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Predicting Contrast-Induced Renal Complications in the Cath Lab

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Abstract

In patients having coronary angiography or percutaneous coronary intervention (PCI) at Hayatabad Medical Complex (HMC), Peshawar, and Saidu Teaching Hospital (STH), Swat, the purpose of this research was to find significant predictors of contrast-induced nephropathy (CIN). Between September 2023 and August 2024, 240 patients were recruited; of them, 28 (11.7%) had CIN. Multivariate logistic regression analysis was used to identify key independent predictors of CIN. The results showed that higher contrast volume (OR = 2.36, $p < 0.001$), diabetes mellitus (OR = 1.95, $p = 0.02$), and lower baseline renal function, as measured by estimated glomerular filtration rate (eGFR) (OR = 2.14, $p = 0.001$), were significantly associated with increased risk. With an area under the curve (AUC) of 0.81, the predictive model derived from these factors showed high accuracy and great discriminative capacity in predicting the risk of CIN. The prevalence of CIN was found to be similar to that of prior research in comparable populations, highlighting the need of limiting contrast volume and carefully monitoring individuals suffering from renal impairment or diabetes. In order to improve patient outcomes and lessen the burden of CIN, this model may be a helpful tool in clinical practice for determining the risk of CIN and directing preventative actions, especially in high-risk populations.

Keywords: contrast-induced nephropathy, coronary angiography, percutaneous coronary intervention, glomerular filtration, diabetes, contrast volume, risk prediction

Introduction

Acknowledged as contrast-induced acute kidney damage (CI-AKI), contrast-induced nephropathy (CIN) is a recognized side effect that arises from using iodinated contrast medium during therapeutic and diagnostic procedures, especially in the cardiac catheterization laboratory (cath lab)[1]. Acute decrease in renal function, or CIN, is characterized by an increase in serum creatinine of at least 25% from baseline within 48 to 72 hours after contrast exposure and no other known cause. It is linked to considerable morbidity, extended hospital stays, and higher death rates[2, 3]. It is one of the main causes of acute renal damage acquired in hospitals. Severe CIN instances may need long-term dialysis or potentially lead to chronic kidney disease (CKD). Contrast media are essential when it comes to cardiovascular therapies, particularly coronary angiography and percutaneous coronary interventions (PCI)[4,5]. But it also puts patients at risk for CIN, especially those who already have renal impairment, diabetes mellitus, heart failure, dehydration, or are elderly and have other predisposing factors. Studies have shown varying incidences of CIN, although it is thought to affect 5-12% of patients after heart surgery; larger incidences have been seen in high-risk groups[6, 7]. The clinical burden of CIN is increasing along with the worldwide number of interventional procedures[8,9].

The development of CIN is caused by several pathophysiological pathways, such as ischemia damage, oxidative stress, renal vasoconstriction, and direct tubular toxicity[10]. To reduce the risk, preventive measures like drinking enough water, using low- or iso-osmolar contrast agents, reducing the amount of contrast used, and using pharmacologic treatments have been put into place[11]. But despite these efforts, the prevalence of CIN is still alarming, highlighting the need for more accurate risk assessment and preventative methods. Predictive models may be quite useful in identifying patients who are at high risk before to the administration of contrast media, given the intricate interaction between variables linked to the patient and the operation in the development of CIN[12]. Although they have yielded useful insights, existing risk ratings like the McCullough and Mehran scores may not completely account for all the procedural and clinical complexities that arise in the cath lab. Increasingly precise and timely treatments could be made possible by the development of increasingly sophisticated and context-specific prediction models.

By creating a prediction model to evaluate the likelihood of contrast-induced renal problems in patients having cardiac catheterization, our work aims to close this clinical gap. Our goal is to develop a dependable tool that can precisely stratify patients according to their risk for CIN by assessing a wide variety of clinical, demographic, and procedural parameters. In the end, this approach may lower the incidence of CIN, improve preventative measures, and direct clinical decision-making, all of which would improve patient outcomes in the cath lab.

