Cardiovasc Intervent Radiol (2016) 39:489–499
DOI 10.1007/s00270-015-1239-4

REVIEW

Patient Evaluation and Preparation in Vascular and Interventional Radiology: What Every Interventional Radiologist Should Know (Part 2: Patient Preparation and Medications)

Bedros Taslakian[1] · Mikhael Georges Sebaaly[2] · Aghiad Al-Kutoubi[2]

Received: 26 June 2015 / Accepted: 4 November 2015 / Published online: 25 November 2015

Abstract Performing an interventional procedure imposes a commitment on interventional radiologists to conduct the initial patient assessment, determine the best course of therapy, and provide long-term care. Patient care before and after an interventional procedure, identification, and management of early and delayed complications of various procedures are equal in importance to the procedure itself. In this second part, we complete the comprehensive, methodical review of pre-procedural care and patient preparation before vascular and interventional radiology procedures.

Keywords Clinical practice · Arterial intervention · Venous intervention · Non-Vascular interventions

Abbreviation

ACCP	American College of Chest Physicians
ACR	American College of Radiology
aPTT	Activated partial thromboplastin time
ASA	American Society of Anesthesiologists
CIN	Contrast-induced nephropathy
FFP	Fresh frozen plasma
GFR	Glomerular filtration rate
ICM	Iodinated contrast medium
IV	Intravenous
LMWH	Low molecular weight heparin
NAS/NRC	National Academy of Sciences/National Research Council
NSAID	Non-steroidal anti-inflammatory drugs
INR	International normalized ratio
SC	Subcutaneous
SIR	Society of Interventional Radiology
UH	Unfractionated heparin
VIR	Vascular and interventional radiology

✉ Aghiad Al-Kutoubi
mk00@aub.edu.lb

Bedros Taslakian
btaslakian@gmail.com

Mikhael Georges Sebaaly
ms246@aub.edu.lb

[1] Department of Radiology, NYU Langone Medical Center, 660 First Avenue, New York, NY 10016, USA

[2] Department of Diagnostic Radiology, American University of Beirut Medical Center, Riad El-Solh, Beirut 1107 2020, PO Box: 11-0236, Lebanon

Introduction

The aim of this review in its second part is to provide a stepwise approach for patient preparation before VIR procedures based on the latest guidelines in the literature. Details vary among institutions, but the principles are universal.

Patient Preparation

Prevention of complications starts with a thorough pre-procedural patient assessment and careful preparation.

Diet and Hydration

Fasting status is an important major predictor of aspiration. For this reason, when preparing a patient for a VIR procedure in which sedation/analgesia is planned, a careful assessment of the gastrointestinal status is essential. This is particularly important as complex interventional procedures requiring the administration of sedation and analgesia are

now frequently performed in the interventional suite and managing patient discomfort has become an integral aspect of interventional procedures. Gastrointestinal and oral intake or gastrostomy feeding restrictions must comply with local fasting guidelines which vary among institutions. Gastrointestinal status report should include a history of conditions in which delayed gastric emptying or gastric reflux occurs, such as pregnancy, diabetic gastroparesis, gastroesophageal reflux disease, hiatal hernia, gastric surgery, peritonitis, and trauma. The presence and severity of related symptoms have practical implications. A history of nausea and vomiting may imply abnormal gastric motility. The American Society of Anesthesiologists (ASA) guidelines for minimum fasting periods prior to sedation/analgesia apply to ''healthy patients'' who are undergoing elective procedures [1]. The ASA guidelines recommend a minimum fasting period of at least 2 h for clear liquid, defined as liquid which one can see through it (e.g., water, fruit juices without pulp, carbonated beverages, clear tea, and black coffee) [1]. A light meal which consists of dry toast and a clear liquid should be withheld for at least 6 h [1]. For meals beyond those considered light, such as fatty foods and meat that may delay gastric emptying, a prolonged fasting period of at least 8 h is recommended and both the amount and type of food ingested must be considered [1]. In urgent and emergent cases, or when conditions in which delayed gastric emptying occurs, the potential risk for aspiration must be taken into consideration to determine the target level of sedation, the need to delay the procedure if possible, or to protect airway by intubation [2]. In these cases, metoclopramide 10 mg intravenous (IV) and an H2 blocker (e.g., 10 mg famotidine IV) may also be administered to stimulate gastric emptying and reduce the likelihood of aspiration [3].

