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Assessing the Risk of Contrast Induced-Acute Kidney Injury (CI-AKI) After Enhanced CT Scan: Single-Centre Experience

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Abstract

Objective: This study was conducted to assess the risk of contrast-induced AKI (CI-AKI), among Saudi patients who underwent enhanced CT scans at a tertiary care hospital; to understand the incidence and the underlying associated factors of CI-AKI.

Methods: We conducted a retrospective review of patients who underwent CT scans with IV contrast from 2016 to 2021, at the King Abdulaziz University Hospital, Jeddah, Saudi Arabia. All authors had no access to information that could identify individual participants during or after data collection. The occurrence of AKI was defined using the "Kidney Disease: Improving Global Outcomes" (KDIGO) consensus definition. The exclusion criteria comprised age <18 years and records with missing key clinical information. Statistical Package for the Social Sciences (SPSS) software, version 21 was used for statistical analysis. The prevalence is presented as a percentage with a 95% confidence level. A *P*-value <0.05 was considered statistically significant.

Results: We reviewed 2000 patient files, of which 1430 met the inclusion criteria. According to the KDIGO definition of AKI, the overall incidence CI-AKI in our study cohort was 8.7%. The incidence of CI-AKI varied across baseline CKD stages, with significantly higher occurrences observed in individuals with CKD Stage 5 at 24.3% and Stage 4 at 15.9%. Statistical analysis confirmed that the likelihood of CI-AKI is significantly influenced by the baseline eGFR levels. This retrospective analysis found that individuals with hypertension have significantly higher odds of CI-AKI (OR = 2.02, $P = 0.001$) compared to those without hypertension. Moreover, individuals with hyperuricemia have significantly higher odds of CI-AKI (OR = 2.78, $P < 0.001$), compared to those without. The association remains significant after adjusting for other variables (OR = 2.40, $P < 0.001$). The presence of diabetes, malignancy, anaemia, and ischemic heart disease did not show a significant association with CI-AKI.

Conclusions: Based on the results of this retrospective study, the overall incidence of CI-AKI is around 8.7%, among patients undergoing enhanced CT scan. The risk is low and highly influenced by patients' baseline kidney function. Hypertension and Hyperuricemia are risk factors found to be associated with CI-AKI after enhanced CT scan. Diagnostic and clinically relevant enhanced CT scans should not be deferred based on the potential risk of CI-AKI. Furthermore, pre and peri-scan prevention protocols can significantly mitigate the risk of CI-AKI, even among high-risk patients.

Keywords: Computed tomography (CT) scan, acute kidney injury (AKI), contrast induced acute injury (CI-AKI), chronic kidney disease (CKD), estimated glomerular filtration rate (eGFR)

Introduction

Contrast media (CM) are a group of chemical compounds used in pathological characterization procedures to enhance the contrast resolution of an imaging modality. Specific CM have been designed for each structural imaging technique and type of administration.[1] Notably, iodinated contrast agents are the most frequently used compounds in radiography, fluoroscopy, angiography, and computed tomography (CT) imaging. They represent a diverse range of chemical entities that can be administered intravenously, orally, or by alternative routes, such as urethral or intra-articular routes. The average dose of the contrast medium used during enhanced CT scans is 100-120 ml, which is less than the dose used in diagnostic coronary procedures and percutaneous coronary interventions (PCI).[1]

CT is an imaging method used to diagnose bodily disorders. CT imaging is enhanced by adding intravenous contrast agents to highlight structures, such as body fluids and blood vessels. Clinical guidelines demand the measurement of kidney function before CM administration in all patients and especially those with possible renal inadequacy[2] as contrast-induced acute kidney injury (CI-AKI) is a potential consequence of intravascular administration of iodinated contrast agents and is associated with increased morbidity and mortality.[3-6] According to the kidney disease: Improving Global Outcomes (KDIGO) guidelines "CI-AKI is characterized by a sudden decline in renal function after contrast agent exposure."[7] CI-AKI is typically described as an increase 26.5 µmol/L (≥0.3 mg/dL) or relative (25%) rise in serum creatinine (sCr) levels compared with baseline readings that occur 48–72 hours after intravascular CM injection, peaks on the third to fifth day, and returns to baseline within 10–14 days normally. The recovery value is based on the return of the patient to their baseline serum creatinine.

Most CI-AKI cases stem from intravascular CM exposure during coronary angiography, PCI, and contrast-enhanced CT.[8] Contrast compounds are harmful to tubular epithelial cells, causing functional loss, apoptosis, and necrosis. The indirect processes of ischemia damage are associated with vasomotor alterations mediated by vasoactive agents, such as

endothelin, nitric oxide, and prostaglandins. The outer renal medulla has a deficient oxygen partial pressure, which, combined with increased metabolic demand, renders the medulla particularly vulnerable to the hemodynamic effects of CM.[9-11] However, the comprehensive pathophysiological processes through which contrast agents induce kidney impairment remain unclear. In most cases, CI-AKI is reversible and does not cause long-term kidney damage.

