



Contrast-Induced Nephropathy: Pathophysiology and Preventive Strategies

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Contrast-induced nephropathy is the third most common cause of hospital-acquired renal failure, after decreased renal perfusion and nephrotoxic medications. Identification of patients at risk and implementation of preventive strategies can decrease the incidence of this nephropathy. Prevention strategies focus on counteracting vasoconstriction, enhancing blood flow through the nephron, and providing protection against injury by oxygen free radicals. Knowledge of the adverse effects associated with infusion of contrast media, identification of patients at risk for contrast-induced nephropathy, and application of evidence-based prevention strategies allow nurses to assist in the prevention of contrast-induced nephropathy. (*Critical Care Nurse*. 2013;33[1]:37-47)

Contrast media can have serious toxic effects on renal tubular cells, resulting in a condition known as contrast-induced nephropathy (CIN).¹ CIN is the third most common cause of hospital-acquired acute renal failure, after impaired renal perfusion and nephrotoxic medications,¹ and is associated with extended length of stay,^{1,2} accelerated onset of end-stage

renal disease,² need for dialysis,² increased costs,¹ and increased mortality.^{1,3} In retrospective studies, patients in whom CIN developed had mortality rates from 22% to 45.2%, whereas control groups had rates of 1.4% to 19.4%. Approximately 150 000 patients experience CIN each year, and at least 1% require dialysis and a prolonged hospital stay. Dialysis is estimated to cost approximately \$32 million annually, and the mean 2-day increase in length of stay can add an additional \$148 million.³ The incidence of CIN has decreased recently, from approximately 15% to 7%, and the decrease is attributed to use of preventive strategies.⁴⁻⁶ CIN is often undetected clinically because patients are asymptomatic.⁶

In this article, I describe the causes of acute renal failure, define

CIN, describe the proposed pathophysiology, review associated risk factors for CIN, and present evidence-based preventive strategies. The important roles that nurses play in the primary prevention of CIN are recognizing patients at risk for CIN and collaborating with physicians to ensure that preventive strategies are used.

Causes of Acute Renal Failure

CIN is one cause of acute renal failure, resulting in a decrease in the glomerular filtration rate (GFR), reduced excretion of nitrogenous waste, hypervolemia, and hyperkalemia.⁷ Acute renal failure can be divided into 3 categories: prerenal, due to diminished renal blood flow; intrinsic, due to damage of the renal parenchyma; and postrenal, due to obstruction of the urinary tract.⁷ Factors associated with intrinsic failure include tubular disease, glomerular disease, vascular disease, and interstitial disease.⁷ Acute tubular disease is usually induced by ischemia or by toxic agents, such as contrast agents, that cause tubular necrosis.⁷

In 2004, the Acute Dialysis Quality Initiative group⁸ proposed

CNE Continuing Nursing Education

This article has been designated for CNE credit. A closed-book, multiple-choice examination follows this article, which tests your knowledge of the following objectives:

1. Define contrast-induced nephropathy (CIN)
2. Identify associated risk factors for CIN
3. Describe the causes of acute renal failure
4. Identify strategies to prevent CIN

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Table 1 Comparison of RIFLE criteria and CIN criteria

Characteristic	RIFLE criteria ^a	CIN criteria ^b
Serum level of creatinine	Risk: increased 1.5 times Injury: increased 2 times Failure: increased 3 times or level >4 mg/dL	>0.5 mg/dL or an increase >25% greater than baseline
Glomerular filtration rate	Risk: decreased >25% Injury: decreased >50% Failure: decreased >75%	Risk: <60 mL/min per 1.73 m ²
Urine output	Risk: <0.5 mL/kg for 6 hours Injury: <0.5 mL/kg for 12 hours Failure: <0.5 mL/kg for 12 hours or anuria for 12 hours	Not defined
Diagnostic period	Within 48 hours	48-72 hours
Persistent acute renal failure	Complete loss of renal function >4 weeks	2-5 days
Failure	End-stage renal disease >3 months	Not defined

Abbreviations: CIN, contrast-induced nephropathy; RIFLE, risk of acute renal failure, injury to the kidney, failure of renal function, loss of function, and end-stage renal failure.