Adequate pre-procedural hydration is vital for patients who will receive significant volumes of intravascular iodinated contrast medium (ICM) to decrease the risk of contrast-induced nephropathy (CIN) [4]. For inpatients, overnight IV hydration using isotonic fluid (Lactated Ringer's or 0.9 % normal saline) [4] should be considered when feasible. There is no consensus on the ideal infusion rate and volume [5], but infusion of 0.9 % saline at 100 mL/hr, beginning 6–12 h before intravascular ICM administration is probably adequate [4]. Pediatric infusion rates vary based on patient weight. Outpatients are encouraged to drink plenty of clear fluids until 2 h before their scheduled procedure to maintain good hydration, but with less demonstrated effectiveness when compared to IV hydration. In patients with cardiac or renal disease, IV hydration should be ordered in consultation with the referring physician, to avoid the risk and complications of fluid overload.

Adjusting Regular Medications

A medication history, including supplements and prior allergies to medications and sedatives, should be meticulously obtained. Certain sedatives, such as meperidine (Demerol®) can interact with many prescription and over-the-counter medications resulting in life-threatening adverse drug reactions [3], highlighting the importance of careful review of medication history in the pre-procedural period. Regular medications such as cardiovascular and respiratory drugs should be continued with sips of water even when pre-procedural fasting is required. Insulin-dependent diabetic patients are instructed to continue their usual insulin doses for early morning procedures and reduce their morning dose by one-half for midday cases to avoid hypoglycemia. Non-insulin-dependent diabetics may be instructed to withhold oral anti-hyperglycemic medications until after the procedure, with special instructions for patients on metformin-containing medications [6]. Metformin, which has a urinary elimination, can rarely lead to the development of metformin-associated lactic acidosis in patients with underlying conditions of delayed renal excretion, decreased metabolism of lactic acid, or increased anaerobic metabolism [4]. Blood sugar levels should be routinely monitored in all patients with diabetes in the peri-procedural period.

Metformin-associated lactic acidosis is a life-threatening condition with a very high mortality rate [4]. For this reason, although ICM is not an independent risk factor for patients taking metformin, intravascular administration of ICM to a patient taking metformin-containing medications is of a potential clinical concern, specifically in patients with comorbidities for lactic acidosis [4, 6]. To assess the risk of lactic acidosis in patients taking metformin, it is essential to stratify the risk of CIN, particularly in the presence of conditions that reduce lactate metabolism (e.g., liver dysfunction or alcohol abuse) or increase lactate production by increasing anaerobic metabolism (e.g., cardiac failure, cardiac or peripheral muscle ischemia, or severe infection) [4]. The American College of Radiology (ACR) recommends classifying patients on metformin, who will be exposed to ICM, into three categories to simplify the pre-procedural management (Fig. 1) [4]. The interventionalist may elect to withhold metformin for 48 h before elective procedures and in these cases diabetic control can be obtained using alternative therapy such as insulin injections in the peri-procedural period [7].

Management of Antithrombotic Agents

Current and emerging antiplatelet and anticoagulant agents are rapidly evolving. Development of novel agents continues to transform the landscape of antithrombotic

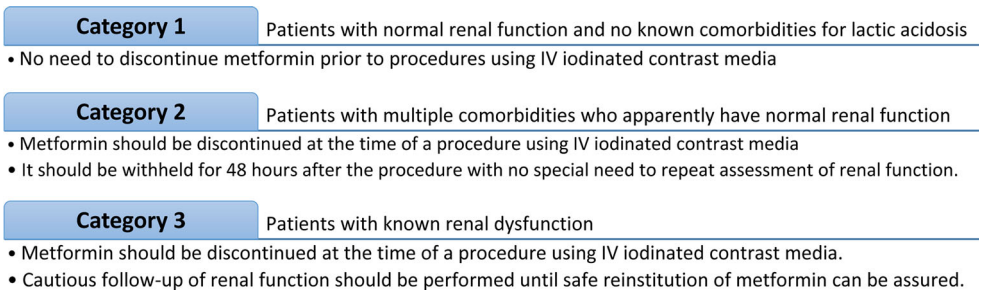

Fig. 1 Pre-procedural assessment in non-insulin-dependent diabetics taking metformin-containing oral hypoglycemic medications [23]

therapy. Oral anticoagulation has advanced with the use of direct thrombin and factor Xa inhibitors that do not require therapeutic monitoring. Management of patients who are receiving antithrombotic drugs during the pre-procedural period requires an understanding of the underlying pathology, indications of administration, pharmacokinetics, and drug interactions. Furthermore, the risks and benefits of discontinuing or continuing these drugs should be assessed, according to the procedure urgency and patient's risk of developing peri-procedural thrombotic or bleeding complications [8, 9].

