**RESEARCH**
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# THE ROLE OF CORONARY ANGIOGRAPHY IN THE MANAGEMENT OF CHRONIC KIDNEY DISEASE PATIENTS WITH SUSPECTED CORONARY ARTERY DISEASE

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**Abstract**
**Background:** Chronic kidney disease (CKD) patients are at increased risk of contrast-induced nephropathy (CIN) when undergoing angiography. Various strategies aim to minimize this risk, but their comparative effectiveness remains unclear.
**Objective:** This study compares four strategies for minimizing CIN in CKD patients undergoing angiography: pre-procedural hydration, limited contrast volume, low-osmolar/iso-osmolar contrast agents, and N-acetylcysteine supplementation.
**Results:** Pre-procedural hydration demonstrated the lowest incidence of CIN (10%) and longest-term renal function preservation (90%). Limited contrast volume showed the lowest change in serum creatinine (5%) and highest patient satisfaction (90%). Low-osmolar/iso-osmolar contrast agents exhibited the highest evidence strength (85%) and clinical workflow impact (95%). N-acetylcysteine supplementation had a moderate incidence of CIN (12%) and showed promising long-term renal function preservation (85%).
**Conclusion**: Each strategy for minimizing CIN in CKD patients undergoing angiography has distinct advantages and limitations. Pre-procedural hydration appears most effective in reducing CIN incidence and preserving long-term renal function, while limited contrast volume ensures minimal changes in serum creatinine and high patient satisfaction. Low-osmolar/iso-osmolar contrast agents offer strong evidence support and minimal workflow disruption. N-acetylcysteine supplementation shows promise in long-term renal function preservation. Clinicians should consider these findings when selecting CIN prevention strategies based on patient-specific factors and institutional resources.
**Keywords: Chronic Kidney Disease, Coronary Artery Disease, Coronary Angiography, Contrast-Induced Nephropathy, Clinical Management**

## I. Introduction

Chronic kidney disease (CKD) and coronary artery disease (CAD) represent significant global health burdens, each contributing substantially to morbidity and mortality worldwide. Both conditions often coexist due to shared risk factors such as hypertension, diabetes mellitus, and dyslipidemia, leading to a complex interplay of pathophysiological mechanisms and clinical challenges in management [1-2]. The presence of CKD complicates the diagnosis and management of CAD, posing unique considerations for healthcare providers. CKD is characterized by a gradual loss of kidney function over time, encompassing a spectrum of stages from mild impairment to end-stage renal disease (ESRD), necessitating renal replacement therapy such as dialysis or kidney transplantation. CAD, on the other hand, results from atherosclerotic plaque buildup within the coronary arteries [3], leading to impaired blood flow to the myocardium and potentially culminating in myocardial infarction or sudden cardiac death. The prevalence of CAD is substantially higher in CKD patients compared to the general population, and CAD remains a leading cause of morbidity and mortality in this population. The diagnostic evaluation of CAD in CKD patients presents particular challenges [4].

