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Repeated contrast exposure and renal risk in intensive care unit patients with reduced baseline glomerular filtration rate: a single-center prospective cohort study

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Abstract

Objectives: The study evaluates contrast-associated acute kidney injury, decline in eGFR category, and dialysis requirement in intensive care (ICU) patients with reduced baseline glomerular filtration rate (GFR).

Methods: A single-center prospective observational cohort study included 112 patients with baseline eGFR<90 mL/min/1.73 m² who underwent one or two intravascular contrast administrations. Renal outcomes were assessed for 6 months.

Results: Single exposure group (62 patients) versus 50 in repeated exposure group. No statistically significant difference was observed between the two groups in the incidence of CA-AKI after the first exposure (25.8% vs. 25%, p=0.8), nor in the decline in eGFR category or initiation of dialysis at 3 and 6 months (p>0.5). The incidence of CA-AKI after the second exposure was 64%. Prior CA-AKI strongly predicted subsequent CA-AKI (adjusted OR 11.63, 95% CI 1.37–98.5; p=0.02), as well as decline in eGFR category at six months in both the single-exposure group (adjusted OR 5.29, 95% CI 1.55–18.03; p=0.008) and the repeated-exposure group (adjusted OR 10.36, 95% CI 2.50–42.99; p=0.001). These associations remained statistically significant among patients with established CKD (n=80), p<0.05. In the repeated-exposure group, baseline eGFR-based stage independently predicted decline in eGFR category at 3 (OR 0.36, p=0.02) and 6 months (OR 0.55, p=0.05). Across eGFR categories (2–5), renal outcomes did not differ between exposure groups, though all patients with eGFR< <15 mL/min/1.73 m² developed CA-AKI after the second contrast. Decline in eGFR category at six months was significantly more common with cumulative contrast volumes >100 ml (p=0.047). Mehran score underestimated AKI risk (26% predicted vs. 64% observed) after the 2nd exposure and the need for dialysis (1.09% predicted vs. 6.45% observed).

Conclusions: In studied patients, CA-AKI occurred frequently after second contrast exposure especially those with prior CA-AKI even in patients who initially recovered. Early post-contrast renal response therefore helps identify high-risk patients before re-imaging. The Mehran score substantially underestimated both CA-AKI and dialysis risk when applied outside its original context. Multicenter studies are needed to build ICU-specific prediction models.

Keywords: Intensive care unit; re-contrast; chronic kidney disease; contrast associated acute kidney injury

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Introduction

The use of contrast media is an established and unavoidable practice in critical care settings serving as a cornerstone for advanced diagnostic imaging [1]. Chronic kidney disease (CKD) and end-stage renal disease (ESRD) patients have been considered highly prone to contrast-associated acute kidney injury (CA-AKI), a complication long believed to accelerate renal decline, precipitate dialysis and increase morbidity [2-4]. This concern has frequently led to hesitancy in ordering essential diagnostic tests, potentially delaying important interventions for critical care patients.

Within ICU, patients with reduced baseline esti-

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mated glomerular filtration rate (eGFR) represent a distinct and underexplored population, characterized by a higher risk of adverse renal outcomes compared with those patients who have preserved kidney function. The interplay between reduced baseline eGFR and repeated contrast administration in this setting has not been systematically studied. Published studies on repeated contrast exposure in trauma-related ICU patients did not specifically address patients with reduced glomerular filtration rate (GFR) or CKD, nor were they designed to evaluate cumulative exposure or long-term renal outcomes leaving a significant blind spot in literature [5-11].

Consequently, the available evidence remains insufficient to define risk in ICU patients with reduced baseline eGFR. By focusing on this high-risk group, our research addresses a novel dimension.

Aim of the study: To evaluate the impact of repeated iodinated contrast exposure on the short and long-term kidney function in ICU patients with reduced baseline eGFR.

Materials and methods

Study design, recruitment and study location

This is a single-center prospective observational cohort study in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [12]. Patients were consecutively recruited from the intensive care units of Cairo University hospitals between March 2024 and November 2025. Those patients were followed up through Cairo University outpatient clinics.

Inclusion criteria

Adults aged 18 years or older with baseline eGFR <90 mL/min/1.73 m^2 who underwent at least one intravascular contrast study and had the required renal data available at the predefined assessment intervals were eligible. Patients could undergo re-exposure even in the absence of full renal recovery, as clinically indicated within the same admission, different admissions or ongoing course of care.

Exclusion criteria

Kidney transplant within the preceding 6 months, ongoing renal replacement therapy, patients with pre-existing AKI defined by KDIGO criteria [13] before enrolment. Hemodynamic shock, severe sepsis, vasopressor dependence, recent nephrotoxic drug exposure, or prior contrast allergy.

Exposure groups

According to the number of intravascular contrast administrations received during the study period:

- Group I: patients who underwent a single contrast exposure with impaired kidney function.
- Group II: Patients who received two contrast administrations with impaired kidney function.