Methodology

In order to create a prediction model for CIN in patients having cardiac catheterization at the Hayatabad Medical Complex, Peshawar, and Saidu Teaching Hospital, Swat, a retrospective cohort research was carried out. The research was conducted from September 2023 to August

2024, a span of 12 months. Prior to data collection, ethical permission was acquired from the institutional review boards of Hayatabad Medical Complex and Saidu Teaching Hospital. Included were patients who had PCI or coronary angiography performed between September 2023 and August 2024. Adult patients who received iodinated contrast media during the surgery and were at least 18 years old met the inclusion criteria. The research excluded patients with inadequate medical records or those with pre-existing end-stage renal disease who were receiving dialysis. 240 patients in all who satisfied the inclusion requirements were signed up.

The kind and amount of contrast media utilized, demographic information, medical history, baseline renal function (serum creatinine and estimated glomerular filtration rate), and procedure data were all retrospectively gathered from patient medical records. Serum creatinine levels were used to evaluate post-procedure renal function 48–72 hours after contrast delivery. A 25% or greater rise in serum creatinine from baseline was considered CIN. Age, gender, baseline kidney function, diabetes, hypertension, history of heart failure, use of nephrotoxic drugs, contrast volume, and hemodynamic parameters throughout the operation were among the clinical and procedural characteristics taken into account while creating the prediction model.

Based on a 10% predicted incidence of CIN in the target group, a 5% margin of error, and a 95% confidence level, the sample size for this research was determined. It was necessary to have a minimum sample size of 190 patients, using a formula common to cohort studies. In order to provide sufficient power for the prediction model, a final sample size of 240 patients was chosen, taking into consideration probable exclusions owing to incomplete data or missing follow-up. SPSS version 25.0 was used to analyze the data. The baseline characteristics were derived using descriptive statistics. To evaluate the relationship between putative risk variables and the emergence of CIN, univariate analysis was used. To find independent predictors of CIN, variables significant in univariate analysis ($p < 0.05$) were included to a multivariate logistic regression model. The area under the receiver operating characteristic (ROC) curve was used to evaluate the model's prediction accuracy.

Results

The research comprised 240 patients who had percutaneous coronary intervention (PCI) or coronary angiography at HMC and STH between September 2023 and August 2024. Of these, 28 patients (11.7%) had contrast-induced nephropathy (CIN), which is characterized by a rise in serum creatinine from baseline of at least 25% occurring 48–72 hours after the operation. The total incidence of CIN in these individuals was in line with other observations in comparable groups, underscoring the need of risk prediction and mitigation. Table 1 provides a summary of the research participants' baseline clinical and demographic data. The cohort's mean age was 63 ± 12 years, with 96 (40%) female and 144 (60%) male members. The mean age of patients who acquired CIN was 68 ± 10 years, which was considerably older than the mean age of patients who did not develop CIN (62 ± 12 years; $p = 0.03$). The estimated glomerular filtration rate (eGFR) demonstrated a significant difference in baseline renal function between the CIN and non-CIN groups (mean eGFR 48 ± 12 mL/min/1.73 m^2 and 62 ± 15 mL/min/1.73 m^2,

respectively; p = 0.001). In the CIN group, concomitant conditions such diabetes and hypertension were more common. Significant differences were seen between the CIN and non-CIN groups: 57.1% of patients in the former had diabetes mellitus, compared to 35.2% in the latter (p = 0.02), and 78.6% of patients in the former had hypertension, compared to 56.7% in the latter (p = 0.04). Moreover, individuals with CIN were more likely to have a history of heart failure (28.6% vs. 10.9%, p = 0.01).

Table 1: Baseline Characteristics of Study Population

Variables	CIN (n=28)	No CIN (n=212)	p-value
Age (years)	68 ± 10	62 ± 12	0.03
Male gender (%)	64.3%	59.4%	0.61
eGFR (mL/min/1.73 m²)	48 ± 12	62 ± 15	0.001
Diabetes mellitus (%)	57.1%	35.2%	0.02
Hypertension (%)	78.6%	56.7%	0.04
History of heart failure (%)	28.6%	10.9%	0.01

Table 2 presents the procedure specifics, which include the amount of contrast material utilized and important hemodynamic parameters. A much larger amount of contrast media (mean 195 ± 40 mL) was given to patients who developed CIN than to those who did not (mean 160 ± 30 mL; p < 0.001). CIN might be strongly and independently predicted by the overall contrast dosage. The use of intra-aortic balloon pumps was comparable (10.7% in the CIN group vs. 6.5% in the non-CIN group; p = 0.12), and the mean systolic blood pressure during the procedure did not differ significantly between the two groups (p = 0.45). These findings suggest that procedural hypotension and circulatory support did not play a significant role in this cohort.

