JOJ
Urology & Nephrology
ISSN: 2476-0552

Juniper Publishers
key to the Researchers

Review Article
Volume 7 Issue 4 - August 2022
DOI: 10.19080/JOJUN.2022.07.555720

JOJ uro & nephron

Contrast-Induced Acute Kidney Injury: Assessing The Effects of Pharmacological Preventive Measures

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Submission: August 05, 2022; **Published:** August 17, 2022

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Abstract

Contrast-induced acute kidney injury is a well-recognized nosocomial entity that usually arises 3 - 5 days after IV contrast administration. CI-AKI is characterized by an increase in serum creatinine, blood urea nitrogen, or a decrease in the glomerular filtration rate due to iodine-induced oxidative damage to vascular endothelial cells and renal tubular epithelium. Despite the advances in understanding the pathophysiology that has been achieved, there is still no complete and adequate prevention measure for this condition. AKI continues to be one of the most severe adverse effects related to the use of intravascular contrast agents. The condition can range from mild and asymptomatic serum creatinine elevation to acute renal failure with a hemodynamic compromise that could culminate in chronic kidney disease or patient dismissal. CI-AKI is challenging to predict and tends to be more prevalent in patients with preexisting comorbid conditions such as kidney disease, organ failure, diabetic nephropathy, and advanced age.

Prophylactic hydration with normal saline is currently the most studied and accepted preventive and therapeutic measure. However, using sodium bicarbonate, N-acetyl cysteine, prostaglandins, high-dose statins, trimetazidine, probucol, tocopherol, hemodialysis, and hemofiltration have also been studied. The effects and utility of these pharmacological measures are discussed over the scope of this review. The administration of Sodium Bicarbonate is not superior to NSS and is associated with severe adverse effects such as hypotension, which could enhance kidney injury. NAC could provide renal protection, but the protocols required for its administration are more complex than those of NSS, which makes it less suitable for clinical practice. Similarly, statins might have a potential benefit, but their limited use in specific populations generates considerable limitations. In patients with heart disease, the administration of TMZ, alprostadil, or probucol could provide nephroprotection. However, data is limited, and results from available studies remain inconclusive. Prevention and management of CI-AKI must be individualized according to the patient's previous conditions and other essential factors, and clinical criteria play an important role in this process..

Keywords: CI-AKI; Contrast-Induced Acute Kidney Injury; Pharmacological Preventive Measures

Abbreviations: CI-AKI: Contrast-Induced Acute Kidney Injury; BUN: Blood urea nitrogen; eGFR: estimated Glomerular Filtration; ROS: Reactive Oxygen Species; NO: Nitric Oxide; CECT: Contrast-Enhanced Computed Tomography; NSS: Normal Saline Solution; NAC: N-acetyl cysteine; PG: Prostaglandins; PGE1: Prostaglandin E1; HD: Hemodialysis; COX: Cyclooxygenase; PGT: prostaglandin transporter; PGR: Prostaglandin Receptor; cAMP: Cyclic Adenosine Monophosphate; FDA: Food and Drug Administration; HMG-CoA: 3-hydroxy-3-methylglutaryl-coenzyme A; KAT: 3-ketoacyl-CoA thiolase; CHF: Congestive Heart Failure; DNA: deoxyribonucleic acid; CPI: Coronary Percutaneous Intervention; RRT: Renal replacement therapy; CRRT: Continuous renal replacement therapy; IRRT: Intermittent Renal Replacement Therapy; ICU: Intensive Care Unit; CVVH: Continuous Venovenous Hemofiltration.