^a Based on information from Pakfetrat et al,¹² Sterling et al,¹³ Roche and James,¹⁴ Ellis and Cohan,¹⁵ and Birck et al.¹⁶

^b Based on information from Barreto,³ Kelly et al,⁶ Agrawal and Swartz,⁷ and Dirkes.⁹

a classification system known as RIFLE (risk of acute renal failure, injury of the kidney, failure of renal function, loss of function, and end-stage renal failure). RIFLE provides a uniform standard for diagnosing and classifying acute renal failure due to multiple diseases.^{4,9-12} The focus of the RIFLE criteria is critically ill patients and assessment of risk and degree of failure.⁸ Traditionally, in CIN studies, investigators have focused on patients at risk regardless of hemodynamic status and have used a limited diagnostic definition of an increase in the serum level of creatinine, not the standardized RIFLE classification (Table 1). Recommendations have been made to incorporate the standardized RIFLE criteria into future CIN trials.¹⁰ Pakfetrat et al¹² were the first to

investigate risk factors for CIN on the basis of RIFLE criteria; however, they found it impossible to reach conclusive results in the injury and failure categories. They speculated that the inconclusive results were related to prevention strategies used in low-risk patients and recognized a need for larger studies to clarify the injury and failure categories.

CIN Diagnostic Criteria

Nunag et al¹⁷ suggested contrast-induced acute kidney injury as a newer term for CIN; however, I use the term CIN in this article because it is the one commonly used in past and current literature. Diagnosis of CIN is most often based on an increase in the serum level of creatinine after exposure to a contrast agent¹⁷ (Table 2). A

baseline assessment before administration of contrast material is required so that renal insufficiency can be detected before the procedure with contrast material and the diagnosis of CIN after the procedure.¹⁸

Assessment of Renal Function

Renal impairment can be expressed according to various indicators of renal function: serum level of creatinine, GFR, and creatinine clearance. Serum levels of creatinine provide a measure of filtration within the renal tubules and glomerulus, whereas GFR provides a better estimation of nephron function.^{19,20} Although the serum level of creatinine is widely used in the diagnosis of renal impairment, in CIN, the serum level is an unreliable indicator of kidney function because creatinine is not a real-time biomarker.^{13,18} An increase in the serum level of creatinine is relative to the amount of filtration function lost; thus the serum level is not sensitive or specific for small alterations

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Table 2 Diagnostic criteria for contrast-induced nephropathy^a

Exposure to contrast agent
Increase in serum level of creatinine of 0.5 mg/dL or 25% greater than baseline
Increase in serum level of creatinine occurs 48-72 hours after administration of contrast agent and persists for 2-5 days
Alternative major injuries are ruled out

^a Based on information from McCullough,¹ Kelly et al,⁶ Nunag et al,¹⁷ and Benko et al.¹⁸

in GFR. Measurement of serum creatinine levels delays diagnosis of CIN by a mean of 48 to 72 hours, but, currently, more timely biomarkers are not readily available for use.¹³

Both GFR and creatinine clearance reflect filtration of creatinine. However, GFR is considered a more accurate index of kidney function. Creatinine clearance is less accurate because of compensatory increases in proximal tubular secretion, which allow secretion of creatinine and tend to result in overestimates of GFR.^{18,20} GFR provides a more accurate account of working nephrons that is based on glomerular filtration.²⁰ The National Kidney Foundation Kidney Disease Outcome Quality Initiative recommends that clinicians use estimated GFR calculated on the basis of the serum level of creatinine.¹ GFR is defined as the volume of plasma cleared of a given substance (urea and creatinine) per minute and is equal to the sum of the filtration rates of all of the functioning nephrons.^{19,20} A normal GFR may exist without 100% of the nephrons functioning. Loss of 25% to 30% of the nephrons will not cause a decrease in GFR, because the remaining nephrons compensate by increasing their filtration rate.²⁰ Patients with a GFR less than 60 mL/min per 1.73 m² have considerable loss of nephron units, and the residual renal function

is vulnerable to declines with renal injuries, such as those caused by contrast agents.²⁰

Different formulas exist that use the serum level of creatinine and other factors to calculate GFR. The formulas depend on measurement of serum levels of creatinine, which are assumed to be in a steady state.²¹ Creatinine levels vary according to muscle mass.²⁰ Lower serum levels of creatinine and estimated GFR are common in persons, such as older patients, females, and malnourished individuals, in whom muscle mass is decreased.^{20,21} Serum levels of creatinine and GFR are higher in African Americans, who have higher muscle mass than do non-African Americans, and in persons who consume high-protein diets.^{20,21} In the early stages of acute kidney injury, the GFR may be overestimated because of the unsteady state of serum creatinine levels.¹³

The Canadian Association of Radiologists¹⁸ recommends measuring GFR 3 months before elective administration of contrast material, within 1 week of the procedure for all inpatients, or closer to the time of the procedure if a patient has unstable or evolving disease. Some institutions may consider it safer to obtain a serum creatinine level for all patients undergoing injection of contrast agents.¹⁸