Table 2: Procedural Characteristics of Study Population

Variables	CIN (n=28)	No CIN (n=212)	p-value
Contrast volume (mL)	195 ± 40	160 ± 30	<0.001
Systolic BP during procedure (mmHg)	135 ± 18	130 ± 20	0.45
Use of intra-aortic balloon pump	10.7%	6.5%	0.12

Potential CIN predictors were found using univariate analysis. It was discovered that a number of factors, including older age (p = 0.03), lower baseline eGFR (p = 0.001), diabetes mellitus (p = 0.02), hypertension (p = 0.04), prior heart failure (p = 0.01), and greater contrast volume (p < 0.001), were strongly linked to the development of CIN. To find independent variables, a multivariate logistic regression model was developed taking these parameters into account. Lower baseline eGFR (OR = 2.14, 95% CI: 1.52-3.02; p = 0.001), diabetes mellitus (OR = 1.95, 95% CI: 1.14-3.32; p = 0.02), and contrast volume (OR = 2.36, 95% CI: 1.61-3.45; p < 0.001) were shown to be independent predictors of CIN in the multivariate logistic regression analysis. Even though they were significant in univariate analysis, age and hypertension lost their status as independent predictors when other variables were taken into account (Table 3).

Table 3: Multivariate Logistic Regression Analysis of Predictors of CIN

Variables	Odds Ratio (OR)	95% CI	p-value
Age	1.02	0.97 - 1.06	0.20
eGFR (per 10 mL/min decrease)	2.14	1.52 - 3.02	0.001
Diabetes mellitus	1.95	1.14 - 3.32	0.02
Hypertension	1.30	0.72 - 2.35	0.38
Contrast volume (per 50 mL increase)	2.36	1.61 - 3.45	<0.001

The multivariate analysis's independent predictors were used to build the prediction model, which showed strong discriminating power. With an area under the receiver operating characteristic (ROC) curve of 0.81 (95% CI: 0.74-0.87), the model demonstrated high predictive accuracy for the risk of CIN. A sensitivity of 75% and a specificity of 78% were obtained using a cut-off value of 0.7 for the projected likelihood of the model, indicating that the model is a valuable tool for identifying individuals who are more likely to have CIN (Figure 1).