Introduction

Contrast-induced acute kidney injury (CI- AKI) is defined as an increase in serum creatinine, blood urea nitrogen (BUN), or a decrease in estimated glomerular filtration rate (eGFR) within 3 to 5 days following administration of iodinated contrast material [1,2]. Endothelial cells experience significant cell damage and apoptosis when exposed to contrast media. Free-iodine is released from the contrast during the procedure and provides a direct cytotoxic effect on the surrounding endothelial cells. In addition, contrast media have a detrimental effect on the tubules of the nephron. Cell damage on both fronts leads to oxidative stress and the formation of free radicals. The generation of free radicals and reactive oxygen species (ROS) consumes nitric oxide (NO) and consequently prevents the protective effect of NO as a vasodilator. The sustained vasoconstriction decreases the glomerular filtration rate, causes medullary hypoperfusion, and increases blood viscosity through the nephron. Medullary hypoperfusion impedes oxygen delivery, resulting in ischemic injury to the tubules, which sustains the vicious cycle [1].

The frequency of contrast-induced acute kidney injury has been reported to range from 2.1% to 14.8%. Patients with CI-AKI requiring dialysis have higher rates (around 34%) of in-hospital mortality and postdischarge adverse events compared with patients without CI-AKI [1,3]. There are several risk factors for CI-AKI, including pre-existing chronic kidney disease, diabetes mellitus, diabetic nephropathy, congestive heart failure, older age, simultaneous use of nephrotoxic drugs, multiple myeloma, dehydration, use of contrast-enhanced computed tomography (CECT) and intravenous contrast media administration. Some adverse effects of contrast media are nausea, vomiting, thyroid dysfunction, and hypersensitivity reactions (urticaria, laryngeal edema, bronchospasm, hypotension, and anaphylactic shock) [4]. The diagnosis of CI-AKI is made by renal evaluation: an increase in serum creatinine by 0.3 mg/dL or increased creatinine to ⩾1.5 times baseline within 3 to 5 days after contrast exposure [1]. Several pharmacological options can prevent CI-AKI. The most frequently used: normal saline solution (NSS), sodium bicarbonate, N-acetyl cysteine (NAC), prostaglandins (PG), statins, trimetazidine (TMZ), probucol, tocopherol, hemodialysis (HD), and hemofiltration. In this review article, we aim to identify when these medications should be used, taking into account their adverse effects, and the symptoms and comorbidities of the patient that may worsen the disease process.

Normal Saline

Patients with normal renal function and no established risk factors for contrast nephropathy generally do not require prophylactic flares prior to the procedure. Another type of diagnostic imaging should be considered in the case of a glomerular filtration rate less than 50 ml/min/1.73 m^2 [5,6]. Hydration has been the most used prophylactic strategy in the prevention of contrast nephropathy. This property is probably due to its ability to dilute high concentrations of toxic substances at the tubular level, avoiding prolonged contact with kidney tissue and ensuring adequate blood flow at the medullary level. Many studies support the beneficial prophylactic effects of hydration [6,7]. A lower increase in creatinine has been observed in patients who received NSS 24 hours before and 12 hours after the procedure compared to those who received oral hydration (3.7% vs. 34.6%) [6].

Bader et al. compared the use of intravenous hydration with NSS for 12 hours prior to the contrast study vs. oral hydration plus a simple intravenous bolus of NSS. Results demonstrated a smaller decline in the glomerular filtration rate in those who received continuous intravenous hydration (-18.3 vs. -34.6 ml/min/1.73 m^2 body surface) [7,8].

These data highlight the importance of the hydration route (preferably intravenous), the mode of administration (continuous infusion), and the type of fluid to be used (0.9% NSS). Current evidence supports, with the greatest statistical significance, the use of IV infusion of 0.9% NSS at 1cc/kg/hour, 12 hours before and 12 hours after the application of contrast medium, with strict monitoring of fluid balance [6,8]. For the time being, we can conclude that the most significant advantage of NSS is demonstrated in patients with normal renal function and a low risk of nephropathy. However, this superiority is not evident in patients with moderate to severe renal function impairment.