A set of consensus guidelines were provided by a panel of experts in VIR to guide practitioners when managing antithrombotic agents in the pre-procedural period (Table 1) [8, 10].

Warfarin (Coumadin®), a vitamin K antagonist, reduces the hepatic production of vitamin K-dependent extrinsic pathway clotting factors (II, VII, IX, X), as well as protein C and S [11]. Different factors, including genetics, patient comorbidities, concomitant medication use, as well as diet and nutritional supplements may significantly alter the effect of warfarin leading to over- or under-coagulation [8, 11]. Its clinical effect is monitored by the international normalized ratio (INR), which mainly reflects the reduction of factor VII, which has the shortest half-life of approximately 6 h [11]. Therapeutic INR values may vary by indication for anticoagulation, ranging from 2.2 to 2.8 in most cases. When vitamin K antagonist interruption is required in a stable patient, withholding warfarin with or without the oral administration of vitamin K might be sufficient whenever the procedure is elective [8, 12]. Withholding warfarin for 3–5 days before the procedure is recommended based on the bleeding risk of each specific procedure (Table 1) [8, 10]. The American College of Chest Physicians (ACCP) guidelines recommend that patients at high risk of a thromboembolic event who have a mechanical heart valve, atrial fibrillation, or venous thromboembolic disease have bridging anticoagulation with IV unfractionated heparin (UH) or subcutaneous (SC) low molecular weight heparin (LMWH) [13]. Subsequently, the therapeutic doses of IV UH and SC LMWH can be stopped 2–4 h or 12–24 h before the procedure, respectively, as per Society of Interventional Radiology (SIR) guidelines [8, 10]. On the other hand, patients at low risk, no bridging therapy with heparin is required after withholding warfarin [13]. Vitamin K therapy is a safe and effective method for reversing warfarin-induced anticoagulation. It can be used in conjunction with vitamin K antagonist interruption and administration of blood products, depending on the INR levels and urgency of the procedure. Measuring the INR on the day before the procedure identifies patients with a residual anticoagulant effect in whom vitamin K can be given with the aim of normalizing their INR, avoiding the necessity to transfuse fresh frozen plasma (FFP) on the day of the procedure or deferring the procedure. However, it must also be borne in mind that inappropriate use of vitamin K therapy, particularly in excessive doses, may be more hazardous than the hemorrhagic complications related to a prolonged prothrombin time. The oral route is preferred whenever there is no need for rapid reversal of the warfarin effect, due to the risk of anaphylaxis associated with IV injection [11, 12]. When warfarin interruption alone does not normalize INR, the oral administration of 1.0–2.5 mg of vitamin K is effective in normalizing the INR with no subsequent resistance to warfarin re-anticoagulation after the procedure [13, 14]. Higher doses of vitamin K (5–10 mg) [8] might be, however, required in cases of over-anticoagulation (INR $>$ 4). In urgent cases on the other hand, FFP transfusion (2–4 units or 15–30 mL/kg) [8] with possible concomitant use of vitamin K infusion (5–10 mg slow IV infusion) in the absence of liver disease is required for rapid correction [8].

Unfractionated heparin, usually administered by continuous IV infusion, potentiates the action of antithrombin III. It has a half-life ranging from 23 min to 2.48 h [15], and its clinical effect is monitored by measuring activated partial thromboplastin time (aPTT). It is recommended to withhold IV UH for 2–4 h before performing high-risk procedures with no consensus about management of procedures with low-to-moderate risk for bleeding (Table 1) [8, 10]. In emergency cases, rapid reversal of heparin can be achieved using protamine, which has a rapid onset of action within 10 min after administration [8]. To reverse

Table 1 SIR pre-procedural management guidelines for current antithrombotic medications [10]

