

CT Coronary Angiography Vs Cardiac Catheterization and Risk of Acute Kidney Injury – Comparative Study

Swatam Jain^{1,*}, Farzad Majidi²

¹Department of Internal Medicine, HCA Healthcare, MountainView Hospital, Las Vegas, NV, USA

²Department of Cardiovascular Medicine, HCA Healthcare, MountainView Hospital, Las Vegas, NV, USA

*Correspondence should be addressed to Swatam Jain, Swatam.Jain@hcahealthcare.com

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Abstract

Background: CT coronary angiography (CTCA) and invasive coronary angiography (ICA) are widely used to evaluate coronary artery disease (CAD). Both involve iodinated contrast, which may cause contrast-induced acute kidney injury (CI-AKI), particularly in high-risk patients. This study compared the incidence of AKI following CTCA versus ICA in hospitalized patients with symptomatic CAD.

Methods: We conducted a retrospective cohort study using the TriNetX electronic health record network (2010–2025). Patients were identified using ICD-10 and CPT codes. Inclusion criteria were hospitalized adults with CAD and angina who underwent CTCA or diagnostic cardiac catheterization. Patients with myocardial infarction, prior revascularization, or end-stage renal disease were excluded. Patients were placed into mutually exclusive cohorts based on the procedure performed. The primary outcome was AKI within 1–4 days post-procedure. Propensity score matching (1:1) was used to balance baseline characteristics.

Results: A total of 160,111 patients underwent CTCA and 88,081 underwent cardiac catheterization. After matching, 72,946 patients per group were analyzed. AKI occurred in 0.64% of CTCA patients vs. 1.29% of ICA patients. CTCA was associated with significantly lower odds of AKI (OR 0.496; 95% CI, 0.440–0.556) and an absolute risk reduction of 0.64% ($p < 0.001$).

Conclusion: Among hospitalized patients with angina and Coronary artery disease, CT Coronary Angiography was associated with a significantly lower risk of Acute kidney injury compared to diagnostic catheterization. While absolute rates were low, the difference may reflect reduced invasiveness and contrast exposure with CT Coronary Angiography. These findings suggest CT Coronary Angiography may be a safer initial diagnostic option in coronary artery disease patients at increased risk for renal complications.

Keywords: Acute kidney injury, CT coronary angiography, Cardiac catheterization, Angina pectoris, Coronary artery disease, Contrast medium

Introduction

Coronary artery disease (CAD) is the narrowing or blockage of coronary arteries due to atherosclerosis and remains a leading cause of morbidity and mortality worldwide. It may present as chronic stable angina or as part of the acute coronary syndrome (ACS) spectrum, including unstable angina, non ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI). While acute presentations often necessitate urgent invasive coronary angiography (ICA) and potential revascularization, stable angina typically prompts diagnostic evaluation to assess coronary anatomy and risk. Initial assessment includes electrocardiography, stress testing

and echocardiography. For direct anatomical visualization, CT coronary angiography (CTCA) and ICA are the two principal imaging modalities [1]. CTCA is a noninvasive test with high negative predictive value, particularly suited for ruling out significant CAD in patients with stable chest pain and intermediate pretest probability [2,3]. ICA remains the gold standard for diagnosing and managing CAD, especially in ACS, offering both visualization and the opportunity for immediate intervention, though it carries procedural risks including vascular injury and contrast-induced acute kidney injury [4].

Both CTCA and ICA utilize iodinated contrast media, which have been associated with nephrotoxicity and the

development of contrast-induced acute kidney injury (CI-AKI) [5]. Contrast-associated AKI is a broader term for CI-AKI, where the kidney injury is not directly attributed to contrast exposure. CI-AKI remains one of the most common causes of hospital-acquired acute kidney injury (AKI), ranking third among iatrogenic causes [6]. The pathogenesis of CI-AKI is multifactorial, involving a combination of direct cytotoxic injury to renal tubular epithelial cells, oxidative stress from reactive oxygen species, and medullary ischemia due to vasoconstriction and altered renal hemodynamics [5,6]. The renal medulla is particularly vulnerable to hypoxia, especially in patients with pre-existing chronic kidney disease. Additional risk factors for CI-AKI include diabetes mellitus, dehydration, advanced age, high contrast volume, and concurrent use of nephrotoxic medications [7].

CTCA involves intravenous administration of iodinated contrast, typically using a standardized volume between 50 and 100 mL [8]. In contrast, cardiac catheterization delivers contrast intra-arterially, with volumes that vary depending on the procedure. While diagnostic cardiac catheterization generally uses lower contrast volumes, significantly higher amounts are required during ventriculography or when the procedure includes interventions such as percutaneous coronary intervention (PCI) or percutaneous transluminal coronary angioplasty [9].