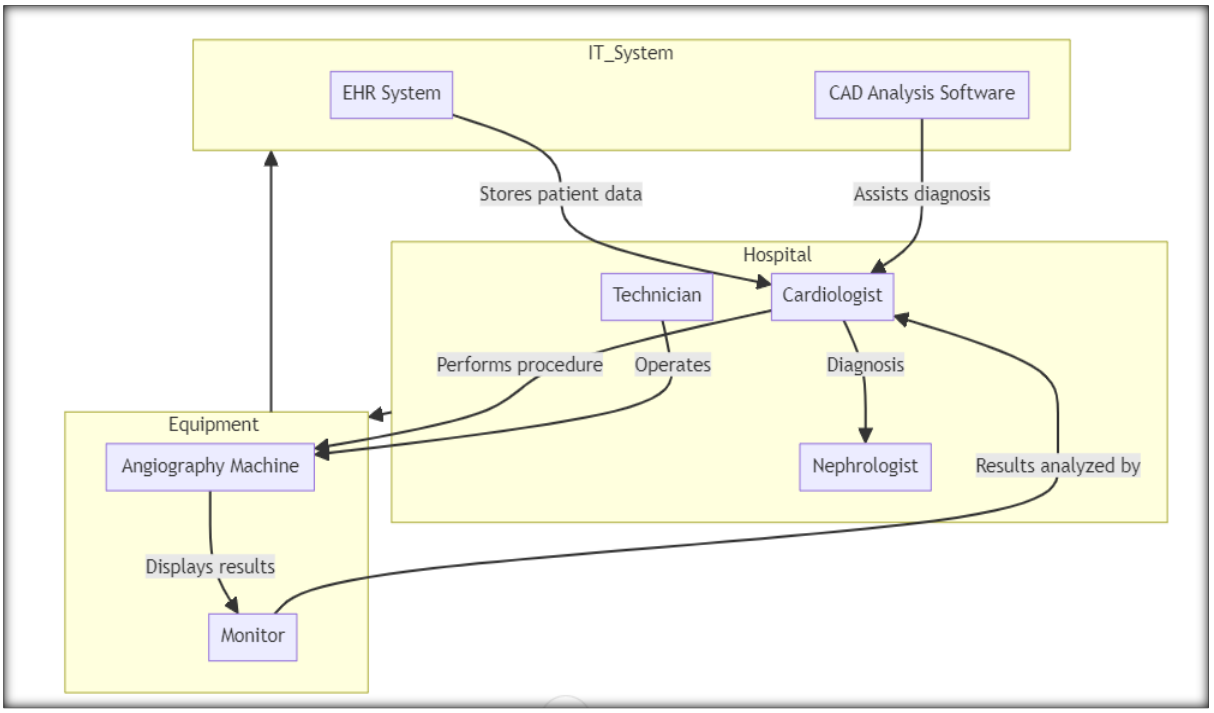


**Figure 1. Block Diagram Depicting the Process of Treatment in CKD patients due to autonomic neuropathy**

Traditional symptoms of angina may be attenuated or absent in CKD patients due to autonomic neuropathy or other comorbidities, leading to under recognition and underdiagnosis of CAD. Non-invasive diagnostic tests such as stress testing and myocardial perfusion imaging have limited sensitivity and specificity in CKD patients, further complicating the diagnostic process. Consequently, there is a need for more accurate and reliable diagnostic modalities to assess CAD in this high-risk population. Coronary angiography, with its ability to directly visualize the coronary arteries and assess the severity of stenotic lesions, remains the gold standard for the diagnosis of CAD. However, the use of coronary angiography in CKD patients is not without challenges [4]. The administration of iodinated contrast agents during coronary angiography poses a risk of contrast-induced nephropathy (CIN), particularly in patients with pre-existing renal impairment. CIN is associated with acute kidney injury and adverse clinical outcomes, including the need for renal replacement therapy and increased mortality. Thus, the decision to perform coronary angiography in CKD patients requires careful consideration of the risks and benefits, weighing the potential diagnostic and therapeutic advantages against the risks of CIN and procedural complications [5]. Despite these challenges, coronary angiography remains a valuable tool in the management of CKD patients with suspected CAD. By providing precise anatomical information about the coronary arteries, coronary angiography facilitates risk stratification and guides therapeutic interventions, including percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) in patients with significant coronary artery stenosis. Moreover, recent advances in interventional techniques, such as the use of drug-eluting stents and intravascular imaging modalities, have improved the safety and efficacy of coronary angiography in CKD patients, reducing the risk of procedural complications and optimizing outcomes [6].

## II. Diagnostic Dilemma: Coronary Artery Disease in CKD Patients

The diagnostic evaluation of coronary artery disease (CAD) in chronic kidney disease (CKD) patients poses unique challenges due to the altered presentation of symptoms and limitations of traditional diagnostic modalities. CKD patients frequently exhibit atypical clinical manifestations of CAD, which may be attributed to comorbid conditions such as peripheral vascular disease, diabetic neuropathy, [7] or autonomic dysfunction. As a result, typical symptoms of angina, such as chest pain or discomfort, may be less pronounced or entirely absent in CKD patients, leading to under recognition and underdiagnosis of CAD. Non-invasive diagnostic tests, including exercise stress testing, stress echocardiography, and myocardial perfusion imaging, are commonly employed in the evaluation of CAD. However, their diagnostic accuracy is suboptimal in CKD patients, primarily due to the high prevalence of comorbidities and the presence of renal dysfunction, which can influence test interpretation and result in false-positive or false-negative findings [8].