Data collection

Baseline variables were extracted from the hospital database. All records were comprehensively anonymized to ensure confidentiality. Collected data included demographic characteristics, clinical parameters, comorbid conditions, medication history, number of contrast enhanced procedures performed, time between first and second contrast exposure (in case of repeated exposures) and total volume and cumulative volume of contrast administered (in case of repeated exposures). Mehran score was used to predict risk of contrast-associated acute kidney injury (CA-AKI) and probability of requiring dialysis [14]. Laboratory investigations at baseline were recorded for all patients.

Frequency of renal function monitoring during the study

Creatinine was measured pre-procedural (baseline), at day 7, and at 1, 3, and 6 months after the final exposure, while eGFR was assessed at baseline (pre-procedural) and at 3, and 6 months. In addition, urine output (ml/hour) was monitored hourly during ICU stay.

Outcomes

Primary outcomes

The incidence of contrast-associated AKI defined by KDIGO criteria following each exposure [13], haemodialysis requirement at predefined time intervals. CA-AKI after each exposure was defined using the creatinine value obtained within 48–72 hours after that specific contrast administration relative to the pre-contrast creatinine for that exposure.

Secondary outcomes

≥50% increase in serum creatinine, doubling of serum creatinine, decline in eGFR category (applied only to CKD stages 2 - 4) after 3, and 6 months of last contrast

exposure.

For patients in CKD stage 5, progression to a higher CKD stage was not applicable; therefore, only the requirement for dialysis was assessed.

eGFR-based stage stratification and verification of chronicity of kidney disease

Baseline staging was performed solely on the basis of eGFR value obtained at enrollment using the 2021 CKD-EPI equation (Chronic Kidney Disease Epidemiology Collaboration) formula: [eGFR = 142×min (Scr/κ,1) $^{\alpha}$×max (Scr/κ,1) $^{-1.200}$ × 0.9938 ^{Age}× Sex Factor] [16]. However, most patients had a well-documented chronic kidney disease extending beyond three months. Chronicity was verified through previously available laboratory data—either retrieved from hospital records or provided by patients. Those to whom this does not apply, particularly in acute or emergency settings where rapid clinical decision-making limits comprehensive renal evaluation—our ability to ascertain true baseline kidney status was restricted. Accordingly, we consider the use of "eGFR-based stages" rather than established CKD stages.

Variables of 2021 CKD-EPI formula: Scr = serum creatinine (mg/dL), κ *(kappa) = 0.7 for females, 0.9 for males,* α *(alpha) = – 0.241 for females, – 0.302 for males, Sex Factor = 1.012 for females, 1.000 for male, Age = age in years, min (Scr/*κ*, 1) = the smaller of Scr/*κ *or 1, max (Scr/*κ*, 1) = the larger of Scr/*κ *or 1.*

eGFR based stages (baseline/decline) were assigned according to the KDOQI (Kidney Disease Outcomes Quality Initiative) classification [15].

Contrast data

All patients received a low-osmolar, non-ionic, iodinated contrast agent—either iohexol (Omnipaque 350 mgI/mL) or iopromide (Ultravist 370 mgI/mL). Dose was calculated according to institutional protocols (typically 1 mL/kg for CT examinations, 50–100 mL for coronary angiography, not to exceed 250 ml for combined procedures per time). Dehydration was avoided by discontinuation of diuretic medication on the day before and on the days of the study. Intravenous isotonic saline (0.9 % NaCl at 1 mL/kg/h for 6 h pre- and post-contrast) was administered whenever hemodynamic status permitted; in patients with volume overload or heart failure, oral hydration was encouraged if possible.

Bias Minimization

Bias was minimized through uniform creatinine measurement on one enzymatic platform ensured consistency and the same equation for GFR estimation. Baseline characteristics were comparable between groups, and logistic regression adjusted for relevant confounders. However, because exposure assignment followed clinical indication rather than randomization, residual confounding by indication remains possible.

Sample size

This study was designed as a pilot investigation. No formal a-priori power calculation was performed because no prior data existed for this specific ICU population with reduced baseline eGFR undergoing repeated contrast exposure. A pragmatic sample size of approximately 50 patients per group was chosen to allow estimation of event rates and generation of hypotheses for future larger studies.

Statistical analysis

Descriptive statistics were done and categorical variables were presented as frequency and percentage. Numerical variables were tested for normality, and normally distributed data were presented as mean and standard deviation, while non-normally distributed ones were presented as median and interquartile range. Numerical data were tested for normality using Shapiro Wilk test. Comparison between the two study groups was performed using the Chi-square test or Fischer's exact test for the categorical variables as appropriate. For the comparison of the numerical variables, the 2 groups Student's t test was used for normally distributed data, while the Wilcoxon rank-sum test was used for non-normally distributed data. For the comparison of the change in relevant variables in two different time points the Wilcoxon rank matched pairs test was used. Comparative analyses were performed both across the entire studied groups and within each eGFR based stage, contrasting outcomes between patients with repeated versus single contrast administration. Logistic regression analysis was performed to explore predictors of CA-AKI and decline of eGFR category, with adjustment for clinically relevant covariates. The dependent variables used include decline of eGFR category at different time points, CA-AKI. STATA 15.1 was used for the analysis, Copyright 1985-2017 STATA Crop LLC, College Station, Texas 77845 USA. P values < 0.05 were deemed significant.