Understanding the absolute risk of AKI with each modality and comparing them directly provides important insight into their relative renal safety. In a randomized trial by *Schönenberger et al.*, the incidence of acute kidney injury (AKI) was significantly higher in patients undergoing cardiac catheterization compared to those undergoing CTCA for suspected coronary artery disease. Notably, even among patients in the catheterization group who did not undergo coronary intervention, the incidence of AKI was similar to or higher than those who did, suggesting that factors beyond intervention and contrast dose may contribute to renal risk [10].

Despite differences in contrast route and volume, the risk of contrast-associated AKI (CA-AKI) is likely multifactorial, influenced by patient comorbidities, baseline renal function and procedural hemodynamics. Building on prior evidence, this study seeks to directly compare these two diagnostic strategies—CTCA and diagnostic cardiac catheterization—to assess differences in the risk of AKI and better define their renal safety profiles.

Materials and Methods

Data source

An analysis was conducted using data from the TriNetX database. The TriNetX database is a global federated health research network providing access to electronic medical

records across large healthcare organizations. The data were obtained from 60 healthcare organizations across the United States, which included academic and non-academic hospitals. Patients in the database were all hospitalized individuals with symptomatic coronary artery disease between 2010-2025.

Ethical compliance with human studies

The data reviewed are a secondary analysis of existing data, do not involve intervention or interaction with human subjects, and are de-identified per the de-identification standard defined in Section §164.514(a) of the HIPAA Privacy Rule. The process of de-identifying data is attested to through a formal determination by a qualified expert as defined in Section §164.514(b)(1) of the HIPAA Privacy Rule - this formal determination by a qualified expert, refreshed in December 2020.

Study population

TriNetX was queried using the Internal Classification of Diseases 10th version, clinical modification (ICD-10 CM) codes. Inclusion criteria for the patient population were hospitalized patients with a diagnosis of coronary artery disease or angina pectoris and who had received computed tomography coronary angiography or cardiac catheterization. Angina pectoris is a commonly used diagnosis for various clinical presentations of angina, including unstable, vasospastic, microvascular, and unspecified forms, and is widely used in hospitalized patients presenting with chest pain (See **Supplementary Table 1** for inclusion of ICD-10 codes). Patients were excluded if they had end-stage renal disease, myocardial infarction, prior coronary stenting or prior coronary artery bypass grafting (See **Supplementary Table 2** for ICD-10, CPT codes).

Study design

We conducted a retrospective cohort study to compare patients who underwent CT coronary angiography (CTCA) with those who underwent cardiac catheterization, in order to evaluate the association between imaging modality and the risk of acute kidney injury (AKI) in hospitalized patients with symptomatic coronary artery disease and angina pectoris. Patients who underwent CTCA were excluded from the cardiac catheterization group and vice versa, ensuring the two cohorts were mutually exclusive.

Study cohorts

Cohort 1 included 160,111 patients who underwent CT coronary angiography (CTCA), while cohort 2 included 88,081 patients who underwent cardiac catheterization (**Figure 1**). All patients in this analysis had a primary diagnosis of angina pectoris or coronary artery disease. After 1:1 propensity score matching based on key demographics and comorbidities, each cohort included 72,946 patients (**Tables 1 and 2**).

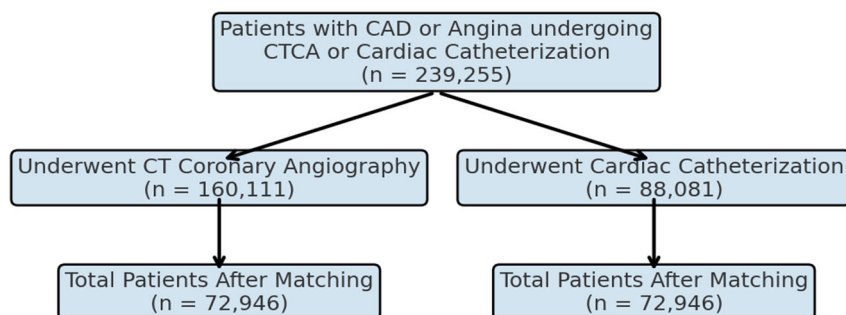


Figure 1. Study population and cohorts.

Table 1. Patient characteristics - before matching.