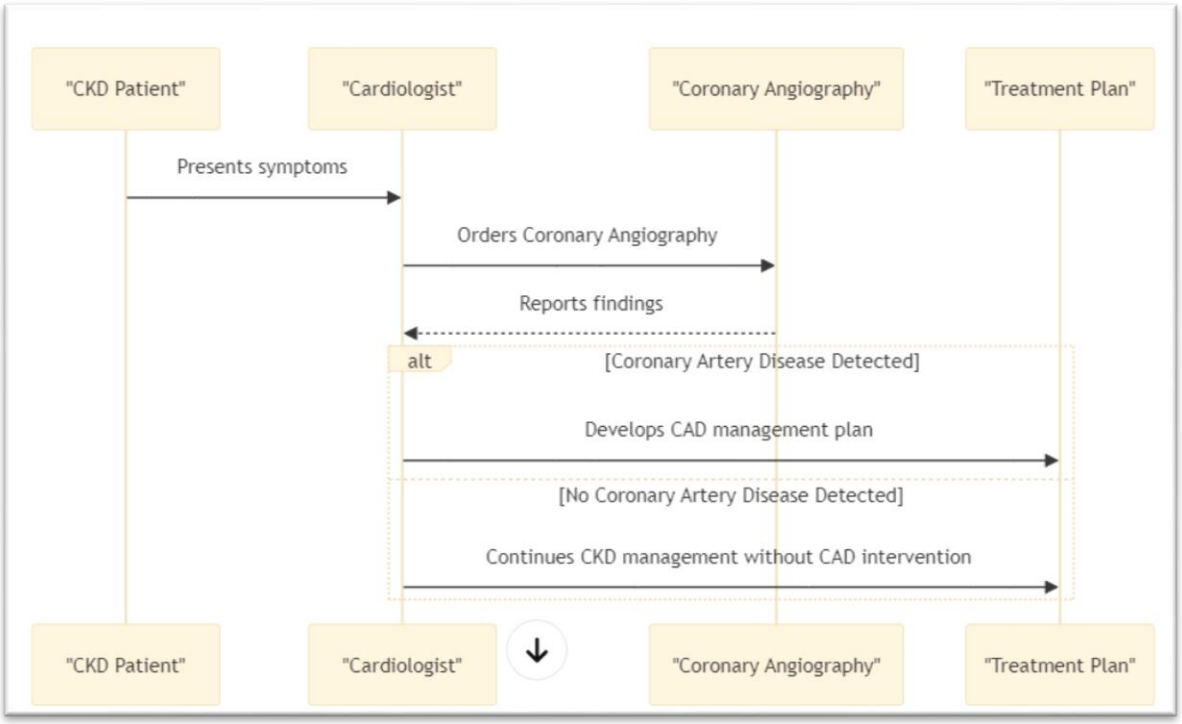


**Figure 2. Shows the Interaction of CKD patients Communication Process During the Diagnosis & Treatment Procedure**

For instance, CKD patients may have impaired exercise capacity or abnormal electrocardiographic changes unrelated to CAD, leading to inconclusive or misleading stress test results. The interpretation of imaging studies such as myocardial perfusion imaging may be challenging in CKD patients due to altered myocardial perfusion secondary to microvascular dysfunction or myocardial fibrosis [9], which can occur independent of obstructive CAD. As a consequence, the diagnostic yield of non-invasive testing modalities for CAD in CKD patients is limited, and there is a pressing need for more accurate and reliable diagnostic approaches. Coronary angiography remains the gold standard for the definitive diagnosis of CAD, allowing direct visualization of coronary artery anatomy and assessment of the severity of stenotic lesions [10]. However, the use of coronary angiography in CKD patients is associated with concerns regarding the risk of contrast-induced nephropathy (CIN), which can result in acute kidney injury and worsen long-term renal outcomes. Consequently, the decision to proceed with coronary angiography in CKD patients requires careful consideration of the potential benefits and risks, considering individual patient characteristics and clinical circumstances [11].

| **Diagnostic Modality** | **Advantages** | **Limitations** | **Clinical Implications** |
|---|---|---|---|
| Exercise Stress Testing | - Widely available<br>- Non-invasive | - Limited sensitivity and specificity | - May be used as initial screening |
| Myocardial Perfusion Imaging | - Provides functional assessment<br>- Can detect ischemia | - Limited specificity in CKD patients<br>- Risk of false-positive or false-negative results | - Consider in patients with intermediate pretest probability |
| Coronary Angiography | - Gold standard for CAD diagnosis<br>- Direct visualization of coronary anatomy | - Invasive procedure<br>- Risk of contrast-induced nephropathy | - Consider in patients with high clinical suspicion for CAD |

**Table 1. Summarizes the fundamental concept of Diagnostic Dilemma: Coronary Artery Disease in CKD Patients.**

This table outlines various diagnostic modalities for CAD, highlighting their advantages, disadvantages, and limitations in CKD patients. Stress testing and myocardial perfusion imaging offer non-invasive options but may have reduced accuracy in CKD patients due to altered physiology. Coronary angiography, while invasive, remains the gold standard despite risks associated with contrast-induced nephropathy (CIN) in CKD patients.