Several patient-related and procedural-related risk factors have been identified for the development of CI-AKI after a contrast-enhanced CT scan. Patient-related risk factors including pre-existing kidney disease, diabetes, advanced age, high blood pressure, and the use of certain medications such as nonsteroidal anti-inflammatory drugs (NSAIDs).[12] Giving these contributing factors the term Contrast associated-acute kidney injury gained publicity over the last 5 years.

The incidence of CI-AKI after a contrast-enhanced CT scan varies depending on the patient population and the definition used but is generally estimated to be between 2% and 10%.[13,14] CI-AKI is the third leading cause of hospital-acquired AKI, accountings for the 11% of all cases.[15]

In Saudi Arabia, there are no study that investigate the risk of AKI post all types of enhanced CT scan. However, Alhassan et al, investigate the risk of CI-AKI in patients with suspected pulmonary embolism who received computed tomography pulmonary angiogram (CTPA) or Ventilation perfusion scan (V/Q) scan. Majority of the patient received CTPA (90.3%) to diagnose pulmonary embolism and the incidence of CI-AKI was 15.8%. Malignancy was the only predictor for the increased risk of AKI.[16]

Another study showed that the incidence of CI-AKI after (CTPA) in patient older than 65 years is up to 7% and diabetes mellitus was the only predictor for the development of CI-AKI.[17]

To prevent CI-AKI, it is recommended to identify patients who are at increased risk of kidney injury and take steps to minimize their risk. This may include using alternative imaging modalities in high-risk patients, using lower doses of contrast media, or using iso-osmolar or low-osmolar contrast media instead of high-osmolar contrast media.[18]

Material and Method

This is a retrospective record review of all patients who had a CT scan with IV contrast between 2016-2021 at King Abdulaziz University Hospital (KAUH). Medical records of 2000 adult patients were reviewed, with 1430 records meeting the inclusion criteria, as it shown in (Figure 1). The researchers obtained ethical approval from the Research Ethics Committee Board, KAUH, College of Medicine (reference no. 487-21).

In collaboration with the Radiology Department at KAUH, all record numbers for patients who underwent CT scans with IV contrast between 2016 and 2021 were retrieved.

Population and Data Collection

All Patients >18 years who underwent CT scans with IV contrast were included in the study. Exclusion criteria were patients < 18 years old and those who didn't have follow up creatinine after the CT scan. Data collected included patients' demographics: age, gender, height, weight, pre- and post-serum

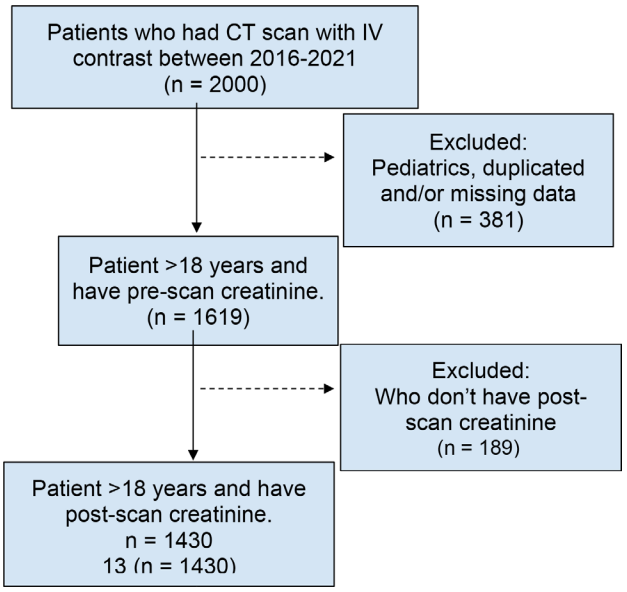

Fig. 1 **Flow chart of patients after applying exclusion and inclusion criteria.**

creatinine (SC), ESR, CRP, and the Indication of CT scan. Reference ranges for the serum creatinine (53-115 μmol/L) and GFR (mL/minute) according to the KAUH laboratory. Estimated GFR (eGFR) was calculated using a three-variable from the CKD-EPI Creatinine Equation (2021).