Results

Study groups and baseline characteristics

A total of 112 patients with an eGFR <90 mL/min/1.73 m² who fulfilled the inclusion criteria were enrolled. Of them 62 patients underwent a single contrast exposure (Group I), while 50 received multiple exposures (Group II). Established CKD was reported in 80 patients (71.4%); 47 patients (75.8%) in Group I compared with 33 patients (66%) in Group II.

Baseline clinical and laboratory characteristics of all patients including the baseline serum creatinine and eGFR were comparable with no significant statistical differences between the two groups, (all p>0.05), Supplementary file 1.

Creatinine and eGFR changes during the follow up period within each group

Serum creatinine showed no statistically significant change immediately after the first contrast exposure at day 7 following the last exposure, (p >0.05). A *significant* rise in creatinine was observed at 3 months compared with 1 month in both groups (*p=0.002 and 0.03* for single and multiple exposures, respectively). Creatinine continued to increase *significantly* at 6 months compared with 3 months (*p=0.003* for single exposure; *p<0.0001* for multiple exposures), Figure 1.

eGFR increased *significantly* 3 months after last contrast in the single exposure group, *p=0.01*. It *significantly* decreased at 6 months follow up compared to 3 months, *p=0.01* for both studied groups. However, the net change from baseline to 6 months follow up revealed non-significant change, p>0.5 in both groups, Figure 1.

Between-group differences in short, long-term renal outcomes

CA-AKI following the initial exposure was observed in 26.7% of the whole patients with comparable rates between the single and multiple exposure groups (25.8% vs. 25%), p=0.8. The incidence of (CA-AKI) after the second exposure (in group II) was 64%, Table 1.

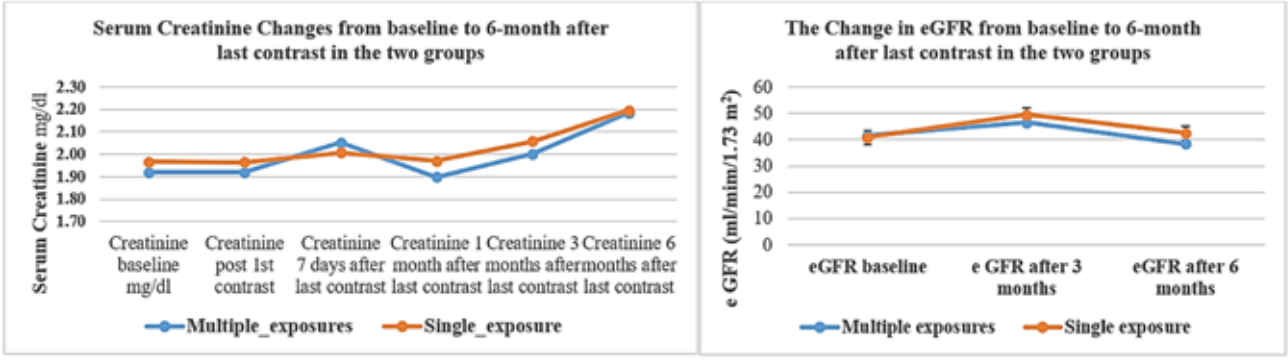
In analysis excluding patients who underwent repeated contrast administration within 7 days of the initial examination, 18 individuals (36%) were re-exposed after an interval exceeding 7 days. Within this subgroup, the incidence of CA-AKI following the second exposure reached 77.8%, compared with 55% among those re-exposed within a shorter interval (≤7 days).

Renal trajectory between exposures (Group II)

Out of the 14 patients who had CA-AKI post first contrast in group II, eight patients recovered during the follow up period. After second contrast, 7/8 who recovered had AKI again compared to 6/6 of those who did not achieve recovery after first contrast.

The Mehran score predicted a CA-AKI risk of approximately 26% in both groups. The score predicted dialysis risk of 1.09% compared to actual observed incidence of about 6.45%, Table 1.

At 3 months, decline in eGFR category occurred in 25 patients (22.3 %); by 6 months this figure had risen to 35 patients (31.3 %). A >50% rise in serum creatinine was observed in (4.5%) at three months and in (17.8%) at 6 months. Doubling of serum creatinine remained infrequent. However, none of these long-term renal outcomes differed significantly between the two groups, with all p-values exceeding 0.5 as shown in Table 1.