Medication	Low-bleeding risk	Moderate-bleeding risk	High risk for bleeding
Warfarin	Withhold for 3–5 days (INR $\leq$ 2.0)	Withhold for 5 days (INR $\leq$ 1.5)	Withhold for 5 days (INR $\leq$ 1.5)
Heparin[a]	No consensus (check aPTT)	No consensus (aPTT $\leq$ 1.5 $\times$ control)	Withhold for 2–4 h (aPTT $\leq$ 1.5 $\times$ control)
LMWH[b]	Withhold one dose or for 12 h	Withhold one dose or for 12 h	Withhold two doses or for 24 h
Fondaparinux	No need to withhold	Withhold for 2–3 days if CrCl $\geq$ 50 mL/min 3–5 days if CrCl $\leq$ 50 mL/min	Withhold for 2–3 days if CrCl $\geq$ 50 mL/min 3–5 days if CrCl $\leq$ 50 mL/min
Argatroban	No need to withhold	Urgent cases $\rightarrow$ withhold for 4 h	Urgent cases $\rightarrow$ withhold for 4 h
Bivalirudin	No need to withhold	Urgent cases $\rightarrow$ withhold for 2–3 h if CrCl $\geq$ 50 mL/min 3–5 h if CrCl $\leq$ 50 mL/min	Urgent cases $\rightarrow$ withhold for 2–3 h if CrCl $\geq$ 50 mL/min 3–5 h if CrCl $\leq$ 50 mL/min
Dabigatran	No need to withhold	Urgent cases $\rightarrow$ withhold for 2–3 days if CrCl $\geq$ 50 mL/min 3–5 days if CrCl $\leq$ 50 mL/min	Urgent cases $\rightarrow$ withhold for 2–3 days if CrCl $\geq$ 50 mL/min 3–5 days if CrCl $\leq$ 50 mL/min
Aspirin	No need to withhold	No need to withhold	Withhold for 5 days
NSAIDs[c]	No need to withhold	No need to withhold	*Short acting* withhold for 24 h *Intermediate-acting* withhold for 2–3 days *Long-acting* withhold for 10 days
Clopidogrel	Withhold for 0–5 days	Withhold for 5 days	Withhold for 5 days
Abciximab	Withhold for 12–24 h	Withhold for 24 h	Withhold for 24 h
Eptifibatide Tirofiban	Withhold immediately pre-procedure	Withhold for 4 h	Withhold for 4 h

CrCl creatinine clearance, *LMWH* low molecular weight heparin, *h* hour, *d* day

[a] Heparin (unfractionated heparin)

[b] LMWH: recommendations regarding therapeutic doses

[c] Short acting NSAIDs: half-life 2–6 h (e.g., ibuprofen, diclofenac, ketoprofen, indomethacin), intermediate-acting NSAIDs: half-life 7–15 h (e.g., naproxen, sulindac, diflunisal, celecoxib), long-acting: half-life >20 h (e.g., meloxicam, nabumetone, piroxicam)

heparin effect, a 1 mg protamine/100 unit heparin ratio can be administered with slow IV push or infusion over 5–10 min [8].

Subcutaneous *low molecular weight heparin* provides anticoagulation by inhibiting factor Xa. It has a short half-life of 2–4 h, and is poorly reversible with protamine and its clinical action cannot be monitored by measuring aPTT or INR [16]. There is consensus to withhold one therapeutic dose of LMWH or for a period of 12 h before performing VIR procedures with a low-to-moderate-bleeding risk, while high-bleeding risk procedures require withholding two therapeutic doses of LMWH or for a period of 24 h before the procedure (Table 1) [8, 10].

Fondaparinux is a subcutaneous anticoagulant that acts as an indirect selective inhibitor of factor Xa with a half-life of approximately 17 h. In addition to the procedural risk for bleeding, recommendation for pre-procedural management varies depending on the renal function, as fondaparinux has a urinary elimination (Table 1) [8, 10].

Direct thrombin inhibitors, such as *bivalirudin* and *dabigatran*, inhibit fibrin-bound as well as circulating thrombin, producing a more predictable anticoagulant response than heparin [17]. Recommendation for pre-procedural management of these drugs is complex and depends on the procedural risk for bleeding, urgency of the procedure, half-life of the antithrombotic agent, and renal function (Table 1) [10].

Drugs that affect platelet function play an essential role in the primary and secondary prevention of atherosclerotic diseases. Different antiplatelet agents are used in the management of thrombotic diseases such as peripheral vascular disease, stroke, acute myocardial infarction, acute coronary syndrome, angina, percutaneous coronary intervention, and cardiac surgery, as well as in the primary and secondary prevention of cardiovascular diseases.

