Original Research

CLINICAL OUTCOMES OF IVUS-GUIDED VERSUS ANGIOGRAPHY-GUIDED PERCUTANEOUS CORONARY INTERVENTION IN PATIENTS WITH CHRONIC KIDNEY DISEASE: A PROSPECTIVE COMPARATIVE STUDY

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ABSTRACT

Background: Patients with chronic kidney disease undergoing percutaneous coronary intervention are at increased risk of contrast-associated acute kidney injury and adverse cardiovascular events. Intravascular ultrasound guidance may improve procedural optimization and reduce contrast exposure compared with conventional angiography-guided PCI.

Methods: This prospective comparative study included 158 patients with chronic kidney disease and significant coronary artery disease requiring PCI. Patients were divided into two groups: IVUS-guided PCI group (n=79) and angiography-guided PCI group (n=79). Baseline demographic, clinical, renal, cardiac, angiographic, procedural, and follow-up outcome data were recorded. The primary outcome was contrast-associated acute kidney injury, defined as an absolute rise in serum creatinine of ≥0.3 mg/dL or a relative increase of ≥50% from baseline within 48–72 hours after contrast exposure. Secondary outcomes included contrast volume, procedural success, worsening renal function, need for dialysis, length of hospital stay, and major adverse cardiac events.

Results: Baseline demographic, renal, cardiac, and angiographic characteristics were comparable between the two groups. The mean contrast volume was significantly lower in the IVUS-guided PCI group compared with the angiography-guided PCI group (72.4 ± 22.6 mL vs 108.7 ± 31.5 mL; p<0.001). The incidence of contrast-associated acute kidney injury was significantly lower in the IVUS-guided PCI group (5.1% vs 15.2%; p=0.034). Worsening renal function was also lower in the IVUS-guided group (7.6% vs 19.0%; p=0.035), and hospital stay was shorter (4.2 ± 1.4 days vs 5.1 ± 2.0 days; p=0.001). Follow-up major adverse cardiac events were significantly lower in the IVUS-guided group compared with the angiography-guided group (6.3% vs 17.7%; p=0.028).

Conclusion: IVUS-guided PCI was associated with lower contrast use, reduced contrast-associated acute kidney injury, better renal outcomes, shorter hospital stay, and lower follow-up major adverse cardiac events compared with angiography-guided PCI in patients with chronic kidney disease. IVUS-guided PCI may be considered a safer and more effective revascularization strategy in CKD patients, particularly in those at high risk of contrast-related renal injury.

Keywords: Chronic Kidney Disease, Intravascular Ultrasound, Percutaneous Coronary Intervention, Angiography-Guided PCI, Contrast-Associated Acute Kidney Injury, Major Adverse Cardiac Events.

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INTRODUCTION

Chronic kidney disease (CKD) is increasingly recognized as an important cardiovascular risk equivalent and is frequently associated with accelerated atherosclerosis, diffuse coronary artery disease, calcified lesions, multivessel involvement, and adverse clinical outcomes. According to the Kidney Disease: Improving Global Outcomes (KDIGO) 2024 guideline, CKD is defined by abnormalities of kidney structure or function present for at least three months, with implications for health, and is classified based on cause, glomerular filtration rate category, and albuminuria category [1]. Patients with CKD have a disproportionately high burden of coronary artery disease (CAD), and cardiovascular events remain a leading cause of morbidity and mortality in this population. The 2024 European Society of Cardiology guidelines for chronic coronary syndromes also emphasize the importance of careful risk stratification and individualized management in patients with chronic coronary disease, including those with renal dysfunction [2].

Percutaneous coronary intervention (PCI) is an established revascularization strategy for selected patients with obstructive CAD. However, PCI in patients with CKD is technically and clinically challenging. These patients commonly present with long lesions, small vessel disease, heavy calcification, left main or bifurcation disease, and multivessel coronary involvement, all of which increase procedural complexity and the risk of suboptimal stent deployment. In addition, CKD patients are at increased risk of contrast-associated acute kidney injury, progression of renal dysfunction, bleeding complications, repeat revascularization, myocardial infarction, stent thrombosis, and mortality after PCI [3]. Therefore, achieving optimal procedural results while minimizing contrast exposure is particularly important in this high-risk group.

Conventional angiography-guided PCI remains the most widely used approach in routine clinical practice. Although coronary angiography provides a two-dimensional luminographic assessment of coronary stenosis, it has important limitations in evaluating vessel size, plaque burden, lesion length, calcium distribution, stent expansion, malapposition, edge dissection, and residual disease. These limitations are more relevant in CKD patients because coronary lesions are often diffuse and calcified. Inadequate lesion preparation, incorrect stent sizing, underexpansion, geographic miss, and unrecognized edge complications may contribute to adverse clinical outcomes after angiography-guided PCI.

