Incidence and Predictors of Contrast-Associated Acute Kidney Injury Following Low-Volume Contrast-Enhanced CT Using Low-kVp Acquisition: A Retrospective Cohort Study

Dr. Prajwal M P[1*], **Dr. Anand S H**[1], **Kotresh N S**[1]
[1*]Department of Radio-Diagnosis, Sri Siddhartha Medical College, Tumkur, Karnataka, India
[1]Junior Resident III (Dr. Prajwal M P) | Email: prajwalmp7@gmail.com
[1]Professor and HOD, Radiology (Dr. Anand S H) | Email: anandsh78@gmail.com
[1]Junior Resident, Radiology (Kotresh N S) | Email: nskotresh5@gmail.com
***Corresponding Author:** Dr. Prajwal M P, Junior Resident III, Department of Radio-Diagnosis, Sri Siddhartha Medical College, Tumkur, Karnataka, India | Email: prajwalmp7@gmail.com

ABSTRACT

Background

Contrast-associated acute kidney injury (CA-AKI) remains a recognized complication following contrast-enhanced computed tomography (CT), particularly among patients with pre-existing renal impairment and multiple comorbidities. Recent advances in CT technology, including low-kilovoltage peak (low-kVp) acquisition and low-volume iodinated contrast protocols, have enabled significant reduction in contrast dose while maintaining diagnostic image quality. Whether these optimized imaging techniques reduce the incidence of CA-AKI remains an area of ongoing investigation.

Objective

To determine the incidence of contrast-associated acute kidney injury following low-volume contrast-enhanced CT using low-kVp acquisition and to identify independent predictors associated with its development.

Methods

A retrospective cohort study was conducted among 486 adult patients who underwent contrast-enhanced CT using low-volume iodinated contrast media with low-kVp acquisition between January 2022 and December 2024. Demographic characteristics, comorbidities, baseline renal function, laboratory investigations, contrast volume, CT acquisition parameters, and post-procedural renal function were reviewed. Contrast-associated acute kidney injury was defined according to Kidney Disease: Improving Global Outcomes (KDIGO) criteria. Multivariate logistic regression analysis was performed to determine independent predictors of CA-AKI.

Results

Contrast-associated acute kidney injury occurred in 34 (7.0%) patients. Older age, chronic kidney disease, diabetes mellitus, reduced baseline estimated glomerular filtration rate, anemia, heart failure, and emergency CT examinations were significantly associated with CA-AKI ($p<0.05$). Low-volume contrast administration combined with low-kVp acquisition demonstrated a low overall incidence of CA-AKI while preserving diagnostic image quality.

Conclusion

Low-volume contrast-enhanced CT using low-kVp acquisition was associated with a relatively low incidence of CA-AKI. Baseline renal dysfunction and major systemic comorbidities remained the strongest predictors of renal injury despite contrast dose reduction.

Keywords: Contrast-associated acute kidney injury, Computed tomography, Low-kVp, Low-volume contrast, Acute kidney injury, Retrospective cohort.

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INTRODUCTION

Contrast-associated acute kidney injury (CA-AKI) is one of the most frequently discussed complications following administration of iodinated contrast media for diagnostic imaging. Although recent evidence suggests that the nephrotoxic potential of intravenous contrast media has historically been overestimated, CA-AKI continues to represent an important clinical concern among patients with chronic kidney disease, diabetes mellitus, heart failure, advanced age, and other predisposing conditions. Acute deterioration in renal function following contrast-enhanced computed tomography may prolong hospitalization, increase healthcare costs, and contribute to adverse clinical outcomes. Consequently, minimizing contrast exposure while maintaining diagnostic accuracy has become a major objective in contemporary radiology practice.[1–4] Recent systematic reviews indicate that the overall risk of intravenous contrast-associated AKI is lower than previously believed, particularly when modern low-osmolar contrast agents and optimized imaging protocols are used. (PMC)

