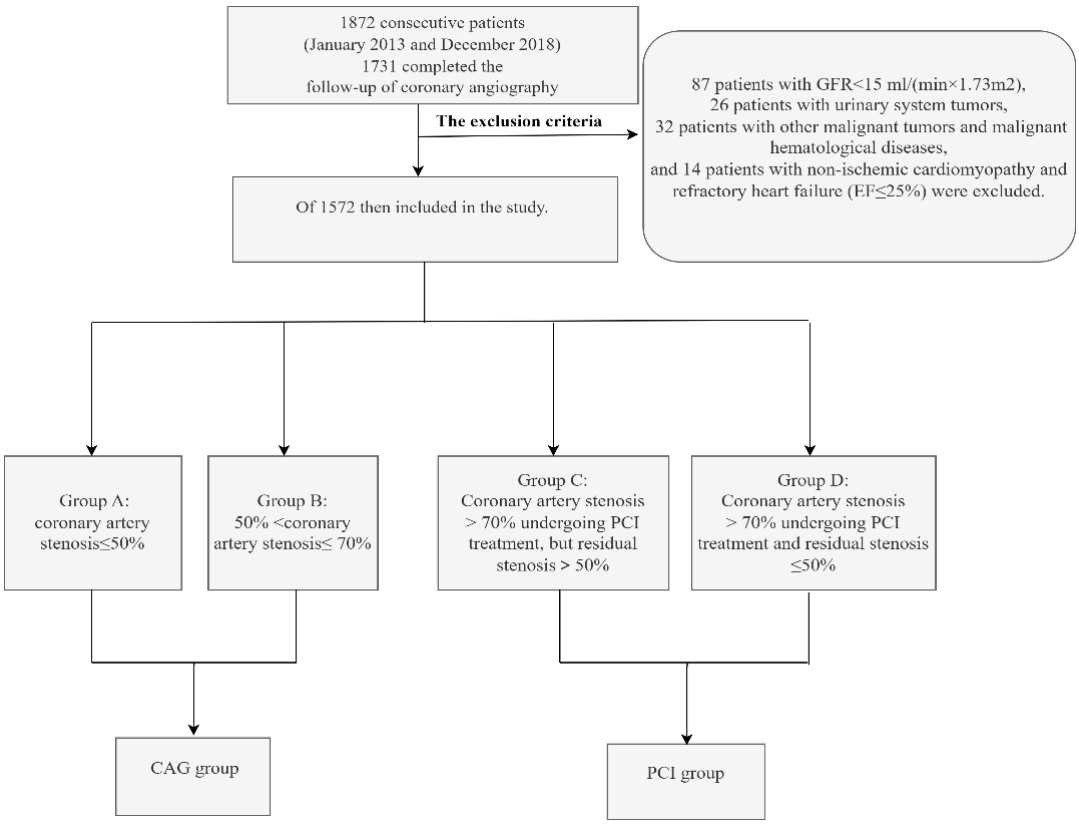

Figure 1. Enrollment criteria and trial flow.

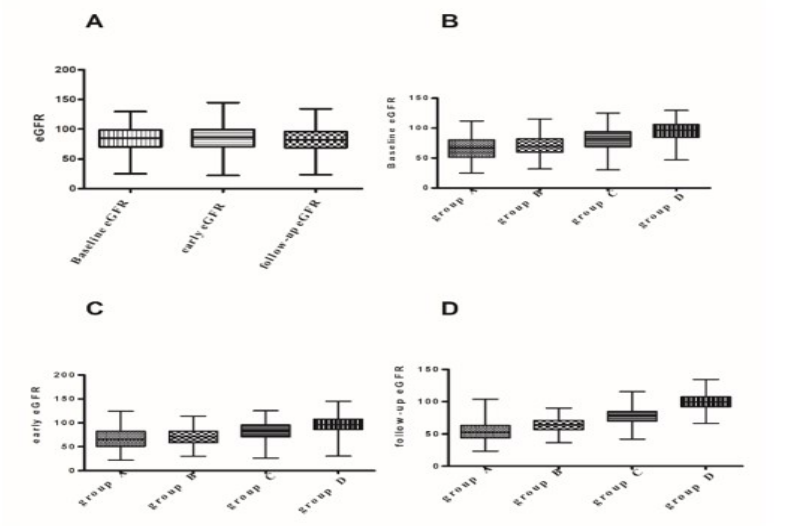

Fig A: Profile plot showing overall eGFR changes from baseline to follow-up

Fig B: Baseline eGFR in four group

Fig C: Early eGFR in four group

Fig D: Follow-up eGFR in four group

Figure 2. Change in eGFR variation.

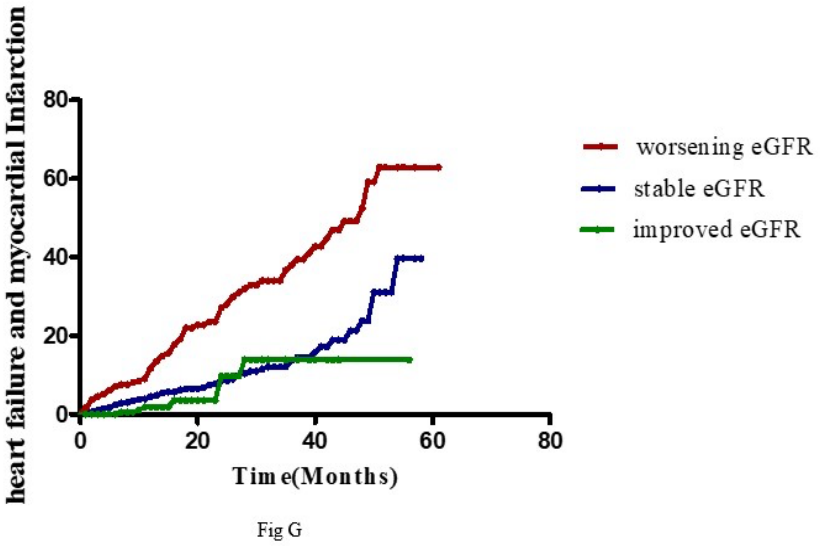

Figure 3. Kaplan-Meier estimates of the incidence of heart failure and myocardial infarction in worsening, stable or improved eGFR.

