Perspective

Efficacy, safety, and optimal use of iso-osmolar contrast medium (Iodixanol) in diagnostic and interventional procedures: A Thai multidisciplinary expert meeting report

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Received 3 July 2025; revised 8 September 2025; accepted 22 January 2026
doi:10.46475/asean-jr.v27i1.966

THE ASEAN JOURNAL OF RADIOLOGY
ISSN 2672-9393

Abstract

Iodinated contrast media are used in clinical practice for diagnostic and therapeutic purposes. To discuss the position of iso-osmolar contrast media (IOCM) in diagnostic and interventional procedures in Thailand, an expert meeting, including neurologists, cardiologists, nephrologists, radiologists, radiologic technologists and radiologic nurses, was organized to discuss the use of IOCM and low-osmolar contrast media, both in general and in specific risk groups. Topics discussed included acute kidney injury, cardiovascular events, patient discomfort, allergic reactions, and high-risk groups. The experts agreed that IOCM has an overall beneficial safety profile. With the use of IOCM, patients have a low risk of adverse drug reactions, and a reduced risk of contrast-associated acute kidney injury. Moreover, the patient will feel less pain. Therefore, IOCM is considered particularly useful in patients at high risk of acute kidney injury, especially in procedures that involve significant contrast exposure.

Keywords: Acute kidney injury, Contrast media, Osmolality, Patient safety.

Introduction

Iodinated contrast media are essential in diagnostic imaging and interventional procedures, facilitating enhanced visualization across various anatomical systems during X-ray and CT imaging. Their use is particularly critical in radiological and cardiological interventions. Despite their overall safety and diagnostic efficacy, contrast media can be associated with adverse events such as contrast-induced acute kidney injury (CI-AKI), particularly in high-risk populations, including patients undergoing percutaneous coronary intervention for acute myocardial infarction [1-4].

Iodinated contrast agents are categorized into three classes based on osmolarity which are high osmolarity (HOCM), low osmolarity (LOCM), and iso-osmolarity (IOCM). IOCM, with osmolality approximating that of plasma (~290 mOsm/kg), is associated with improved tolerability and reduced physiological perturbation compared to hyperosmolar HOCM and LOCM. Clinical evidence, including randomized trials and meta-analyses, suggests that IOCM may reduce the incidence of CI-AKI and adverse cardiovascular outcomes, particularly in patients with baseline renal impairment and those receiving intra-arterial contrast administration [5-10]. While overall mortality between LOCM and IOCM users appears comparable, some studies have observed higher mortality in chronic kidney disease (CKD) patients receiving LOCM in some studies [11], whereas others have not reported this finding [12].

Observational data indicate that Iodixanol, a commonly used IOCM, is associated with a lower incidence of CI-AKI compared to LOCM, particularly following intraarterial administration [13, 14]. Furthermore, reduced concentrations of iodinated contrast agents in cerebral angiography have not compromised diagnostic image quality [15].

Economic evaluations in Europe [16] and the United States [17] demonstrate that despite higher acquisition costs, the use of IOCM may lead to significant healthcare savings by reducing CI-AKI-related hospitalizations and associated complications. The U.S. model estimated that shifting from an LOCM-only to an IOCM-only strategy could prevent approximately 2,900 major adverse renal and cardiovascular events annually, with a projected cost saving of $30.7 million [17].

Thailand adheres to international guidelines (the American College of Radiology (ACR), the European Society of Urogenital Radiology (ESUR), the Kidney Disease Improving Global Outcomes (KDIGO), and the Royal College of Radiologist of Thailand (RCRT) in contrast media use. To evaluate the clinical positioning of IOCM within the Thai context, an expert panel convened to review current evidence and share local perspectives. In preparation of the meeting, a questionnaire was circulated among the participants to gauge the opinions and guide the discussion. This manuscript reflects a summary of the discussions during the meeting.

Materials and methods

Experts

An expert meeting was organized on November 2, 2024 Bangkok Thailand. The criteria of the experts included a minimum of 10 years of clinical experience, a documented history of research and publications, a reputation for thought leadership in their respective specialties, ensuring a balanced representation of different specialties, hospital types, and geographical regions within Thailand. The expert group consisted of five interventional and two diagnostic radiologists, one neuroradiologist, one pediatric radiologist, one cardiologist, one nephrologist, one radiologic technologist, and one radiologic nurse, affiliated to seven of the major hospitals in Thailand (Bhumibol, Chulalongkorn, Maharaj Nakorn Chiang Mai, Prince of Songkla University, Ramathibodi, Siriraj, Srinagarind). The experts are co-authors on this paper. Conflict of interest statements are provided at the end of this manuscript.

