

A PROSPECTIVE STUDY ON THE INCIDENCE AND RISK FACTORS OF CONTRAST-INDUCED NEPHROPATHY IN PATIENTS UNDERGOING PCI

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ABSTRACT

Contrast-induced nephropathy (CIN) is a significant cause of acute kidney injury following percutaneous coronary intervention (PCI) and remains a major concern in cardiovascular care. The occurrence of CIN is associated with prolonged hospitalization, increased healthcare costs, and adverse clinical outcomes. This prospective study was conducted to evaluate the incidence of CIN and identify the major risk factors contributing to its development among patients undergoing PCI. A total of [sample size] patients scheduled for PCI were enrolled and monitored throughout the study period. Baseline demographic data, clinical characteristics, renal function parameters, comorbidities, and procedural details were recorded. CIN was defined as an increase in serum creatinine of at least 25% or 0.5 mg/dL from baseline within 48–72 hours following contrast administration. The incidence of CIN was determined, and potential risk factors were analyzed using appropriate statistical methods. The study found that CIN occurred in [percentage]% of patients undergoing PCI. Advanced age, diabetes mellitus, pre-existing renal dysfunction, hypertension, and higher volumes of contrast media were identified as significant predictors of CIN. Patients with reduced estimated glomerular filtration rate (eGFR) demonstrated a markedly higher susceptibility to renal impairment after contrast exposure. Furthermore, preventive strategies such as adequate hydration and minimization of contrast volume were associated

with a lower incidence of CIN. The findings emphasize the importance of early risk stratification and implementation of preventive measures in high-risk patients. Timely identification and management of modifiable risk factors can significantly reduce the occurrence of CIN and improve clinical outcomes in patients undergoing PCI. Therefore, careful monitoring of renal function and adherence to evidence-based preventive protocols are essential components of patient care in interventional cardiology.

Keywords: Contrast-induced nephropathy, Percutaneous coronary intervention, Acute kidney injury, Risk factors, Renal dysfunction, Contrast media.

I. INTRODUCTION

Percutaneous Coronary Intervention (PCI) has become one of the most widely performed therapeutic procedures for the management of coronary artery disease, significantly improving patient outcomes by restoring coronary blood flow and reducing cardiovascular morbidity and mortality. The success of PCI relies heavily on the use of iodinated contrast media, which facilitates visualization of the coronary vasculature and guides interventional procedures. Despite its clinical benefits, the administration of contrast agents is associated with several adverse effects, among which Contrast-Induced Nephropathy (CIN) remains a major concern.

Contrast-Induced Nephropathy is an acute deterioration of renal function that occurs following the intravascular administration of

contrast media in the absence of other identifiable causes of kidney injury. It is commonly defined as an increase in serum creatinine of at least 0.5 mg/dL or a 25% increase from baseline within 48–72 hours after contrast exposure. CIN is recognized as one of the leading causes of hospital-acquired acute kidney injury and is associated with prolonged hospitalization, increased healthcare costs, higher rates of cardiovascular complications, and increased mortality.

The pathogenesis of CIN is multifactorial and involves a combination of renal vasoconstriction, medullary hypoxia, oxidative stress, and direct tubular toxicity induced by contrast agents. Although CIN can occur in any patient exposed to contrast media, certain populations are particularly vulnerable. Established risk factors include pre-existing renal impairment, diabetes mellitus, advanced age, hypertension, congestive heart failure, anemia, dehydration, and the use of large volumes of contrast media. Procedure-related factors such as emergency PCI, repeated contrast exposure, and hemodynamic instability further contribute to the risk of developing CIN.

With the increasing prevalence of cardiovascular diseases and the growing number of PCI procedures performed worldwide, the burden of CIN continues to be a significant clinical challenge. Early identification of patients at risk and implementation of preventive measures, including adequate hydration, optimization of renal function, minimization of contrast volume, and careful selection of contrast agents, are essential to reduce the incidence and severity of CIN. However, despite advances in preventive strategies, CIN remains a common complication, particularly among high-risk patient groups.

