REVIEW ARTICLE

CONTENTS

Advancements in Preventing Post-Contrast Acute Kidney Injury in EVAR: Clinical Strategies and Future Directions

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ABSTRACT

Abdominal Aortic Aneurysm (AAA) represents a significant global health issue with a high risk of rupture, resulting in substantial mortality rates. Endovascular Aneurysm Repair (EVAR) has emerged as the preferred treatment method due to its minimally invasive nature. However, the procedure carries a risk of acute kidney injury (AKI), particularly post-contrast acute kidney injury (PC-AKI), which can adversely affect patient outcomes. This review examines the incidence, pathophysiology, and prevention strategies for PC-AKI in the context of EVAR. It synthesizes current research on the mechanisms underlying PC-AKI, such as renal vasoconstriction, oxidative stress, and tubular toxicity. The effectiveness of various preventive measures, including pre-procedural hydration, use of low-osmolality contrast agents, and alternative imaging techniques, is evaluated. Additionally, the review explores patient-specific risk factors and the potential of novel pharmacologic interventions. The incidence of PC-AKI in EVAR varies based on procedural complexity and patient-specific factors like preexisting renal insufficiency, diabetes, and hypertension. Preventive strategies such as intravenous hydration and the use of less nephrotoxic contrast agents have shown effectiveness. Advances in imaging technology and innovative pharmacologic interventions, including antioxidants and vasodilatory drugs, present promising approaches to reducing the risk of PC-AKI. Effective management of PC-AKI in EVAR necessitates a comprehensive and multifaceted approach that considers both procedural and patient-specific factors. Future research should aim to standardize diagnostic criteria, refine preventive strategies, and explore novel therapies. Enhanced understanding of PC-AKI pathophysiology and personalized preventive measures can improve patient safety and outcomes in EVAR procedures.

KEY WORDS: nephrotoxicity, acute kidney injury, abdominal aortic aneurysm, endovascular aneurysm repair, post-contrast acute kidney injury, preventive strategies

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INTRODUCTION

Abdominal Aortic Aneurysm (AAA) remains a pressing global health issue characterized by the abnormal dilation of the aorta, posing a significant risk of life-threatening rupture if left untreated [1]. The Global Burden of Disease (GBD) study in 2019 highlighted its severity, reporting approximately 170,000 deaths annually attributed to aortic aneurysms, underscoring the critical need for effective management strategies [2]. Endovascular Aneurysm Repair (EVAR) has emerged as the preferred treatment for AAA due to its minimally invasive nature, associated with reduced 30-day mortality, shorter hospital stays, and quicker recovery compared to traditional open surgical repair [3]. However, EVAR is not without its complications, notably including acute kidney injury (AKI), which significantly impacts both short-term outcomes and long-term renal function [4].

AIM

This review examines the incidence, pathophysiology, and prevention strategies for PC-AKI in the context of EVAR. It synthesizes current research on the mechanisms underlying PC-AKI, such as renal vasoconstriction, oxidative stress, and tubular toxicity. The effectiveness of various preventive measures, including pre-procedural hydration, use of low-osmolality contrast agents, and alternative imaging techniques, is evaluated. Additionally, the review explores patient-specific risk factors and the potential of novel pharmacologic interventions.

MATERIALS AND METHODS

The review was performed in the period from 01.2024 to .07.2024. The materials for the literature review were publications on research from January 2001 to July

2024. Relevant articles were identified by two authors (BA, PK) searching PubMed's, Scopus, Web of Science, Embase databases, and Cochrane Library using advanced search and keywords: [[PC-AKI] OR [AKI]] AND [EVAR]].

REVIEW AND DISCUSSION

ACUTE KIDNEY INJURY (AKI) AND EVAR

Acute kidney injury following AAA repair, whether through EVAR or open surgical approaches, presents a substantial clinical challenge. The incidence varies widely and is influenced by procedural complexity, the type of repair performed, and patient-specific risk factors such as preexisting renal insufficiency, diabetes mellitus, hypertension, and overall cardiovascular health.[5,6] Studies indicate that up to 20% of patients undergoing elective EVAR may experience AKI, which has been linked to increased morbidity, prolonged hospital stays, and higher mortality rates.[7,8] Effective management of AKI in this context necessitates rigorous perioperative surveillance and optimization of renal function to attenuate adverse outcomes [9].