Sodium Bicarbonate

In order to regulate sudden changes in blood pH, sodium bicarbonate is produced to neutralize acids by absorbing them. Due to these characteristics, sodium bicarbonate has been implemented as a nephroprotective agent, not only because it acts as an expander of extracellular volume but also because it decreases the generation of free radicals induced by the use of a contrast agent since membrane apoptosis occurs when kinases are activated. Sodium bicarbonate is considered a second-line medication for renal protection since the most frequent first-line is intravenous hydration. However, some meta-analyses have shown more promising results in patients undergoing coronary angiography. Nephroprotection with sodium bicarbonate can be achieved by diluting 1.4mg in 5% dextrose and administering it intravenously at 3ml/kg/hr one hour before the procedure and three hours before contrast is administered.

During a prospective study between 2002 and 2003 where the use of NSS and sodium bicarbonate were compared, it was concluded that bicarbonate was more effective than NSS in preventing CI-AKI [9,10]. However, the population sample did not allow the study to be conclusive. Zapata et al. systematic review and meta-analysis determined that the administration of sodium bicarbonate is not superior to NSS in the prevention of contrast-induced nephropathies, even in combination with NAC [11].

When choosing sodium bicarbonate therapy, adequate pulmonary ventilation should be considered to ensure excretion.

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In the case of metabolic and respiratory alkalosis with primary CO_2 retention, sodium bicarbonate therapy is contraindicated [12]. Caution should also be exercised in administering this drug in patients under sedation and analgesia due to its hypotensive effect by causing peripheral vasodilation. At the time of administration, care must be taken with extravasation due to necrosis and desquamation at the puncture site [12].

N-Acetyl Cysteine

NAC reduces kidney damage by eliminating oxygen radicals. The last is generated as a result of toxic damage to the renal tubular cells. NAC is an antioxidant agent that may have direct vasodilatory effects on the kidney through an increase in the biological effects of nitric oxide [13]. NAC reduced thiol is a precursor to L-cysteine and can serve as a precursor to glutathione, which improves the vasomotor endothelium in the peripheral and coronary circulation. This substance is a potent antioxidant scavenging oxygen-dependent free radicals [13]. For the prevention of CI-AKI, several studies have proposed a single dose of 600 mg orally 48 hours before the procedure in combination with NSS hydration at 1 ml/kg/h 12 hours before and 12 hours after the procedure. For patients requiring high volumes of contrast, the administration of higher doses of NAC (two doses of 1200 mg or one dose of 2000 mg) has proven to be effective in reducing the incidence of nephropathy [13,14].

Two studies reported that hydration alone before the procedure reduced the risk of nephropathy from using a contrast medium by 56% in patients with kidney failure compared to NAC plus hydration [14,6]. A hydration issue may arise for patients undergoing urgent contrast-enhanced imaging since they cannot comply with the complete hydration protocol [14]. In these patients, the critical benefit of using NAC has been verified to significantly reduce rates of acute kidney injury [14]. In addition, NAC has been shown to be effective in preventing contrast-induced nephropathy in patients with non-terminal chronic renal failure, with no significant effect on clinical outcomes of greatest interest (need for dialysis, mortality, and length of hospital stay) [6,15].

Prostaglandins: Alprostadil

Prostaglandins (PGs) are a group of endogenous compounds produced by the fatty acid arachidonic acid. Initially, arachidonic acid is created when the enzyme phospholipase A2 cleaves the lipid diacylglycerol into the molecule arachidonic acid. Cyclooxygenase (COX) enzymes then produce PGs from arachidonic acid via sequential oxidation of each compound [16]. The COX-1 enzyme produces basal amounts of PGs production. PGs are highly lipophilic molecules that enter cells via a special prostaglandin transporter (PGT), binding to prostaglandin receptors (PGR) to exert their effects [16]. There are nine known PGRs in the body on which PG exerts its effects [17]. PGs cause vasodilation or vasoconstriction in vascular smooth muscle cells, which activate or inhibit platelet aggregation, induce labor, regulate hormones, and decrease intraocular pressure. PGs are essential lipid mediators in numerous physiological and pathophysiological processes in the kidney. Under physiological conditions, PGs exert essential functions in regulating renal hemodynamics, renin release, and water and salt balance [17].