A prospective evaluation of the incidence and associated risk factors of CIN in patients undergoing PCI is therefore crucial for understanding its prevalence and identifying

modifiable determinants. Such studies provide valuable insights into patient characteristics and procedural variables that contribute to renal impairment following contrast exposure. The findings can assist healthcare professionals in developing effective risk stratification models and evidence-based preventive protocols to improve patient safety and clinical outcomes.

Therefore, the present study aims to assess the incidence of Contrast-Induced Nephropathy among patients undergoing Percutaneous Coronary Intervention and to identify the demographic, clinical, and procedural risk factors associated with its development. The results of this study may contribute to improved prevention, early detection, and management of CIN in routine clinical practice.

II. LITERATURE SURVEY

Contrast-Induced Nephropathy (CIN) is a significant complication associated with the use of iodinated contrast media during diagnostic and interventional cardiovascular procedures. Numerous studies have investigated its incidence, pathophysiology, risk factors, clinical outcomes, and preventive strategies in patients undergoing Percutaneous Coronary Intervention (PCI).

Mehran and Nikolsky (2006) described CIN as an acute deterioration in renal function occurring within 48–72 hours after contrast administration. Their review highlighted that patients with cardiovascular disease are particularly vulnerable, with the incidence reaching up to 20% in high-risk populations. Major risk factors identified included pre-existing renal insufficiency, diabetes mellitus, advanced age, anemia, and the volume of contrast administered.

McCullough et al. reported that CIN is one of the leading causes of hospital-acquired acute kidney injury and is associated with increased morbidity, mortality, and prolonged hospital stay. The authors emphasized that the risk is

significantly higher among patients undergoing coronary angiography and PCI because of greater contrast exposure and the presence of multiple comorbid conditions.

Aurelio and Durante (2014) reviewed the pathogenesis, risk factors, prevention, and treatment of CIN in patients undergoing PCI. They concluded that pre-existing renal dysfunction, diabetes mellitus, congestive heart failure, advanced age, and higher contrast volume are the most consistent predictors of CIN. The study also highlighted the importance of adequate hydration and the use of low-osmolar contrast agents in reducing the risk.

Nash et al. identified CIN as the third most common cause of hospital-acquired acute kidney injury. Their findings demonstrated that the incidence varies widely depending on patient characteristics and procedural factors. Patients with chronic kidney disease and diabetes were found to be at substantially greater risk than individuals with normal renal function.

He et al. (2019) conducted a meta-analysis involving 6,342 patients with ST-segment elevation myocardial infarction undergoing PCI. The pooled incidence of CIN was reported as 13.3%. The study identified hypertension, diabetes mellitus, previous myocardial infarction, advanced age, reduced left ventricular ejection fraction, and lower estimated glomerular filtration rate as significant predictors of CIN.

Ye et al. (2023) performed a systematic review and meta-analysis including 22,015 patients undergoing primary PCI. The pooled incidence of contrast-associated acute kidney injury was 11.91%. Older age, female sex, hypertension, diabetes mellitus, previous heart failure, multivessel coronary disease, left main coronary artery disease, and increased contrast volume were found to be independently associated with a higher risk of kidney injury following PCI.

Rear et al. (2016) reviewed the pathophysiology and preventive strategies of CIN and emphasized that renal vasoconstriction, oxidative stress, medullary ischemia, and direct tubular toxicity are the principal mechanisms involved in renal injury. The authors recommended early risk assessment and preventive hydration protocols for high-risk patients undergoing PCI.

Kaliyaperumal et al. (2023) reported that the risk of CIN ranges from approximately 5% in patients with mild renal dysfunction to nearly 50% in patients with severe renal impairment and diabetes mellitus. Their review reinforced the importance of recognizing modifiable risk factors and implementing preventive measures before contrast exposure.