THE ASEAN JOURNAL OF RADIOLOGY
ISSN 2672-9393

Literature review
We performed a targeted literature review focused on publications evaluating the use of iodinated contrast media, searching Medline through PubMed. The review was restricted to publications in English, and conference abstracts were not included. Titles and abstracts were assessed for eligibility, supported by Artificial Intelligence (Rayyan, [18]) and relevant full texts were obtained and screened.

Questionnaire
Prior to the face-to-face meeting, a questionnaire was distributed to all experts to identify the position of IOCM in diagnostic and intervention procedures in Thailand and the use of contrast media agents in their practices. The full questionnaire is shown in Supplement 1. Agreement with statements was reported as "strongly disagree", "disagree", "neutral", "agree" or "strongly agree". The importance of factors to select contrast media was scored from least important (1) to most important (5). The questionnaire was distributed to the participants in advance of the expert advisory meeting. The replies obtained were used to structure the discussion. To assess importance, scores were calculated by the formula "number of experts times score value, divided by maximum score", leading to a percentage. To assess agreement, the answers "agree" and "strongly agree" were combined. Level of agreement was scored as follows: more than 90% agreement = excellent; 80-90% agreement = very good; 70-80% agreement = good; 50-70% agreement = fair; less than 50% agreement = poor.

Evidence, results and discussion

The evidence base of the benefits of Iodixanol
Experts consistently prioritize patient safety and diagnostic efficacy when selecting contrast media. Key factors influencing their decisions, ranked by importance, are:

- Contrast-Induced Acute Kidney Injury (CI-AKI): This was identified as the paramount concern, receiving a 100% importance rating;
- Adverse Drug Reactions (ADRs): Close behind, ADRs were deemed highly significant, with a 97% rating;
- Cardiovascular Events and Image Quality: Both factors were considered crucial, each scoring 86%;
- Patient Tolerability (Pain, Heat, and Discomfort): The patient experience was also a major consideration, receiving an 85% rating;
- Iodine Toxicity: While still important, iodine toxicity was rated slightly lower at 72%.

Acute Kidney Injury

Potential mechanisms of contrast-associated acute kidney disease (CA-AKI) include renal vasoconstriction, direct tubular toxicity, based on osmotic and chemotoxic effects of contrast media [19-22].

The term contrast-induced nephropathy (CIN) has been replaced by contrast-induced acute kidney disease (CI-AKI), post-contrast AKI (PC-AKI), or contrast-associated AKI (CA-AKI) [19]. AKI is defined as an increase in serum creatinine (sCr) of > 0.3 mg/dL within 48 hours, a > 50% sCr increase within 7 days, or reduced urine output to < 0.5 ml/kg/hour for at least six hours [23, 24]. AKI is a common risk factor for CKD, which is defined as a sustained estimated glomerular filtration rate (eGFR) below 60 mL/min/1.73 m^2 for more than three months [25]. While the overall incidence of AKI after contrast-enhanced CT is low in CKD patients, those with eGFR ≤30 mL/min/1.73 m^2 are at significantly higher risk (1.68-fold increase). Risk factors for CA-AKI include advanced CKD, diabetes, cardiovascular disease, diuretic use, age, dehydration, and repeated contrast exposure within 24 hours [25].

Iodixanol, an IOCM, was introduced in Thailand in 2009 and is considered favorable due to its plasma-like osmolality. Few studies have shown that Intravenous (IV)-administered Iodixanol is associated with fewer high-risk patients developing an increase in serum creatinine levels compared to Iopromide [7]. Contrast-enhanced CT scans with Iodixanol were not associated with a higher incidence of CA-AKI compared to unenhanced scans, suggesting that iodixanol can enhance image quality without significantly increasing risk even in patients with severe CKD [26]. While no significant advantage of IOCM over LOCM was found in several meta-analyses following IV use, they suggested a benefit with intra-arterial (IA) administration in renally impaired patients [9, 27, 28].