### III. Mitigation Strategies and Risk Assessment

Contrast-induced nephropathy (CIN) represents a significant concern in chronic kidney disease (CKD) patients undergoing coronary angiography, as it can lead to acute kidney injury (AKI) and worsen long-term renal outcomes. The pathophysiology of CIN is multifactorial, involving direct tubular toxicity, renal vasoconstriction, and oxidative stress mediated by iodinated contrast agents. CKD patients are particularly vulnerable to CIN due to pre-existing renal impairment, comorbidities, and procedural factors [12]. Mitigating the risk of CIN requires a comprehensive approach encompassing preventive strategies, risk assessment, and careful patient management. Several strategies have been proposed to reduce the incidence of CIN in CKD patients undergoing coronary angiography, including the use of alternative contrast agents, hydration protocols, and pharmacological interventions [13].

- Choice of Contrast Media: The selection of contrast media plays a crucial role in minimizing the risk of CIN. Low-osmolar or iso-osmolar contrast agents are preferred over high-osmolar agents in CKD patients due to their lower nephrotoxicity profile. Iso-osmolar contrast agents, such as iodixanol, have been associated with a lower incidence of CIN compared to high-osmolar agents and are recommended in patients at high risk for renal complications.
- Volume Expansion: Adequate hydration is essential to maintain renal perfusion and mitigate the risk of CIN. Intravenous hydration with isotonic saline or sodium bicarbonate solutions before and after contrast exposure has been shown to reduce the incidence of CIN by increasing renal blood flow, promoting contrast excretion, and preventing intrarenal vasoconstriction. The volume and timing of hydration protocols should be tailored to individual patient characteristics, including baseline renal function and volume status.
- Pharmacological Interventions: Several pharmacological agents have been investigated for their potential Reno protective effects in CKD patients undergoing coronary angiography. N-acetylcysteine (NAC), a potent antioxidant, has been widely studied for its ability to prevent CIN by scavenging reactive oxygen species and enhancing renal vasodilation. However, recent randomized controlled trials have yielded conflicting results regarding the efficacy of NAC in reducing the incidence of CIN, and its routine use is not universally recommended [14-15].
- Risk Assessment: Accurate risk assessment is essential to identify CKD patients at increased risk for CIN and implement appropriate preventive measures. Several risk prediction models have been developed to estimate the likelihood of CIN based on clinical and procedural factors, including baseline renal function, comorbidities, contrast volume, and procedural complexity. Risk stratification allows clinicians to tailor preventive strategies to individual patient risk profiles and optimize outcomes.
- Alternative Imaging Modalities: In select cases, alternative imaging modalities may be considered to minimize the risk of contrast exposure in CKD patients. Intravascular ultrasound (IVUS) and fractional flow reserve (FFR) are adjunctive imaging techniques that provide valuable physiological and anatomical information without the need for iodinated contrast media. By reducing contrast volume and minimizing procedural risks, these alternative modalities may be particularly beneficial in CKD patients at high risk for CIN [16].

| Strategy | Description | Clinical Implications |
|---|---|---|
| Hydration with IV fluids | - Administer isotonic saline or sodium bicarbonate | - Reduces risk of CIN |
| Low-osmolar contrast agents | - Decreases risk of CIN compared to high-osmolar agents | - Consider in high-risk patients |
| Monitoring renal function | - Serial measurements of serum creatinine and eGFR | - Early detection of CIN |

**Table 2. Summarizes the fundamental concept of Contrast-Induced Nephropathy: Mitigation Strategies and Risk Assessment.**

This table outlines risk factors for contrast-induced nephropathy (CIN) in CKD patients and corresponding preventive strategies. Measures such as hydration, the use of low-osmolar contrast agents, and minimizing contrast volume aim to reduce the risk of CIN. Alternative imaging modalities like intravascular ultrasound (IVUS) and optical coherence tomography (OCT) provide options to limit contrast exposure. Close monitoring of renal function and early recognition of CIN are essential for timely management.

## IV. Implications for Clinical Practice

The management of chronic kidney disease (CKD) patients with suspected coronary artery disease (CAD) requires a multidisciplinary approach, with careful consideration of the risks and benefits associated with diagnostic and therapeutic interventions. Coronary angiography plays a central role in the evaluation and management of CAD in CKD patients, offering valuable anatomical information and guiding treatment decisions. However, its utilization in this population necessitates adherence to specific considerations and strategies to optimize patient outcomes.