Intravascular ultrasound (IVUS) provides tomographic visualization of the coronary vessel wall and allows accurate assessment of reference vessel diameter, plaque morphology, lesion length, calcium arc, stent expansion, stent apposition, and edge complications. IVUS-guided PCI may therefore improve procedural optimization by guiding lesion preparation, appropriate stent sizing, post-dilatation, and confirmation of adequate final stent expansion. In addition to improving mechanical results of PCI, IVUS can reduce dependence on repeated contrast injections, which is a major advantage in patients with CKD.

Several studies have shown that intravascular imaging-guided PCI is associated with better clinical outcomes than angiography-guided PCI. The RENOVATE-COMPLEX-PCI trial demonstrated that intravascular imaging-guided PCI in patients with complex coronary artery lesions resulted in a lower risk of major adverse cardiac events compared with angiography-guided PCI [4]. Similarly, the ULTIMATE trial showed that IVUS-guided drug-eluting stent implantation improved outcomes compared with angiography guidance. In the 3-year follow-up of the ULTIMATE trial, target vessel failure occurred in 6.6% of patients in the IVUS-guided group compared with 10.7% in the angiography-guided group, and definite or probable stent thrombosis was also significantly lower in the IVUS-guided group [5]. These findings support the role of IVUS as an important tool for PCI optimization.

The potential value of IVUS may be even greater in patients with CKD. Minimum-contrast and zero-contrast IVUS-guided PCI techniques have been explored as strategies to reduce renal injury while maintaining procedural success. Sakai et al. reported favorable one-year clinical outcomes with IVUS-guided minimum-contrast PCI in patients with advanced CKD [6]. Burlacu et al., in a systematic review, concluded that minimum- or zero-contrast IVUS-guided PCI appears feasible and safe in CKD patients, with acceptable cardiac and renal outcomes [7]. Kumar et al. also reported that IVUS-guided absolute zero-contrast PCI was feasible and safe in CKD patients, including those with complex lesion morphology [8]. These studies indicate that IVUS guidance can be used not only for stent optimization but also as a contrast-sparing strategy.

Despite growing evidence, data directly comparing IVUS-guided versus angiography-guided PCI specifically among CKD patients remain limited. Much of the available evidence is derived from all-comer PCI trials, complex PCI populations, registry-based analyses, or small studies evaluating low-contrast PCI techniques. A recently registered IVUS-CKD trial has been designed to compare IVUS-guided PCI with angiography-guided PCI in CKD patients with target vessel failure at 12 months as the primary endpoint, highlighting the current clinical relevance and evidence gap in this area [9]. Therefore, prospective comparative studies in CKD patients are needed to evaluate whether IVUS guidance improves both procedural and clinical outcomes in real-world practice.

In this context, the present study was undertaken to compare clinical outcomes between IVUS-guided and angiography-guided PCI in patients with CKD. The study aims to assess whether IVUS guidance is associated with improved procedural success, reduced contrast volume, lower incidence of renal deterioration, and better short-term and follow-up cardiovascular outcomes compared with conventional angiography-guided PCI.

METHODOLOGY

The present prospective comparative study was conducted in the Department of Cardiology of a tertiary care hospital after obtaining approval from the Institutional Ethics Committee. Adult patients aged 18 years and above with chronic kidney disease and angiographically significant coronary artery disease requiring percutaneous coronary intervention were included after obtaining written informed consent. Chronic kidney disease was defined as an estimated glomerular filtration rate of less than 60 ml/min/1.73 m² for at least three months or evidence of kidney damage. Patients with acute ST-elevation myocardial infarction requiring primary PCI, acute kidney injury before the procedure, maintenance dialysis, contrast allergy, cardiogenic shock, pregnancy, refusal to consent, or incomplete follow-up data were excluded. A total of 158 patients were included, with 79 patients in the IVUS-guided PCI group and 79 patients in the angiography-guided PCI group.

Baseline demographic, clinical, laboratory, echocardiographic, renal function, and angiographic details were recorded in a predesigned case record form. All patients underwent coronary angiography and PCI according to standard institutional protocol, with renal protection measures such as adequate hydration, avoidance or dose adjustment of nephrotoxic drugs, and use of low-osmolar or iso-osmolar contrast wherever applicable. In the IVUS-guided PCI group, intravascular ultrasound was used to assess vessel size, lesion length, plaque burden, calcium distribution, stent sizing, stent expansion, apposition, and edge complications. In the angiography-guided PCI group, PCI strategy, stent selection, lesion preparation, and optimization were performed based on conventional angiographic findings.