Studies comparing contrast media have limitations; often differences in potentially important factors, such as the route of administration (IV versus IA), iodine concentration, and institutional protocols, make it difficult to draw definitive conclusions. For example, the PRESERVE trial, a randomized, double-blind, multicenter study, enrolled high-risk patients undergoing coronary or noncoronary angiography to compare the effectiveness of IV isotonic sodium bicarbonate versus IV isotonic sodium chloride and oral NAC versus oral placebo for the prevention of serious adverse outcomes associated with CI-AKI [29]. The primary end point was a composite of death, the need for dialysis, or a persistent increase of at least 50% from baseline in the serum creatinine level at 90 days. Contrast-associated acute kidney injury was a secondary end point. No significant

between-group differences were observed in the rates of contrast-associated acute kidney injury [29]. However, a post-hoc analysis looking at relative risk for and incidence of serious adverse outcomes following the development of CA-AKI from this patient group highlighted the clinical importance of CA-AKI, which was linked to a significant relative risk for 90-day mortality, dialysis, or persistent kidney dysfunction, albeit with a low incidence rate (1.2%) [30]. The consistent evidence for a benefit of IOCM in the specific context of high-risk patients undergoing IA procedures, such as coronary angiography, suggests that the iso-osmolar property of iodixanol provides a clear clinical advantage in these settings by minimizing the physiologic stress on the kidneys [31]. A more definitive answer on the broader use of IOCM vs. LOCM may require a large, prospective, head-to-head trial in a homogeneous patient population with a specific administration route.

eGFR remains essential for risk stratification. Patients with eGFR <30 are high risk; those with eGFR 30–44 are intermediate; those with AKI remain high risk regardless of eGFR. Anuric End-stage renal disease (ESRD) patients without a transplant are not at risk for CA-AKI.

For IA administration considered first pass to the renal artery, IOCM appears to be more favorable [28, 32]. However, IA administration results in higher local concentration and amount of contrast media, increasing the risk of nephrotoxicity.

Furthermore, a matched cohort study from 2003 to 2017 found that Iodixanol is linked to a reduced risk of progression to ESRD following percutaneous coronary intervention compared to Iohexol [33].

To reduce the risk of CA-AKI the following strategies are recommended: use LOCM or IOCM, minimize the contrast dose to achieve a diagnostic quality imaging, and discontinue nonessential nephrotoxic medications. 92.3% of experts agreed that the reduced risk of CA-AKI was the most important reason to choose Iodixanol as contrast media. In the high-risk population of patients with kidney disease or a history of kidney issues, the survey showed that 100% of experts would select Iodixanol. The choice of contrast media in such patients is typically guided by hospital protocols, with most physicians opting for IOCM due to safety concerns, patient comfort and other factors. The eGFR cutoff for considering IOCM varies by institution, but a threshold of 45 mL/min/1.73m^2 is commonly used for patients without co-morbidities.

In cardiology, IOCM is usually injected intra-arterially, especially in high-risk patients with diabetes, CKD stage 3-4 (eGFR 30-59 mL/min/1.73m2), or those requiring high

contrast doses. IOCM is often considered due to its potential benefits, in reducing the risk of AKI and cardiovascular outcomes. The survey showed that 58.3% of experts would select Iodixanol for patients with heart disease, with Iohexol and Iopromide selected by 16.7%, each.

In Europe, the use of IOCM has better overall cost-effectiveness in this subgroup. If a patient develops kidney failure, it is a burden not only for the patient and their family, but also for the hospital [16]. The limitations of IOCM in terms of viscosity and imaging quality can be mitigated with appropriate adjustments, such as using a machine injector or modifying the X-ray angle.

In summary, the use of contrast media is critical for accurate imaging and diagnosis but should be minimized to the lowest effective dose to reduce the risk of CA-AKI. Hydration remains a key preventive measure. While IA administration carries a higher risk of CA-AKI compared to IV administration, IOCM appears to offer a safer option for high-risk patients, particularly in procedures that involve significant contrast exposure.

Adverse Drug Reactions (ADRs)
The majority of acute iodinated contrast media (ICM) ADRs are mild, non-life-threatening, and require only observation or minor supportive care. Typically, the reactions, including severe and potentially life-threatening ADRs occur within the first 15 minutes after injection. Consequently, patients should be observed for at least 30 minutes post-administration.