Aspirin, which acts as an irreversible inhibitor of platelet cyclooxygenase (COX)-1, is one of the commonly used oral medications in the prevention of thromboembolic complications from atherosclerotic diseases [18].

Therefore, the effect of aspirin can only be reversed by the generation of new platelets, which have a lifespan of approximately 10 days [19], and only about half of platelets will have a normal function at the time of the procedure if aspirin was withheld for 5 days [8]. On the other hand, the effect of *non-steroidal anti-inflammatory drugs (NSAIDs)* on platelet aggregation is reversible and decreases after clearing the drug from the circulation. Therefore, the antiplatelet effect of NSAISs depends only on the half-life of the drug, unlike aspirin. It is recommended to withhold aspirin administration for 5 days before high-bleeding risk interventional procedures (Table 1) [8, 10]. Withholding NSAIDs is recommended in procedures with high-bleeding risk for a period of 24 h to 10 days, based on the half-life of the drug (Table 1) [10].

Thienopyridines, such as clopidogrel, ticlopidine, and prasugrel, irreversibly inhibit adenosine diphosphate-induced platelet aggregation [18]. In the SIR consensus guidelines, it is recommended to withhold clopidogrel and prasugrel for 0–5 days before procedures with low-bleeding risk and 5 days before procedures with moderate-to-high risk of bleeding (Table 1) [8, 10]. Ticlopidine should be withheld for a longer period of time (7 days) before moderate-to-high-bleeding risk interventions [10].

Glycoprotein IIb/IIIa Inhibitors, such as abciximab, eptifibatide, and tirofiban, are intravenously administered agents that inhibit platelet aggregation by antagonizing the integrin complex glycoprotein IIb/IIIa [20]. They have a short half-life and withholding the drug is recommended before IVR procedures based on the bleeding risk of the procedure and the half-life of the drug (Table 1) [8, 10].

Knowledge of the pharmacodynamics and pharmacokinetics of antithrombotic agents is essential as it allows the interventionalist to understand different factors associated with drug withdrawal and administration in the pre-procedural period, including the potential for drug interactions and the effect of variable associated comorbidities.

Prophylactic Antibiotics

Despite recent advances in both minimally invasive interventional techniques and antibiotic therapy, procedure-related infection remains one of the most common major complications, which can result in serious adverse outcomes. Newly emerging virulent and antibiotic-resistant organisms, increased numbers of immunocompromised patients, as well as adoption of more aggressive therapeutic interventional techniques such as chemoembolization and complex biliary interventions, have presented new challenges in relation to peri-procedural management of infections. Despite the widespread use of prophylactic antibiotics in VIR, the risk of peri-procedural infection can never be completely eliminated yet almost no randomized controlled trials concerning the clinical efficacy and indications for antibiotic prophylaxis exist. Furthermore, non-selective use of broad-spectrum antibiotics can alter the normal flora, predisposing patients to risk of superimposed infections such as Clostridium difficile colitis or facilitating the emergence of antibiotic-resistant bacterial strains such as methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci [21]. Therefore, when selecting peri-procedural prophylactic antibiotics, it should be directed at specific organisms known to be encountered during the procedure, preferably with a narrow-spectrum of activity. 27 years ago, Spies et al. [22] adapted the National Academy of Sciences/National Research Council (NAS/NRC) classification of surgical wounds to classify VIR procedures into four main categories: clean, clean-contaminated, contaminated, and dirty, based on the risk of entering an infected space or crossing of a colonized mucosal surface [23]. However, it should be kept in mind that pathogenesis and infection risk of open surgeries differ from those of percutaneous VIR procedures [24]. Antibiotic prophylaxis is one of the main methods of reducing the risk of peri-procedural infection, in addition to strict adherence to aseptic techniques during the procedure. The SIR standards of Practice Committee published guidelines in 2010 to provide recommendations concerning appropriate pre-procedural antibiotic prophylaxis (Tables 2 and 3) [25]. The use of wound classification system may, to some extent, aid in guiding antibiotic prophylaxis, although its use has been challenged by recent advances in VIR technology and emergence of multidrug resistance organisms [24]. For example, most vascular procedures are classified as clean procedures in the absence of any break in aseptic techniques or infection at the access site (one of contraindications of using the access site). Therefore, in cases of vascular interventions, antibiotic prophylaxis is not required except when using an intravascular grafts or when transvascular embolization is performed with the intent to create tissue infarction or has a high likelihood of solid organ infarction (Table 3) [25]. In addition, when procedure-related infections do occur in vascular interventions, these are most commonly caused by gram-positive bacteria present in mucosal or skin flora such as *Staphylococcus aureus* and *Staphylococcus epidermidis* [24, 25]. Exceptions exist in cases of chemoembolization with the most commonly encountered organisms including *S. aureus*, *Streptococcus* species, *Corynebacterium* species with or without enteric flora [25]. Most procedures requiring antibiotic prophylaxis involve administration of a single dose of an antimicrobial agent within 1 h before incision, preferably by the interventional nurse while preparing the patient in the interventional suite [24, 25]. However, special circumstances should be taken into consideration, such as allowing about 2 h for the