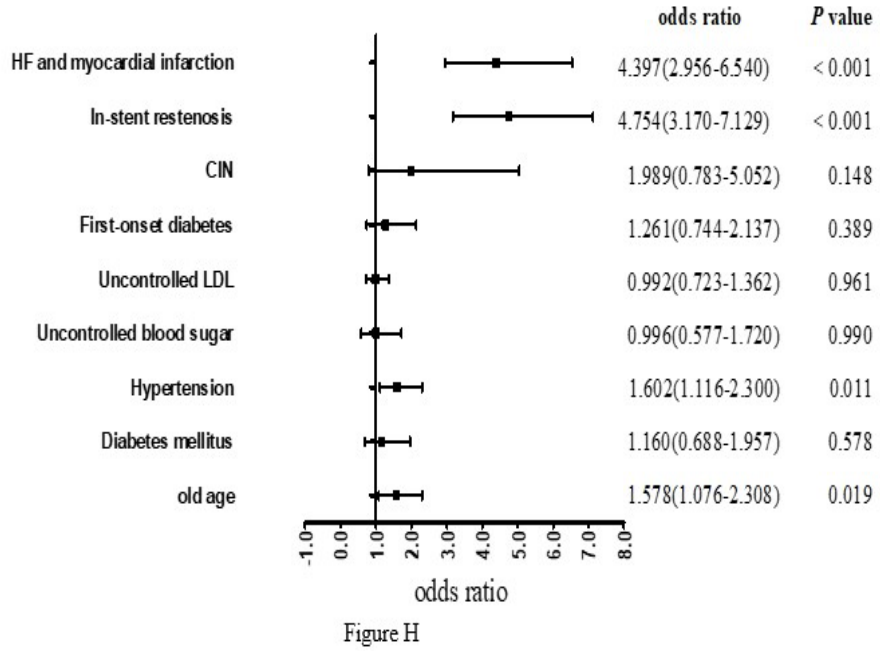

Figure 4. Multivariate logistic regression analysis of worsening eGFR.

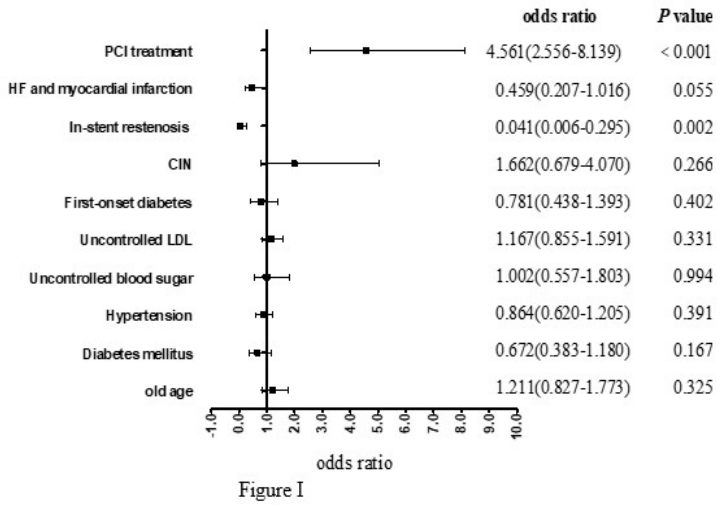

Figure 5. Multivariate logistic regression analysis of improved eGFR. PCI=percutaneous coronary intervention; HF=heart failure; CIN=contrast-induced nephropathy; LDL=low-density lipoprotein.

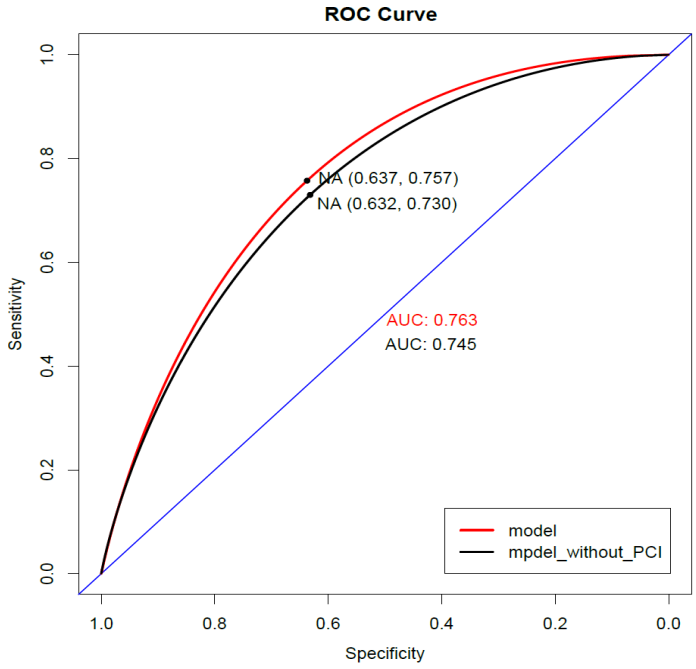

Figure 6. Model for PCI to predict improvement in renal function.