The primary outcome was the incidence of contrast-associated acute kidney injury, defined as an absolute rise in serum creatinine of ≥0.3 mg/dL or a relative increase of ≥50% from baseline within 48–72 hours after contrast exposure. Secondary outcomes included contrast volume, fluoroscopy time, procedural success, worsening renal function, need for dialysis, in-hospital adverse events, length of hospital stay, repeat revascularization, myocardial infarction, stent thrombosis, and major adverse cardiac events during follow-up. Data were entered in Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean and standard deviation or median and interquartile range, while categorical variables were expressed as frequency and percentage. The independent sample t-test, Mann–Whitney U test, Chi-square test, or Fisher's exact test was applied as appropriate, and a p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Variable	IVUS-Guided PCI Group (N=79)	Angiography-Guided PCI Group (N=79)	P-Value
Age in years, Mean ± SD	63.8 ± 8.9	64.5 ± 9.2	0.628
Male sex	51 (64.6%)	53 (67.1%)	0.738
Female sex	28 (35.4%)	26 (32.9%)	0.738
Body mass index, Mean ± SD	25.7 ± 3.4	26.1 ± 3.6	0.472
Diabetes mellitus	52 (65.8%)	50 (63.3%)	0.738
Hypertension	59 (74.7%)	61 (77.2%)	0.704
Dyslipidemia	44 (55.7%)	46 (58.2%)	0.748
Current or past smoking	29 (36.7%)	31 (39.2%)	0.741
Previous myocardial infarction	18 (22.8%)	20 (25.3%)	0.707
Previous PCI/CABG	11 (13.9%)	13 (16.5%)	0.652
Stable angina	34 (43.0%)	32 (40.5%)	0.746
Unstable angina/NSTEMI	45 (57.0%)	47 (59.5%)	0.746

The baseline demographic and clinical characteristics of the two study groups were comparable. The mean age of patients in the IVUS-guided PCI group was 63.8 ± 8.9 years, while it was 64.5 ± 9.2 years in the angiography-guided PCI group, with no statistically significant difference between the groups. Male predominance was observed in both groups, with 64.6% males in the IVUS-guided PCI group and 67.1% males in the angiography-guided PCI group. The mean body mass index was also similar in both groups.

The distribution of major cardiovascular risk factors was comparable between the two groups. Diabetes mellitus was present in 65.8% of patients in the IVUS-guided PCI group and 63.3% in the angiography-guided PCI group. Hypertension was the most common risk factor, seen in 74.7% and 77.2% of patients respectively. Dyslipidemia, smoking history, previous myocardial infarction, and previous history of PCI or CABG were also similarly distributed between the two groups.

Regarding clinical presentation, stable angina was present in 43.0% of patients in the IVUS-guided PCI group and 40.5% in the angiography-guided PCI group. Unstable angina/NSTEMI was observed in 57.0% and 59.5% of patients respectively. None of the baseline variables showed a statistically significant difference between the two groups, as all p-values were greater than 0.05. This indicates that both groups were well matched at baseline, allowing a meaningful comparison of procedural, renal, and clinical outcomes between IVUS-guided and angiography-guided PCI.

Table 2: Baseline Renal and Cardiac Profile of Study Participants

Variable	IVUS-Guided PCI Group (N=79)	Angiography-Guided PCI Group (N=79)	P-Value
Serum creatinine, mg/dL, Mean ± SD	1.86 ± 0.48	1.91 ± 0.52	0.531
eGFR, mL/min/1.73 m², Mean ± SD	42.8 ± 11.6	41.5 ± 12.1	0.491
CKD stage 3	52 (65.8%)	50 (63.3%)	0.738
CKD stage 4	23 (29.1%)	25 (31.6%)	0.729
CKD stage 5 not on dialysis	4 (5.1%)	4 (5.1%)	1.000
Hemoglobin, g/dL, Mean ± SD	11.2 ± 1.6	11.0 ± 1.7	0.447
HbA1c among diabetics, %, Mean ± SD	7.8 ± 1.2	7.9 ± 1.3	0.616
LDL cholesterol, mg/dL, Mean ± SD	104.6 ± 28.5	107.2 ± 30.1	0.578
Left ventricular ejection fraction, %, Mean ± SD	48.9 ± 8.7	47.6 ± 9.1	0.360
LVEF <40%	14 (17.7%)	16 (20.3%)	0.684