Data are medians with interquartile-range error bars. n = patients with available data in Group I (n=62) / Group II (n=50) at each time point.

Figure 1. Serum Creatinine and eGFR Changes from baseline to 6-month after last contrast in the two groups

The need for temporary dialysis was reported in 1 patient (1.6%) in Group I and 2 patients (4%) in Group II after one month, and in 1 patient (1.6%) in Group I after three months. No patient required permanent long-term maintenance haemodialysis during the follow-up period, Table 1.

Contrast dose-outcomes relationship

Contrast exposure parameters in the studied groups shown in Table 2. By 6 months, decline in eGFR category was significantly more common among patients receiving ≥100 mL contrast (35.5% vs. 13.6%, p=0.047), whereas other endpoints remained comparable between groups, Table 3.

Short and long-term renal outcomes by baseline eGFR-based stage

In general, across stages (2, 3a, 3b, 4 and 5); none of the evaluated renal outcomes showed statistically significant differences between Group I and Group II, all p>0.05. All patients with eGFR< <15 mL/min/1.73 m² developed CA-AKI after the second contrast exposure (Table 4).

Logistic regression analysis

In Group II (N=50), prior development of CA-AKI after the first contrast was a predictor of subsequent CA-AKI after the 2nd contrast exposure, with an eleven-fold 11.63 (1.37-98.5) increased risk (p=0.02). Baseline serum creatinine before the second administration was also significant (OR 18.59, p=0.007), Table 5. These associations remained statistically significant among patients with established CKD (n=33), with prior development of CA-AKI after the first contrast exposure conferring an odds ratio of 6.21 (95% CI: 1.14–33.85; p=0.04) for the subsequent CA-AKI after the 2nd contrast exposure, and serum creatinine measured immediately before the second contrast administration demonstrating an odds ratio of 32.46 (95% CI: 1.15–917; p=0.04), Supplementary file 2.

In the whole included patients, baseline eGFR-based stage was a significant predictor (overall OR 0.51, 95% CI 0.31–0.84, p = 0.009), with stage 4 showing 10% less risk of progression compared to stage 2 (OR 0.10, p = 0.01). Sub analysis by the study group revealed that this change was seen only in Group II (p=0.02). CA-AKI after the first contrast exposure was independent predictor of decline in eGFR category after 3 months (OR 7.15, 95% CI 2.83–17.92, p < 0.0001), supplementary file 3 and Table 6. Similar finding was found at 6 months with (OR 0.49 (0.31-0.77), P=0.002), (OR 7.13 (2.83-17.91), p< 0.0001) for baseline CKD stage and CA-AKI after the first contrast exposure respectively, supplementary file 3. Sub analysis by the study group revealed that this change was seen in both studied groups (OR 0.43 (0.22-0.87), p=0.02 and OR 0.55 (0.30-1.01), p=0.05 for single and multiple exposure groups respectively as regards baseline CKD stage) and (OR 5.29, p=0.008) for single exposure and (OR 10.36, p=0.001) for multiple exposure groups as regards CA-AKI after the first contrast exposure, Table 6.

Higher BMI (OR 1.32, p=0.01), and cardiovascular disease (OR 9.33, p=0.001) were found to associated with decline in eGFR category after 6 months. In patients exposed to multiple contrast doses, HTN became significant predictors; associated with decreasing risk of eGFR based stage worsening (OR 0.20, p=0.01), Table 6.

Among the 80 patients with established CKD, CA-AKI after the first contrast exposure was the most consistent predictor of CKD progression at 6 months. It approximately sixfold higher odds of CKD progression than those who did not develop CA-AKI (OR 6.19, 95% CI 1.76–21.76; P = 0.004). Baseline CKD stage was a significant predictor (overall OR 0.30, 95% CI 0.13-0.68; P=0.004), supplementary file 2.

Discussion

Our finding that, CA-AKI after the initial exposure in ICU patients predicts both recurrent CA-AKI as well as decline in eGFR category after six months following contrast re-exposure is a clinically useful warning flag. Previous literature on non-ICU populations or relevant cardiac patients shows that patients with CA-AKI are at higher risk of recurrent AKI and sustained long term eGFR decline [4, 9, 17-19].

In our patients, serum creatinine remained stable up to day 7 but demonstrated a significant rise at follow-up intervals. This delayed deterioration suggests that the renal consequences of contrast re-exposure in ICU patients with pre-existing reduced eGFR may extend beyond the conventional short observation window. The reliance solely on early creatinine changes may underestimate the overall renal impact of repeated contrast exposure in this population.