POST CONTRAST ACUTE KIDNEY INJURY (PC-AKI) IN EVAR

Iodinated contrast media are indispensable for accurate imaging during EVAR procedures but carry a significant risk of nephrotoxicity, commonly referred to as post-contrast acute kidney injury (PC-AKI) or formerly termed contrast-induced nephropathy (CIN). [10] The exact pathophysiology of PC-AKI involves multifactorial mechanisms, including renal vasoconstriction, oxidative stress, and direct tubular toxicity. The reported incidence of PC-AKI varies widely across studies, influenced by factors such as the volume and type of contrast used, procedural characteristics, and patient-specific factors like baseline renal function and comorbidities [11]. The lack of standardized diagnostic criteria for PC-AKI contributes to inconsistencies in its diagnosis and management across clinical settings [12].

CHALLENGES AND CURRENT UNDERSTANDING

Current research underscores the intricate interplay between contrast media properties, procedural factors, and patient susceptibility in the development of PC-AKI [11]. Despite advancements in preventive strategies, including intravenous hydration and the use of less nephrotoxic contrast agents, uncertainties persist regarding the precise impact of contrast media on renal function and the optimal management of PC-AKI in EVAR patients. The variability in study designs and diagnostic criteria further complicates efforts to establish definitive guidelines for the prevention and management of PC-AKI in this vulnerable patient population [10, 13].

PATHOPHYSIOLOGICAL INSIGHTS INTO PC-AKI

The pathophysiology of PC-AKI in EVAR involves complex mechanisms contributing to renal injury. Iodinated contrast media induce renal vasoconstriction through endothelin-mediated pathways, leading to decreased renal blood flow and subsequent ischemia. Additionally, contrast agents generate reactive oxygen species (ROS) within renal tubular cells, promoting oxidative stress and cellular damage. Direct tubular toxicity results from the accumulation of contrast media within renal tubules, disrupting cellular integrity and function. These multifaceted mechanisms underscore the complexity of PC-AKI pathophysiology and highlight the need for targeted preventive strategies [14].

PREVENTIVE STRATEGIES AND CLINICAL MANAGEMENT

Efforts to mitigate PC-AKI risk in EVAR patients focus on several key strategies. Pre-procedural hydration remains a cornerstone intervention, aiming to maintain adequate renal perfusion and enhance contrast media excretion. Intravenous administration of isotonic saline solutions has shown efficacy in reducing PC-AKI incidence by optimizing intravascular volume and promoting renal blood flow [15]. Additionally, the selection of low-osmolality or iso-osmolality contrast agents, which exhibit reduced nephrotoxicity profiles compared to high-osmolality agents, represents another preventive approach [16]. Clinical decision-making regarding contrast media volume and type is crucial, with current guidelines recommending the use of minimal contrast volumes necessary for diagnostic accuracy and procedural success. Tailoring contrast media protocols to patient-specific factors, such as baseline renal function and comorbidities, further optimizes PC-AKI prevention [17]. Advances in imaging technology, including the development of non-contrast imaging modalities and the utilization of magnetic resonance angiography (MRA), provide alternative strategies to minimize contrast exposure in high-risk patients [18].

FUTURE DIRECTIONS IN RESEARCH

Future research endeavours in PC-AKI associated with EVAR should focus on advancing diagnostic criteria and refining preventive strategies. Prospective multicenter studies incorporating standardized definitions and robust outcome measures will facilitate a comprehensive understanding of PC-AKI epidemiology and risk factors across diverse patient populations [19]. Personalized preventive measures can be enabled by biomarker research's potential to identify early predictors of renal injury and stratify PC-AKI risk. Novel treatment approaches, such as antioxidant therapy and vasodilatory drugs, that target certain pathways implicated in PC-AKI development should be investigated in order to minimize renal damage and improve clinical outcomes [20].

DETAILED ANALYSIS OF PROCEDURAL FACTORS

One of the primary procedural factors influencing PC-AKI incidence is the volume of contrast media used during EVAR. While minimal contrast volume is recommended, achieving optimal imaging quality and procedural success often requires a delicate balance. Studies have shown that high volumes of contrast media correlate with a higher risk of renal impairment, necessitating a strategic approach to contrast administration [21]. Techniques such as contrast dilution, selective angiography, and the use of adjunctive imaging modalities can help minimize contrast volume without compromising procedural efficacy [16,17]. Another critical procedural consideration is the type of contrast media employed. Low-osmolality and iso-osmolality contrast agents have been shown to have a reduced nephrotoxic profile compared to high-osmolality agents. This difference is attributed to their lower propensity to cause renal vasoconstriction and tubular toxicity. The selection of contrast media should be tailored to individual patient risk profiles, considering factors such as preexisting renal insufficiency and comorbidities [16].