Alprostadil is a synthetic analog of prostaglandin E1 (PGE1). It binds to the G proteins coupled to PGE1 receptors on the surface of smooth muscle cells activating cyclic adenosine monophosphate (cAMP) pathways [16]. Alprostadil dilates the blood vessels, inhibits platelet aggregation, and improves microcirculation. Therefore, it is commonly used to treat limb ulcers caused by chronic arterial occlusion, limb pain at rest caused by impaired microvascular circulation, cardiovascular and cerebrovascular microcirculation disorders, and as anticoagulation therapy after organ transplantation. Many clinicians utilize alprostadil in the treatment of hypertensive nephropathy [18].

Patients with CI-AKI have decreased PG levels, causing a shift in physiologic vasoconstriction/vasodilatation balance. Therefore, it is believed that prophylactic administration of PGE1 might be beneficial in reducing incidences of CI-AKI in patients having cardiac angiography or percutaneous coronary intervention with intravascular contrast [19]. Geng et al. systematic reviews and meta-analysis (PRISMA) demonstrated that periprocedural PGE1 decreased the incidence of CI-AKI and was associated with lower postprocedure CysC levels but not with lower Scr levels at 48 hours after the procedure. However, PGE-1s have a significant side effects profile, with the most common adverse reactions being fever, edema, diarrhea, bradycardia, disseminated intravascular coagulation, flushing, hypotension, tachycardia, urethral burning, ventricular fibrillation, prolonged erection, penile fibrosis, seizure and sepsis, cerebral hemorrhage, lethargy, thrombocytopenia and second-degree arterial block [20]. Contraindications for using PGE-1s include sickle cell disease or trait, multiple myeloma, leukemia, polycythemia vera, and thrombocythemia, as these conditions are known to precipitate priapism and Peyronie disease of the penis (as alprostadil is known to cause penile fibrosis and may worsen the condition). The FDA approved PGE-1 in 1981 for use in infants with congenital heart disease that required maintenance of ductal patency until palliative, or corrective surgery could be performed [21]. Since its approval, it has been used for various conditions, including erectile dysfunction, critical limb ischemia, and contrast-induced nephropathy.

High Dose Statins

Statins, also known as 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase inhibitors and one of the most distinguished pharmacological treatments for cardiovascular disease, are also being used for the prevention of CI-AKI [22-25]. Although the exact mechanism of action by which statins reduce the risk of CI-AKI is unknown, it may be due to their pleiotropic effects. Such effects include anti-inflammation and antioxidant

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effects, which inhibit renal hypoperfusion by suppressing endothelin-1 and angiotensin, enhancing vascular endothelial function by reducing the release of proinflammatory cytokines, and halting the liberation of free oxygen radicals [22-25]. These pleiotropic effects have mainly been observed with atorvastatin and rosuvastatin and are dose-dependent [22,23]. At high doses, both atorvastatin and rosuvastatin were more effective than the standard dose, placebo, and other statins [23]. However, only rosuvastatin was effective even at the standard dose [23]. While atorvastatin has been shown to be safe in patients with renal impairment, rosuvastatin can be safely used in patients with liver impairment [26].

Multiple studies showed that short-term statin treatment before contrast media exposure could successfully prevent CI-AKI. The most significant benefit has been seen in patients with a high risk of developing CI-AKI, such as chronic kidney disease, diabetes, advanced age, and cardiovascular disease [22-24]. In addition, some studies reported that pretreatment with statin decreased the incidence of CI-AKI in patients with renal impairment [25] and the risk of dialysis [23]. While the most common adverse effect is myalgia, less common adverse effects are shortness of breath, interstitial lung disease, increased serum transaminases, irritability, aggression, peripheral neuropathy, insomnia, sexual dysfunction, gynecomastia, oligospermia, hematuria, and albuminuria [26,27]. Although very rare, the most severe adverse effect is rhabdomyolysis, which can lead to acute renal failure due to myoglobinuria [26,27]. Statins are contraindicated in patients with acute liver failure, decompensated cirrhosis, and hypersensitivity to the medication [26,27]. Additionally, they should be avoided during pregnancy, as they were considered category X by the previous FDA pregnancy classification and should not be used while breastfeeding [26,27]. Despite the adverse effects, statins are a safe and effective pharmacological option for preventing CI-AKI.