However, caution is needed in attributing causality entirely to contrast exposure, since underlying illness

Table 1. Short and long-term renal outcomes in the studied groups

	Group I (n=62)	Group II (n=50)	P value
Short-term Renal Outcomes			
Immediate post 1st contrast creatinine (mg/dl) Median (IQR)	1.64 (1.36-2.17)	1.6 (1.42-2.38)	0.8
CA-AKI post 1st contrast (N, %)	16 (25.8%)	14 (25%)	0.8
Urine output post 1st contrast (ml/hour) Median (IQR)	65 (60-80)	70 (60-80)	0.5
Pre 2nd contrast serum creatinine Median IQR		1.56 (1.2-2.4)	-
Pre 2nd contrast eGFR Median IQR		45.25 (26.3-57)	-
Renal recovery after 1st exposure; n %		8/14 (57.14%)	
Post 2nd contrast creatinine (mg/dl) Median (IQR)	-	1.92 (1.4-2.9)	-
eGFR post 2nd dose (mL/min/1.73 m²)	-	34 (20-49)	-
CA-AKI post 2nd contrast (N, %)	-	32 (64%)	-
Urine output post 2nd contrast (ml/hour) Median (IQR)	-	75 (50-85)	-
Need of dialysis after the last contrast (within 7 days), (N, %)	4 (6.45%)	3 (6%)	1
Mehran score	12.39 (5.34)	12.86 (5.21)	0.6
Predicted risk CA-AKI (%)Median (IQR)	26.1 (14-26.1)	26.1 (14-57.3)	0.5
Predicted risk dialysis (%) Median (IQR)	1.09 (0.12-1.09)	1.09 (0.12-12.6)	0.5
Long-term Renal Outcomes			
Decline in eGFR category after 3 months (N, %)	13 (20.9)	12 (24)	0.7
>50% rise in creatinine after 3 months (N, %)	2 (3.2)	3 (6)	0.6
Doubling of serum creatinine at 3 months (N, %)	1 (1.6)	0	0.6
Decline in eGFR category after 6 months (N, %)	18 (29)	17 (34)	0.5
>50% rise in creatinine after 6 months (N, %)	9 (14.5)	11(22)	0.5
Doubling of serum creatinine at 6 months (N, %)	3 (4.8)	3 (6)	1
Need for temporary dialysis after 1 month (N, %)	1(1.6)	2 (4)	0.2
Need for temporary dialysis after 3 months of last contrast (N, %)	1(1.6)	0	1
Need of temporary dialysis after 6 months of last contrast (N, %)	0	0	-
Need of long-term maintenance dialysis within the follow up period(N, %)	0	0	-

CA-AKI: Contrast-associated acute kidney injury, CKD: Chronic kidney disease, eGFR: Estimated glomerular filtration rate, IQR: Interquartile range, N: number.

in ICU patients also play a major role in the resulting renal outcomes. The observational design does not permit a straightforward causal comparison between single and repeated contrast exposure; differences in severity of illness or intervening events could contribute to the observed outcomes. The absence of a significant difference in overall 6-month eGFR change between the single- and multiple-exposure groups should not be interpreted as evidence of no harm. Stability of the group as a whole can obscure clinically meaningful injury within vulnerable subgroups, particularly when recovery in some patients compensates for deterioration in others.

Acute kidney injury may be followed by incomplete recovery when the interval between contrast exposures is short [17]. In ICU patients, repeated imaging is often dictated by clinical needs and may occur before full renal recovery has been achieved [2].

The high incidence of CA-AKI after the second exposure reaching 64% in this study exceeds the reported incidence of (5–20%) in other comparable high risk or CKD patients [17]. Because the median inter-exposure interval was only 4.5 days, temporal attribution of AKI to the first versus the second exposure is difficult for patients re-exposed before full recovery; our analysis excluding early re-exposures still yielded a high incidence (77.8 %), supporting the robustness of the observation.

The comparable CA-AKI incidence around 25% (in both studied groups) after the first exposure and the similarity in baseline laboratory and clinical characteristics between our studied groups indicates that the observed difference in CA-AKI incidence after the 2nd contrast was not attributable to pre-existing imbal-

Table 2. Contrast exposure parameters in the studied groups

	Group I (n=62)	Group II (n=50)	P value
1st contrast volume (ml) Median (IQR)	100 (70-120)	80 (50-100)	0.1
2nd contrast volume (ml)	-	100 (80-150)	-
Time between 1st and 2nd contrast exposure (days) Median (IQR)		4.5 (2-10)	-
Total contrast volume (ml) Median (IQR)	100 (70-120)	200 (150-230)	**<0.0001**

Table 3. Dose-outcomes relationship (exploratory analysis using pre-specified 100 mL threshold)

	Contrast <100 ml (n=22)	Contrast ≥ 100 ml (n=90)	P value
CA-AKI post 1st contrast (N, %)	6 (27.27%)	24 (26.67%)	1
CA-AKI post 2nd contrast (N, %)	-	32/50 (64%)	-
Decline in eGFR category after 3 months, (N, %)	3 (13.6%)	22 (24.4%)	0.3
>50% rise in creatinine after 3 months, (N, %)	0	5 (5.5%)	0.25
Doubling of serum create. At 3 months, (N, %)	0	1 (1.1%)	0.6
Decline in eGFR category after 6 months, (N, %)	3 (13.6%)	32 (35.5%)	**0.047**
>50% rise in creatinine after 6 months, (N, %)	4 (18.2%)	16 (17.7%)	0.9
Doubling of serum create. At 6 months, (N, %)	1 (4.5%)	5 (5.5%)	0.85