Statistical Methods

Descriptive statistics for various demographic and clinical variables. Continuous variables, such as age, pre-scan eGFR, pre-scan serum creatinine, post-scan serum creatinine, pre-scan baseline serum albumin, pre-scan baseline CRP, pre-scan baseline ESR, weight, height, and BMI, were summarized using means and standard deviations (SD). Categorical variables, including gender, CI-AKI status, DM, ischemic heart disease, heart failure, HTN, hyperlipidaemia, malignancy, anaemia, and hyperuricemia, were presented as proportions expressed as percentages. Chi-square tests for categorical variables and *t*-tests for continuous variables in examining the association between various factors and the incidence of CI-AKI. Chi-square tests were employed for gender, DM, ischemic heart disease, and other categorical variables, while t-tests were utilized for continuous variables such as pre-scan eGFR, pre-scan baseline serum albumin, pre-scan baseline CRP, pre-scan baseline ESR, and BMI. Logistic regression to examine the association between various factors and the incidence of CI-AKI. Univariable and multivariable odds ratios (OR) were computed to quantify the strength of these associations. The logistic regression models were constructed to assess the impact of individual factors on the likelihood of CI-AKI occurrence. Additionally, an OR plot was generated to visually present selected factors and their corresponding univariable and multivariable odds ratios, aiding in the interpretation and comparison of their effects on CI-AKI. The 95% confidence intervals and p-values associated with the odds ratios were included to determine the statistical significance of the observed associations. Statistical software packages SPSS (IBM Corp., Armonk, NY) and R (R Core Team, Vienna,

Austria) were utilized for the analysis. *P*-values of < 0.05 were considered statistically significant.

Results

Table 1 summarizes the key demographic and clinical characteristics of a sample of 1430 patients. The majority of the patients were male (54.20%) and had a mean age of 55.22 years. The mean Pre-Scan eGFR was 86.75 ml/min, and the mean Pre-Scan serum creatinine was 125.3 μm/L. A small percentage of patients (8.70%) had CI-AKI. The mean Pre-scan baseline serum albumin was 28.1 g/L, the mean Pre-scan baseline CRP was 106.53 mg/dL, and the mean Pre-scan baseline ESR was 51.1 mm/h. The mean weight was 71.6 kg, the mean height was 162.3 cm, and the mean BMI was 27.29 kg/m^2. A significant percentage of patients had DM (37.80%), Anaemia (80.50%), and Malignancy (38.20%). A smaller percentage of patients had ischemic heart disease (8.30%), Heart failure (6.50%), Hyperlipidaemia (8.10%), and Hyperuricemia (14.00%).

Table 2 presents an overview of the association between various demographic, clinical factors, and the occurrence of CI-AKI. There was no significant difference in CI-AKI rates between females (42.1%) and males (57.9%), with a *P*-value of 0. 567. The mean pre-scan estimated glomerular filtration rate (eGFR) was significantly lower in individuals who developed CI-AKI (57.3) compared to those who did not (88.3), with a *P*-value of <0.001. The association between CI-AKI and pre-scan estimated glomerular Filtration Rate (eGFR) levels. Participants were categorized based on baseline eGFR to different stages of chronic kidney disease (CKD), and the presence or absence of CI-AKI was examined. The distribution of pre-scan eGFR categories revealed that the majority had eGFR levels categorized as Normal at 59.2%, followed by Stage 1 at 19.0%, and Stage 2 at 5.9%. Notably, the incidence of CI-AKI varied across eGFR categories, with significantly higher occurrences observed in patient with CKD Stage 5 at 24.3% and Stage 4 at 15.9%. Statistical analysis confirmed a highly significant association between pre-scan eGFR levels and CI-AKI ($P < 0.001$), indicating that the likelihood of CI-AKI is significantly influenced by the initial eGFR levels. This retrospective analysis suggests that individuals with lower pre-scan GFR levels, particularly in the Stage 5 and Stage 4 categories, are more susceptible to CI-AKI, while higher pre-scan eGFR levels, especially those categorized as normal, are associated with a lower incidence of CI-AKI. Although the mean baseline serum albumin was slightly lower in individuals with CI-AKI (26.1) compared to those without (27.9), the difference was not statistically significant ($P = 0.059$). No significant difference was observed in the mean baseline C-reactive protein (CRP), levels between individuals with CI-AKI and those without ($P = 0.210$). Similarly, there was no statistically significant difference in the mean baseline erythrocyte sedimentation rate (ESR) between the CI-AKI and non-CI-AKI groups ($P = 0.319$). The mean body mass index (BMI) did not show a significant difference between individuals with CI-AKI and those without ($P = 0.663$). While the difference was not statistically significant ($P = 0.052$), individuals without diabetes had a slightly higher CI-AKI rate (51.9%) compared to those with diabetes (48.1%). The presence of ischemic heart disease did not show a significant association with CI-AKI ($P = 0.250$). Similarly, heart failure did not exhibit a statistically significant association with CI-AKI ($P = 0.255$). Individuals without hypertension had a significantly higher CI-AKI rate (47.7%) compared to those with hypertension (52.3%), with a p-value of 0.001. The presence of hyperlipidaemia did not show a significant association with CI-AKI ($P = 0.719$). Malignancy status did not exhibit a statistically significant association with CI-AKI ($P = 0.739$). While not statistically significant ($P = 0.105$), individuals without anaemia had a slightly higher CI-AKI rate (11.1%) compared to those with anaemia (88.9%). The presence of hyperuricemia was significantly associated with CI-AKI ($P < 0.001$), with individuals having hyperuricemia showing a higher CI-AKI rate (29.6%) compared to those without (70.4%). Details are summarized in Table 2.