Advances in multidetector CT technology have enabled acquisition of high-quality diagnostic images using lower tube voltages (low-kVp), thereby increasing iodine attenuation and permitting substantial reduction in administered contrast volume without compromising image quality. Low-kVp protocols, particularly those utilizing 70–100 kVp, enhance vascular contrast because the X-ray energy approaches the k-edge of iodine. Consequently, lower doses of iodinated contrast media can achieve diagnostic enhancement comparable to conventional protocols while potentially reducing renal exposure to contrast material. These techniques have gained widespread acceptance in abdominal, vascular, and oncologic CT imaging, especially among patients considered at increased risk of renal dysfunction.[5–9] Recent studies have demonstrated that low-kVp acquisition combined with reduced contrast volume provides excellent diagnostic performance with favorable renal safety profiles. (PMC)

The development of CA-AKI is multifactorial and depends not only on contrast administration but also on patient-related factors including baseline renal impairment, diabetes mellitus, cardiovascular disease, dehydration, anemia, advanced age, and concomitant nephrotoxic medications. Contemporary guidelines increasingly distinguish contrast-associated acute kidney injury from true contrast-induced nephrotoxicity because many episodes of acute kidney injury occurring after contrast administration are attributable to underlying illness rather than direct contrast toxicity. Current recommendations therefore emphasize individualized risk assessment, optimization of hydration status, minimization of unnecessary contrast exposure, and use of low-volume contrast protocols in high-risk patients.[10–15] Current radiology and nephrology guidance supports careful patient selection and recognizes that intravenous contrast-enhanced CT is often safer than previously assumed when appropriate preventive measures are followed. (PMC)

Despite widespread adoption of low-kVp CT protocols, relatively limited clinical data are available regarding the incidence and predictors of CA-AKI following low-volume contrast-enhanced CT in routine clinical practice. Identification of patients who remain susceptible despite optimized imaging protocols may facilitate individualized preventive strategies and improve patient safety. Therefore, the present retrospective cohort study was undertaken to determine the incidence of contrast-associated acute kidney injury following low-volume contrast-enhanced CT using low-kVp acquisition and to identify independent clinical predictors associated with its occurrence.[16–20] Recent cohort studies continue to refine risk stratification models by incorporating baseline kidney function, comorbidities, and imaging-related variables. (PMC)

METHODOLOGY

This retrospective cohort study was conducted in the Department of Radiodiagnosis after approval from the Institutional Ethics Committee. Electronic medical records of adult patients who underwent contrast-enhanced CT examinations using low-volume iodinated contrast media with low-kVp acquisition between January 2022 and December 2024 were reviewed retrospectively.

Patients aged 18 years or older who underwent contrast-enhanced CT with documented baseline and follow-up serum creatinine measurements within 48–72 hours after imaging were included. Patients receiving dialysis, those with kidney transplantation, pregnancy, obstructive uropathy, septic shock before CT examination, or incomplete clinical records were excluded. A total of 486 patients fulfilled the eligibility criteria and were included in the final analysis.

Clinical information including age, sex, indication for CT examination, diabetes mellitus, hypertension, chronic kidney disease, heart failure, malignancy, baseline estimated glomerular filtration rate (eGFR), serum creatinine, hemoglobin concentration, hydration status, use of nephrotoxic medications, contrast volume administered, tube voltage, and emergency or elective imaging status was extracted from hospital records.

All CT examinations were performed using multidetector CT scanners employing low-kVp acquisition (80–100 kVp) with individualized low-volume low-osmolar iodinated contrast protocols based on patient body weight and clinical indication. Contrast-associated acute kidney injury was defined according to KDIGO criteria as an increase in serum creatinine of ≥0.3 mg/dL within 48 hours or ≥1.5 times baseline within seven days following contrast administration.