Trimetazidine

Trimetazidine (TMZ) is proposed to modulate mitochondrial metabolism by blocking the long-chain 3-ketoacyl-CoA thiolase (KAT), a key enzyme in the β-oxidation of fatty acids. This blockade is thought to shift the mitochondrial substrate utilization toward glycolysis, which requires 10% to 15% less oxygen than fatty acid oxidation to yield the same energy [28]. Partial inhibition of fatty acid oxidation can potentially prevent the intracellular accumulation of lactate and protons, which are associated with impaired contraction–relaxation coupling in ischemic myocytes. The most documented effect of TMZ has been in stable coronary artery disease, hypertrophic cardiomyopathy, and diabetic and ischemic congestive heart failure (CHF) [28,29]. Administration of TMZ in a dose of 35mg twice daily orally in conjunction with standard early NSS hydration is an effective method to prevent or reduce the incidence of contrast-induced renal dysfunction following the administration of contrast media during coronary angiography procedures in patients with mild-moderate basal renal insufficiency [30,31].

TMZ has a significant side effects profile, with the most common adverse reactions being nausea, vomiting, fatigue, dizziness, and myalgia. In addition, the medicament can induce or increase parkinsonian symptoms: extrapyramidal rigidity, bradykinesia, and tremor [28]. The mechanism responsible for these reactions is not known. However, the presence of a piperazine nucleus in TMZ suggests that a blockade of central D2 dopamine receptors is involved. Are contraindicated in Parkinson's disease, parkinsonian symptoms, restless leg syndrome, tremors, and other related movement disorders. It is also contraindicated in lactation and severe renal impairment [28]. The FDA has not approved TMZ medicament for use in the United States.

Probucol

Probucol is a lipid-lowering drug with strong anti-lipid peroxidation and anti-inflammatory properties. It reduces endogenous nitric oxide synthase inhibitor concentration, improving the renovascular endothelial function. Additionally, it increases the synthesis of prostacyclins, suppresses the expression of various adhesion molecules, and helps the proliferation of endothelial cells preventing their apoptosis due to oxidative injury [32,33]. Probucol is often used in clinical practice to prevent and treat atherosclerosis and diabetic nephropathy [34]. In addition, some studies have shown that probucol can be used as a prophylactic in developing contrast-induced acute kidney injury. Oxidative stress and inflammation play an essential role in the pathogenesis of CI-AKI. The antioxidative stress and anti-inflammatory effects of probucol may help to prevent the occurrence of CI-AKI in patients greater than 18 years with coronary heart disease undergoing coronary percutaneous intervention (CPI) [32]. Probucol can prevent the occurrence of CI-AKI after coronary intervention in patients with chronic renal failure, reducing its incidence from 15% to 8% [33]. The doses are 500 mg twice daily, one day before and three days after operation [32,34]. The most frequent adverse effects include abdominal cramps, bloating, diarrhea, nausea, and vomiting [33]. Whether probucol can effectively reduce the incidence of CI-AKI requires further study in a large sample, multicenter randomized controlled trials [32-34].

Tocopherol (Vitamin E)

Tocopherol is a lipid-soluble, non-enzymatic antioxidant that protects tissues and cells from free radical attack by acting as a cell membrane stabilizer and maintaining cell bioactivity [35,36]. Because of its potent antioxidant and anti-inflammatory properties, Tocopherol has been studied to prevent chronic diseases associated with oxidative stress and inflammation due to its ability to bind to ROS. These substances play a crucial role in CI-AKI as they might cause extensive damage to DNA, proteins, and carbohydrates [35]. Patients undergoing computed