Characteristic	CTCA (n = 160,111)	Cardiac Catheterization (n = 88,081)
Mean Age (years)	66.9 ± 12.8	73.1 ± 11.3
Female (%)	46.3%	37.15%
White (%)	73.6%	67.2%
Black (%)	9.61%	8.88%
Hispanic (%)	8.20%	5.12%
Hypertension (%)	61.97%	68.18%
Diabetes Mellitus (%)	23.03%	28.09%
Chronic Kidney Disease (%)	14.02%	12.12%
Serum Creatinine (mg/dL)	0.929 ± 1.34	0.977 ± 1.17

Table 2. Patient characteristics - after matching.

Characteristic	CTCA (n = 72,946)	Cardiac Catheterization (n = 72,946)
Mean Age (years)	71.7 ± 11.4	71.2 ± 11.4
Age at Index (years)	66.8 ± 11.4	66.8 ± 11.7
Female (%)	40.75%	37.14%
Male (%)	59.25%	59.27%
White (%)	76.68%	75.62%
Black or African American (%)	10.72%	8.88%
Hispanic (%)	5.69%	5.12%
Asian (%)	2.34%	2.27%
Other Race (%)	2.73%	2.47%
Not Hispanic or Latino (%)	74.99%	73.52%
Hypertension (%)	83.18%	68.18%
Diabetes Mellitus (%)	36.26%	28.09%
Chronic Kidney Disease (%)	16.93%	12.12%
Serum Creatinine (mg/dL)	1.04 ± 1.04	1.02 ± 0.98

Study outcomes and variables

The primary outcome of interest was acute kidney injury (AKI) occurring within 1–4 days following the index procedure. AKI was identified using validated ICD-10 codes. Additional clinical variables included age, sex, race, ethnicity, hypertension, diabetes mellitus, chronic kidney disease and serum creatinine. These were selected based on their relevance to AKI risk and overall patient health status.

All variables were classified as binary (presence or absence of the condition), except for continuous measures such as age and serum creatinine, which were incorporated into the propensity score model. A full list of diagnostic and procedural codes is available in the **Supplementary Material**.

Statistical analysis

To reduce bias and ensure balanced comparison between the two cohorts, we employed 1:1 propensity score matching using variables including age, sex, race, ethnicity, hypertension, diabetes mellitus, chronic kidney disease and baseline serum creatinine. This matching created comparable groups, enabling a focused analysis on the impact of the imaging modality on the incidence of AKI.

Post-matching, logistic regression analyses were performed to evaluate the odds of AKI in the CTCA group versus the cardiac catheterization group while controlling for age, sex, race, ethnicity, diabetes mellitus, hypertension, chronic kidney disease and baseline serum creatinine. Results were presented using odds ratio (OR) and absolute risk difference, each with 95% confidence intervals.

Results

A total of 160,111 patients underwent CTCA and 88,081 underwent cardiac catheterization. After propensity score matching, 72,946 patients remained in each group with well-matched baseline characteristics. AKI occurred in 470 patients (0.64%) in the CTCA group and 938 patients (1.29%) in the cardiac catheterization group (**Table 3**). The odds ratio for AKI was 0.496 (95% CI: 0.440–0.556) with an absolute risk difference of -0.642% (95% CI: -0.742% to -0.542%) (**Table 4**). An absolute risk reduction of 0.64% corresponds to a number needed to treat of approximately 157—about 157

CTCA procedures instead of ICA are needed to prevent one case of AKI. These findings suggest that CTCA is associated with a statistically significantly lower risk of AKI in patients hospitalized with symptomatic coronary artery disease when compared to cardiac catheterization, but the effect size was small, suggesting limited practical significance.

Discussion

Our study demonstrated that among hospitalized patients with symptomatic coronary artery disease, CT coronary angiography (CTCA) and diagnostic cardiac catheterization had relatively low AKI rates. The incidence of AKI was 0.64% in the CTCA group versus 1.29% in the cardiac catheterization group. The incidence of acute kidney injury (AKI) was statistically lower in the CT coronary angiography (CTCA) group compared to the cardiac catheterization group, with an absolute risk reduction of 0.64%; however, the small effect size suggests that the practical significance may be modest.

Contrast-induced acute kidney injury (CI-AKI) is characterized by an acute decline in renal function, typically defined by a $\geq 25\%$ increase in serum creatinine from baseline or an absolute rise of ≥ 0.5 mg/dL within 48 to 72 hours following iodinated contrast exposure [5]. According to Kidney Disease: Improving Global Outcomes (KDIGO) criteria, AKI is identified by a creatinine increase of ≥ 0.3 mg/dL within 48 hours, a $\geq 50\%$ increase within seven days, or urine output reduction to < 0.5 mL/kg/h for more than six hours [11]. In CI-AKI, serum creatinine typically rises within 24 hours, peaks at 3–5 days, and returns to baseline within 7–10 days [12].