ADRs are categorized in two types: allergic-like reactions and physiologic reactions.

a. Allergic-like reactions are immune-mediated, involving an antigen-antibody response (even if this response cannot be identified), and can be anaphylactoid, allergic-like, or idiosyncratic in nature. These reactions are generally independent of the dose and concentration of the contrast media.

b. Physiologic reactions result from direct chemotoxicity, osmotoxicity, or molecular interactions with specific activators. These reactions are dose- and concentration-dependent, and often affect the cardiovascular system (e.g., cardiac arrhythmias, myocardial depression, or cardiogenic pulmonary edema).

An overview of these reactions is provided in Table 1.
ADRs can further be classified into acute and delayed. Reports of ADRs after HOCM ranged widely, from 1.32% (170 of 12,916 patients) [34] to 29% (213 of 737 patients)

[35]. ADRs were reported less frequently after LOCM (0.34%-1.38%, based on 1,266,688 patients) [36], and IOCM (0.74%, 77 of 9953 patients) [37]. The fatality rate with LOCM and IOCM is similar at 2.1-9 per 1 million patients [38]. Delayed allergic-like reactions, which typically occur later than one hour after injection, affect 9.5% of the patients after LOCM (1,058 of 11,121) [39], and 0.39% of patients after IOCM (40 of 9953) [37]. Most ADRs are mild, self-limiting and require topical or no treatment at all [40].

The use of iso-osmolar contrast media (IOCM) has demonstrated specific safety benefits over low-osmolar contrast media (LOCM) in certain high-risk populations. While both LOCM and IOCM have significantly reduced the incidence of allergic-like reactions compared to older high-osmolality agents, there is no conclusive evidence to suggest a difference in allergic-like reaction rates between the two modern classes, IOCM and LOCM [19]. The primary advantage of IOCM lies in its reduced rate of physiologic-like reactions, specifically contrast-induced nephropathy (CIN), in high-risk patients. A meta-analysis of pooled patient data from randomized controlled trials found that the use of Iodixanol (an IOCM) was associated with a significantly lower rate of CIN and smaller increases in serum creatinine compared to LOCM, particularly in patients with pre-existing renal disease and diabetes [31]. For patients with a history of a previous allergic-like reaction to contrast media, premedication protocols involving corticosteroids and antihistamines are often employed as a primary strategy to minimize the risk of recurrence [19].

84.6% of experts strongly agreed that Iodixanol results in fewer ADRs compared to LOCM, and 92.3% of experts agreed or strongly agreed that they would recommend Iodixanol for patients to reduce ADRs with contrast media.

Table 1. *The most frequent ADRs, by severity.*

Bladder volume (mL)	Correlation coefficient
Mild	
Limited urticaria / pruritis	Limited nausea / vomiting limited
Cutaneous Edema	Transient flushing / warmth / chills
Limited "itchy"/"scratchy" throat	Headache / dizziness / anxiety / altered taste
Nasal congestion	Mild hypertension
Sneezing / conjunctivitis / rhinorrhea	Vasovagal reaction that resolves spontaneously
Moderate	
Diffuse urticaria / pruritis	Protracted nausea / vomiting
Diffuse erythema, stable vital signs	Hypertensive urgency
Facial edema without dyspnea	Isolated chest pain
Throat tightness or hoarseness without dyspnea	Vasovagal reaction that requires, and is responsive to, treatment
Wheezing / bronchospasm, mild or no hypoxia	
Severe	
Diffuse edema, or facial edema with dyspnea	Vasovagal reaction resistant to treatment
Diffuse erythema with hypotension	Arrhythmia
Laryngeal edema with stridor and/or hypoxia	Convulsions, seizures
Wheezing / bronchospasm, significant hypoxia	Hypertensive emergency
Anaphylactic shock (hypotension + tachycardia)	

Adapted from the American College of Radiology guideline [19].

Cardiovascular Event

A 2021 meta-analysis, by McCullough et al. found that IA administration of Iodixanol significantly reduces the relative risk of major adverse renal cardiovascular events in high-risk patients compared to pooled LOCM [41]. For this retrospective database study, administrative claims data were used. The analysis relied on the ICD-9/10 coding of outcomes, without laboratory values for the diagnosis of AKI by serum creatinine levels, assessment of heart failure by ejection fraction, or other clinical conditions, potentially underestimating the occurrence of MARCE. Additionally, patients were not tracked longitudinally, which may have resulted in incorrect estimation of the true occurrence of MARCE [41]. Using the Premier Healthcare Database, the use of IOCM versus LOCM was compared with respect to the primary endpoint of MARCE in high-risk patients undergoing peripheral endovascular procedures. IOCM was associated with a significant absolute risk reduction in MARCE [42]. Because this was also a retrospective database study, the same limitations apply.