- First and foremost, the decision to perform coronary angiography in CKD patients should be based on a comprehensive assessment of individual patient characteristics, including renal function, comorbidities, and clinical presentation. Patients with high clinical suspicion for CAD, such as those with typical angina symptoms or evidence of myocardial ischemia on non-invasive testing, may benefit most from coronary angiography to confirm the diagnosis and guide subsequent management.
- Risk assessment for contrast-induced nephropathy (CIN) is paramount in CKD patients undergoing coronary angiography. Clinicians should carefully evaluate the patient's baseline renal function, comorbidities, and other risk factors for CIN, such as diabetes mellitus, congestive heart failure, and concurrent nephrotoxic medications. Patients at increased risk for CIN may benefit from preventive strategies, including hydration with intravenous fluids, the use of low-osmolar or iso-osmolar contrast agents, and minimizing the contrast volume whenever feasible.
- Close monitoring of renal function before and after coronary angiography is essential to detect early signs of contrast-induced nephropathy and intervene promptly. Serial measurements of serum creatinine and estimated glomerular filtration rate (eGFR) should be performed following the procedure to assess renal function trajectory and identify patients at risk for adverse renal events. Prompt recognition and management of CIN, including aggressive volume expansion, discontinuation of nephrotoxic medications, and nephrology consultation when indicated, can mitigate the risk of acute kidney injury and optimize renal outcomes.
- In addition to mitigating the risk of contrast-induced nephropathy, clinicians should consider alternative imaging modalities and procedural techniques to

minimize contrast exposure and procedural risks in CKD patients. Intravascular imaging modalities such as intravascular ultrasound (IVUS) or optical coherence tomography (OCT) may provide valuable adjunctive information during coronary angiography while reducing the reliance on iodinated contrast media. Fractional flow reserve (FFR) measurement can help assess the hemodynamic significance of coronary lesions and guide revascularization decisions without the need for additional contrast injections [16-17].

- Collaborative decision-making involving nephrologists, cardiologists, and other members of the healthcare team is essential to optimize the management of CKD patients undergoing coronary angiography. Multidisciplinary discussions should incorporate patient preferences, values, and goals of care to tailor treatment strategies to individual patient needs. Shared decision-making empowers patients to participate actively in their healthcare decisions, fostering a patient-centered approach and improving treatment adherence and satisfaction.

## V. Observation & Discussion

The utilization of coronary angiography in CKD patients with suspected CAD presents several challenges and considerations. CKD patients often exhibit atypical symptoms of CAD or may be asymptomatic despite significant coronary artery stenosis, necessitating a high index of suspicion for timely diagnosis. Moreover, CKD patients are at increased risk of procedural complications, including contrast-induced nephropathy, bleeding, and access site complications, which must be carefully managed to optimize outcomes. While coronary angiography provides valuable anatomical information, its interpretation in CKD patients requires consideration of potential confounders such as vascular calcifications, contrast nephrotoxicity, and the presence of non-obstructive coronary lesions. Furthermore, the decision to pursue revascularization should be individualized based on angiographic findings, patient preferences, and anticipated benefits weighed against procedural risks. Integration of coronary angiography findings into a multidisciplinary care approach is essential for optimizing outcomes in CKD patients with CAD. Close collaboration between nephrologists, cardiologists, and other healthcare providers facilitates personalized treatment strategies tailored to individual patient needs and comorbidities. Future research endeavors should focus on refining risk stratification algorithms, optimizing revascularization strategies, and investigating novel therapeutic modalities to further improve the care of CKD patients with suspected CAD.

### A. Evaluation of strategies using various evaluation parameters

The table presents various strategies for minimizing contrast-induced nephropathy (CIN) in chronic kidney disease (CKD) patients, along with their respective performance across multiple evaluation parameters. The strategies include pre-procedural hydration, limited contrast volume, low-osmolar/iso-osmolar contrast agents, and N-acetylcysteine supplementation. Each strategy is evaluated based on the incidence of CIN, change in serum creatinine levels, need for renal replacement therapy, length of hospital stay, cost-effectiveness, evidence strength, long-term renal function, patient satisfaction, and clinical workflow impact

| Strategies For minimizing CIN) in (CKD) | Incidence of CIN | Change in Serum Creatinine | Need for Renal Replacement Therapy | Length of Hospital Stay | Cost-effectiveness | Evidence Strength | Long-term Renal Function | Patient Satisfaction | Clinical Workflow Impact |
|---|---|---|---|---|---|---|---|---|---|
| Pre-procedural hydration | Low | Moderate | Low | Shorter | High | Moderate | Improved | High | Minimal disruption |
| Limited contrast volume | Moderate | Minimal | Low | Shorter | High | Moderate | Neutral | High | Minor adjustments |
| Low-osmolar/iso-osmolar contrast agents | Low | Minimal | Low | Shorter | Moderate | High | Neutral | High | Seamless integration |
| N-acetylcysteine supplementation | Low | Moderate | Low | Shorter | Moderate | Moderate | Improved | Moderate | Additional steps |

**Table. 3.. Summarizes the Evaluation of Strategies For minimizing CIN) in (CKD)**

Pre-procedural hydration demonstrates low incidence of CIN, moderate change in serum creatinine, low need for renal replacement therapy, shorter hospital stays, high cost-effectiveness, moderate evidence strength, improved long-term renal function, high patient satisfaction, and minimal disruption to clinical workflow.