Coronary CT angiography and other contrast-enhanced CT procedures carry an extremely low risk of contrast-induced AKI (CI-AKI) in patients with stable kidney function ($\text{eGFR} \geq 30$ mL/min/1.73 m²). Specifically, in patients with eGFR 30–44, the incidence of CI-AKI is only 0–2%, despite a 15% overall rate of contrast-associated AKI (CA-AKI). In patients with $\text{eGFR} < 30$, the risk of CI-AKI is more uncertain, ranging from 0–17%, due to limited and conflicting data. In those with $\text{eGFR} \geq 45$, the CI-AKI risk is effectively zero [13]. While CTCA employs a standardized intravenous contrast volume of 50–100 mL [8], cardiac catheterization involves intra-arterial contrast administration, typically starting with lower volumes but often escalating significantly during ventriculography

Table 3. Acute kidney injury outcomes.		
Outcome	CTCA (n = 72,946)	Cardiac Catheterization (n = 72,946)
AKI within 1–4 days post index	470 (0.64%)	938 (1.29%)

Table 4. Risk measures for AKI in CTCA versus cardiac catheterization.			
Measure	Estimate	95% CI	p-value
Absolute Risk Difference	-0.642%	-0.742% to -0.542%	<0.001
Odds Ratio	0.496	0.440 to 0.556	<0.001

or interventional procedures [7]. The incidence of contrast-induced AKI varies widely depending on both the procedure type and patient population ranging from 1.6–2.3% in non-invasive diagnostic imaging to as high as 14.5% following coronary interventions, where intra-arterial contrast exposure is typically greater [7]. Notably, patients requiring coronary interventions such as PCI or PTCA were excluded from this study.

The route of contrast administration significantly influences the risk of acute kidney injury (AKI). CT coronary angiography (CTCA) utilizes intravenous (IV) contrast, while cardiac catheterization involves intra-arterial (IA) contrast administration. A randomized trial by *Schönenberger et al.* demonstrated that patients undergoing CTCA had a significantly lower rate of AKI than those undergoing cardiac catheterization [10]. This suggests that factors beyond contrast volume—particularly the administration route—may contribute to nephrotoxicity. A meta-analysis by *Dong et al.* similarly reported higher rates of contrast-induced nephropathy with IA contrast compared to IV contrast, possibly due to first-pass renal exposure and hemodynamic factors [14].

Several risk factors have been identified that increase the likelihood of developing CI-AKI. These include pre-existing renal impairment, diabetes mellitus, advanced age, dehydration and the use of high volumes of contrast media [15,16]. To minimize the risk of contrast-induced acute kidney injury (CI-AKI), several renal-protective strategies are routinely employed in patients undergoing cardiac catheterization. These include limiting the contrast dose to the maximum allowable contrast dose (MACD), typically calculated as $5 \times$ body weight (kg) divided by serum creatinine (mg/dL) [17]. Cardiologists often adopt a cautious approach by using the lowest feasible contrast volume. Additional measures such

as intravenous hydration with isotonic fluids and temporary discontinuation of potentially nephrotoxic medications (e.g., NSAIDs) in high-risk patients further contribute to renal protection [18].

Higher AKI rates persisted in the diagnostic catheterization group in our study, suggesting that factors other than contrast volume alone contribute to renal risk. One such factor is the route of contrast administration. Intra-arterial contrast injection delivers a higher contrast concentration directly to the renal arteries during first-pass circulation, which is known to be more nephrotoxic than intravenous delivery [10]. Additionally, catheter manipulation during diagnostic catheterization may trigger atheroembolic events, further impairing renal perfusion [19]. Another procedural factor is the vascular access site. Radial access has been associated with lower AKI rates compared to femoral access, likely due to reduced bleeding, fewer vascular complications, and better hemodynamic stability. The AKI-MATRIX trial demonstrated that radial access significantly reduced AKI incidence following coronary procedures [20].

Although rare, hemodynamic compromise during catheterization such as transient hypotension can reduce renal perfusion and contribute to AKI [21]. These multifactorial contributors emphasize that procedural invasiveness, vascular access, hemodynamic effects, and contrast delivery route—not just absolute contrast volume—may influence renal outcomes (**Figure 2**).

While the difference in renal safety between CTCA and diagnostic cardiac catheterization is modest, the statistically significant reduction in AKI with CTCA suggests it may be a preferable initial diagnostic approach for patients with symptomatic coronary artery disease, particularly those at risk for renal complications.