Table 2 SIR practice guidelines for adult antibiotic prophylaxis during non-vascular interventional procedures [25]

Non-vascular procedures	Procedure classification	Routine prophylaxis	Antibiotic regimen
Percutaneous gastrostomy and gastrojejunostomy	Clean-contaminated	Pull technique Recommended Push technique No consensus	Pull technique 1 g IV cefazolin at the time of the procedure* Patients with head and neck cancer 1 g IV cefazolin at the time of the procedure + 500 mg oral cephalexin twice daily for 5 days 600 mg IV clindamycin at the time of the procedure + 600 mg oral clindamycin twice daily for 5 days
Percutaneous nephrostomy, ureteral stenting	Clean-contaminated, contaminated	Recommended	No consensus on first choice agent 1 g IV ceftriaxone** 1 g IV cefazolin** 1.5–3 g IV ampicillin/sulbactam** 1–2 g IV ampicillin + 1.5 mg/kg IV gentamicin**
Percutaneous biliary drainage	Clean-contaminated, contaminated	Recommended	No consensus on first choice agent 1 g IV ceftriaxone** 1 g IV cefotetan IV + 4 g IV mezlocillin** 1.5–3 g IV ampicillin/sulbactam** 2 g IV ampicillin + 1.5 mg/kg IV gentamicin**
Tumor ablation	clean; clean-contaminated	No consensus[a]	No consensus on first choice agent 1.5 g IV ampicillin/sulbactam IV (liver)*** 1 g ceftriaxone IV (renal)*** 1 g cefazolin IV (bone)***
Abscess drainage	Dirty	Recommended[b]	No consensus on first choice agent 1–2 g cefoxitin IV every 6 h*** 1–2 g cefotetan IV every 12 h*** 1 g ceftriaxone IV every 24 h*** 3 g ampicillin/sulbactam IV every 6 h***
Percutaneous biopsy	Clean, except transrectal → dirty	Recommended only if transrectal	No consensus on first choice agent for transrectal biopsy 80 mg gentamicin IM + 250 mg ciprofloxacin twice daily orally for 5 days 500 mg ciprofloxacin twice daily orally for 4 days Start antibiotics the day before biopsy
Vertebroplasty/kyphoplasty	Clean	Yes	First choice 1 g IV cefazolin *

* Penicillin-allergic patients → vancomycin or clindamycin

** Penicillin-allergic patients → vancomycin or clindamycin plus aminoglycoside

*** Penicillin-allergic patients: vancomycin or clindamycin for Gram-positive coverage and aminoglycoside for Gram-negative coverage

[a] Many interventionalists continue to use prophylaxis, with special consideration in patients at risk (e.g., hepatic tumor ablation in cases where retrograde enteric bacterial communication with the biliary tract is present)

[b] Patients referred for abscess drainage are typically being treated with empiric antimicrobial agent, the operator should ensure the appropriateness of empiric agent and may elect to administer a dose before the procedure if a long period of time since the last dose has elapsed

administration of antibiotics with long infusion times (e.g., vancomycin and fluoroquinolones) [24], and for procedures where prolonged prophylaxis or antibiotic treatment is indicated in the presence of clinical infection [25]. Prolonged prophylaxis is recommended in cases of instrumentation of an obstructed viscus where it is recommended to continue antibiotic therapy for 48 h until satisfactory drainage of the obstructed system is achieved [22, 25, 26] or in cases when previous surgical manipulation at the site of the procedure facilitates the spread of infectious organisms (e.g., bilioenteric anastomosis or biliary drainage before chemoembolization) [25]. In patients with clinical infection who have been already started on antibiotic treatment, the operator needs to check the appropriateness of the antibiotic relative to the specific procedure (e.g., a patient might be on gram-positive antibiotic coverage, whereas the procedure predisposes the patient to gram-negative organisms), as well as the time of