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tomography and cardiac catheterization using Iopromine and Iodixanol receive variations in tocopherol regimens (oral or intravenous, starting five days before contrast administration of 12 hours before, a total dose of tocopherol of 1,000 mg or 2,800 mg). Intravenous hydration at a rate of 1 mL/kg/hr for 12 hours before and after procedures, in addition to tocopherol or placebo, reduced the risk of CI-AKI by 62%, and SCr increased after contrast administration compared with hydration alone [35]. However, changes in GFR after contrast administration were not significantly different between the vitamin E plus hydration and hydration alone. Therefore, the use of vitamin E is reasonable in patients with pre-existing renal impairment. The most significant prophylactic effect of α-tocopherol was observed in the subgroups of patients with diabetes mellitus, hypertension, patients aged 55 years or older, male gender, anemic patients, and CI-AKI risk score <10 [37]. Tocopherol's common adverse effects include nausea, vomiting, and abdominal discomfort, but no serious adverse effects were reported [35].

Hemodialysis

Hemodialysis is one of the extracorporeal mechanisms that has been considered to prevent CI-AKI due to its ability to reduce the concentration of contrast media. This mechanism removes contrast media by considering the dialysis time, flow, membrane surface area, molecular size of the contrast medium, and transmembrane pressure. For this reason, hemodialysis is potentially beneficial for removing contrast media in patients who are already on chronic hemodialysis or are at high risk for contrast-induced nephropathy [38]. Contributing factors that increase the risk of developing CI-AKI include low kidney function and volume depletion and procedural factors such as higher osmolality, higher volume, and multiple administrations of contrast media [39]. While some patients may have higher risk factors than others, it is crucial to note that hemodialysis has not demonstrated significant results in preventing CI-AKI in patients with normal GFR and few risk factors [4]. Moreover, it is pertinent to note the limitations of the current literature regarding the efficacy of hemodialysis for the prevention of CI-AKI since many studies have generally excluded patients with eGFR < 30 mL/min/1.73 m^2 [39]. However, hemodialysis has not been demonstrated to have a benefit for the prevention of CI-AKI, even in patients undergoing maintenance hemodialysis. Administration of iodinated contrast media does not require a schedule change for patients with maintenance hemodialysis or residual function [40].

Hemofiltration

Renal replacement therapy (RRT) is a series of blood purification techniques that enclose the inherent principles of kidney function support for achieving solute and fluid homeostasis continuously and are intended to be applied for 24 hours or longer. RRT Includes hemodialysis, peritoneal dialysis, hemofiltration, and hemodiafiltration. These techniques can be continuous or intermittent and can use the arteriovenous route (blood leaves from an artery and returns via a vein) or the venovenous route (blood leaves from a vein and returns via a vein) [41]. The last results in two major types and several subtypes of RRT: 1. Continuous renal replacement therapy (CRRT) 2. Intermittent renal replacement therapy (IRRT). CRRT is considered a prominent form of dialysis in the intensive care unit (ICU) due to its accurate volume control, constant acid-base balance, electrolyte correction, and clearance of uremic toxins. CRRT is based on four main physiologic principles: diffusion, ultrafiltration, convection, and adsorption. Continuous venovenous hemofiltration (CVVH) specifically uses convection as a mechanism of solute transport. It requires a substitution fluid to replace part or all removed fluid to keep volume homeostasis. The ultrafiltrate passes through the membrane driven by a transmembrane pressure gradient. It imitates the functioning of the glomerular system. In CVVH, the substitution fluid allows for correcting metabolic acidosis and electrolyte disturbances [42]. CRRT is indicated in hemodynamic instability or shock, diuretic-resistant fluid overload, severe metabolic acidosis (pH <7.2), and refractory hyperkalemia (K+ >6.5).