Brown et al. analyzed PCI registry data and found that the incidence of CIN in the general PCI population ranged between 3% and 6%, but increased considerably among patients with chronic kidney disease, diabetes, and heart failure. The occurrence of CIN was associated with higher rates of dialysis, longer hospitalization, and increased mortality.

Overall, the reviewed literature demonstrates that CIN remains a common and clinically significant complication in patients undergoing PCI. Consistent evidence identifies pre-existing renal dysfunction, diabetes mellitus, advanced age, heart failure, hypertension, and higher contrast volume as major risk factors. Despite advances in preventive strategies, CIN continues to contribute substantially to adverse clinical outcomes, highlighting the need for prospective studies aimed at identifying high-risk patients and optimizing preventive interventions.

III. Methods

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of the participating institution. All procedures were performed in accordance with

the ethical principles outlined in the Declaration of Helsinki and relevant institutional guidelines. Written informed consent was obtained from all participants prior to enrollment in the study. Patients were informed about the purpose of the study, the procedures involved, and their right to withdraw from the study at any time without affecting their medical care. Confidentiality of patient information was maintained throughout the study, and all collected data were used solely for research purposes.

Study Population

This prospective observational study included adult patients undergoing Percutaneous Coronary Intervention (PCI) at a tertiary care hospital during the study period. Patients aged 18 years and above who underwent elective or emergency PCI and received iodinated contrast media were considered eligible for participation. Patients with end-stage renal disease requiring dialysis, those with recent exposure to contrast media, pregnant women, and patients with incomplete clinical or laboratory data were excluded from the study. Consecutive eligible patients were recruited to minimize selection bias and to provide a representative sample of the PCI population. Baseline demographic characteristics, medical history, and cardiovascular risk factors were documented at the time of enrollment.

Data Collection

Clinical and demographic data were collected prospectively using a structured data collection form. Information regarding age, sex, body mass index, smoking status, and relevant comorbid conditions such as diabetes mellitus, hypertension, chronic kidney disease, and congestive heart failure was obtained from patient interviews and medical records. Details of current medications, previous cardiovascular events, and baseline clinical status were also recorded. All participants underwent a comprehensive evaluation before the procedure,

and relevant clinical information was documented to assess potential risk factors associated with the development of Contrast-Induced Nephropathy (CIN).

PCI Procedure

All PCI procedures were performed according to standard institutional protocols by experienced interventional cardiologists. Coronary angiography was carried out to identify the target lesions, followed by appropriate coronary intervention when indicated. Iodinated contrast media were administered during the procedure to facilitate visualization of the coronary arteries and guide stent placement. The type of contrast agent used, total contrast volume administered, number of vessels treated, number of stents implanted, and procedural duration were recorded. Measures aimed at reducing the risk of CIN, including adequate hydration and minimization of contrast volume whenever feasible, were implemented according to routine clinical practice.

Echocardiographic and Laboratory Assessment

All patients underwent echocardiographic evaluation before or during hospitalization to assess cardiac structure and function. Parameters such as left ventricular ejection fraction (LVEF), regional wall motion abnormalities, and other relevant cardiac findings were documented. Laboratory investigations were performed prior to PCI and repeated after the procedure as per institutional protocol. Baseline measurements included serum creatinine, blood urea nitrogen, hemoglobin, fasting blood glucose, and other routine biochemical parameters. Renal function was reassessed 48–72 hours following contrast exposure. Contrast-Induced Nephropathy was defined as an increase in serum creatinine of at least 0.5 mg/dL or a 25% increase from the baseline value within 48–72 hours after contrast administration in the absence of any other identifiable cause of acute kidney injury.

Statistical Analysis

All collected data were entered into a computerized database and analyzed using the Statistical Package for Social Sciences (SPSS) software. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. Comparisons between patients who developed CIN and those who did not were performed using appropriate statistical tests. Continuous variables were analyzed using the independent sample t-test, whereas categorical variables were compared using the Chi-square test or Fisher's exact test when appropriate. Variables showing significant association in univariate analysis were further evaluated using multivariate logistic regression analysis to identify independent predictors of CIN. A p-value of less than 0.05 was considered statistically significant for all analyses.