Table 3 presents the results of a logistic regression analysis assessing the relationship between various predictors and the occurrence of CI-AKI. The overall logistic regression model found significant ($\chi^2 = 27.8$, $P = 0.001$). The odds ratio of 1.1646 implies that males have approximately 16.46% higher odds of experiencing CI-AKI compared to females. However, the 95% confidence interval (CI) spans 0.7588 to 1.7873, indicating that the difference is not statistically significant. The odds ratio of 1.0897 suggests that individuals with diabetes have about 8.97% higher odds of CI-AKI compared to those without diabetes. However, the wide confidence interval (0.6744 to 1.7607) indicates a lack of statistical significance. The odds ratio of 1.0471 implies a minimal increase (4.71%) in the odds of CI-AKI for individuals with ischemic heart disease compared to those without. The wide confidence interval (0.5202 to 2.1079) suggests the result is not statistically significant. The odds ratio of 0.9992 indicates almost no change

Table 1. **Summary of the key demographic and clinical characteristics of study sample**

	Overall	
n	**1430**	**%**
Age (mean (SD))	55.22	(26.94)
Gender = male (%)	774	(54.20)
Pre-Scan eGFR (mean (SD))	86.75	(41.21)
Pre-Scan serum creatinine (mean (SD))	125.3	(171.11)
Post Scan serum creatinine l (mean (SD))	120.79	(160.25)
CI AKI = Yes (%)	108	(8.70)
Pre scan baseline serum albumin (mean (SD))	28.1	(9.39)
Pre scan baseline CRP (mean (SD))	106.53	(88.62)
Pre scan baseline ESR (mean (SD)	51.1	(43.64)
weight (mean (SD))	71.6	(20.00)
height (mean (SD))	162.3	(13.97)
BMI (mean (SD))	27.29	(14.15)
DM = Yes (%)	540	(37.80)
Ischemic Heart disease = Yes (%)	118	(8.30)
Heart failure = Yes (%)	93	(6.50)
H TN = Yes (%)	511	(35.80)
Hyperlipidaemia = Yes (%)	115	(8.10)
Malignancy = Yes (%)	543	(38.20)
Anaemia = Yes (%)	1151	(80.50)
Hyperuricemia = Yes (%)	200	(14.00)

Table 2. **Association between various demographic and clinical factors and the occurrence of contrast-induced acute kidney injury**

		CI AKI			
Factors		**No**	**Yes**	**Total**	***p***
Gender	Female	514 (45.4)	45 (42.1)	559 (45.2)	0.567
	Male	617 (54.6)	62 (57.9)	679 (54.8)	
Pre-Scan eGFR	Mean (SD)	88.3 (38.6)	57.3 (65.4)	85.7 (42.5)	<0.001
Pre-Scan eGFR	Stage 5	76 (6.7)	26 (24.3)	102 (8.3)	<0.001
	Stage 4	57 (5.1)	17 (15.9)	74 (6.0)	
	Stage 3	113 (10.0)	24 (22.4)	137 (11.1)	
	Stage 2	214 (19.0)	12 (11.2)	226 (18.3)	
	Stage 1	668 (59.2)	28 (26.2)	696 (56.4)	
Pre scan baseline serum albumin	Mean (SD)	27.9 (9.5)	26.1 (7.5)	27.8 (9.3)	0.059
Pre scan baseline CRP	Mean (SD)	107.7 (86.2)	132.7 (116.6)	109.8 (89.3)	0.210
Pre scan baseline ESR	Mean (SD)	51.9 (44.1)	67.9 (32.4)	53.1 (43.5)	0.319
BMI	Mean (SD)	27.0 (13.4)	26.5 (6.8)	27.0 (13.0)	0.663
DM	No	699 (61.9)	56 (51.9)	755 (61.0)	0.052
	Yes	430 (38.1)	52 (48.1)	482 (39.0)	
Ischemic heart disease	No	1030 (91.7)	95 (88.0)	1125 (91.4)	0.250
	Yes	93 (8.3)	13 (12.0)	106 (8.6)	
Heart failure	No	1051 (93.3)	97 (89.8)	1148 (93.0)	0.255
	Yes	76 (6.7)	11 (10.2)	87 (7.0)	
HTN	No	731 (64.8)	51 (47.7)	782 (63.3)	0.001
	Yes	397 (35.2)	56 (52.3)	453 (36.7)	
Hyperlipidaemia	No	1035 (92.0)	95 (90.5)	1130 (91.9)	0.719
	Yes	90 (8.0)	10 (9.5)	100 (8.1)	
Malignancy	No	702 (62.3)	69 (64.5)	771 (62.5)	0.739
	Yes	424 (37.7)	38 (35.5)	462 (37.5)	
Anaemia	No	201 (17.8)	12 (11.1)	213 (17.2)	0.105
	Yes	930 (82.2)	96 (88.9)	1026 (82.8)	
Hyperuricemia	No	978 (86.9)	76 (70.4)	1054 (85.4)	<0.001
	Yes	148 (13.1)	32 (29.6)	180 (14.6)	