Statistical analysis was performed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Student's *t*-test and Chi-square test were used for comparison between study groups. Variables demonstrating statistical significance in univariate analysis were entered into multivariate logistic regression analysis to determine independent predictors of CA-AKI. A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 1. Baseline Demographic and Clinical Characteristics

Variable	CA-AKI (n=34)	No CA-AKI (n=452)	p-value

Age (years)	71.2 ± 8.4	61.5 ± 12.1	<0.001
Male sex	22 (64.7%)	258 (57.1%)	0.384
Diabetes mellitus	22 (64.7%)	154 (34.1%)	<0.001
Hypertension	26 (76.5%)	236 (52.2%)	0.007
Chronic kidney disease	18 (52.9%)	58 (12.8%)	<0.001
Heart failure	12 (35.3%)	48 (10.6%)	<0.001

Patients who developed CA-AKI were significantly older and had a higher prevalence of diabetes mellitus, hypertension, chronic kidney disease, and heart failure than patients without renal injury. These findings indicate that pre-existing systemic comorbidities remain major determinants of post-contrast renal dysfunction despite low-volume contrast administration.

Table 2. CT Protocol and Contrast Administration Characteristics

Variable	CA-AKI	No CA-AKI	p-value
Contrast volume (mL)	48.6 ± 6.5	44.8 ± 5.7	0.002
Tube voltage (80 kVp)	18 (52.9%)	266 (58.8%)	0.506
Tube voltage (100 kVp)	16 (47.1%)	186 (41.2%)	0.506
Emergency CT	20 (58.8%)	136 (30.1%)	0.001
Scan duration (seconds)	11.4 ± 2.3	11.1 ± 2.1	0.437
Image quality score	4.6 ± 0.5	4.7 ± 0.4	0.192

Although the administered contrast volume remained low in both groups, patients developing CA-AKI received slightly higher contrast volumes and more frequently underwent emergency CT examinations. Diagnostic image quality remained excellent irrespective of renal outcome, demonstrating the effectiveness of low-kVp acquisition with reduced contrast volume.

Table 3. Laboratory Parameters

Variable	CA-AKI	No CA-AKI	p-value
Baseline serum creatinine (mg/dL)	1.64 ± 0.42	1.02 ± 0.28	<0.001
Baseline eGFR (mL/min/1.73 m²)	46.8 ± 12.7	82.6 ± 18.4	<0.001
Hemoglobin (g/dL)	10.8 ± 1.6	12.9 ± 1.8	<0.001
Serum albumin (g/dL)	3.3 ± 0.5	3.9 ± 0.4	<0.001
Follow-up creatinine (mg/dL)	2.04 ± 0.53	1.04 ± 0.31	<0.001
AKI Stage 1	26 (76.5%)	—	—

Patients who developed CA-AKI demonstrated significantly impaired baseline renal function together with lower hemoglobin and serum albumin concentrations. Most cases were classified as KDIGO Stage 1, suggesting that renal injury was generally mild and detected early through routine laboratory surveillance.

Table 4. Multivariate Logistic Regression Analysis of Independent Predictors of CA-AKI

Variable	Odds Ratio	95% CI	p-value
Chronic kidney disease	4.38	2.11–9.08	<0.001
Baseline eGFR <60 mL/min/1.73 m²	3.84	1.96–7.52	<0.001
Diabetes mellitus	2.41	1.18–4.91	0.015
Heart failure	2.16	1.01–4.62	0.046
Emergency CT examination	1.98	1.03–3.83	0.041
Anemia	1.87	1.02–3.43	0.043

Multivariate analysis demonstrated that chronic kidney disease and reduced baseline eGFR were the strongest independent predictors of CA-AKI following low-volume contrast-enhanced CT. Diabetes mellitus, heart failure, emergency imaging, and anemia also independently increased the likelihood of renal injury, emphasizing that patient-related risk factors remain more influential than contrast volume when modern low-kVp CT protocols are employed.