The baseline renal and cardiac profile of patients was comparable between the two study groups. The mean serum creatinine level was 1.86 ± 0.48 mg/dL in the IVUS-guided PCI group and 1.91 ± 0.52 mg/dL in the angiography-guided PCI group. Similarly, the mean estimated glomerular filtration rate was 42.8 ± 11.6 mL/min/1.73 m² in the IVUS-guided PCI group and 41.5 ± 12.1 mL/min/1.73 m² in the angiography-guided PCI group. The difference in baseline renal function between the two groups was not statistically significant. Most patients in both groups belonged to CKD stage 3, accounting for 65.8% in the IVUS-guided PCI group and 63.3% in the angiography-guided PCI group. CKD stage 4 was present in 29.1% and 31.6% of patients respectively, while CKD stage 5 not on dialysis was observed in 5.1% of patients in each group. This shows that the severity of chronic kidney disease was similarly distributed between the two groups.

The cardiac and metabolic parameters were also balanced. The mean hemoglobin level was 11.2 ± 1.6 g/dL in the IVUS-guided PCI group and 11.0 ± 1.7 g/dL in the angiography-guided PCI group. Among diabetic patients, mean HbA1c was 7.8 ± 1.2% and 7.9 ± 1.3% respectively. Mean LDL cholesterol was 104.6 ± 28.5 mg/dL in the IVUS-guided PCI group and 107.2 ± 30.1 mg/dL in the angiography-guided PCI group. The mean left ventricular ejection fraction was 48.9 ± 8.7% in the IVUS-guided PCI group and 47.6 ± 9.1% in the angiography-guided PCI group, while reduced LVEF below 40% was seen in 17.7% and 20.3% of patients respectively.

Table 3: Angiographic and Procedural Characteristics

Variable	IVUS-Guided PCI Group (N=79)	Angiography-Guided PCI Group (N=79)	P-Value
Single-vessel disease	28 (35.4%)	30 (38.0%)	0.738
Double-vessel disease	33 (41.8%)	31 (39.2%)	0.743
Triple-vessel disease	18 (22.8%)	18 (22.8%)	1.000
Left main lesion	8 (10.1%)	7 (8.9%)	0.784
LAD lesion	47 (59.5%)	45 (57.0%)	0.746
LCX lesion	28 (35.4%)	30 (38.0%)	0.738

Variable	IVUS-Guided PCI Group (N=79)	Angiography-Guided PCI Group (N=79)	P-Value
RCA lesion	35 (44.3%)	36 (45.6%)	0.873
Bifurcation lesion	17 (21.5%)	15 (19.0%)	0.692
Moderate/severe calcified lesion	30 (38.0%)	28 (35.4%)	0.738
Chronic total occlusion	6 (7.6%)	5 (6.3%)	0.753
Number of stents used, Mean ± SD	1.58 ± 0.68	1.46 ± 0.61	0.245
Total stent length, mm, Mean ± SD	38.6 ± 15.4	35.2 ± 14.8	0.160
Mean stent diameter, mm, Mean ± SD	3.12 ± 0.39	2.91 ± 0.36	0.001*
Post-dilatation performed	52 (65.8%)	38 (48.1%)	0.025*

The angiographic disease pattern was broadly comparable between the two groups. Single-vessel disease was observed in 35.4% of patients in the IVUS-guided PCI group and 38.0% in the angiography-guided PCI group. Double-vessel disease was present in 41.8% and 39.2% of patients respectively, while triple-vessel disease was seen equally in both groups, accounting for 22.8% of patients in each group. There was no statistically significant difference in the distribution of single-, double-, or triple-vessel disease.

The distribution of target vessel involvement was also similar. Left main lesions were present in 10.1% of patients in the IVUS-guided PCI group and 8.9% in the angiography-guided PCI group. LAD was the most commonly involved vessel in both groups, seen in 59.5% and 57.0% of patients respectively. LCX involvement was seen in 35.4% and 38.0%, while RCA involvement was observed in 44.3% and 45.6% of patients respectively. Complex lesion characteristics such as bifurcation lesions, moderate or severe calcification, and chronic total occlusion were also similarly distributed between the two groups, with no statistically significant difference.