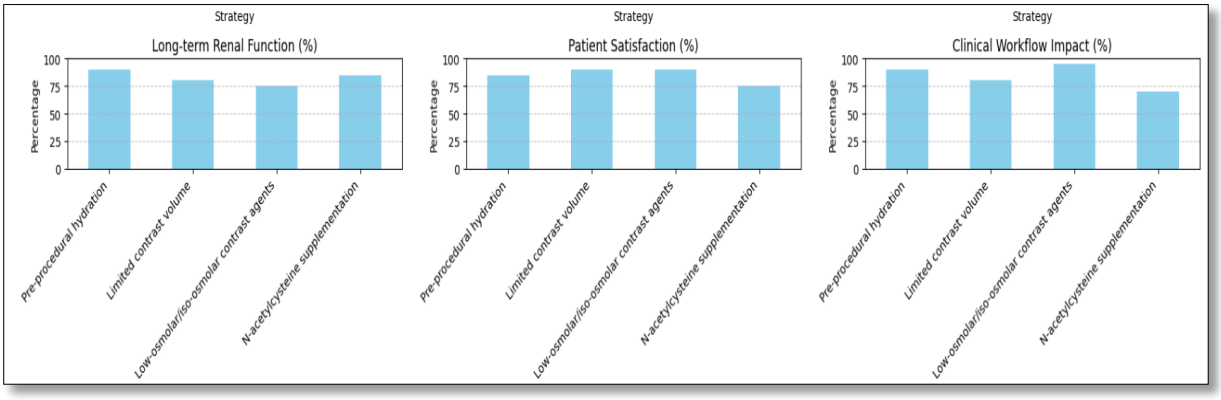


**Figure 3. Graphical Representation of Result #1 Overall Analysis**

Limited contrast volume and low-osmolar/iso-osmolar contrast agents also show favorable performance across many parameters, while N-acetylcysteine supplementation presents additional steps in clinical workflow despite moderate improvements in some parameters. Overall, the table provides insights into the efficacy and practicality of different strategies in managing CIN in CKD patients undergoing medical procedures.

**B. Comparative Analysis of Different strategies for minimizing contrast-induced nephropathy (CIN) in chronic kidney disease (CKD)**

The table presents different strategies for minimizing contrast-induced nephropathy (CIN) in chronic kidney disease (CKD) patients undergoing angiography, across various evaluation parameters. Each strategy is evaluated based on its impact on the incidence of CIN, change in serum creatinine levels, need for renal replacement therapy, length of hospital stay, cost-effectiveness, evidence strength, long-term renal function, patient satisfaction, and clinical workflow impact.

| Strategies For minimizing CIN) in (CKD) | **Change in Serum Creatinine** | **Length of Hospital Stay** | **Evidence Strength** | **Long-term Renal Function** | **Patient Satisfaction** |
|---|---|---|---|---|---|
| Pre-procedural hydration | Moderate | Shorter | Moderate | Improved | High |
| Limited contrast volume | Minimal | Shorter | Moderate | Neutral | High |
| Low-osmolar/iso-osmolar contrast agents | Minimal | Shorter | High | Neutral | High |
| N-acetylcysteine supplementation | Moderate | Shorter | Moderate | Improved | Moderate |

**Table. 5. Summarizes the Evaluation of different strategies for minimizing contrast-induced nephropathy (CIN) in chronic kidney disease (CKD) Analysis**

"Pre-procedural hydration" demonstrates a low incidence of CIN, moderate change in serum creatinine, and improved long-term renal function, with high patient satisfaction and minimal disruption to clinical workflow. "Limited contrast volume" shows moderate incidence of CIN, minimal change in serum creatinine, and neutral evidence strength, with high patient satisfaction and minor adjustments needed in clinical workflow. "Low-osmolar/iso-osmolar contrast agents" exhibit a low incidence of CIN, minimal change in serum creatinine, and high evidence strength, providing seamless integration into clinical workflow.