CA-AKI: Contrast-associated acute kidney injury, CKD: Chronic kidney disease, N: number.

ance. In many ICU patients, the kidney may tolerate an initial exposure but the second exposure identifies a subgroup with reduced renal reserve or incomplete recovery. However, because most of our patients were in eGFR based stages 3, our findings are applicable to ICU patients with moderate CKD, rather than those with very early or very advanced disease.

Among patients who developed CA-AKI after the first contrast exposure and were subsequently re-exposed, 8 of 14 recovered renal function before the second exposure. Nevertheless, CA-AKI occurred after the second exposure in 7 of 8 patients who had recovered and in all 6 patients who had not recovered. These observations suggest that renal recovery after the first episode did not eliminate the risk of recurrent CA-AKI. However, these results should be interpreted descriptively because the denominators are very small and no formal comparison or adjusted analysis is presented.

Prior evidence has established a dose-dependent increase in CA-AKI with cumulative contrast volumes exceeding 100 ml [20-22]. Our study did not find an association between higher contrast doses and AKI. Furthermore, evidence from a low-contrast-volume CTA protocol has shown a substantial reduction in AKI incidence, even among individuals with advanced CKD [23]. Cumulative contrast burden and the number of procedures had not been associated with worse long-term renal outcomes in prior observational studies [9,18], in contrast to our findings which showed significant decline in eGFR category after 6 months with cumulative volume > 100 ml.

Evidence regarding the frequency of repeated contrast exposure and exposure intervals on CA-AKI risk remains inconsistent. [5-7,21, 24]. A study with a median gap of 3.1 days between repeated exposures showed a low CA-AKI incidence of 2.5% [11], while another study documented substantial higher AKI rates [13% after CTA] despite a four-week interval which considered sufficient for renal recovery [8]. These findings suggest that timing and frequency alone do not adequately explain CA-AKI risk. Instead, patient-specific factors and clinical context [5] are likely more decisive, reinforcing the importance of individualized risk stratification in ICU patients with reduced eGFR.

No statistically significant difference was found between different eGFR based stages in our study as regards the short and long-term renal outcomes however, 100% of patients with eGFR< <15 mL/min/1.73 m^2 in our study developed CA-AKI following the second contrast exposure but these subgroup findings are exploratory given the small numbers within several strata and the risk of type I error from multiple testing.

Table 4. Risk of renal outcomes by baseline eGFR-based stage in each of the study groups

Baseline eGFR-based stage / Outcome	Group I (n=62)	Group II (n=50)	P value
stage 2 (n=10)			
CA-AKI post 1st contrast (N, %)	2/4 (50%)	1/6 (16.67 %)	0.5
CA-AKI post 2nd contrast (N, %)	-	1/6 (16.67%)	-
Decline in eGFR category after 3 months, (N, %)	1/4 (25%)	4/6 (66.67%)	0.5
>50% rise in creatinine after 3 months, (N, %)	0/4	1/6 (16.67%)	1
Doubling of serum create. At 3 months, (N, %)	0	0	-
Decline in eGFR category after 6 months, (N, %)	3/4 (75%)	2/6 (33.33%)	0.5
>50% rise in creatinine after 6 months, (N, %)	1/4 (25%)	1/6 (16.67%)	1
Doubling of serum create. At 6 months, (N, %)	0	0	-
stage 3a (n= 39)			
CA-AKI post 1st contrast (N, %)	3/21 (14.29%)	4/18 (22.22%)	0.7
CA-AKI post 2nd contrast (N, %)	-	13/18 (72.22%)	-
Decline in eGFR category after 3 months, (N, %)	6/21 (50%)	4/18 (22.22%)	0.7
>50% rise in creatinine after 3 months, (N, %)	1/21 (4.76%)	1/18 (5.56%)	1
Doubling of serum create. At 3 months, (N, %)	0	0	-
Decline in eGFR category after 6 months, (N, %)	7/21 (33.33%)	8/18 (44.44%)	0.5
>50% rise in creatinine after 6 months, (N, %)	2/21 (9.52%)	4/18 (22.22%)	0.4
Doubling of serum create. At 6 months, (N, %)	1/21 (4.76%)	2/18 (11.11%)	0.6
stage 3b (n= 35)			
CA-AKI post 1st contrast (N, %)	8/23 (34.78%)	6/12 (50%)	0.4
CA-AKI post 2nd contrast (N, %)		8/12 (66.67%)	-
Decline in eGFR category after 3 months, (N, %)	4/23 (17.39)	4/12 (33.33%)	0.4
>50% rise in creatinine after 3 months, (N, %)	1/23 (4.35%)	1/12 (8.33%)	1
Doubling of serum create. At 3 months, (N, %)	1/23 (4.35%)	0/12	1
Decline in eGFR category after 6 months, (N, %)	7/23 (30.43%)	7/12 (58.33%)	0.1
>50% rise in creatinine after 6 months, (N, %)	4/23 (17.39%)	5/12 (41.67%)	0.2
Doubling of serum create. At 6 months, (N, %)	1/23 (4.35%)	1/12 (8.33%)	1
Stage 4 (n=23)			
CA-AKI post 1st contrast (N, %)	1/11 (9%)	2/12 (16.7%)	1
CA-AKI post 2nd contrast (N, %)		8/12 (66.67%)	
Decline in eGFR category after 3 months, (N, %)	2/11 (18%)	0/12	0.2
>50% rise in creatinine after 3 months, (N, %)	0	0	-
Doubling of serum create. At 3 months, (N, %)	0	0	-
Decline in eGFR category after 6 months, (N, %)	1/11 (9%)	0/12	0.5
>50% rise in creatinine after 6 months, (N, %)	2/11 (18%)	1/12 (8.4%)	0.6
Doubling of serum create. At 6 months, (N, %)	1/11 (9%)	0/12	0.5
Stage 5 (n=5)			
CA-AKI post 1st contrast (N, %)	2/3 (66.67%)	1/ 2 (50%)	1
CA-AKI post 2nd contrast (N, %)	-	2/2 (100%)	-
>50% rise in creatinine after 3 months, (N, %)	0	0	-
Doubling of serum create. At 3 months, (N, %)	0	0	-
>50% rise in creatinine after 6 months, (N, %)	0	0	-
Doubling of serum create. At 6 months, (N, %)	0	0	-