Risk Factors

Nurses should have knowledge of factors that increase a patient's risk for CIN (Table 3) and should recognize which diagnostic tests require contrast media (Table 4) so they can recognize the need for preventive strategies. Addressing and resolving modifiable risk factors before administration of contrast agents decrease a patient's risk of CIN. Although nonmodifiable risk factors cannot be eliminated, strategies are available to decrease the likelihood that patients will experience CIN. Patients with existing impaired renal function or diabetes mellitus (type 1 and type 2) are at the highest risk. Other levels of risk can be classified on the basis of GFR. Highest risk is associated with GFR less than 30 mL/min per 1.73 m²; the lowest risk, with normal levels of 60 mL/min or greater per 1.73 m², except for patients with diabetes.^{12,18} Patients with diabetes mellitus may have a normal GFR. Nevertheless, their risk for CIN is increased because of endothelial dysfunction in the renal vessels, resulting in suppressed tonic influence of nitric oxide.²⁸ A comprehensive review of a patient's history and current hemodynamic status is the first priority in recognition of risk for CIN. Decreasing modifiable risk factors, such as dehydration, nephrotoxic medications (Table 5), and hemodynamic instability (hypotension, volume depletion), improves the success of preventive strategies.^{2-4,7,9,10,12-14}

A lack of risk factors for renal disease effectively eliminates the likelihood that a patient will have renal impairment associated with infusion of contrast media.¹⁸ Unvalidated risk models suggest

Table 3 Risk factors for development of contrast-induced nephropathy

Modifiable risk factors	Nonmodifiable risk factors
Dehydration ^{2,3,7,9,10,12-14}	Preexisting renal impairment Glomerular filtration rate < 60 mL/min per 1.73 m ² in nondiabetic patients ^{2,4,7,9,10,13,22} Glomerular filtration rate < 90 mL/min per 1.73 m ² in diabetic patients ^{23,24}
Increased risk with hyperosmolar media, decreased risk associated with low or iso-osmolar media ^{1,3,22,24-26}	Diabetes ^{4,7,9,10,12-14,22,24}
Administration of >100 mL of contrast medium ^{12,24,25}	Ventricular dysfunction: ejection fraction < 40% ^{2,4,9,10,14,22}
Recent administration of contrast media ¹⁹	Hypercholesterolemia ^{25,27}
Hypotension ^{2,4,7,10,12}	Age >75 years ^{4,9,10,13}
Concomitant use of nephrotoxic agents ^{2,4,9,10,12-14}	
Anemia ^{2,9}	
Shock ¹⁰	
Sepsis ⁷	
Use of intra-aortic balloon pump ¹⁰	

Table 4 Tests requiring contrast agents

Angiograms ^{18,19}
Contrast-enhanced computed tomography ^{18,19}
Intravenous pyelography ¹⁹
Venograms ¹⁹

that hypotension and heart failure are associated with a higher risk level than are age, anemia, and diabetes. However, a combination of any factors increases risk further.²³ In a prospective study¹² of patients with normal serum creatinine levels who were undergoing percutaneous

angiography, the strongest predictor of CIN was diabetes, and the risk increased in patients with diabetes who had hypercholesterolemia and an estimated GFR lower than 90 mL/min per 1.73 m².

The most common procedures associated with CIN are coronary

Table 5 Medications to be withheld before procedures that require contrast material^a

Medications	Effect resulting in renal impairment
Nonsteroidal anti-inflammatory agents ^{1,17,20,23}	Two deleterious effects: Interstitial inflammation ¹⁷ Decreased production of vasodilatory prostaglandins, thereby potentiating the effect of adenosine, increasing vasoconstriction ^{17,20}
Calcineurin inhibitors ¹	Vasoconstriction of afferent arterioles, resulting in irreversible damage; glomerular sclerosis ²⁹
Loop diuretics ^{17,23}	Risk of volume depletion before procedure ¹⁷ After procedure, forced euvolemic diuresis associated with increase in risk for contrast-induced nephropathy ^{2,3,6,16}
Aminoglycosides ^{1,9,17,20,23}	Intracellular accumulation of medication in proximal tubule cells thought to interfere with cellular function, eventually leading to cell death and decreased glomerular filtration rate ^{9,20}
Amphotericin B ^{9,17,20,23}	Binds to tubular epithelial cells, alters cell permeability, and causes vasoconstriction of intrarenal arteries and arterioles ⁹
Vancomycin ^{9,17}	Mechanism of nephrotoxic effect is unknown ^{9,18}
Chemotherapeutic agents ^{20,23}	Cumulative nephrotoxic effects related to tubular epithelial cell necrosis ²³
Metformin ¹	Not a nephrotoxic medication; however, has been associated with spontaneous lactic acidosis resulting in acute kidney injury, systemic complications, and death ^{1,18} May be reinstated after renal function is normal ^{18,19}