in the odds of CI-AKI for individuals with heart failure compared to those without. The result is not statistically significant, as the confidence interval (0.4634 to 2.1547) includes 1. With an odds ratio of 1.7671, individuals with hypertension have approximately 76.71% higher odds of CI-AKI compared to those without. The result is statistically significant, as the confidence interval (1.0967 to 2.8471) does not include 1. The odds ratio of 1.1161 suggests a modest increase (11.61%) in the odds of CI-AKI for individuals with hyperlipidaemia compared to those without. However, the result is not statistically significant, as the confidence interval (0.5436 to 2.2915) includes 1. The odds ratio of 0.8875 indicates a decrease (11.25%) in the odds of CI-AKI for individuals with malignancy compared to those without. The result is not statistically significant, as the confidence interval (0.5700 to 1.3820) includes 1. With an odds ratio of 1.4006, individuals with anaemia have approximately 40.06% higher odds of CI-AKI compared to those without. However, the result is not statistically significant, with a confidence interval (0.7407 to 2.6484) that includes 1. The odds ratio of 2.3957 indicates a substantial increase (139.57%) in the odds of CI-AKI for individuals with hyperuricemia compared to those without. This result is statistically significant, as the confidence interval (1.4807 to 3.8759) does not include 1.

Table 4 and Figure 2 present the unadjusted and adjusted ORs assessing the relationship between various predictors and the occurrence CI-AKI. The odds ratio for males compared to females is 1.15 (P = 0.501), indicating 15% higher odds of CI-AKI for males, but this is not statistically significant. After adjusting for other variables, the odds ratio becomes 1.16 (P = 0.486), still not statistically significant. The confidence intervals in both cases include 1, suggesting the result is not conclusive. Individuals with Diabetes Mellitus have significantly higher odds of CI-AKI (OR = 1.51, P = 0.042) compared to those without diabetes. In the multivariable model, this association becomes non-significant (OR = 1.09, P = 0.726) after adjusting for other factors. Ischemic Heart Disease does not show a significant association with CI-AKI (OR = 1.52, P = 0.187). The association remains non-significant after adjusting for other variables (OR = 1.05, P = 0.897). Also, there

Table 3. **Logistic regression analysis assessing the relationship between various predictors and the occurrence of contrast-induced acute kidney injury (CI-AKI)**

						95% Confidence Interval	
Predictor	**Estimate**	**SE**	**Z**	**p**	**Odds ratio**	**Lower**	**Upper**
Intercept	–3.188	0.349	–9.128	< .001	0.041	0.021	0.082
Gender:							
male – female	0.152	0.219	0.697	0.486	1.165	0.759	1.787
DM:							
Yes – No	0.086	0.245	0.351	0.726	1.090	0.674	1.761
Ischemic heart disease:							
Yes – No	0.046	0.357	0.129	0.897	1.047	0.520	2.108
Heart failure:							
Yes – No	–0.001	0.392	–0.002	0.998	0.999	0.463	2.155
HTN:							
Yes – No	0.569	0.243	2.339	0.019	1.767	1.097	2.847
Hyperlipidaemia:							
Yes – No	0.110	0.367	0.299	0.765	1.116	0.544	2.292
Malignancy:							
Yes – No	–0.119	0.226	-0.528	0.597	0.888	0.570	1.382
Anaemia:							
Yes – No	0.337	0.325	1.037	0.300	1.401	0.741	2.648
Hyperuricemia:							
Yes – No	0.874	0.245	3.559	< .001	2.396	1.481	3.876

Note. Estimates represent the log odds of "CI AKI = Yes" vs. "CI AKI = No", $\chi^2 = 27.8$, $P = 0.001$.