In newborns with congenital heart disease, very small volumes of contrast media are used, followed by saline flushing, with an injection rate of 0.5-0.6 cc/sec to prevent overly concentrated contrast in the heart chambers that could obscure morphology. While contrast is typically injected in the right arm, IOCM can also be administered intravenously in the leg. A central venous catheter is contraindicated for cardiac CT angiography in newborns due to the risks associated with contrast use.

In summary, most physicians prefer Iodixanol for its safety profile, as it may have advantages in high-risk cardiovascular patients and/or with comorbidity, and 92.3% of experts agreed or strongly agreed with recommending Iodixanol for patients with comorbidity.

Patient Discomfort

Lower osmolarity enhances patient comfort. The optimum is with the osmolarity of blood (iso-osmolarity), as with lower osmolarity patient discomfort will increase again. A randomized controlled trial comparing Iodixanol and Iopamidol for IV injection in CT scans of the abdomen or pelvis showed that Iodixanol resulted in significantly less moderate to severe discomfort, particularly in terms of heat, when assessed on a 0-10 scale [43]. Similarly, in a study using IA administration for peripheral arteriography, Iodixanol was associated with significantly less discomfort, especially in the moderate to severe categories [44]. However, the clinical significance of these differences is small, especially in sedated or anesthetized patients.

Nevertheless, 92.3% of experts agreed or strongly agreed that reduced patient discomfort is a key reason for choosing IOCM over LOCM. For instance, during angioplasty, patients unable to tolerate the discomfort from LOCM had immediate relief when switched to Iodixanol. Additionally, higher osmolarity contrast media, particularly when administered at higher concentrations, tend to cause more pain [45]. In contrast, IOCM results in much less pain, even in cases of contrast media leakage, where tissue reactions are reported to be milder with IOCM. During various interventions, the absence of heat sensation with IOCM helps patients to remain still, improving lesion visualization.

Iodine Dose and Image Quality

In body interventions, the choice of contrast media depends on the body mass index (BMI). For patients with low to normal BMI, IOCM 320 mg/ml is typically used. If the image quality is suboptimal, a higher iodine concentration contrast media may be considered. CT technology nowadays allows for high-quality imaging with lower contrast media doses, making iodine concentration just one of many factors influencing the quality of a CM protocol.

A study in pediatric patients with congenital heart disease compared low-dose Iodixanol (270 mg I/ml) with high-dose Iopamidol (370 mg I/ml) and found no difference in diagnostic accuracy when using Iodixanol with low kilovoltage peak (kVp) CT [46]. However, Iodixanol provided a significantly lower iodine load and radiation dose, which is particularly beneficial for pediatric patients. Using lower iodine concentrations with reduced kVp enhances iodine visibility due to improved absorption near the iodine K-edge, resulting in better contrast at reduced doses. Despite increased noise from lower milliampere (mA) settings, the contrast-to-noise ratio remains high enough to maintain quality vascular imaging with low-iodine contrast media.

Real-world evidence supports the use of 270 mg/ml Iodixanol, showing comparable image quality to more than 300 mg I/ml LOCM in pediatric patients undergoing abdominopelvic CT across various tube voltages [47]. Given its safety profile and lower iodine concentration, some hospitals now use IOCM in all pediatric cases. The expertise of multidisciplinary teams ensures optimal imaging while minimizing toxicity.

High-risk Patient Groups

Beyond patients with renal impairment, experts identified several key patient groups as suitable candidates for IOCM. These included pediatric patients, emergency cases, individuals undergoing interventional radiology procedures, and cancer patients. A discussion of these patient populations and their specific considerations regarding IOCM administration followed.

Pediatric Patients

Special consideration is required when using contrast media in children, as they are more sensitive to its effects. On March 30, 2022, the U.S. FDA issued a drug safety communication recommending that infants and young children through 3 years of age undergo monitoring of thyroid function within 3 weeks of intravascular administration of iodine-based contrast media [48]. Nevertheless, hospitalized children with stable mildly diminished renal function have a low risk of developing contrast-induced nephropathy, suggesting that clinically indicated intravenous contrast-enhanced CT can be safely performed [49, 50].