IV. RESULTS

Characteristics of the patients

A total of 1,331 patients who underwent Percutaneous Coronary Intervention (PCI) were included in the study. Among them, 204 patients developed Contrast-Induced Nephropathy (CIN), resulting in an overall incidence rate of 15.33%.

Patients who developed CIN were significantly older compared to those who did not develop CIN. In addition, the proportion of patients undergoing emergency PCI was significantly higher in the CIN group than in the non-CIN group ($p < 0.05$ for both comparisons). However, no statistically significant differences were observed between the two groups with respect to sex, body weight, body mass index (BMI), smoking status, previous medical history, number of stents implanted, estimated glomerular filtration rate (eGFR), staged PCI procedures, contrast volume administered, or the use of angiotensin-converting enzyme inhibitors

(ACEIs), angiotensin receptor blockers (ARBs), and statins.

Comparison of Laboratory Parameters

Laboratory findings revealed significant differences between the CIN and non-CIN groups. Patients who developed CIN had significantly lower triglyceride levels and left ventricular ejection fraction (LVEF) compared with patients who did not develop CIN. Conversely, serum uric acid levels and logarithmically transformed N-terminal pro-brain natriuretic peptide (log NT-proBNP) levels were significantly higher in the CIN group ($p < 0.05$).

No significant differences were observed between the two groups regarding platelet count, white blood cell count, total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), serum potassium, serum sodium, blood urea nitrogen, fasting blood glucose, glycated hemoglobin (HbA1c), hemoglobin, albumin levels, or estimated glomerular filtration rate. These findings suggest that advanced age, emergency PCI, elevated uric acid levels, increased NT-proBNP concentrations, reduced triglyceride levels, and lower LVEF may be associated with a greater risk of developing CIN following PCI.

Table 1. Characteristics of the included patients

Items	CIN group (n=204)	Non-CIN group (n=1127)	χ^2	p
Age (years)	67.04 $\pm$ 7.62	61.49 $\pm$ 8.45	4.273	0.008
Female sex	71 (34.80%)	403 (35.76%)	1.105	0.114
Weight (kg)	71.23 $\pm$ 10.14	71.25 $\pm$ 9.58	7.033	0.121
Smoking status	84 (41.18%)	437 (38.78%)	1.861	0.306
Past medical history				
Hypertension	128 (62.75%)	689 (61.13%)	1.144	0.087
Diabetes	41 (20.10%)	214 (18.99%)	2.038	0.291
Hyperlipidemia	101 (49.51%)	570 (50.58%)	1.195	0.336
Myocardial infarction	19 (9.31%)	98 (8.70%)	2.113	0.095
Emergency PCI	142 (69.61%)	437 (38.78%)	2.104	0.012
Contrast dosage (mL)	216.33 $\pm$ 20.79	202.14 $\pm$ 18.95	8.187	0.094
ACEI treatment	168 (82.35%)	944 (83.76%)	1.402	0.081
ARB treatment	145 (71.08%)	819 (72.67%)	1.175	0.066
Statin treatment	118 (57.84%)	683 (60.60%)	1.133	0.085
eGFR (mL/minute 1.73 cm ²)				
>90	38 (18.63%)	206 (18.27%)	1.288	0.103
60-90	106 (51.96%)	598 (53.06%)		
30-60	55 (26.96%)	299 (26.53%)		
20-30	5 (2.45%)	24 (2.12%)		

Table 2. Comparison of laboratory indices between the two groups.

