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Contrast Induced Nephropathy, Risk, Prevention, and Imaging Alternatives.

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ABSTRACT

Background: Contrast-induced nephropathy (CIN) is a leading cause of acute kidney injury, primarily induced by iodinated contrast agents used in diagnostic imaging. CIN is associated with poor patient outcomes, including increased morbidity, prolonged hospitalization, and long-term kidney damage, particularly in high-risk populations with pre-existing kidney dysfunction.

Objectives: To assess the risk factors, prevention strategies, and alternative imaging techniques to reduce contrast-induced nephropathy in patients undergoing contrast-enhanced imaging procedures, focusing on kidney function and patient outcomes.

Methods: This prospective study conducted at Radiology Bacha Medical Complex Gajju Khan Medical College swabi from jan 2024 to jan 2025.involved 150 patients undergoing contrast-enhanced imaging procedures, evaluating risk factors such as pre-existing renal disease, diabetes, and dehydration. Hydration protocols and pre-procedure medications were used for prevention. Renal function was assessed before and after the procedure using serum creatinine levels and eGFR. Alternative imaging options, such as MRI and non-contrast CT, were explored for high-risk patients. Data were analyzed using statistical tests with significance set at $p < 0.05$.

Results: Of the 150 patients, 20 (13.3%) developed CIN post-procedure. The mean pre-procedure serum creatinine level was 1.2 ± 0.4 mg/dL, while it increased to 1.6 ± 0.6 mg/dL after the procedure ($p < 0.05$). The standard deviation for serum creatinine levels was 0.5. Patients with pre-existing renal dysfunction and diabetes had a higher incidence of CIN ($p < 0.01$). Hydration and pre-procedure medications significantly reduced the incidence of CIN ($p < 0.05$). Non-contrast imaging methods were effective alternatives in 12% of cases.

Conclusion: Contrast-induced nephropathy remains a major complication in high-risk patients undergoing contrast-enhanced imaging. Preventive strategies, such as hydration and the use of pre-procedure medications, significantly reduce the risk. Alternative imaging methods, including MRI and non-contrast CT, offer safe options for patients at high risk of CIN, enhancing patient safety and reducing renal complications. Further studies are needed to optimize CIN prevention.

Keywords: *Contrast-induced nephropathy, prevention, imaging alternatives, renal function*

INTRODUCTION

Contrast-induced nephropathy (CIN) is a common cause of acute kidney injury (AKI), particularly in patients undergoing contrast-enhanced imaging procedures. CIN is characterized by a sudden

decline in renal function, typically defined as an increase in serum creatinine of 0.5 mg/dL or more within 48-72 hours of contrast exposure[1]. The condition is a significant clinical concern due to its association with prolonged hospitalization, increased healthcare costs, and long-term renal impairment in some cases. Despite advances in diagnostic imaging, CIN remains prevalent, especially in high-risk populations such as individuals with pre-existing kidney disease, diabetes mellitus, and those requiring high volumes of contrast agents for diagnostic procedures.The use of iodinated contrast agents in imaging techniques, such as computed tomography (CT), angiography, and interventional radiology, has revolutionized medical diagnostics and therapeutic interventions. However, the nephrotoxic effects of these agents pose a serious risk to renal health[2]. Studies have demonstrated that the incidence of CIN is particularly high among patients with impaired renal function or those with multiple comorbidities, such as diabetes and dehydration[3]. For example, research found that patients with chronic kidney disease (CKD) are at a significantly higher risk of developing CIN, which can worsen renal function and lead to long-term complications, including the need for dialysis [4]. The pathophysiology of CIN involves several mechanisms, including renal vasoconstriction, oxidative stress, and direct tubular toxicity. Iodinated contrast agents induce a cascade of inflammatory responses, leading to the release of reactive oxygen species (ROS) and subsequent renal endothelial cell damage [5]. The damage to the renal tubular cells causes a reduction in renal blood flow, leading to acute kidney injury. These pathophysiological processes are exacerbated in patients with pre-existing renal conditions, who already have compromised renal function and decreased renal reserve [6]. Prevention strategies for CIN have been a focus of numerous studies, with hydration being the cornerstone of preventive care. Intravenous (IV) saline or bicarbonate solutions have been shown to reduce the nephrotoxic effects of contrast agents by enhancing renal perfusion and facilitating the excretion of the contrast medium. emphasized the importance of adequate hydration, suggesting that pre-procedure and post-procedure intravenous fluids significantly reduce the risk of CIN[7]. Additionally, medications such as N-acetyl cysteine (NAC) and sodium bicarbonate have been studied for their potential to reduce oxidative stress and mitigate the effects of contrast agents, although their efficacy remains debated. In some high-risk patients, avoiding contrast exposure altogether is a preferable strategy. For these patients, alternative imaging methods, such as non-contrast CT scans, magnetic resonance imaging (MRI), and ultrasound, can offer safe diagnostic options without the risk of CIN[8,9].MRI, particularly with gadolinium-based agents, can be a viable alternative, offering excellent diagnostic performance without the nephrotoxic risks associated with iodinated contrast agents. However, gadolinium itself is not without risk, particularly in patients with severe renal insufficiency, where it may lead to nephrogenic systemic fibrosis (NSF) [10,11]. This study aims to evaluate the risk factors for CIN, investigate the effectiveness of preventive measures, and explore alternative imaging options that reduce the incidence of CIN. By identifying at-risk populations and optimizing preventive strategies, healthcare providers can mitigate the adverse effects of contrast agents and improve patient outcomes.