CA-AKI: Contrast-associated acute kidney injury, CKD: Chronic kidney disease, N= number.

Table 5. Predictors of CA-AKI post second contrast (in Group II only, N=50)

	OR (95% CI)	P value
Age	1.03 (0.97-1.1)	0.35
Gender	0.98 (0.24-3.94)	0.98
DM	0.54 (0.1-3.02)	0.4
HTN	0.93 (0.29-3.03)	0.9
Hypotension	0.91 (0.26-3.12)	0.88
Baseline creatinine	2.57 (0.72-9.14)	0.1
CA-AKI post 1st contrast (prior CA-AKI)	11.63 (1.37-98.5)	**0.02**
Creatinine pre 2nd contrast	18.59 (2.21-156.6)	**0.007**
Total contrast volume	1.001 (0.99-1.01)	0.98
Time between 1st and 2nd contrast	1.003 (0.99-1.01)	0.5

CA-AKI: Contrast-associated acute kidney injury, CA-AKI: Contrast-associated nephropathy, DM: Diabetes mellitus, HTN: Hypertension, OR: Odds ratio.

Table 6. Predictors of eGFR-based stage worsening at 3 and 6 months in both groups

	At 3 months				At 6 months			
	Group I		Group II		Group I		Group II	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Age	1.01 (0.96-1.06)	0.7	0.97 (0.91-1.04)	0.4	0.99 (0.95-1.04)	0.9	0.99 (0.94-1.05)	0.9
Gender	0.93 (0.12-3.27)	0.6	1.25 (0.27-5.72)	0.8	0.38 (0.07-1.90)	0.2	0.67 (0.15-2.94)	0.6
BMI	0.92 (0.78-1.1)	0.3	0.98 (0.80-1.20)	0.9	0.90 (0.77-1.05)	0.2	1.32 (1.06-1.65)	**0.01**
DM	2 (0.22-17.89)	0.5	0.24 (0.05-1.15)	0.1	3.22 (0.37-28.24)	0.3	0.45 (0.1-2.08)	0.3
HTN	1.20 (0.32-4.46)	0.8	0.91 (0.24-3.42)	0.9	0.73 (0.23-2.29)	0.6	0.20 (0.06-0.72)	0.01
CVD	2.76 (0.78-9.71)	0.1	0.71 (0.19-2.65)	0.6	9.33 (2.56-34.05)	0.001	0.31 (0.-09-1.07)	0.06
Baseline eGFR-based stage	0.68 (0.35-1.34)	0.3	0.36 (0.16-0.82)	0.02	0.43 (0.22-0.87)	0.02	0.55 (0.30-1.01)	0.05
Previous use of SGLT2i	1.30 (0.23-7.36)	0.8	0.48 (0.05-4.49)	0.5	2.86 (0.63-12.98)	0.2	0.28 (0.03-2.55)	0.3
Previous use of ACEI/ARBs	0.70 (0.19-2.60)	0.6	3.44 (0.90-13.19)	0.07	1.55 (0.50-4.74)	0.8	3 (0.88-10.18)	0.08
Previous Statins	0.49 (0.08-3.02)	0.4	0.14 (0.01-1.65)	0.1	2.18 (0.24-20.09)	0.5	1	-
First contrast volume	0.99 (0.98-1.01)	0.8	1.02 (0.99-1.03)	0.06	1.01 (0.99-1.02)	0.3	1.01 (0.99-1.03)	0.2
Cumulative contrast volume	0.99 (0.98-1.01)	0.8	1.005 (0.99-1.02)	0.3	1.01 (0.99-1.02)	0.3	0.99 (0.98-1.01)	0.4
CA-AKI after the first contrast	2.16 (0.59-7.95)	0.2	1.4 (0.35-5.68)	0.6	5.29 (1.55-18.03)	0.008	10.36 (2.50-42.99)	0.001