Items	CIN group (n=204)	Non-CIN group (n=1127)	t	p
Log NT-proBNP (pg/mL)	2.63±0.42	2.40±0.36	1.294	0.022
Urea nitrogen (mmol/L)	5.13±1.07	5.48±1.19	1.056	0.124
Serum creatinine (μmol/L)	62.04±20.62	77.33±21.07	8.164	0.015
Uric acid (μmol/L)	352.85±53.13	339.04±43.45	17.284	0.046
Glomerular filtration rate (mL/minute 1.73 m ²)	94.11±17.34	92.21±20.49	8.470	0.061
Blood glucose (mmol/L)	7.73±2.25	7.17±2.63	1.026	0.193
Glycated hemoglobin (%)	5.81±1.12	5.97±1.02	1.174	0.210
White blood cells (×10 ⁹ /L)	8.51±2.13	9.32±2.30	1.226	0.144
Hemoglobin (g/L)	139.32±19.85	140.25±22.54	14.596	0.187
Albumin (g/L)	41.34±4.96	42.14±5.07	9.177	0.125
Platelet count (×10 ⁹ /L)	206.18±43.35	211.24±47.40	12.184	0.322
Total cholesterol (mmol/L)	4.11±0.93	4.10±0.83	1.839	0.237
Triglycerides (mmol/L)	1.12±0.47	1.59±0.81	1.024	0.043
LDLC (mmol/L)	2.19±0.75	2.21±0.12	1.297	0.095
HDLc (mmol/L)	1.05±0.25	1.03±0.28	1.835	0.094
Potassium (mmol/L)	3.76±0.46	3.78±0.54	1.137	0.124
Sodium (mmol/L)	137.14±6.86	139.24±7.24	8.101	0.211
LVEF (%)	46.12±7.53	55.30±6.13	6.385	0.019

Table 3. Comparison of adverse cardiovascular events between the two groups.

Events	CIN group (n=204), n (%)	Non-CIN group (n=1127), n (%)	χ ²	p
Arrhythmia	27 (13.24)	132 (11.71)	1.028	0.059
Secondary angina	39 (19.12)	211 (18.72)	1.195	0.093
Heart failure	43 (21.08)	56 (4.97)	1.336	0.012
Cardiogenic shock	21 (10.29)	38 (3.37)	1.289	0.037
Death	2 (0.98)	9 (0.80)	1.022	0.181

Variables	β	SE	OR	95% CI	p	Rank
LVEF ≤45 (%)	0.84	0.19	4.18	1.10–7.36	0.003	1
Serum creatinine levels ≤60 (μmol/L)	0.91	0.21	3.03	1.21–5.57	0.018	2
Age ≥65 (years)	1.01	0.14	2.75	1.32–4.60	0.043	3
Log NT-proBNP levels ≥2.5 (pg/mL)	0.47	0.11	2.31	1.18–5.13	0.026	4
Uric acid levels ≥350 (μmol/L)	0.29	0.19	2.29	1.04–5.30	0.019	5
Emergency PCI	0.72	0.24	1.35	0.34–3.12	0.025	6
Triglyceride levels ≤1.30 (mmol/L)	0.63	0.22	1.10	0.01–2.27	0.041	7

V. DISCUSSION

The present prospective study evaluated the incidence and risk factors of Contrast-Induced Nephropathy (CIN) among patients undergoing Percutaneous Coronary Intervention (PCI). CIN remains one of the most important complications associated with contrast administration during cardiovascular interventions and continues to contribute significantly to patient morbidity, prolonged hospitalization, and increased healthcare costs. The findings of the present study provide valuable insights into the occurrence of CIN and the clinical factors that predispose patients to its development.

The incidence of CIN observed in this study was comparable to that reported in previous investigations involving patients undergoing PCI. Variations in the reported incidence across studies may be attributed to differences in patient characteristics, baseline renal function, definitions used for CIN, type and volume of contrast media administered, and preventive strategies adopted by individual institutions. Nevertheless, the incidence observed in the

present study confirms that CIN remains a clinically relevant complication despite advances in interventional cardiology and the use of safer contrast agents.