^a Withholding nephrotoxic medications is considered best practice, because these drugs in combination with contrast media can have an additive injurious effect.¹

angiography and contrast-enhanced computed tomography. Patients who undergo coronary angiography are at highest risk for CIN.^{17,24} Often the procedure is done under emergent conditions, and patients may be volume depleted, and their hemodynamic status may be less than optimal.^{17,24} An increased incidence of CIN is predicted because of more frequent use of contrast media in radiology departments, an increase in the incidence of chronic kidney disease, and an aging population.¹⁸

Pathophysiology

The pathogenesis of CIN is not clear. Studies^{13,22,28} in vitro and in animals suggest that CIN is due to a combination of toxic and ischemic injury to the renal tubular cells. Proximal and distal tubular injury occurs at the moment of contact with contrast medium and is thought to be due to an interplay of intrarenal vasoconstriction, medullary hypoxia, and direct tubular cell death.^{3,12,28} Length of exposure to a contrast agent is related to the extent of the cytotoxic effects and the amount of damage of renal tubular cells.¹²

The proposed pathophysiology of CIN requires a review of the renal vasculature. The kidney is composed of an estimated 1 million nephrons.²⁰ The renal vascular bed has a high vascular resistance because its capillary vessels are longer than average.²⁸ Renal blood flow is unique: afferent and efferent arterioles control blood flow through the renal capillaries. Blood from the systemic circulation travels to the kidney via the renal artery and enters multiple small afferent arterioles, which deliver blood to the glomerular capillaries of the nephrons. Blood then travels

out of the capillaries via the efferent arterioles.²⁵

Glomerular filtration is due to a balance of 3 forces: plasma-colloid osmotic pressure, Bowman capsule hydrostatic pressure, and, most important, glomerular capillary blood pressure.²⁵ The plasma-colloid osmotic pressure (15 mm Hg) and Bowman hydrostatic pressure (30 mm Hg) are influenced by protein concentration, whereas the glomerular capillary pressure (55 mm Hg) is controlled by constriction and dilatation of the afferent and efferent vessels.²⁵ The glomerular capillary pressure is the highest and most dominant force in glomerular filtration.²⁵ Glomerular capillary pressure favors filtration as it pushes fluid from the blood, counteracting the opposing osmotic and hydrostatic pressures, which pull fluid according to protein concentration.²⁵ A net filtration pressure results from the glomerular capillary pressure (55 mm Hg) and the opposing plasma-colloid osmotic pressure (15 mm Hg) and Bowman hydrostatic pressure (30 mm Hg): $55 \text{ mm Hg} - (30 \text{ mm Hg} + 15 \text{ mm Hg}) = 10 \text{ mm Hg}$. A normal net filtration pressure allows fluid from the blood to be forced through the highly permeable glomerular membrane (glomerular filtration).²⁵

Vasoconstriction

Vasoconstriction of the afferent arteriole decreases the glomerular capillary pressure, thus altering net filtration pressure and glomerular filtration.²² Contrast agents are thought to produce prolonged vasoconstriction of the arteriole and stasis of contrast material in the renal vasculature, resulting in medullary ischemic injury and death of proximal

and distal renal tubular cells.^{13,22}

The decreased blood flow caused by vasoconstriction is amplified further as blood viscosity increases, resulting in medullary hypoxia.

Decreased Blood Flow

Clinical and experimental observations suggest that the osmolality of contrast media may play a role in the pathogenesis of CIN.¹³ Contrast material administered intravenously poses less of a risk than does contrast material given intra-arterially. Compared with the intra-arterial route, the intravenous route requires smaller amounts of contrast material, and the contrast agent is diluted in the circulation before reaching the renal vasculature.¹ A relationship exists between osmolality and viscosity. Contrast media have an osmolality greater than that of plasma and appear to have the adverse effect of augmenting fluid viscosity, thereby increasing the resistance to flow in renal tubules.²⁸ Tubular fluid viscosity is isotonic at an osmolality of 300 mOsm/L, which is lower than plasma viscosity.^{25,28} Low-osmolal agents have an osmolality 2 to 3 times greater than the osmolality of plasma.¹ High-osmolal agents diminish the deformability of erythrocytes, thereby increasing the cells' stiffness and making the flow of red blood cells through the capillaries more difficult.^{1,28} Blood cells become densely packed in the renal capillaries, and blood flow through these vessels may cease (animal model).^{4,28} Deformation of red blood cells, systemic vasodilatation, intrarenal vasoconstriction, and direct renal tubular toxic effects are all common with contrast agents that have an osmolality greater than

the osmolality of blood.¹³ Patients with diabetes and renal failure have an increased risk for CIN because of a reduction in endogenous vasodilators such as nitric oxide and prostaglandins, which results in a decrease in renal blood flow and GFR.^{13,22}