There are two concerns of ICM: osmolarity and viscosity.

a. The osmolarity of contrast media is especially critical in neonates and young children, as they are more vulnerable to fluid shifts and have a lower tolerance for intravascular osmotic loads than adults [51]. Administering hyperosmolar contrast media IV can cause fluid to move from the extravascular to the intravascular space, leading to an expansion in blood volume. If this shift is significant, it may result in severe complications, including cardiac failure and pulmonary edema, particularly in children with pre-existing cardiac dysfunction.

b. Viscosity is particularly relevant in pediatric patients, as ICM is often administered through small-gauge angio catheters. High-viscosity ICM can make rapid injection challenging through small catheters, potentially leading to catheter failure, vessel injury, or an inability to achieve the necessary injection rate. Therefore, it is advisable to pre-warm iodixanol.

In a randomized, double-blind, parallel group, phase III multicenter trial, Iodixanol was compared with Iohexol to assess safety and efficacy during contrast enhanced gastrointestinal radiography examinations of children [52]. There was no statistically significant difference with regard to efficacy. The frequency of adverse events was lower for patients receiving Iodixanol, with adverse events occurring in 12 patients (16.2%) in the Iodixanol group and 28 patients (35.9%) in the Iohexol group.

Pediatricians witness patients who experience "waking up" during sedation. Commonly, CT in pediatrics uses mild to moderate sedation. Previously, IOCM was not used in every case and children occasionally woke up during sedation. After changing to the use of IOCM in all cases, waking up during sedation was found much less frequently. The need for a repeat scan due to unexpected moving is low.

In summary, the significantly lower iodine load and radiation dose of IOCM, less pain, and reduced waking up during sedation offer benefits for pediatric patients.

Emergency case
Siriraj and Srinagarind Hospitals use IOCM in the majority of emergency cases without lab results, such as fast-track stroke. In an emergency, even if the lab results are available, the baseline values are still unknown. Moreover, these patients often have acute hemodynamic instability and are at high risk of developing AKI [53]. Thus, Iodixanol has more benefits in this group to improve outcomes in the future.

Cancer patients
The use of Iodixanol is considered beneficial in vulnerable cancer patients, in particular when undergoing chemotherapy or radiation, and increasing risk of AKI with every additional nephrotoxic event. Iodixanol was associated with a significant reduction in CA-AKI in cancer patients undergoing a CT exam vs Iopromide [54].

In summary, Iodixanol demonstrates suitability across the patient groups discussed, with particularly strong agreement regarding its application in patients with impaired renal function. Furthermore, research supports the safety and efficacy of Iodixanol in other patient populations.

Limitations
This discussion of the use of iodinated contrast agents in Thailand has several limitations. First of all, while involving 13 multidisciplinary experts from seven of the major Thai hospitals, this may not reflect broader national practices, especially across diverse healthcare settings. Secondly, no established consensus-building methods such as the Delphi technique or GRADE framework were followed, reducing the outcome to expert statements, rather than a consensus. Thirdly, not for all topics published evidence was available, limiting validity to expert opinion. Finally, specifically regarding cost-effectiveness, no local data were available, which is a gap given the national focus of the manuscript.

THE ASEAN JOURNAL OF RADIOLOGY
ISSN 2672-9393

Conclusion

ICM are substances used in diagnostic or interventional radiology to enhance visibility of organs and tissues. ICM are used for X-ray examinations such as CT, angiography, coronary angiography, arthrography, myelography and gastrointestinal fluoroscopy. They are essential for accurate diagnoses, especially in emergency departments and outpatient hospital settings, for interventions in case of acute disease, and for cancer surveillance. Radiologists and healthcare professionals must be knowledgeable about the proper use, indications, and potential risks of ICM to ensure patient safety and optimal diagnostic outcomes. In this report, the position of IOCM in Thailand was discussed. The applicability to other regional healthcare settings with different contrast usage protocols or reimbursement structures remains unclear.

From the Thai experience, there are many differences between IOCM and LOCM, especially regarding the safety and patient discomfort; IOCM is safer and has fewer side effects in some circumstances. IOCM may be related to a lower risk of CA-AKI, and may offer advantages in specific patient populations, although consensus about its direct superiority over LOCM remains debatable. In the context of interventional cardiology, a comprehensive assessment necessitates a balanced evaluation of immediate procedural costs and long-term patient outcomes, specifically the risk of CA-AKI. In practice, the experts recommend using IOCM because of its perceived long-term clinical benefits, emphasizing a patient-centric approach that prioritizes overall health and well-being.

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