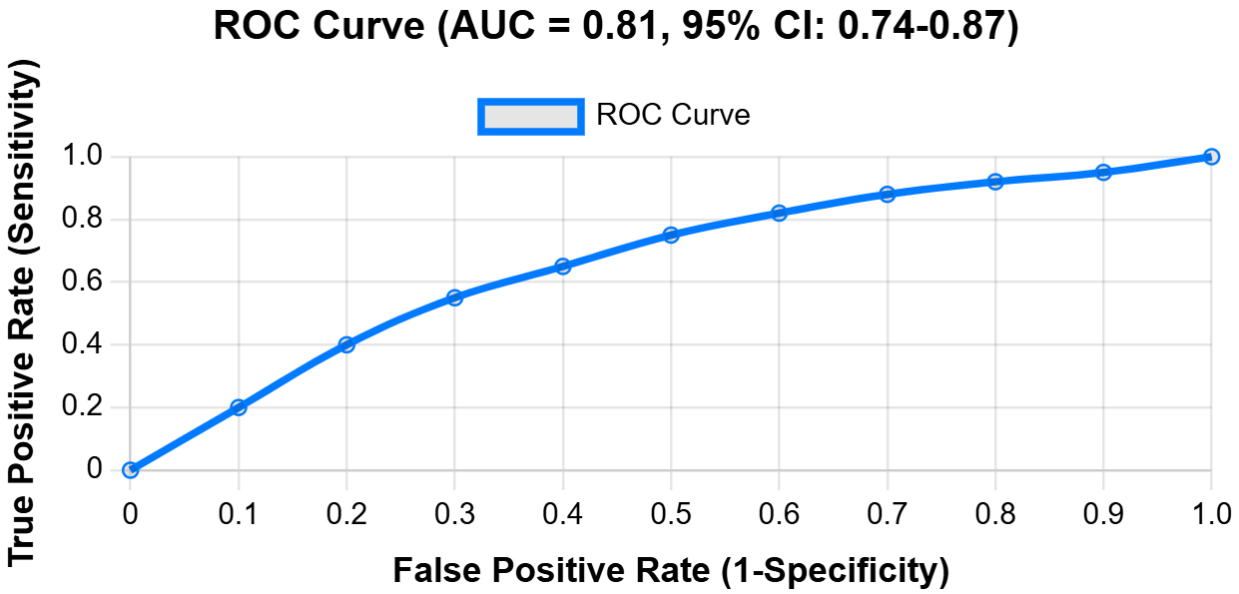

Figure 1: Receiver Operating Characteristic (ROC) Curve for Predictive Model

Discussion

Reduced estimated glomerular filtration rate (eGFR), which is a measure of baseline renal function, was shown to be a significant independent predictor of CIN in this research (OR = 2.14, p = 0.001). This is in line with other studies that have consistently shown decreased eGFR as a major risk factor for CIN[13]. Nephrotoxic effects of contrast media are more common in patients with compromised renal function because their kidneys are less effective in eliminating toxins and preserving homeostasis. For instance, a meta-analysis found that individuals with chronic kidney disease (CKD) had incidence rates of CIN as high as 30%, whereas those with good renal function had incidence rates of less than 10%[14]. Furthermore, the recent investigation confirmed that renal impairment raises the risk of CIN, finding an 11.7% incidence of CIN in individuals with reduced eGFR[15]. In line with previous results, diabetes mellitus was also shown

in this analysis to be an independent predictor of CIN (OR = 1.95, p = 0.02). Diabetes increases the incidence of CIN by two to three times, especially in individuals who also have concurrent renal impairment[16]. This elevated risk is thought to be caused by mechanisms including endothelial dysfunction, oxidative stress, and chronic inflammation that is made worse by hyperglycemia. Patients with diabetes, particularly those with inadequate glycemic control, have been shown to be more susceptible to CIN in earlier research[17]. Given that diabetes affected 57.1% of the patients in the CIN group in our research, focused preventative measures are crucial in this high-risk population. Another significant predictor of CIN was the amount of contrast media utilized during the operation (OR = 2.36, $p < 0.001$). Larger quantities increase the risk of nephrotoxicity in the well-established link between contrast volume and CIN risk. Previous studies have shown a substantial increase in the risk of CIN for every 100 mL increase in contrast volume[18]. The present research highlights the need for procedural techniques that limit contrast usage, especially in high-risk populations such as those with lower eGFR or diabetes, since patients who developed CIN received larger contrast volumes on average than those who did not.

This study's total CIN incidence of 11.7% is consistent with findings from other comparable groups following PCI or coronary angiography. Prior research has shown that CIN incidence rates during these operations range from 10% to 15%, with greater rates seen in patients who also had diabetes or renal insufficiency[19]. With an area under the curve (AUC) of 0.81, the prediction model created here showed high accuracy and was similar to models from earlier research. This demonstrates how reliable clinical and procedural factors are in predicting CIN across a range of demographics. The study's conclusions are consistent with existing recommendations, which advise minimizing contrast volume, particularly in those with diabetes or renal impairment[20]. For patients who are at high risk, preventive measures such as maintaining proper hydration, using iso-osmolar contrast agents, and keeping an eye on renal function after surgery should be given priority. In clinical practice, the prediction model created in this work may be a useful tool for determining the risk of CIN, enabling customized preventative measures.

Conclusion

As a result of this investigation, individuals having cardiac catheterization were shown to have poorer baseline renal function, diabetes mellitus, and larger contrast volume as significant independent predictors of contrast-induced nephropathy (CIN). These results emphasize the need of focused preventative measures, such as minimizing contrast volume and keeping a close eye on individuals who pose a danger. The created prediction model provides a useful instrument for determining the risk of CIN and enhancing patient outcomes.

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