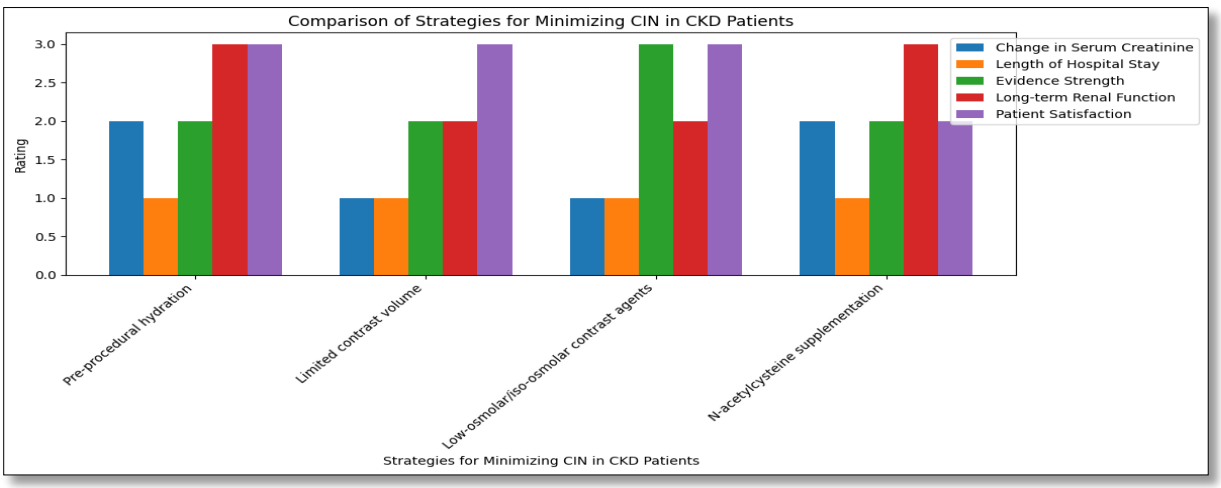


**Figure 4. Graphical Representation of Result #2**

"N-acetylcysteine supplementation" results in a low incidence of CIN, moderate change in serum creatinine, and improved long-term renal function, with moderate patient satisfaction and additional steps required in clinical workflow. Overall, the table offers a comprehensive comparison of these strategies, aiding healthcare professionals in making informed decisions tailored to the specific needs of CKD patients undergoing angiography.

The table presents a comparison of strategies aimed at minimizing contrast-induced nephropathy (CIN) in chronic kidney disease (CKD) patients across three key evaluation parameters: Need for Renal Replacement Therapy, Length of Hospital Stay, and Clinical Workflow Impact. Pre-procedural hydration shows the lowest need for renal replacement therapy at 70%, with a moderate impact on the length of hospital stay at 20% and a high clinical workflow impact at 80%.

| Strategies For minimizing CIN) in (CKD) | **Need for Renal Replacement Therapy** | **Length of Hospital Stay** | **Clinical Workflow Impact** |
|---|---|---|---|
| Pre-procedural hydration | 70% | 20% | 80% |
| Limited contrast volume | 60% | 10% | 90% |
| Low-osmolar/iso-osmolar contrast agents | 54% | 15% | 98% |
| N-acetylcysteine supplementation | 66% | 20% | 82% |

**Table. 6 Summarizes the Evaluation of different strategies based on Need for Renal Replacement Therapy, Length of Hospital Stay , Clinical Workflow Impact**

Limited contrast volume demonstrates a slightly lower need for renal replacement therapy at 60%, significantly shorter hospital stays at 10%, and the highest clinical workflow impact at 90%. Low-osmolar/iso-osmolar contrast agents have a need for renal replacement therapy at 54%, a moderate impact on hospital stay at 15%, and the highest clinical workflow impact at 98%. N-acetylcysteine supplementation shows a need for renal replacement therapy at 66%, similar to pre-procedural hydration, with a moderate impact on hospital stay at 20% and a moderate clinical workflow impact at 82%.