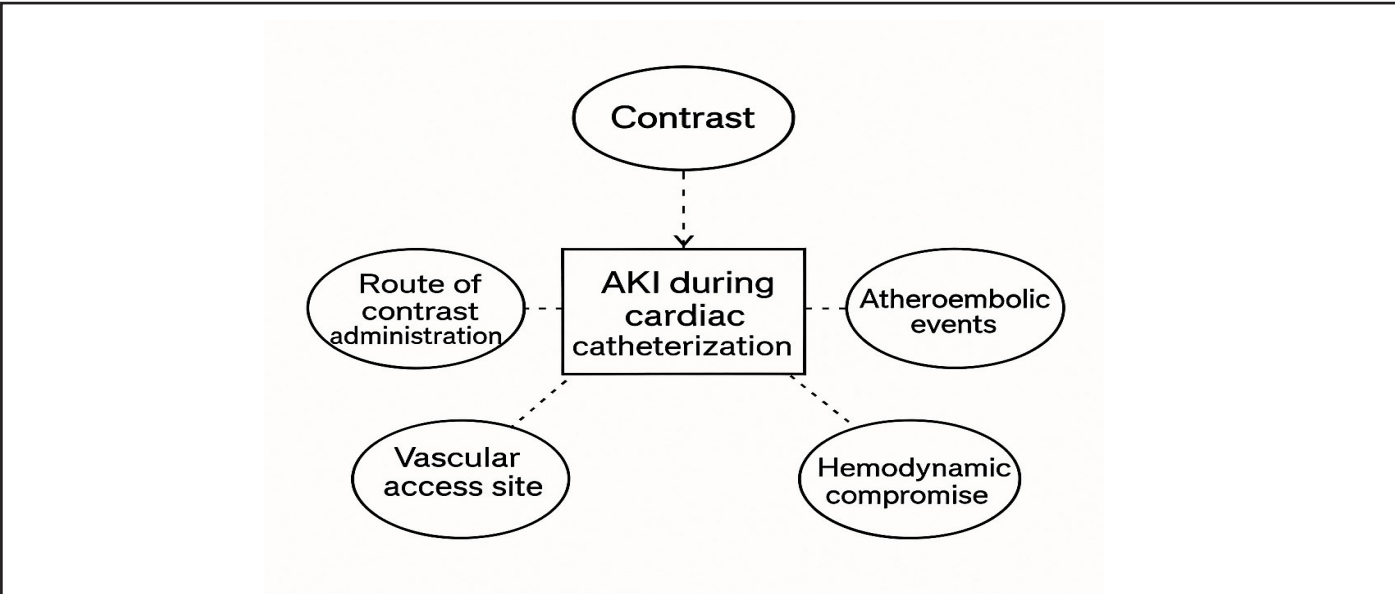


Figure 2. Multifactorial AKI during cardiac catheterization.

Study strengths and limitations

This study's strengths include the use of a large, nationally representative cohort with diverse patient demographics, rigorous exclusion criteria, and well-balanced matched groups through propensity score methods. The clinically relevant outcome window (1–4 days post-procedure) further enhances applicability. This is the first study to directly compare CTCA and diagnostic cardiac catheterization head-to-head in terms of renal safety in the symptomatic coronary artery disease population.

However, limitations must be acknowledged. The retrospective design carries the risk of residual confounding. AKI identification depended on diagnostic coding, which may miss subtle or transient creatinine changes. We lacked data on exact contrast volume, hydration strategies, and nephrotoxic exposures. Importantly, patients with AKI severe enough to require hemodialysis could not be assessed, as they were excluded based on diagnostic coding for end-stage renal disease (ESRD). Furthermore, not all creatinine rises following contrast exposure can be definitively attributed to contrast-induced AKI (CI-AKI), highlighting the need to distinguish true contrast injury from coincidental renal function changes.

Conclusion

In this large retrospective cohort analysis of patients with symptomatic coronary artery disease, CT coronary angiography (CTCA) was associated with a statistically significant reduction in the incidence of acute kidney injury (AKI) compared to diagnostic cardiac catheterization. This difference persisted despite comparable baseline renal function and comorbidity profiles, suggesting that factors such as contrast administration route and procedural invasiveness may influence renal outcomes. Although the clinical impact of this reduction is modest, it remains a pertinent consideration, particularly for patients at elevated risk for acute kidney injury. Given its noninvasive nature and lower nephrotoxic potential, CT Coronary Angiography may be considered a favorable initial diagnostic modality in terms of renal safety for patients with coronary artery disease.

Conflict of Interest

We do not have any financial or non-financial conflicts of interest.

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