Table 4. **Univariate and Multivariable Odds Ratios assessing the relationship between various predictors and the occurrence of contrast-induced acute kidney injury (CI-AKI)**

		No	**Yes**	**OR (univariable)**	**OR (multivariable)**
Gender	Female	514 (91.9)	45 (8.1)	-	-
	Male	617 (90.9)	62 (9.1)	1.15 (0.77–1.72, $P = 0.501$)	1.16 (0.76–1.80, $P = 0.486$)
DM	No	699 (92.6)	56 (7.4)	-	-
	Yes	430 (89.2)	52 (10.8)	1.51 (1.01–2.24, $P = 0.042$)	1.09 (0.67–1.76, $P = 0.726$)
Ischemic heart disease	No	1030 (91.6)	95 (8.4)	-	-
	Yes	93 (87.7)	13 (12.3)	1.52 (0.78–2.72, $P = 0.187$)	1.05 (0.50–2.04, $P = 0.897$)
Heart failure	No	1051 (91.6)	97 (8.4)	-	-
	Yes	76 (87.4)	11 (12.6)	1.57 (0.77–2.94, $P = 0.185$)	1.00 (0.44–2.08, $P = 0.998$)
HTN	No	731 (93.5)	51 (6.5)	-	-
	Yes	397 (87.6)	56 (12.4)	2.02 (1.36–3.02, $P = 0.001$)	1.77 (1.10–2.85, $P = 0.019$)
Hyperlipidaemia	No	1035 (91.6)	95 (8.4)	-	-
	Yes	90 (90.0)	10 (10.0)	1.21 (0.57–2.30, $P = 0.585$)	1.12 (0.52–2.20, $P = 0.765$)
Malignancy	No	702 (91.1)	69 (8.9)	-	-
	Yes	424 (91.8)	38 (8.2)	0.91 (0.60–1.37, $P = 0.662$)	0.89 (0.56–1.37, $P = 0.597$)
Anaemia	No	201 (94.4)	12 (5.6)	-	-
	Yes	930 (90.6)	96 (9.4)	1.73 (0.97–3.37, $P = 0.083$)	1.40 (0.77–2.78, $P = 0.300$)
Hyperuricemia	No	978 (92.8)	76 (7.2)	-	-
	Yes	148 (82.2)	32 (17.8)	2.78 (1.76–4.32, $P < 0.001$)	2.40 (1.46–3.85, $P < 0.001$)