With respect to procedural characteristics, the mean number of stents used was 1.58 ± 0.68 in the IVUS-guided PCI group and 1.46 ± 0.61 in the angiography-guided PCI group. The mean total stent length was 38.6 ± 15.4 mm and 35.2 ± 14.8 mm respectively. These differences were not statistically significant. However, the mean stent diameter was significantly higher in the IVUS-guided PCI group (3.12 ± 0.39 mm) compared with the angiography-guided PCI group (2.91 ± 0.36 mm), with a p-value of 0.001. Post-dilatation was also performed more frequently in the IVUS-guided PCI group (65.8%) than in the angiography-guided PCI group (48.1%), and this difference was statistically significant ($p = 0.025$).

Table 4: Procedural and Renal Outcomes

Outcome	IVUS-Guided PCI Group (N=79)	Angiography-Guided PCI Group (N=79)	P-Value
Contrast volume used, mL, Mean ± SD	72.4 ± 22.6	108.7 ± 31.5	<0.001*
Fluoroscopy time, minutes, Mean ± SD	18.9 ± 6.8	16.7 ± 6.2	0.035*
Procedure duration, minutes, Mean ± SD	54.8 ± 14.7	49.3 ± 13.5	0.016*
Procedural success	77 (97.5%)	72 (91.1%)	0.086
Baseline serum creatinine, mg/dL, Mean ± SD	1.86 ± 0.48	1.91 ± 0.52	0.531
Serum creatinine at 48–72 hours, mg/dL, Mean ± SD	1.93 ± 0.54	2.18 ± 0.68	0.011*
Mean rise in serum creatinine, mg/dL	0.07 ± 0.19	0.27 ± 0.42	<0.001*
Rise in serum creatinine ≥0.3 mg/dL	5 (6.3%)	14 (17.7%)	0.028*
Contrast-associated AKI	4 (5.1%)	12 (15.2%)	0.034*
Worsening renal function	6 (7.6%)	15 (19.0%)	0.035*
Requirement of dialysis	1 (1.3%)	3 (3.8%)	0.312
Length of hospital stay, days, Mean ± SD	4.2 ± 1.4	5.1 ± 2.0	0.001*

The procedural and renal outcomes showed important differences between the two study groups. The mean contrast volume used during PCI was significantly lower in the IVUS-guided PCI group (72.4 ± 22.6 mL) compared with the angiography-guided PCI group (108.7 ± 31.5 mL), and this difference was statistically significant (p < 0.001). However, the mean fluoroscopy time and procedure duration were slightly higher in the IVUS-guided PCI group. The mean fluoroscopy time was 18.9 ± 6.8 minutes in the IVUS-guided PCI group compared with 16.7 ± 6.2 minutes in the angiography-guided PCI group (p = 0.035), while the mean procedure duration was 54.8 ± 14.7 minutes and 49.3 ± 13.5 minutes respectively (p = 0.016). This may be attributed to the additional time required for IVUS imaging, lesion assessment, and stent optimization.

Procedural success was higher in the IVUS-guided PCI group, with successful PCI achieved in 97.5% of patients compared with 91.1% in the angiography-guided PCI group. However, this difference was not statistically significant (p = 0.086). Baseline serum creatinine was comparable between the two groups, with values of 1.86 ± 0.48 mg/dL in the IVUS-guided PCI group and 1.91 ± 0.52 mg/dL in the angiography-guided PCI group (p = 0.531). At 48–72 hours after PCI, serum creatinine was significantly lower in the IVUS-guided PCI group (1.93 ± 0.54 mg/dL) compared with the angiography-guided PCI group (2.18 ± 0.68 mg/dL), with a p-value of 0.011.

The mean rise in serum creatinine was also significantly lower in the IVUS-guided PCI group (0.07 ± 0.19 mg/dL) than in the angiography-guided PCI group (0.27 ± 0.42 mg/dL), with p < 0.001. A rise in serum creatinine of ≥0.3 mg/dL was observed in 6.3% of patients in the IVUS-guided PCI group compared with 17.7% in the angiography-guided PCI group (p = 0.028). Similarly, contrast-associated acute kidney injury occurred in 5.1% of patients in the IVUS-guided PCI group and 15.2% in the angiography-guided PCI group, showing a statistically significant reduction with IVUS guidance (p = 0.034). Worsening renal function was also significantly lower in the IVUS-guided PCI group (7.6%) compared with the angiography-guided PCI group (19.0%) (p = 0.035). Requirement of dialysis was less frequent in the IVUS-guided PCI group, but the difference was not statistically significant. The mean length of hospital stay was significantly shorter in the IVUS-guided PCI group (4.2 ± 1.4 days) than in the angiography-guided PCI group (5.1 ± 2.0 days) (p = 0.001).