DISCUSSION

The present study demonstrated a relatively low incidence of contrast-associated acute kidney injury (CA-AKI) following low-volume contrast-enhanced CT performed using low-kVp acquisition protocols. Only 7.0% of patients developed CA-AKI, and most cases were classified as mild (KDIGO Stage 1). These findings support growing evidence that intravenous administration of low-osmolar iodinated contrast media using optimized imaging protocols carries a substantially lower risk of renal injury than previously believed. Recent multicenter studies and updated international guidelines have reported that modern CT protocols incorporating low-kVp acquisition and reduced contrast volume effectively maintain diagnostic image quality while minimizing renal complications, particularly when

appropriate patient selection and hydration strategies are employed.[1–5]

Pre-existing chronic kidney disease and reduced baseline estimated glomerular filtration rate (eGFR) emerged as the strongest independent predictors of CA-AKI in the present study. Patients with impaired renal reserve are particularly susceptible to transient reductions in renal perfusion and tubular injury following contrast administration. Although recent investigations suggest that many episodes of acute kidney injury previously attributed solely to contrast exposure may instead reflect underlying comorbid illnesses, baseline renal dysfunction continues to be recognized as the most important determinant of post-contrast renal impairment. Contemporary recommendations from nephrology and radiology societies therefore emphasize assessment of baseline kidney function before contrast-enhanced imaging and implementation of individualized preventive measures for high-risk patients.[6–10]

Diabetes mellitus, heart failure, anemia, and emergency CT examinations were also identified as significant predictors of CA-AKI. Diabetes contributes to endothelial dysfunction, chronic inflammation, and microvascular disease, reducing renal tolerance to physiological stress. Similarly, heart failure compromises renal perfusion through reduced cardiac output, while anemia diminishes oxygen delivery to renal tubular cells, increasing susceptibility to ischemic injury. Emergency CT examinations frequently involve critically ill patients with sepsis, dehydration, hypotension, or multiple organ dysfunction, all of which independently increase the likelihood of acute kidney injury irrespective of contrast administration. These findings are consistent with recent prospective cohort studies demonstrating that patient-related clinical factors contribute more substantially to CA-AKI than contrast dose alone.[11–15]

One of the important findings of the present study was that excellent diagnostic image quality was maintained despite administration of relatively low contrast volumes using low-kVp acquisition. Lower tube voltage increases attenuation of iodine because the X-ray energy approaches the k-edge of iodine, thereby enhancing vascular and parenchymal contrast while requiring smaller amounts of contrast media. Several recent studies have demonstrated that 80–100 kVp imaging combined with iterative reconstruction algorithms significantly reduces contrast dose without compromising diagnostic accuracy in abdominal, vascular, oncologic, and emergency CT examinations. Consequently, low-kVp protocols have become an important strategy for reducing potential nephrotoxicity while preserving image quality in patients at increased renal risk.[16–21]

The present study has several strengths, including evaluation of a contemporary cohort undergoing standardized low-volume contrast protocols together with comprehensive assessment of clinical, laboratory, and imaging variables. Nevertheless, certain limitations should be acknowledged. The retrospective single-center design limits causal inference and external generalizability. Serum creatinine was used as the primary marker of renal injury, whereas novel biomarkers of tubular damage were unavailable. Long-term renal outcomes beyond hospital discharge were also not evaluated. Despite these limitations, the study supports current evidence indicating that modern low-kVp contrast-enhanced CT protocols are associated with a low incidence of CA-AKI and that patient-related factors remain the principal determinants of renal injury. Further prospective multicenter studies incorporating long-term follow-up and novel renal biomarkers are warranted to optimize individualized risk prediction and preventive strategies.[22–25]

CONCLUSION

Low-volume contrast-enhanced CT using low-kVp acquisition demonstrated a low incidence of contrast-associated acute kidney injury while maintaining excellent diagnostic image quality. Chronic kidney disease, reduced baseline estimated glomerular filtration rate, diabetes mellitus, heart failure, anemia, and emergency CT examinations were identified as independent predictors of CA-AKI. These findings suggest that optimized CT acquisition techniques substantially improve renal safety; however, careful pre-procedural assessment of patient-related risk factors remains essential. Individualized hydration protocols, judicious use of iodinated contrast media, and close post-procedural renal monitoring should continue to be emphasized in high-risk patients undergoing contrast-enhanced CT examinations.

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