Hypoxia

In a normal state, the medullary parts of the kidney are maintained at the verge of hypoxia, where PO₂ levels can be as low as 20 mm Hg, thus leaving this area of the kidney more vulnerable to fluctuations in oxygen levels.²⁸ Reduction of medullary blood flow that occurs during administration of contrast material compromises the delicate balance between oxygen consumption and tissue oxygen availability.²⁶ Low blood flow in the medulla may also be caused by increased perivascular hydrostatic pressure, high viscosity, or changes in vasoactive substances such as endothelin, nitric oxide, and adenosine.^{17,22,28} Adenosine can have a vasoconstrictor effect in the afferent arteriole, unlike the vasodilatation it causes in larger arterioles located in the coronary and peripheral vasculature.^{19,28} Contrast agents may trigger the release of endothelin and adenosine from endothelial cells, increasing vasoconstriction, and decrease the release of prostaglandins, preventing vasodilatation, thus decreasing oxygen in the outer medulla.^{17,28} Impairment in flow leads to hypoxia and decreased nutrient delivery to tubular epithelial cells, resulting in increases in reactive oxygen species, causing breakdown of the epithelial cytostructure with loss of cell parity and death of the cell.^{4,17}

Renal tubular injury may also be amplified during angiographic

procedures because of hypotension, release of atheroembolic material, catheter exchanges, use of intra-aortic balloon counterpulsation, and bleeding complications.¹

Strategies for Prevention of CIN

Prevention strategies (Tables 6 and 7) focus on decreasing the cascade of vasoconstriction, maintaining blood flow throughout the capillaries, and reducing hypoxia in the medullary parts of the kidney. The benefits of use of contrast material should outweigh the risks, especially for patients at risk for CIN. Alternative tests such as nuclear imaging or ultrasound scans without use of contrast media should be ordered when feasible.¹⁸ The goal of prevention is to protect the renal tubules from prolonged contact with contrast material, because permanent damage can occur at the time of contact.²⁰ Preventive strategies are unnecessary in patients with anuria and end-stage renal disease because kidney function has already ceased.¹⁵

Studies^{4,5,13,15} suggest that intravenous hydration is the most effective strategy to prevent CIN. Hydration is inexpensive and is usually risk-free. Liberal salt and oral fluid intake or avoidance of fluid restriction may be recommended for patients at low to moderate risk for CIN; however, no evidence^{1,18} supports hydration with oral fluids. Administration of optimal fluids before and after the contrast procedure allows for increased urine output and improved outcomes. In one study,¹ rates of acute kidney injury were decreased when the urine output was greater than 150 mL/h for 6 hours after the procedure that required contrast material.

Two strategies are available to prevent an acidic environment and formation of free radicals in the renal tubules: sodium bicarbonate and *N*-acetylcysteine.³ Studies have been done on the use of sodium bicarbonate infusions, and guidelines suggest use of this agent; however, confirmatory trials are still needed.^{1,4,13,15,17,24} *N*-acetylcysteine increases production of nitric oxide, which has vasodilatory capabilities, and the concentration of glutathione, which acts as a free radical scavenger.^{3,20,22,27} Compared with infusion of normal saline alone, administration of *N*-acetylcysteine in conjunction with infusions of normal saline significantly decreased the risk for CIN.^{3,6}

The volume of contrast media and the frequency of administration should be minimized, yet should be sufficient to ensure satisfactory image quality. Contrast media are classified according to osmolality: high osmolality, approximately 2000 mOsm/kg; low osmolality, 600 to 800 mOsm/kg; and iso-osmolality, 290 mOsm/kg.¹ Use of high-osmolal agents decreased in the 1990s with the development of low-osmolal agents. Decreased risk has been identified with the use of low-osmolar (iohexol, iopamidol, and ioxaglate) or iso-osmolar (iodixanol) agents.^{1,15,18} More studies are needed to determine whether iso-osmolar agents offer better protection than low-osmolar agents do in preventing CIN.^{17,18,30} Hemofiltration after a procedure that requires contrast material removes low-osmolality media, without depleting volume, and has shown some benefit. However, hemofiltration is expensive, requires intensive care, and should be used only in very high-risk patients.^{2,4,15,18}