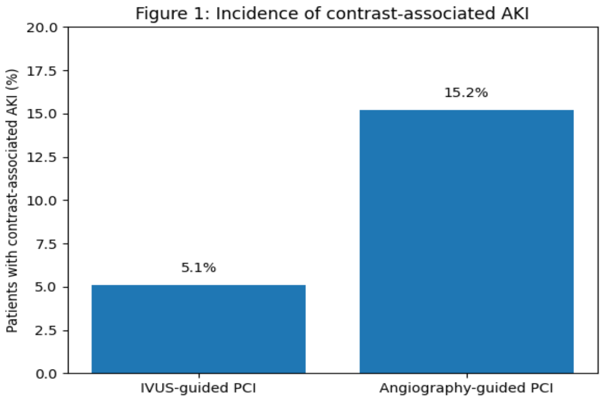


Figure 1 demonstrates that the incidence of contrast-associated AKI was significantly lower in the IVUS-guided PCI group compared with the angiography-guided PCI group. Contrast-associated AKI occurred in 4 patients (5.1%) in the IVUS-guided group and 12 patients (15.2%) in the angiography-guided group. This difference was statistically significant (p = 0.034), suggesting that IVUS-guided PCI was associated with better renal safety in patients with chronic kidney disease.

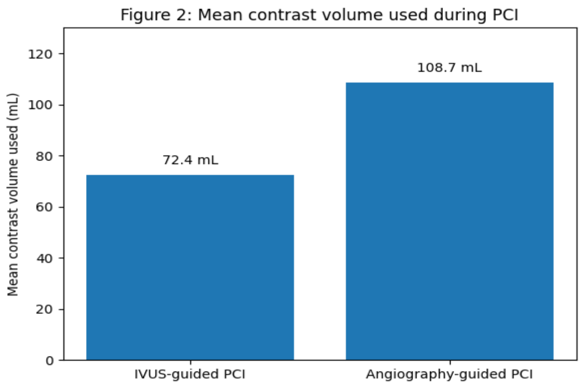


Figure 2 demonstrates that the mean contrast volume used during PCI was significantly lower in the IVUS-guided PCI group compared with the angiography-guided PCI group. The mean contrast volume was 72.4 ± 22.6 mL in the IVUS-guided group and 108.7 ± 31.5 mL in the angiography-guided group. This difference was statistically significant (p <0.001), suggesting that IVUS-guided PCI was associated with reduced contrast requirement in patients with chronic kidney disease.

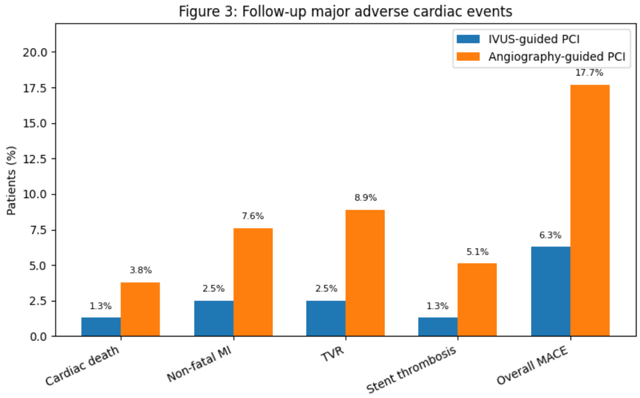
Table 5: In-Hospital and Follow-up Clinical Outcomes

Outcome	IVUS-Guided PCI Group (N=79)	Angiography-Guided PCI Group (N=79)	P-Value
In-hospital death	1 (1.3%)	2 (2.5%)	0.560
In-hospital myocardial infarction	1 (1.3%)	3 (3.8%)	0.312
Stroke	0 (0.0%)	1 (1.3%)	0.316
Major bleeding	2 (2.5%)	4 (5.1%)	0.407
Acute stent thrombosis	0 (0.0%)	2 (2.5%)	0.155
Repeat revascularization during hospital stay	1 (1.3%)	3 (3.8%)	0.312
Readmission during follow-up	6 (7.6%)	13 (16.5%)	0.084
Target vessel revascularization	2 (2.5%)	7 (8.9%)	0.086
Non-fatal myocardial infarction during follow-up	2 (2.5%)	6 (7.6%)	0.145
Definite/probable stent thrombosis	1 (1.3%)	4 (5.1%)	0.172
Cardiac death during follow-up	1 (1.3%)	3 (3.8%)	0.312
Major adverse cardiac events	5 (6.3%)	14 (17.7%)	0.028*

The in-hospital and follow-up clinical outcomes were generally better in the IVUS-guided PCI group compared with the angiography-guided PCI group. In-hospital death occurred in 1 patient (1.3%) in the IVUS-guided PCI group and 2 patients (2.5%) in the angiography-guided PCI group. In-hospital myocardial infarction was reported in 1.3% and 3.8% of patients respectively. Stroke, major bleeding, acute stent thrombosis, and repeat revascularization during hospital stay were also less frequent in the IVUS-guided PCI group; however, these individual differences were not statistically significant.