Table 3 SIR practice guidelines for adult antibiotic prophylaxis during vascular interventional procedures [25]

Vascular procedures	Procedure classification	Routine prophylaxis	Antibiotic regimens
Angiography, venography, thrombolysis, arterial closure device and stenting	Clean	Not recommended	None Patient at risk for stent infection (indwelling vascular sheath, repeated endovascular procedures within 7 days) 1 g IV cefazolin *
Superficial venous insufficiency treatment	Clean	Not recommended	None
Inferior vena cava filter placement	Clean	Not recommended	None
Aortic and peripheral endograft	Clean	Recommended	First choice antibiotic agent 1 g IV cefazolin*
Central venous access	Clean	No consensus, generally not recommended	Immunocompromised or positive history of catheter infection 1 g IV cefazolin*
Embolization, chemoembolization	Clean, clean-contaminated	Recommended	No consensus on first choice agent Hepatic chemoembolization regimen 1.5–3 g IV ampicillin/sulbactam ** 1 g IV cefazolin + 500 mg IV metronidazole ** 2 g IV ampicillin IV + 1.5 mg/kg gentamicin** Hepatic chemoembolization or renal or splenic embolization 1 g IV ceftriaxone** Hepatic chemoembolization with compromised sphincter of Oddi: consider tazobactam/piperacillin + bowel preparation
Uterine artery embolization	Clean, clean-contaminated	Recommended	No consensus on first choice agent 1 g IV cefazolin* 900 mg IV clindamycin + 1.5 mg/kg gentamicin 2 g IV ampicillin* 1.5–3 IV g ampicillin/sulbactam* History of hydrosalpinx: 100 mg doxycycline twice daily for 7 days
Transjugular intrahepatic Portosystemic shunt creation	Clean, clean-contaminated	Recommended	No consensus on first choice agent 1 g IV ceftriaxone** 1.5–3 g IV ampicillin/sulbactam**

* Penicillin-allergic patients → vancomycin or clindamycin

** Penicillin-allergic patients → vancomycin or clindamycin plus aminoglycoside

the last administered dose as an additional dose or a different agent may be required before the procedure to provide adequate coverage of the likely pathogen [26]. In addition, a supplemental dose of antibiotic medication should be considered when a complex procedure is likely to be prolonged for more than 2 h depending on the half-life of the antimicrobial agent [26].

Contrast-Induced Nephrotoxicity: How to Avoid

Contrast-induced nephrotoxicity, defined as an acute decline in renal function in the absence of causes other than intravascular ICM administration, remains one of the most important complications of vascular procedures and is associated with significant morbidity and mortality [4, 27]. It should be differentiated (but often not possible in daily medical practice) from post-contrast acute kidney injury that might occur as a result of a variety of coexisting conditions [5]. When CIN occurs, an increase in the serum creatinine levels is usually detected within 24–48 h of exposure, with a notable peak at 3–5 days, and often returning to baseline within 7–10 days [4, 27]. To date, there are no standardized diagnostic criteria, with the absolute increase in serum creatinine by 0.5 mg/dL from baseline values being one of the most commonly used benchmarks [4, 27]. In addition, some authors use an increase in serum creatinine from the baseline by 25–50 % as a diagnostic criterion for CIN [4, 27].