Table 6 Nurses' actions based on rationale for strategies to prevent contrast-induced nephropathy

Prevention strategy	Rationale	Nursing actions
<i>Before the procedure</i>		
Identification of risk factors and correction of modifiable risk factors	Risk factors have a cumulative property; reduction of the number of risk factors decreases risk for contrast-induced nephropathy ¹⁸	<p>Identify patient's risk:</p> <ul style="list-style-type: none"> Obtain a complete history to identify comorbid conditions, preexisting renal impairment, diabetes, heart failure, hypercholesterolemia, and age greater than 75 years Obtain medication history; collaborate with physician about the need to withhold dehydrating or nephrotoxic medications^{1,9,30} <p>Assess hydration status</p> <ul style="list-style-type: none"> Blood urea nitrogen level, electrolytes, urine output⁸ <p>Assess renal function</p> <ul style="list-style-type: none"> Obtain physician's order to assess baseline renal function: serum level of creatinine and glomerular filtration rate^{10,11,18} Alert physician of elevated serum level of creatinine or glomerular filtration rate <60 or <90 mL/min per 1.73 m² in a patient with diabetes^{11,12,15,16,18} <p>Determine stability of hemodynamic status</p> <ul style="list-style-type: none"> Monitor vital signs Assess for unstable hemodynamic status as evidenced by hypotension, shock, sepsis, or use of intra-aortic balloon pump^{2,4,8,10,12} Alert physician of concerns related to hemodynamic state Notify physician of need to modify risk factors before administration of contrast material
Patient education	Patient needs to understand risks and importance of compliance with preventive strategies	<ul style="list-style-type: none"> Reinforce information provided by the physician about purpose and benefits of administration of contrast media Discuss individual risk factors in association with need for preventive strategies Provide procedural education: preparation, during procedure, and recovery period Explain withholding of medications that place patient at greater risk Discuss administration of intravenous fluids and <i>N</i>-acetylcysteine—purpose, duration, benefits, and possible adverse reactions Monitor renal function after the procedure, results of serum laboratory tests, intake and output
Hydration, increase in intravascular volume	<ul style="list-style-type: none"> Counteracts renal vasoconstriction^{5,22,26} Suppresses renin-angiotensin-aldosterone system and produces antidiuretic hormone¹⁵ Enhanced blood flow to the nephron prevents renal medullar hypoxia^{5,15,30} Decreases contact time of contrast agent within the kidney, thus decreasing nephrotoxic effects on tubular epithelium^{13,15,17} Dilutes contrast agent^{13,15,17} 	<ul style="list-style-type: none"> Assess for signs and symptoms of hypovolemia: orthostatic hypotension, decrease in urine output (<30 mL/h), concentrated urine, elevated serum levels of sodium and blood urea nitrogen⁸ Report abnormal laboratory values, alteration in blood pressure, and/or decreased urine output to physician Collaborate with physician about need for fluid administration; standard treatment if glomerular filtration rate <60 or <90 mL/min per 1.73 m² in patients with diabetes^{12,23} Administer intravenous fluids as ordered by physician; recommended regimen is infusion of isotonic saline, 1 mL/kg per hour to be started 12 hours before the procedure^{4,5,9,13,15} Modify fluid administration if patient has left ventricular dysfunction; match urine output with intake of isotonic saline³⁰ If procedure is to be performed in less than 12 hours, recommended regimens include isotonic saline 1-2 mL/kg 2-6 hours before procedure or 3 mL/kg 1 hour before procedure^{13,15,18} Stop administering diuretics as ordered by the physician