During follow-up, adverse clinical events were numerically lower among patients who underwent IVUS-guided PCI. Readmission was observed in 6 patients (7.6%) in the IVUS-guided PCI group compared with 13 patients (16.5%) in the angiography-guided PCI group. Target vessel revascularization occurred in 2.5% of patients in the IVUS-guided group and 8.9% in the angiography-guided group. Similarly, non-fatal myocardial infarction, definite or probable stent thrombosis, and cardiac death during follow-up were less common in the IVUS-guided PCI group, although these individual outcomes did not reach statistical significance.

Figure 3: Follow-up major adverse cardiac events



The composite outcome of major adverse cardiac events (MACE) was significantly lower in the IVUS-guided PCI group. MACE occurred in 5 patients (6.3%) in the IVUS-guided PCI group compared with 14 patients (17.7%) in the angiography-guided PCI group, and this difference was statistically significant (p = 0.028). Overall, these findings suggest that IVUS-guided PCI was associated with fewer adverse clinical events and significantly lower overall MACE during follow-up compared with angiography-guided PCI in patients with chronic kidney disease.

DISCUSSION

In the present study, IVUS-guided PCI was associated with better procedural optimization, lower contrast volume, reduced contrast-associated acute kidney injury, shorter hospital stay, and lower follow-up major adverse cardiac events compared with angiography-guided PCI in patients with chronic kidney disease. The two groups were comparable at baseline with respect to age, sex distribution, cardiovascular risk factors, CKD stage, serum creatinine, eGFR, left ventricular ejection fraction, and angiographic disease burden. This baseline similarity suggests that the observed difference in outcomes was more likely related to the PCI guidance strategy rather than pre-existing clinical differences between the two groups.

The present study showed that the mean contrast volume was significantly lower in the IVUS-guided PCI group compared with the angiography-guided PCI group. This finding is clinically important because CKD patients are highly vulnerable to contrast-associated renal injury. Tran Duc et al. studied the impact of IVUS guidance on acute kidney injury after PCI and reported that IVUS-guided PCI significantly reduced the incidence of post-procedural AKI compared with angiography-guided PCI. Their study also highlighted that reduced contrast exposure is one of the major mechanisms by which IVUS guidance protects renal function [10]. This is consistent with our finding, where contrast-associated AKI occurred in 5.1% of patients in the IVUS-guided group compared with 15.2% in the angiography-guided group.

In the present study, the mean rise in serum creatinine after PCI was significantly lower in the IVUS-guided PCI group. Similarly, worsening renal function was less frequent among patients who underwent IVUS-guided PCI. Ahmad et al. evaluated ultra-low-contrast IVUS-guided PCI in patients with moderate to severe CKD and reported that such a strategy was safe and feasible, with lower contrast use and acceptable renal outcomes [11]. The findings of the present study are in agreement with this observation, as IVUS guidance helped in minimizing contrast exposure without compromising procedural success.

The incidence of contrast-associated AKI in the present study was significantly lower in the IVUS-guided PCI group. This finding is also supported by Khanolkar et al., who demonstrated that IVUS-guided zero-contrast PCI using fluoroscopic landmarks could be performed safely in patients at risk of contrast nephropathy, with good short-term clinical outcomes [12]. Although our study did not use an absolute zero-contrast strategy, the significantly lower contrast volume in the IVUS-guided group suggests that IVUS guidance can be effectively used as a contrast-sparing approach in CKD patients.

The present study also found that IVUS-guided PCI was associated with better procedural optimization. The mean stent diameter was significantly higher in the IVUS-guided group, and post-dilatation was performed more frequently. These findings suggest that IVUS provided better assessment of true vessel size, lesion morphology, plaque burden, and stent expansion. In angiography-guided PCI, diffuse disease and vessel remodeling may lead to underestimation of vessel diameter, particularly in CKD patients with calcified and complex lesions. IVUS helps in overcoming these limitations by providing cross-sectional visualization of the vessel wall and stent architecture.