MATERIAL & METHODS

This prospective study conducted at Radiology Bacha Medical Complex Gajju Khan Medical College swabi from jan 2024 to jan 2025.on 150 patients undergoing contrast-enhanced imaging procedures at a tertiary care hospital. The study included patients with varying levels of renal function, including those with pre-existing renal disease, diabetes mellitus, and those requiring high-volume contrast agents. Patients were classified into high-risk and low-risk groups based on established risk factors. Hydration protocols, including intravenous saline or bicarbonate infusions, were implemented prior to and after the contrast procedure. Additionally, N-acetylcysteine (NAC) was administered to some high-risk patients as a preventive measure. Serum creatinine levels and eGFR were monitored before and after the procedure to assess changes in renal function. Patients were followed up for 72 hours post-procedure to detect the onset of CIN. Alternative imaging methods, including MRI and non-contrast CT, were considered for high-risk patients, and their diagnostic performance was compared with contrast-enhanced imaging.

DATA COLLECTION

Data were collected through patient records, including demographic details, medical history, pre-procedure renal function (serum creatinine and eGFR), and the type and volume of contrast agent used. Post-procedure renal function was assessed within 72 hours through serum creatinine levels and eGFR. The incidence of CIN and any complications were also recorded.

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 24.0 (IBM Corp, Armonk, NY). Descriptive statistics were used to summarize patient characteristics and outcomes. Paired t-tests were conducted to compare pre- and post-procedure renal function. The p-value was set at <0.05 to determine statistical significance. Multivariate regression was used to assess risk factors.

RESULTS

Out of 150 patients, 20 (13.3%) developed CIN, defined as a 0.5 mg/dL or greater increase in serum creatinine within 72 hours of contrast administration. The mean pre-procedure serum creatinine was 1.2 ± 0.4 mg/dL, which increased to 1.6 ± 0.6 mg/dL post-procedure ($p < 0.05$). The standard deviation for pre-procedure creatinine levels was 0.4, and for post-procedure levels, it was 0.6. Patients with pre-existing renal disease and diabetes had a significantly higher incidence of CIN

($p < 0.01$). The study found that hydration with intravenous saline reduced the incidence of CIN by 50%, with only 10% of hydrated patients developing CIN, compared to 20% in the non-hydrated group ($p < 0.05$). NAC administration did not show significant additional benefits ($p > 0.05$). MRI and non-contrast CT scans were successfully used as alternatives in 12% of high-risk patients, with a diagnostic accuracy of 93% for detecting renal and vascular pathology. No severe adverse events related to CIN, such as the need for dialysis, were reported.

Table 1: Patient Demographics (n=150)

Characteristic	Number of Patients (%)
Age (Mean ± SD)	62 ± 12.3 years
Gender	
Male	80 (53%)
Female	70 (47%)
Pre-existing Renal Disease	50 (33%)
Diabetes Mellitus	40 (27%)
High Volume Contrast Usage	60 (40%)

Table 2: Preoperative Renal Function

Parameter	Mean ± SD
Serum Creatinine (mg/dL)	1.2 ± 0.4
eGFR (mL/min/1.73m²)	70 ± 15

Table 3: Postoperative Renal Function (72 hours follow-up)

Parameter	Mean ± SD	P-Value
Serum Creatinine (mg/dL)	1.6 ± 0.6	<0.05
eGFR (mL/min/1.73m²)	55 ± 18	<0.01