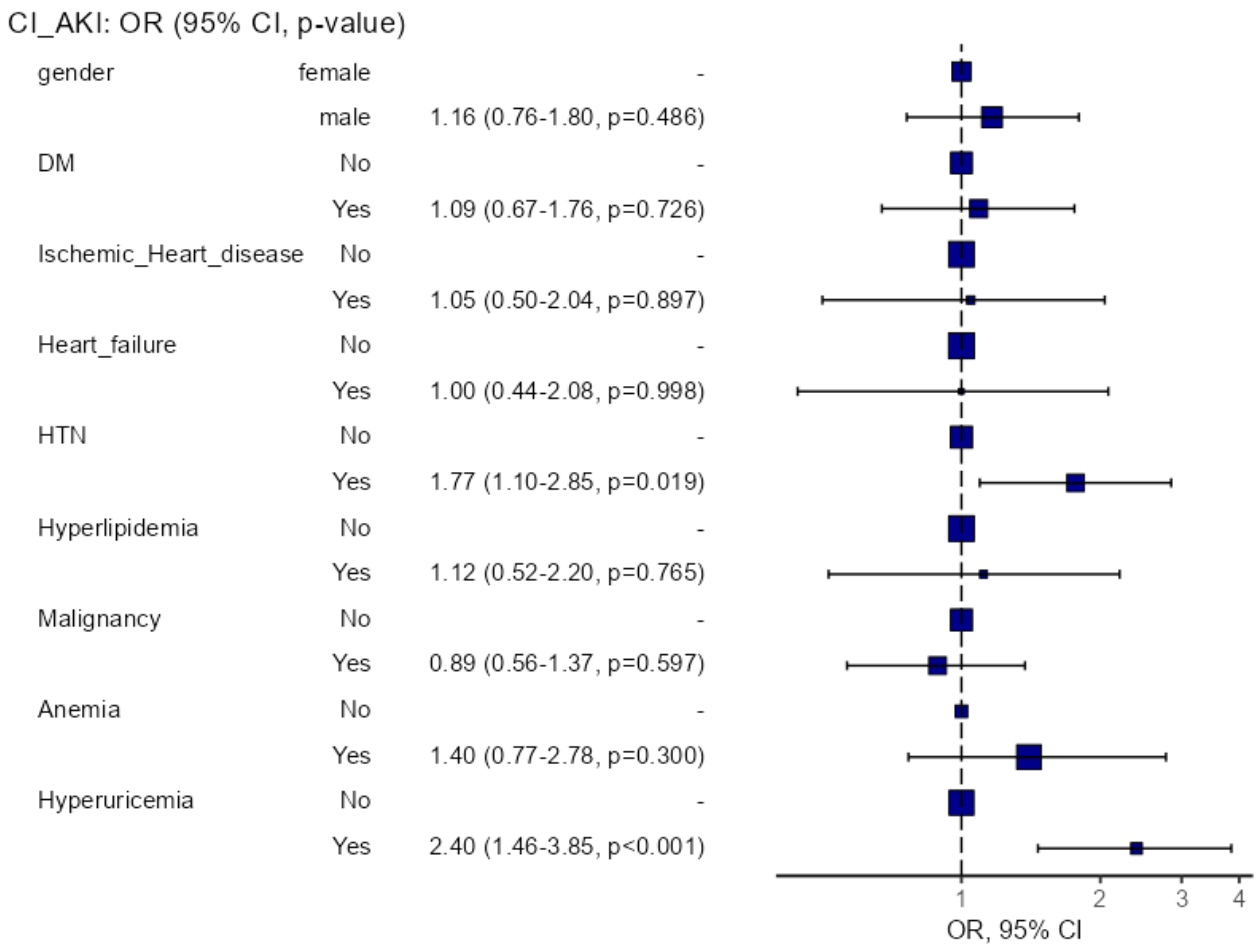

Fig. 2 **Multivariable Odds Ratios assessing the relationship between various predictors and the occurrence of contrast-induced acute kidney injury (CI-AKI).**

is no significant association between heart failure and CI-AKI (OR = 1.57, *P* = 0.185). The association remains non-significant in the multivariable model (OR = 1.00, *P* = 0.998). Individuals with hypertension have significantly higher odds of CI-AKI (OR = 2.02, *P* = 0.001) compared to those without hypertension. The association remains significant after adjusting for other variables (OR = 1.77, *P* = 0.019). There is no significant association between hyperlipidaemia and CI-AKI (OR = 1.21, *P* = 0.585). The association remains non-significant in the multivariable model (OR = 1.12, *P* = 0.765). Malignancy is also not significantly associated with CI-AKI (OR = 0.91, *P* = 0.662). The association remains non-significant after adjusting for other variables (OR = 0.89, *P* = 0.597). Anaemia is not significantly associated with CI-AKI (OR = 1.73, *P* = 0.083). The association remains non-significant in the multivariable model (OR = 1.40, *P* = 0.300). Individuals with hyperuricemia have significantly higher odds of CI-AKI (OR = 2.78, *P* < 0.001) compared to those without. The association remains significant after adjusting for other variables (OR = 2.40, *P* < 0.001).

Discussion

In patients undergoing enhanced CT scan, CI-AKI represents a potential risk attributed to the administration of radio-opaque contrast media. In Saudi Arabia, we lack the epidemiological data regarding CI-AKI, following all types of enhanced CT scan. Hence, we found it necessary to conduct this retrospective review to generate evidence from Saudi Arabia, on this potential complication that may have an impact on mortality and morbidity.

In This retrospective analysis, we screened 1430 records of patients who had enhanced CT scans at our hospital (KAUH). Of these, 8.7% developed CI-AKI, as defined by the KDIGO criteria for AKI. This is similar to the previously reported incidence of CI-AKI across different studies (2–15%) depend on the selected patient population and defining criteria for AKI.[19]

In this study, the majority of the included patients had eGFR ≥ 45 mL/min/1.73 m^2 and the incidence of CI-AKI was higher in individuals with baseline eGFR <30 mL/min/1.73 m^2. Also, the high percentage of patients with eGFR ≥ 45 mL/min/1.73 m^2 may highlight the underusage of enhanced diagnostic CT scan in patients with chronic kidney disease, presumably because of the concern of precipitating AKI. Several studies confirmed that pre-existing chronic kidney disease is one of the strongest patient-related risk factors for AKI after contrast medium exposure.[20] Furthermore, Obed et al, found based on systematic review and meta-analysis of propensity score-matched pairs obtained from 21 cohort studies, that contrast enhanced CT scan was not associated with AKI, dialysis, or mortality among patients with eGFR ≥ 45 mL/min/1.73m^2.[21]