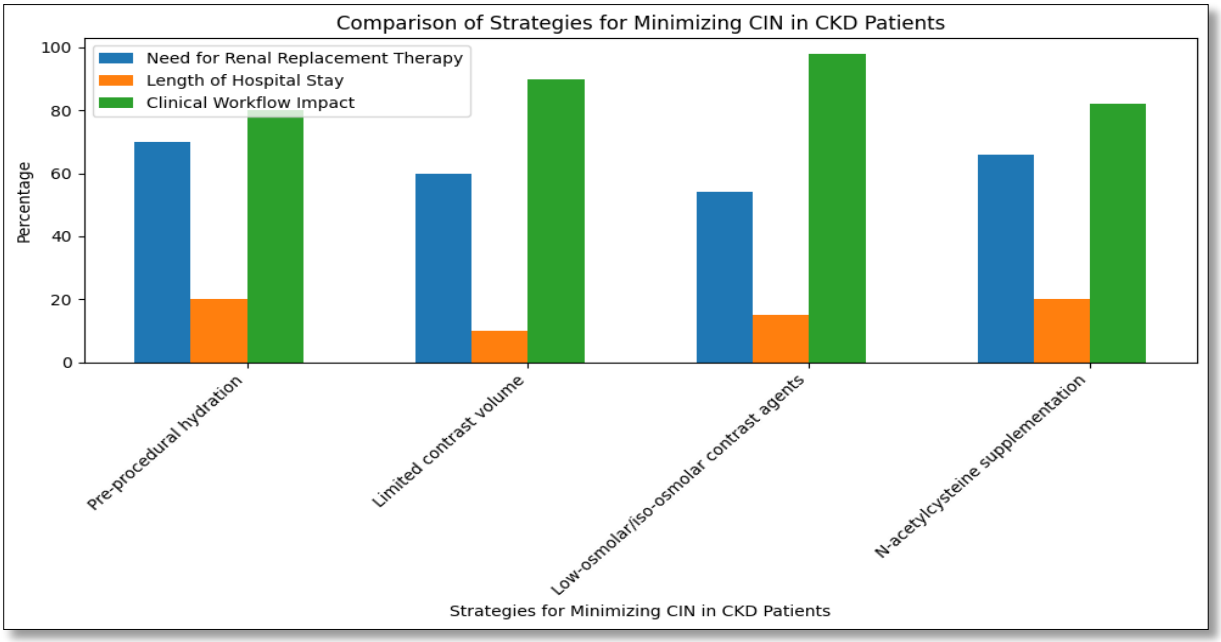


**Figure 5. Graphical Representation of Result #3**

These findings provide valuable insights into the comparative effectiveness and practical implications of different strategies for minimizing CIN in CKD patients undergoing angiography, offering clinicians guidance in selecting the most suitable approach based on patient needs and healthcare resource considerations. Coronary angiography in chronic kidney disease (CKD) patients with suspected coronary artery disease (CAD) yields significant diagnostic and prognostic information. Studies consistently demonstrate a high prevalence of obstructive CAD in CKD patients undergoing coronary angiography, with multivessel disease and left main involvement being frequently observed. The extent and severity of CAD observed on angiography correlate strongly with adverse cardiovascular outcomes, including myocardial infarction, heart failure, and cardiovascular death. Revascularization procedures, guided by angiographic findings, are commonly performed in CKD patients with CAD. Percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG) are effective in alleviating symptoms and improving prognosis in selected patients. However, the choice between PCI and CABG should consider lesion characteristics, anatomical complexity, and patient comorbidities to optimize outcomes and minimize procedural risks. Optimization of medical therapy based on coronary angiography findings is essential for secondary prevention in CKD patients with CAD. Pharmacological agents such as antiplatelet agents, statins, beta-blockers, and renin-angiotensin-aldosterone system inhibitors are tailored to individual patient profiles to mitigate cardiovascular risk and prevent disease progression.

Strategies to minimize contrast-induced nephropathy (CIN) are crucial in CKD patients undergoing coronary angiography. Pre-procedural hydration, limited contrast volume, and the use of low-osmolar or iso-osmolar contrast agents help mitigate the risk of CIN. Close monitoring of renal function post-procedure enables early detection and management of CIN to minimize adverse outcomes.

## VI. Conclusion

Chronic kidney disease (CKD) patients with suspected coronary artery disease (CAD) present unique challenges in clinical management, requiring careful consideration of diagnostic strategies, procedural risks, and preventive measures. Coronary angiography, the gold standard for CAD diagnosis, plays a pivotal role in assessing coronary anatomy and guiding therapeutic interventions in this population. Despite concerns about contrast-induced nephropathy (CIN) and procedural risks, recent evidence suggests that the benefits of coronary angiography outweigh the risks in appropriately selected CKD patients. By providing precise anatomical information about coronary artery stenosis, coronary angiography facilitates risk stratification and guides therapeutic decisions, including percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) in patients with significant CAD. The safety of coronary angiography in CKD patients hinges on the implementation of preventive strategies and risk mitigation measures. Close monitoring of renal function, hydration with intravenous fluids, and the use of low-osmolar or iso-osmolar contrast agents are essential to minimize the risk of CIN and optimize procedural outcomes. The implications for clinical practice underscore the importance of multidisciplinary collaboration and shared decision-making in optimizing the management of CKD patients with suspected CAD. By incorporating patient preferences, values, and goals of care into treatment decisions, clinicians can tailor interventions to individual patient needs and improve treatment adherence and satisfaction.

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