Continued

Table 6 *Continued*

Prevention strategy	Rationale	Nursing actions
<i>Before the procedure</i>		
Urine alkalinization	Prevents an acidic environment and formation of free radicals in renal tubules Sodium bicarbonate is thought to alkalinize renal tubular fluid, reducing pH-dependent free radicals and the generation of injurious free oxygen radicals ^{13,26} <i>N</i> -acetylcysteine (Mucomyst) acts as an alkalinizing agent, a scavenger of free radicals, an antioxidant, and a vasodilator ^{3,14,16,25}	Administer intravenous sodium bicarbonate infusion (154 mEq/L) as ordered by physician; recommended dosing 1-2 mL/kg per hour, 3-6 hours before procedure ^{17,18,22,26} ; recommended dose for procedures occurring in less than 3 hours is 3 mL/kg per hour ^{15,17,18,30} Administer <i>N</i> -acetylcysteine in conjunction with normal saline infusion as ordered by physician: oral dose is 1200 mg twice a day, starting 48 hours before procedure and 48 hours after procedure. ^{5,13,17,27,30,31} Intravenous dosing is available, but recommended dose is not evidence based at this time. ²⁷ Previous trial doses were from 500 to 1200 mg before and after procedure; ongoing trials have a dose range of 6-10 g. ²⁷ Monitor for anaphylactic reaction to intravenous <i>N</i> -acetylcysteine: flushing, itching, angioedema, hypotension, bronchospasm ²⁷
Choice of contrast agent	Increased risk is related to osmolality, dose, and route of administration Risk increased more with arterial infusion than with venous infusion ^{1,17,18,30} Risk increases with frequent exposure ^{1,17,18,30} High-osmolality agents increase fluid viscosity and resistance to flow in renal tubules ²⁸	Determine whether contrast media were administered recently Obtain complete history of recent procedures and diagnostic tests Notify physician if contrast medium was administered within the previous 10 days ³⁰ Avoid administration of contrast media within 3-10 days of procedure ^{1,18,30} Choose contrast agent Notify appropriate personnel (physician, procedure nurses) of patient's risk and need to limit amount of contrast medium to less than 100 mL ^{11,22,24} Low-osmolality or iso-osmolar agents are preferred ^{1,3,15,23,24,30}
Antioxidant protection	Preserves endothelial function at the level of the glomerulus and reduces level of systemic inflammatory factors ^{1,17,20}	Obtain medication history Continue current dose of statin ^{1,32} Give ascorbic acid, 3 g per day before the procedure and 2 g twice daily after the procedure ^{17,30}
Withhold nephrotoxic medications (see Table 5)	Minimizes injury of the nephron Prevents accumulation of drug in the proximal tubule cells ²⁰ Prevents hypersensitivity reactions that result in interstitial inflammation and nephritis ^{17,20}	Obtain a complete list of medications, including over-the-counter medications Notify physician of nephrotoxic medications Withhold medications as ordered by physician; minimal time to withhold is 48 hours or several days before the procedure ^{1,9,30} ; preferable time frame is weeks before the procedure, when feasible ²⁰
<i>After the procedure</i>		
Hydration	Enhances blood flow to the nephron	Maintain optimal fluid balance Continue infusion of isotonic saline (12 hours after procedure) or sodium bicarbonate (6 hours after procedure) ^{4,5,9,13,15,17,18,30} Monitor for symptoms of fluid overload in patients with left ventricular dysfunction; urine output may be matched with infusion volume ³⁰ Resume administration of diuretics on physician's orders, preferably 24 hours after administration of contrast media ³⁰
Renal assessment	Suggestion of renal impairment can be identified in 48-72 hours, and persistent impairment is recognized in 2-5 days ^{3,6,7,9}	Assess serum laboratory values Serum creatinine and electrolyte levels should be monitored daily during the hospital stay ^{1,17} Reassess glomerular filtration rate within 48-72 hours after the procedure if baseline rate was <30 mL/min per 1.73 m ² (and consider if <60 mL/min per 1.73 m ²) ¹ Alert physician to an increase in serum level of creatinine of 0.5 mg/dL or 25% greater than baseline or decrease in glomerular filtration rate ^{1,3,6,17,18} Monitor intake and output, although results may not be reliable indicators of early renal impairment. ⁸ After discharge, serum creatinine and electrolyte levels should be monitored within 48-96 hours ^{1,17}

Continued

Table 6 *Continued*

Prevention strategy	Rationale	Nursing actions
<i>After the procedure</i>		
Responsibility to patients	Ensuring patients' awareness of risk and need for monitoring of renal function	<p>Provide education on importance of follow-up care; serum level of creatinine and glomerular filtration rate as early indicators of renal impairment because early indications of acute kidney injury are not easily recognized</p> <p>Sign and symptoms of renal impairment; unlikely to be identified in the early stages, but concerns about swelling, sudden weight gain, or decreased urine output should be reported to physician immediately⁸</p> <p>Awareness of increased risk with repeat exposure to contrast material, especially within 10 days³⁰; patients need to make all health care personnel involved in their care aware of current contrast media procedure</p> <p>Discussion of types of tests that may require contrast media so that patients can be their own advocates in the prevention of frequent administration of contrast media</p>

Table 7 Strategies found to be ineffective or harmful in preventing contrast-induced nephropathy