ACEI: Angiotensin-converting enzyme inhibitor, ARB: Angiotensin receptor blocker, BMI: Body mass index, CA-AKI: Contrast-associated acute kidney injury, CKD: Chronic kidney disease, CVD: Cardiovascular disease, DM: Diabetes mellitus, HTN: Hypertension, SGLT2: Sodium-glucose cotransporter-2 (inhibitor), OR: Odds ratio.

Previous studies also showed that repeated contrast exposure was associated with progression to ESRD in patients with advanced CKD stages [25,26].

Our finding of that, eGFR stage 4 was significantly associated with less risk of CKD progression compared to stage 2 is unexpected and comes contradictory to published evidences which indicate that advanced CKD stages carry the highest risk of adverse renal outcomes [14,17]. The apparent inverse association between higher baseline eGFR-based stage and subsequent stage decline is counterintuitive and is most plausibly explained by a ceiling effect (stage 4–5 patients cannot progress further by definition) together with small numbers in advanced-stage strata. We therefore regard all stage-stratified analyses as exploratory and do not claim a true protective effect of advanced stage. Initial exposure could trigger persistent tubular damage, endothelial dysfunction, or inflammatory processes that accelerate decline over time. These patients are often monitored less closely and may not receive protective therapies, allowing subtle injury to progress unnoticed until months later. The small sample size could also affect the results.

Our findings also suggest that traditional risk tools may not fully capture the risk associated with repeated exposure in ICU patients with reduced GFR. The Meh-

ran score performed reasonably well for the first exposure, but it underestimated the absolute risk after the second exposure and for dialysis however this represents application of the score outside its original development and validation context (PCI) populations. As a result, clinicians should be cautious about applying standard risk models without considering recent renal trend and prior contrast response.

Limitations and strengths

This is a single-centre study. The study design does not allow a definitive causal comparison between single and repeated contrast exposures. We acknowledge small subgroups and multiple statistical comparisons and the risk of type I error from multiple testing. Baseline staging relied on a single eGFR value without confirmation of chronicity in some patients; however, analysis in patients with documented CKD yielded consistent results. Despite these limitations, the study has important strengths. This study uniquely evaluates repeated contrast exposure in broader ICU patients and showing that prior CA-AKI and pre-second-exposure creatinine are practical, accessible predictors that can guide safer repeat imaging decisions.

CONCLUSIONS:

Among ICU patients with reduced baseline eGFR who underwent repeat contrast administration, CA-AKI was frequent after the second exposure (64 %), particularly in those who had already developed CA-AKI after the first exposure (adjusted OR 11.63, 95 % CI 1.37–98.5). Prior CA-AKI also strongly predicted decline in eGFR category at six months (adjusted OR 5.29 in the single-exposure group and 10.36 in the repeated-exposure group). In analysis restricted to patients with established CKD (n = 80), the principal associations remained directionally consistent. Early post-contrast renal response therefore provides a clinically useful signal for identifying high-risk patients before re-imaging. The observational design cannot determine how much of the observed risk is attributable specifically to contrast versus underlying illness severity or intervening events. When applied outside its original PCI context, the Mehran score substantially underestimated both CA-AKI risk after the second exposure and the observed need for dialysis. Future studies should validate these findings in larger multicenter cohorts and develop more precise, ICU-specific risk-prediction models for repeated contrast exposure.

AUTHOR CONTRIBUTIONS:

All Authors contributed to study design, H.E contributed to Conceptualization, Data collection, Writing – review & editing of the manuscript. F.M, A.S, A.Y and R.M contributed to Conceptualization, Writing – original draft, Writing – review & editing of the manuscript.

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The authors declared no potential conflicts of interest.

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The study protocol obtains approval from the Faculty of Medicine, Cairo University Research Ethics Committee (REC), approval number N-20–2024. All study procedures complied with the ethical principles outlined in the 1975 Declaration of Helsinki, and written informed consent was obtained from each participant prior to enrolment. Clinicaltrials.gov. registration number: NCT07713524

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All data are included in this published article.

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