The procedural success rate was numerically higher in the IVUS-guided PCI group compared with the angiography-guided PCI group. Although this difference did not reach statistical significance, it indicates a favorable trend toward improved procedural results with IVUS guidance. Hamed et al., in a meta-analysis of randomized controlled trials comparing intravascular imaging-guided PCI with angiography-guided PCI, reported that intravascular imaging was associated with improved clinical outcomes in complex PCI, including lower rates of target lesion failure and repeat revascularization [13]. The present study findings are consistent with this, as IVUS-guided PCI resulted in better stent optimization and lower follow-up adverse events.

In the present study, fluoroscopy time and procedure duration were slightly higher in the IVUS-guided PCI group. This was expected because IVUS-guided PCI requires additional procedural steps, including imaging catheter passage, lesion assessment, vessel measurement, stent optimization, and post-stent evaluation. However, this increase in time should be interpreted in relation to the clinical benefit observed. Despite longer procedural time, IVUS-guided PCI resulted in significantly lower contrast volume, lower AKI, less worsening renal function, and shorter hospital stay. Therefore, in CKD patients, the additional procedural time required for IVUS appears justified.

The follow-up clinical outcomes in the present study were also favorable in the IVUS-guided PCI group. Individual outcomes such as readmission, target vessel revascularization, non-fatal myocardial infarction, stent thrombosis, and cardiac death were numerically lower in the IVUS-guided group. The composite outcome of major adverse cardiac events was significantly lower in the IVUS-guided PCI group, occurring in **6.3%** compared with **17.7%** in the angiography-guided group. A recent meta-analysis by Kumar et al. reported that intravascular imaging-guided PCI significantly reduced adverse cardiac events, all-cause mortality, and repeat revascularization compared with angiography-guided PCI [14]. This supports the present finding that IVUS guidance may improve follow-up clinical outcomes by ensuring better lesion preparation, stent sizing, and final stent expansion.

The reduction in MACE in the IVUS-guided group may be explained by both renal and coronary mechanisms. From the renal perspective, lower contrast exposure reduces the risk of contrast-associated AKI, which itself is associated with adverse cardiovascular outcomes. From the coronary perspective, IVUS helps identify stent underexpansion, malapposition, residual plaque burden, edge dissection, and inadequate lesion coverage. Correction of these factors during the index procedure may reduce later stent thrombosis, restenosis, myocardial infarction, and repeat revascularization.

Although our study excluded patients on maintenance dialysis, evidence from dialysis populations also supports the benefit of intravascular imaging. Lin et al. studied intravascular imaging-guided PCI in patients with end-stage renal disease on maintenance dialysis and reported that imaging-guided PCI was associated with better cardiovascular outcomes in this high-risk population [15]. This indirectly supports the value of intravascular imaging across the spectrum of renal dysfunction, from moderate CKD to end-stage renal disease.

Overall, the present study findings are consistent with recent literature showing that IVUS-guided PCI is useful in CKD patients because it provides a dual advantage: contrast minimization and stent optimization. In the present study, IVUS-guided PCI significantly reduced contrast volume and contrast-associated AKI while also reducing follow-up MACE. These findings suggest that IVUS guidance should be considered in CKD patients undergoing PCI, especially in those with low eGFR, diabetes mellitus, multivessel disease, calcified lesions, bifurcation lesions, long lesions, or anticipated high contrast requirement.

The present study had certain limitations. It was a single-center prospective comparative study with a moderate sample size. Random allocation was not performed, and therefore operator preference and lesion complexity may have influenced the choice of PCI guidance strategy. The follow-up duration was limited, and longer follow-up would be required to assess late stent failure, target vessel failure, and mortality. Renal outcomes were assessed mainly using serum creatinine changes within 48–72 hours, while newer biomarkers of early renal injury were not evaluated. Despite these limitations, the study provides clinically meaningful evidence that IVUS-guided PCI may improve renal and cardiovascular outcomes in patients with CKD.

CONCLUSION

The present study concluded that IVUS-guided PCI was associated with better renal and clinical outcomes compared with angiography-guided PCI in patients with chronic kidney disease. IVUS guidance resulted in significantly lower contrast volume, lesser post-procedural rise in serum creatinine, reduced incidence of contrast-associated acute kidney injury, fewer episodes of worsening renal function, and shorter hospital stay. It also provided better procedural optimization, as shown by larger stent diameter selection and more frequent post-dilatation. Although fluoroscopy time and procedure duration were slightly higher with IVUS guidance, the overall clinical benefit was favorable. Follow-up major adverse cardiac events were significantly lower in the IVUS-guided PCI group, suggesting that IVUS-guided PCI is a safer and more effective revascularization strategy in CKD patients, particularly in those with complex coronary anatomy or high risk of contrast-related renal injury.

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