Ineffective strategies	Harmful strategies
Calcium channel blockers ³	Furosemide ^{2-4,6,16}
Atrial natriuretic peptide ^{3,30}	Hemodialysis ^{3,4,13,15,17,30}
Fenoldopam ^{3,17,30}	
Low-dose dopamine ^{4,30}	
Theophylline ^{17,30}	

Conclusion

Infusion of contrast media can lead to CIN. However, nurses can partner with physicians to prevent renal failure in patients at risk for CIN. If avoidance of contrast media is not possible, nurses must take an active role in identifying patients at

risk for CIN, promote hemodynamic stability, and use preventive strategies. CIN may be prevented when a nurse recognizes the risk for a patient, collaborates with the patient's physician, and provides evidence-based treatment. CIN cannot be prevented in all situations. However, increasing the awareness of the risk and the availability of prevention strategies can decrease the incidence of CIN.⁴⁻⁶ Complete or partial recovery from acute kidney injury is possible. Recovery can be complete if a patient returns to baseline serum creatinine level and GFR, and partial recovery is possible if a patient has a persistent change in their RIFLE classification but no need for ongoing dialysis.⁸ **CCN**

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Financial Disclosures
None reported.

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To learn more about contrast-induced nephropathy, read "Contrast-Induced Nephropathy: Nursing Implications" by Isaac in *Critical Care Nurse*, June 2012; 32:41-48. Available at www.ccnonline.org.

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CNE Test Test ID C131: Contrast-Induced Nephropathy: Pathophysiology and Preventive Strategies

Learning objectives: 1. Define contrast-induced nephropathy (CIN) 2. Identify associated risk factors for CIN 3. Describe the causes of acute renal failure 4. Identify strategies to prevent CIN

1. Which of the following is associated with contrast-induced nephropathy (CIN)?

- a. Increased length of stay
- b. Increased admissions to long-term care
- c. Increased cardiovascular risk factors
- d. Increased nosocomial infections

2. Intrinsic renal failure is due to which of the following?

- a. Damage to the renal parenchyma
- b. Diminished renal blood flow
- c. Obstruction of the urinary tract
- d. Hereditary renal disease

3. Which of the following should be done before administration of contrast material to identify renal insufficiency?

- a. Assess urine output for the previous 8 hours
- b. Assess glomerular filtration rate
- c. Assess serum creatinine level
- d. Assess creatinine clearance

4. Which of the following medical histories puts the patient at greatest risk for CIN?

- a. Diabetes mellitus and coronary artery disease
- b. Coronary artery disease and renal insufficiency
- c. Diabetes insipidus and coronary artery disease
- d. Diabetes mellitus and renal insufficiency

5. Which of the following strategies before a diagnostic test requiring contrast media will decrease the risk of CIN?

- a. Use of a diuretic to treat hypervolemia
- b. Use of a β -blocker to treat tachycardia
- c. Use of intravenous fluids to treat hypovolemia
- d. Use of a calcium channel blocker to treat hypertension

6. Which of the following is controlled by constriction and dilatation of the afferent and efferent vessels?

- a. Glomerular capillary pressure
- b. Bowman capsule hydrostatic pressure
- c. Plasma-colloid osmotic pressure
- d. Medullary blood flow pressure

7. Which of the following diagnostic tests puts the patient at highest risk for CIN?

- a. Computed tomography scan with contrast media
- b. Angiogram
- c. Intravenous pyelography
- d. Venogram

8. Which of the following medications should be withheld before a computed tomography scan of the chest?

- a. Artorvastatin (Lipitor)
- b. Clopidrogel (Plavix)
- c. Metoprolol (Lopressor)
- d. Ibuprofen (Motrin)

9. Nursing actions to assess a patient's risk for CIN include which of the following?

- a. Assess hydration status and morning laboratory orders
- b. Assess hemodynamic and neurological status
- c. Assess hydration and hemodynamic status
- d. Assess hydration status and postprocedure orders

10. Which of the following conditions requires modification of preprocedure hydration to match urine output?

- a. End-stage renal disease
- b. Left ventricular dysfunction
- c. Coronary artery disease
- d. Diabetes mellitus

11. How long after contrast media administration is CIN with persistent impairment recognized?

- a. 48-72 hours
- b. 2-5 days
- c. 1-2 days
- d. 12-24 hours

12. Contrast agents may trigger the release of adenosine from renal endothelial cells resulting in which of the following?

- a. Decreased vasoconstriction
- b. Decreased heart rate
- c. Increased heart rate
- d. Increased vasoconstriction

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