Continuous hemofiltration has been highly considered in preventing drug toxicity and contrast-induced acute kidney injury. However, this depends on various factors such as the severity of the kidney injury, the timing of initiation, dose, session length, standards for monitoring, procedures to be performed on the patient, and exposure to other nephrotoxins. For example, in a population including patients with Acute Coronary Syndrome with severe chronic renal failure undergoing coronary angiographic procedures, 6-hour CVVH performed only after contrast medium exposure was able to remove an amount of contrast medium similar to that removed by the kidneys in 12 hours and resulted in a low rate of CI-AKI [43]. As such, hemofiltration has excellent advantages in treating AKI as it has proven to be an effective strategy for CI-AKI prevention in patients with chronic kidney disease who are undergoing cardiovascular procedures [44]. Nevertheless, costs for continuous hemofiltration therapies are usually higher than for intermittent RRT because it requires constant assessment of metabolic and hemodynamic status, adjustment of the therapy based on clinical criteria, well-trained personnel to perform the technique to avoid iatrogenic complications, consideration of vasoactive drugs, location in the hospital, and need for mobilization and physiotherapy. More studies, including all these variables, need to be done to make a generalized conclusion regarding the effectiveness of hemofiltration in preventing CI-AKI [45].

Although there are no absolute contraindications to hemofiltration, extra care is needed for patients at increased risk of hemorrhage (e.g., in severe thrombocytopenia) when the anticoagulation required may be problematic. The most common complications found in hemofiltration therapies are electrolyte imbalances, hypotension, infection, bleeding, decreased cardiac

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output, rhabdomyolysis, respiratory muscle weakness, and hypothermia [42]. Hypotension may contribute to delayed kidney recovery, and hemofiltration-induced hypothermia may mask fever, making body temperature an inaccurate infection sign. However, the current generation CRRT system and blood warmer significantly decrease the risk of hypothermia among critically ill patients treated with continuous renal replacement therapy [46].

Conclusion

The use of diagnostic imaging is a frequent occurrence in health care, which makes pharmacological measures for the prevention of CI-AKI a topic of concern for all healthcare professionals. As part of the preparation of this review, we examined the use of hydration with NSS via IV, which presents an adequate prophylactic strategy and is most commonly used among patients with normal renal function and low risk of nephropathy. The administration of sodium bicarbonate is not superior to NSS. Additionally, since sodium bicarbonate has a hypotensive effect, it should be administered with greater caution. In contrast, NAC significantly reduces the risk of acute kidney injury in patients with non-end-stage renal disease. However, it is of concern to note that hydration with this technique may be problematic for patients who need urgent contrast imaging since they are unable to comply with the complete hydration protocol. Statins (primarily dose-dependent atorvastatin and rosuvastatin) have also demonstrated positive results in patients with a high risk of developing CI-AKI. These medications are contraindicated in patients with acute liver failure, decompensated cirrhosis, hypersensitivity to the medication, and during pregnancy and lactation. TMZ and Alprostadil provide beneficial effects in patients undergoing cardiac angiography or percutaneous coronary intervention with intravascular contrast, but they are associated with significant side effects. TMZ is not approved for use in the United States.

In our references, we also found evidence that probucol effectively prevents the appearance of CI-AKI in patients with coronary heart disease who undergo percutaneous coronary intervention (PCI). However, there are not sufficient adequate data available to conclude. Hemodialysis and tocopherol have not been revealed to prevent CI-AKI in patients with normal GFR and few risk factors. Patients on chronic hemodialysis or at high risk of contrast-induced nephropathy may find hemodialysis beneficial for removing contrast media. Instead of continuous haemofiltration, which has been shown to be beneficial in patients with chronic kidney disease undergoing cardiovascular procedures. Nevertheless, additional care is required in patients with an increased risk of bleeding where the required anticoagulation may be problematic. Accordingly, we observed a significant advantage in hydration using NSS as well as the use of NAC in comparison to other studies. Even so, each patient should be treated according to their individual needs to ensure that they receive timely and appropriate management.

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How to cite this article: Botero FV, SalazarMAN, Salazar Perez FA, Moreno Cortes GA, Salazar Perez JA, et al. Contrast-Induced Acute Kidney Injury: Assessing The Effects of Pharmacological Preventive Measures. JOJ Urology & Nephrology, 2022; 7(4): 555720. DOI: 10.19080/JOJUN.2022.07.555720

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