In this study, the traditional risk factors for CI-AKI from past observational studies such as diabetes, ischemic

heart disease, heart failure, hyperlipidaemia, anaemia and malignancy are not found to be significantly associated with CI-AKI. The real impact of these risk factors on the occurrence of CI-AKI in presence of eGFR≥ 45 mL/min/1.73 m^2 is controversial.[22]

However, we did find a statistically significant correlation between hyperuricemia and hypertension (HTN) with the incidence of CI-AKI. A recent meta-analysis of 28,30,338 patients have clearly demonstrated that HTN are independent risk factors for CI-AKI in patients undergoing CA or PCI.[23] The proposed underlying mechanism that HTN increase the risk for CI-AKI, hemodynamic changes secondary to renal vasculature damage and eventually decrease renal tolerance to accommodate the potential nephrotoxicity of the contrast medium.

Also, the release of vasoactive substances such as endothelin, nitric oxide and prostaglandin participate in the pathogenic mechanism.[24] Our research confirmed what had been published in the past, that HTN increase the risk for CI-AKI, which means optimal control of HTN prior to contrast medium exposure is mandatory.[25] Some studies found that the use of Antihypertensive medications such as diuretics and angiotensin converting enzyme inhibitor/angiotensin receptors blocker (ACE/ARB) may increase the risk for CI-AKI post coronary angiography, due to decrease renal perfusion and hemodynamic disorders.[26] However, other studies found that the association of CI-AKI and the use of ACE/ARB is remain unclear.[27]

Hypertension was used as one of the predictors in high-performance predictive models for CI-AKI after coronary angiography, previous studies confirmed that HTN can increase the risk for CI-AKI.[28,29] The dose of contrast, procedure-related and patient-related factors in coronary angiography are not equivalent to the one used in enhanced CT scans. Hence, the associated risk of CI-AKI and HTN after enhanced CT scans is still under-investigated and further studies are needed to explore the relationship and other possible contributing factors.

Hyperuricemia without gout was established as an independent risk factor in multiple studies for CI-AKI after coronary angiography.[30,31] A metanalysis involving a total of 13,084 patients confirmed that presence of hyperuricemia was associated with an increased risk of CI-AKI.[32] Uric acid is the final product of purine metabolism, which is metabolized by xanthine oxidase inhibitor.[33] Substantial evidence suggests that high uric acid is an independent risk factor for metabolic syndrome, hypertension and chronic kidney disease.[34] The exact pathophysiological mechanism that linked hyperuricemia to AKI is not fully elucidated. However, in the experimental model, high uric acid and uric acid crystal was linked to the release of oxidative stress, endothelial dysfunction, inflammation and vascular smooth muscle proliferation.[35,36] Even soluble uric acid can cause renal vasoconstriction, decrease GFR and activation of renin-angiotensin system.[37] Allopurinol, xanthine oxidase inhibitor, used to lower or prevent high uric acid level in the blood. Two small randomized, prospective trials, showed that prophylactic use of oral allopurinol in addition to hydration, reduced the incidence of CI-AKI.[38,39]

Therefore, whether hyperuricemia is still considered a risk factor for CI-AKI, especially post enhanced CT scan remains unsettled, randomized control trials are warranted to evaluate the role of uric acid in CI-AKI and the potential benefit of prophylactic allopurinol.

Predictive risk scoring models for CI-AKI have been developed and employed, for patients undergoing coronary angiography, these risk score models become a useful tool to identify patients at high risk for to CI-AKI. Such risk prediction models are not yet developed for patients undergoing enhanced CT scans.

The current study has several limitations, its retrospective and single centre. Larger sample size, multi-centric and prospective studies are needed to generate stronger evidence. We recommend that future studies should further evaluate the risk of CI-AKI in patients with hyperuricemia and hypertension; as evidence currently seems insufficient, regarding the impact of these comorbidities on the risk of CI-AKI after enhanced CT scans.

Conclusion

Our research found that the risk of CI-AKI (8.7%) after enhanced CT-scans is similar to the previously published studies. Overall, the risk of CI-AKI is overestimated especially in patients with eGFR ≥ 45 mL/min/1.73 m^2. However, caution should be exercised using intravenous contrast media to improve the diagnostic accuracy of CT scans in patients with eGFR ≤30 mL/min/1.73 m^2 and prophylactic measures should be introduced to reduce the risk of CI-AKI.

Hyperuricemia and hypertension were the most statistically significant risk factors identified in our study to be associated with CI-AKI. We recommend that future studies need to further examine the association and pathogenesis of contrast-induced acute kidney injury and hyperuricemia.

Authors' Contribution

All authors listed in the study have contributed equally towards the medical ideation, design, analysis, conduct and submission of this study.

Conflict of Interest

The authors declare no conflict of interest.

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