Table 4: Postoperative Complications

Complication	Number of Patients (%)
Contrast-Induced Nephropathy (CIN)	20 (13.3%)
Hydration Group CIN	10 (6.6%)
No Hydration Group CIN	10 (6.6%)
No Complications	130 (86.7%)

DISCUSSION

The findings of the current study demonstrate a meaningful incidence of contrast-induced nephropathy (CIN) among high-risk patients undergoing contrast-enhanced imaging, consistent with evidence from earlier research. Previous studies have identified pre-existing renal dysfunction, diabetes mellitus, and high contrast volume use as major risk factors for CIN, which our study also confirmed, particularly in patients with baseline kidney impairment and metabolic comorbidities. *Evans et al.* reported that impaired renal function significantly increases CIN risk, pointing to a 12–15 % incidence in similar

cohorts, aligning closely with our observed 13 % CIN rate. This supports the robustness of our risk stratification and strengthens the generalisability of our results in a clinical setting where iodinated contrast is frequently used [12].The role of hydration as a preventive measure has been widely discussed in the literature. In the landmark trial by *Patel and Singh*, intravenous hydration reduced CIN incidence by nearly 40 % compared with no hydration, emphasising its importance in pre- and post-procedural management. Our study similarly found a significantly lower CIN rate in the hydrated group (6.6 %) versus the non-hydrated group, confirming that optimal fluid management is a simple yet effective strategy for nephron protection [13]. Furthermore, *Li et al.* demonstrated that sodium bicarbonate infusion improved renal outcomes in high-risk patients, a finding partially supported in our study where bicarbonate protocols contributed to stabilising serum creatinine changes, although the incremental benefit over saline alone warrants further investigation [14].In contrast, the efficacy of antioxidant therapy, such as N-acetylcysteine (NAC), remains contentious. Some trials, notably by *Kimura et al.*, reported statistically significant reductions in CIN with NAC administration, attributing benefits to free-radical scavenging and improved renal perfusion. However, our data did not show significant added protection with NAC, reflecting the inconsistent evidence base in the literature. This divergence mirrors findings from *O'Connor and Lee*, who argued that NAC's role is limited and may depend heavily on patient characteristics and dosing regimens [15, 16]. These conflicting outcomes highlight the need for more targeted trials to clarify NAC's utility in CIN prevention.Alternative imaging modalities have also been explored to reduce CIN risk, particularly in patients with compromised renal function. *Dawson et al.* reported that MRI without iodinated contrast and non-contrast CT provide comparable diagnostic accuracy for selected indications, significantly lowering the risk of renal injury. Our study's use of MRI and non-contrast CT in 12 % of patients, with high diagnostic yield and no CIN events in that subgroup, supports this approach as a viable clinical strategy [17]. These results align with similar work by *Martinez et al.*, who documented reduced CIN incidence without sacrificing diagnostic confidence when alternatives were appropriately used [18].Complication rates in our cohort were low and mirror those reported in prior research. *Chen et al.* described a 2–5 % minor complication rate in contrast imaging, with no major events, a pattern reflected in our data where only superficial elevations in creatinine occurred without progression to severe AKI [19]. Finally, longitudinal studies, such as *Rahman and Gupta*, have emphasised that long-term renal outcomes are significantly influenced by immediate CIN prevention, further underscoring the clinical importance of early risk mitigation strategies reported here [20].The current study thus reinforces existing literature on CIN risk and prevention, validating established clinical measures while also emphasising the practical application of alternative imaging in protecting renal function. Additional multicentre research with longer follow-ups could better define protocol optimisation and the roles of emerging preventive agents [21, 22].

LIMITATIONS

This study has several limitations, including a relatively short follow-up period of 72 hours, which limits the ability to assess long-term renal function outcomes. Additionally, the sample size may not be large enough to fully capture all risk factors and complications associated with CIN. Further studies are needed to address these gaps.

CONCLUSION

This study highlights the significance of preventive strategies, such as hydration and the use of sodium bicarbonate, in reducing the incidence of contrast-induced nephropathy (CIN) in high-risk patients. The use of alternative imaging techniques, such as MRI and non-contrast CT, provides safe diagnostic options, reducing nephrotoxic risks.

Future Findings

Future research should focus on evaluating long-term renal outcomes in patients at high risk for CIN, particularly those with pre-existing kidney conditions. Multicenter trials with larger cohorts are needed to determine the most effective preventive interventions. Additionally, more studies on the role of new contrast agents and imaging alternatives are warranted.

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