PATIENT-SPECIFIC RISK FACTORS AND THEIR MANAGEMENT

Following EVAR, patient-specific variables are crucial in the development of PC-AKI. One known risk factor is preexisting renal insufficiency; patients with impaired renal function at baseline are especially vulnerable to further renal injury from contrast exposure. Pre-procedural renal optimizing techniques, including as hydration and medication therapies, are essential in these situations [22]. Diabetes mellitus and hypertension are examples of comorbidities that increase the risk of PC-AKI by causing underlying renal vascular and tubular damage. In the perioperative phase, strict blood pressure and glucose management can help reduce these risks. Additionally, patient-specific risk stratification algorithms that take into account variables like age, renal function, and comorbidities might help identify patients who are at a higher risk and adjust preventative measures accordingly [23]. Recently, HALP score calculated with the formula "hemoglobin × albumin × lymphocyte count/platelet count was reported to be used to predict PC-AKI and medium-long-term mortality in EVAR patients [24].

INNOVATIVE IMAGING MODALITIES AND TECHNIQUES

Advancements in imaging technology offer promising alternatives to traditional contrast-based methods. Non-contrast imaging techniques, such as duplex ultrasound and magnetic resonance angiography (MRA), provide valuable diagnostic information without the nephrotoxic risk associated with iodinated contrast media. These modalities can be particularly beneficial in high-risk patients, reducing the overall burden of contrast exposure [25]. Furthermore, improvements in intraoperative imaging, including as the use of intraoperative ultrasonography and carbon dioxide angiography, have demonstrated the potential to reduce the need for contrast material while preserving procedural accuracy. While not always applicable, these strategies are useful for lowering the risk of PC-AKI.[26]

PHARMACOLOGIC INTERVENTIONS AND NOVEL THERAPIES

Research on pharmacologic treatments to prevent PC-AKI has been conducted extensively. Some agents have demonstrated varying degrees of efficacy in mitigating contrast-induced kidney impairment, including bicarbonate, statins, and N-acetylcysteine. Although these medicines' antioxidative and vasodilatory qualities theoretically help to mitigate kidney damage, the outcomes of varied clinical trials have made routine use of them contentious [27, 28]. Prospective treatments aimed at particular pathophysiological pathways connected to PC-AKI appear promising. Reactive oxygen species (ROS) produced by contrast media can be neutralized by antioxidant therapy, which may lessen oxidative stress and tubular injury [29]. Another possible treatment option is to use vasodilatory drugs to offset the renal vasoconstriction caused by contrast. Those drugs are: prostaglandins, calcium channel blockers, theophylline. Prostaglandins are naturally occurring vasodilators that can improve renal blood flow. Pros-

taglandin analogues, such as misoprostol, have been investigated for their potential to prevent PC-AKI by counteracting the vasoconstrictive effects of contrast media [30, 31]. Calcium channel blockers, such as diltiazem, can dilate blood vessels and potentially improve renal perfusion. However, their role in preventing PC-AKI has not been well-established [32]. Theophylline, a methylxanthine derivative, has vasodilatory properties and can increase renal blood flow. Some studies have indicated that theophylline may help prevent PC-AKI, but like other agents, its use is not universally endorsed due to inconsistent evidence [33].

CONCLUSIONS

In order to fully address the pressing problem of PC-AKI within the framework of EVAR, more research must be done on the various factors that contribute to this illness as well as new approaches to care and prevention. A complicated web requiring a nuanced approach to patient care is created by the combination of procedural variables, patient-specific factors, and the inherent nephrotoxicity of contrast media.

The prevention and management of PC-AKI in the context of EVAR require a comprehensive and multifaceted approach. Procedural factors, patient-specific risk profiles, and the inherent nephrotoxicity of contrast media must all be carefully considered to optimize renal outcomes. Advancements in imaging technology, innovative pharmacologic interventions, and a deeper understanding of pathophysiological mechanisms will continue to shape the landscape of PC-AKI prevention and management. Through continued research and the implementation of evidence-based strategies, clinicians can enhance patient safety, reduce renal complications, and improve overall outcomes in EVAR procedures.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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