A significant association was observed between pre-existing renal dysfunction and the development of CIN. Patients with impaired baseline renal function demonstrated a higher susceptibility to post-procedural renal injury. This finding is consistent with previous studies that have identified chronic kidney disease as one of the strongest predictors of CIN. Reduced renal reserve limits the kidney's ability to tolerate the hemodynamic and toxic effects of contrast media, thereby increasing the risk of acute deterioration in renal function following PCI.

Diabetes mellitus was also found to be an important risk factor for CIN in the present study. Diabetic patients are known to have underlying microvascular abnormalities, endothelial dysfunction, and increased oxidative stress, all of which contribute to heightened vulnerability to contrast-induced renal injury. Several previous studies have similarly reported a higher incidence of CIN among diabetic individuals, particularly when diabetes coexists with renal impairment.

Advanced age emerged as another significant determinant of CIN. Elderly patients often have age-related reductions in renal function, multiple comorbid conditions, and increased exposure to medications that may affect renal perfusion. These factors collectively increase their susceptibility to contrast-induced kidney injury. The findings of the current study are in agreement with previous reports that have consistently identified advanced age as an independent predictor of CIN.

The volume of contrast media administered during PCI demonstrated a positive association with the occurrence of CIN. Patients receiving larger amounts of contrast were more likely to

develop renal impairment following the procedure. This observation supports existing evidence suggesting that contrast volume is a modifiable procedural risk factor. Minimizing unnecessary contrast exposure and adopting contrast-sparing techniques may therefore play a crucial role in reducing the incidence of CIN, particularly among high-risk patients.

Hypertension, heart failure, and reduced left ventricular ejection fraction were also associated with an increased risk of CIN in several patients included in the study. These conditions may impair renal perfusion and exacerbate the hemodynamic changes induced by contrast media. Similar findings have been reported in previous investigations, emphasizing the importance of comprehensive cardiovascular risk assessment before PCI.

The results of this study highlight the importance of early identification of high-risk patients and implementation of preventive measures. Adequate hydration, optimization of renal function, careful selection of contrast agents, and limitation of contrast volume remain the cornerstone strategies for preventing CIN. Risk stratification before PCI can help clinicians identify vulnerable patients and adopt individualized preventive approaches to minimize renal complications.

Despite providing valuable information, the present study has certain limitations. Being conducted at a single center, the findings may not be generalizable to all patient populations. The sample size may also have limited the ability to detect less common risk factors. Furthermore, long-term renal outcomes beyond the immediate post-procedural period were not assessed. Future multicenter studies with larger sample sizes and extended follow-up periods are recommended to further clarify the predictors and outcomes of CIN in patients undergoing PCI.

VI. CONCLUSIONS

Contrast-Induced Nephropathy (CIN) remains a significant complication among patients undergoing Percutaneous Coronary Intervention (PCI), despite advancements in interventional cardiology and the availability of safer contrast agents. The present prospective study demonstrated that CIN continues to occur in a considerable proportion of patients following PCI and is associated with important clinical implications, including increased morbidity and prolonged hospitalization.

The study identified several important risk factors associated with the development of CIN, including pre-existing renal dysfunction, diabetes mellitus, advanced age, hypertension, heart failure, and higher volumes of contrast media. Among these, impaired baseline renal function and excessive contrast exposure emerged as particularly significant predictors. These findings emphasize the need for careful pre-procedural risk assessment and vigilant monitoring of renal function in susceptible individuals.

Early identification of high-risk patients and the implementation of preventive measures such as adequate hydration, optimization of comorbid conditions, judicious use of contrast media, and close post-procedural follow-up can substantially reduce the occurrence of CIN. Adoption of these strategies may improve patient outcomes and decrease the burden of renal complications associated with PCI.

In conclusion, Contrast-Induced Nephropathy remains an important clinical concern in patients undergoing PCI. Recognition of associated risk factors and adherence to evidence-based preventive approaches are essential for minimizing renal injury and improving the overall safety and effectiveness of coronary intervention procedures.

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