Contrast-induced acute kidney injury

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Introduction

The need for radiological studies using contrast media has increased. Diagnostic radiological procedures remain an essential part of patient assessment, while interventional radiology is a burgeoning field that is replacing open procedures, especially in high-risk patients. Contrast-induced acute kidney injury (CIAKI) has subsequently become the third most common reason for the development of in-hospital acute kidney injury in the USA, accounting for 12% of cases.[1] Consequently, anaesthesiologists are more likely to encounter patients who are either at risk of developing CIAKI, or who have already acquired it.

Definition

CIAKI, or contrast-induced nephropathy (CIN), refers to an abrupt deterioration in renal function, temporally associated with the administration of iodinated contrast media, with no alternative clinical explanation.[2]

As described by the Acute Kidney Injury Network, CIAKI is characterised by an acute (within 48 hours) ≥ 26.5 µmol/L (0.3 mg/dL) or ≥ 50% increase in baseline serum creatinine, or a reduction in urine output of < 0.5 ml/kg per hour for more than six hours.[3] The most common definition of CIN is ≥ 44.2 µmol/L (0.5 mg/dL) or ≥ 25% increase in baseline serum creatinine within three days of intravascular contrast medium exposure in the absence of an alternative aetiology.[4] Other investigators have defined CIAKI as a diminution of renal function identified by a decrease in creatinine clearance or the estimated glomerular filtration rate (GFR) two to three days after contrast medium exposure.[5] Such definitions may need to be reviewed in the light of newer, more sensitive and specific markers of renal dysfunction such as cystatin C and neutrophil gelatinase-associated lipocalin which may make earlier detection possible.[6]

Clinical course and outcomes

The serum creatinine increase usually peaks between days three and five, with levels usually returning to baseline within one to three weeks.[7] Persistent serum creatinine elevation, and the underlying renal dysfunction this reflects, can lead to increased morbidity and even death in some patients with CIAKI.

Dangas et al showed that in-hospital outcome rates, such as death (6.3 vs. 0.8%), cardiac death (4.0 vs. 0.5%), coronary artery bypass grafting (5.8 vs. 0.5%), major adverse cardiac events (9.3 vs. 1.1%), packed red cell transfusions (28 vs. 6%), vascular surgery of the access site (5.6 vs. 2.6%), and post-procedure length of stay (6.8 ± 7.1 vs. 2.3 ± 2.5 days), were significantly higher in patients who developed CIAKI when compared with the control patients (p-value < 0.0001).[8]

In a retrospective analysis of 16 248 patients who underwent contrast medium examinations, the in-hospital mortality rates were almost fivefold higher [34 vs. 7%; odds ratio (OR) = 6.5, p-value < 0.01] in CIAKI patients. CIAKI was associated with sepsis, bleeding, coma, or respiratory failure.[9] In all the CIAKI studies, 0.3-4% of the patients required short-term haemodialysis. Renal failure, requiring dialysis after coronary interventions, is associated with a 36% in-hospital mortality rate and has a two-year mortality rate of 81%.[10]

Incidence

The incidence of CIAKI in patients with normal renal function is less than three per cent, but can vary from 12-50% in individuals with one or more risk factors.[11-14]

Pathophysiology

The exact mechanism remains unclear. Following the injection of contrast, renal blood flow initially transiently increases, and then decreases. The oxygen tension in the cortex and medulla is reduced. Renal ischaemia is likely to be a major factor in the pathogenesis of CIAKI.[15] Renal microcirculatory alterations combine with endothelial dysfunction to cause compromised medullary oxygen sufficiency, resulting in outer medullary hypoxic tubular damage. The underlying mechanisms may be related to defective nitric oxide-dependent renal vasodilatation, impaired prostaglandin synthesis, increased reabsorptive work load, enhanced systemic vasoconstrictive stimuli, structural changes of the renal microcirculation, and tubular obstruction or oxidative damage.[16-19] There is also evidence that contrast agents are directly toxic to kidney cells, causing proximal cell vacuolisation, interstitial inflammation, cellular necrosis, and enzymuria.[20]

Risk factors

Risk factors may be related to the patient, contrast media and the procedure. Most patient-related risk factors alter renal protective mechanisms and compromise medullary oxygen sufficiency. Known risk factors for CIAKI include advanced age, pre-existing renal insufficiency, diabetes mellitus, hypotension, hypertension, congestive heart failure and the concomitant use of nephrotoxic drugs.[1,21]

The most common procedure and contrast medium-related risk factors for developing CIAKI are a high total dose, high osmolality, high ionic content and high viscosity of the contrast media, intra-arterial administration of the contrast media, and less than two days between the contrast-using procedures and urgency or emergency procedures.[1,21,22]

Mehran et al developed a simple scoring method using eight variables to assess the risk of CIAKI after percutaneous coronary intervention.[23] The variables used were hypotension (score 5), the use of an intra-aortic balloon pump (score 5), congestive heart failure (score 5), serum creatinine level > 1.5 mg/dl (score 4), age > 75 years (score 4), anaemia (score 3), diabetes mellitus (score 3), and the volume of contrast media (score 1/100 ml). If the total score is five or less, the risk category is low. If the total score is 16 or higher, the risk category is very high.

Prevention strategies

The treatment of established CIAKI is limited to supportive measures and renal replacement therapy. Consequently, identification of at-risk patients and adoption of preventative strategies are vital in reducing CIAKI. Once a patient is identified as being at increased risk, the need for the contrast medium imaging study should be assessed. Alternative, less risky methods of imaging should be considered. If the study is necessary, prophylactic measures should be instituted. Many, including saline hydration, bicarbonate infusion, n-acetylcysteine, theophylline, calcium-channel blockers, diuretics, mannitol, dopamine, atrial natriuretic peptide, endothelin-receptor antagonists, fenoldopam, 5-hydroxytryptamine-receptor antagonist and prophylactic haemodialysis, have been used as prophylactic regimens. Many of these interventions have shown conflicting results.[24-26]

Of all these measures, the following have been shown to be effective in reducing CIAKI: extracellular volume expansion with intravenous saline (1 ml/kg/hour: six to twelve hours pre-contrast and six to twelve hours post-contrast) or sodium bicarbonate (3 ml/kg over one hour pre-contrast, then 1 ml/kg for six hours post-contrast), limiting the total dose of radiographic contrast material below the maximum radiographic contrast dose [5 ml x body weight (kg)/ serum creatinine (mg/dl)], using low-osmolar non-ionic contrast media, stopping the intake of nephrotoxic drugs, and avoiding short intervals between procedures requiring contrast media.[21]

Conclusion

CIAKI is an increasingly common phenomenon that warrants careful assessment of patients. Prevention of CIAKI requires the careful identification of patients at risk, elimination of those factors that could increase risk, institution of measures to minimise risk, and finally, appropriate follow-up to diagnose the presence of CIAKI and to address any long-term sequelae.

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