There are many risk factors for CIN (Fig. 2), with the presence of a pre-existing renal insufficiency being one of

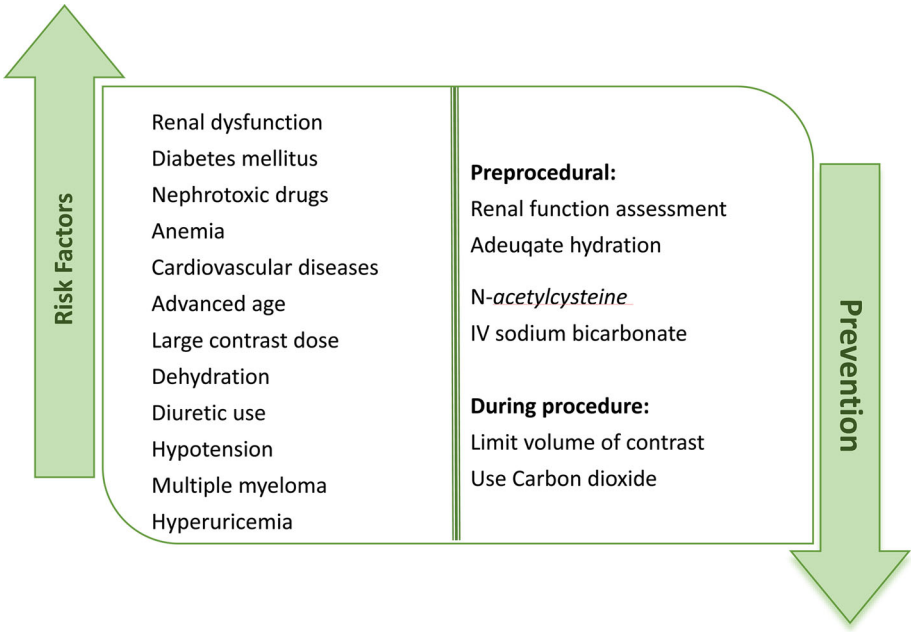

Fig. 2 Risk factors for contrast-induced nephropathy and prevention methods [4]

the most important risk factors especially in patients with diabetic nephropathy [4, 27, 28]. Identifying patient at increased risk of CIN is crucial since the prevention is best achieved by stratifying and managing risk factors, adequate pre-procedural hydration, medical pretreatment, and sometimes using an alternative contrast material such as carbon dioxide or gadolinium-based contrast (Fig. 2) [4, 27].

The risk of CIN in patients with a baseline creatinine level of ≥2.0 mg/dL is about 62 versus 10.4 % in patients with a baseline creatinine of 1.4–1.9 mg/dL and only 2 % if baseline creatinine level is ≤1.2 mg/dL [29]. Therefore, a serum creatinine cutoff level of 2.0 mg/dL in patients with stable chronic renal disease is a safe threshold in most patients [4], although there is no sufficient data available in the literature to set a specific cutoff point. The glomerular filtration rate (GFR), which can be estimated from the serum creatinine is used to more precisely identify patients who are at increased risk for CIN [27]. CIN does occur, but is not common if not non-existent, in patients with normal renal function or stage I–IIIA chronic kidney disease (i.e., GFR of ≥45 mL/min/1.73 m^2) [5, 27, 28] and rarely occurs in children [30]. This conclusion has been reached based on a series of recent large-scale studies that have assessed the risk of CIN after ICM administration in a quantitative fashion, and therefore, the radiology community is becoming increasingly confident that the CIN risk is overemphasized [5]. On the other hand, these studies failed to reach a concordant conclusion for patients with an estimated GFR of ≤45 mL/min/1.73 m^2 stage (i.e., IIIB–V chronic kidney disease), keeping the estimated risk of CIN in this group of patients with severe renal impairment uncertain to date [5]. Based on what mentioned, a new cutoff level of GFR <45 mL/min/1.73 m^2 might be considered in the future, as opposed to the old risk-threshold using an estimated GFR cutoff of <60 mL/min/1.73 m^2 [5]. As a result of the scientific uncertainty about the true incidence and significance of CIN, the ACR suggests that the risk of CIN should be considered as if it is a real phenomenon in patients with renal impairment [4]. In addition, in patients with acute renal failure, intravascular administration of ICM should be avoided regardless of the degree of renal dysfunction. On the other hand, patients with anuric end-stage chronic renal disease have non-functioning kidneys and are at no risk for CIN [4]. Therefore, intravascular administration of ICM in this subgroup of patients is not contraindicated, regardless of the baseline creatinine levels, as it poses no risk of additional renal injury [4], with post-exposure dialysis only considered in patients with underlying cardiac dysfunction or in cases when an unusually high volume of contrast has been administered during the procedure [31].

After identifying patients at risk of CIN, prevention is essential and starts with obtaining pre-procedural renal function tests (Fig. 2). Intravenous volume expansion with normal saline prior to ICM administration plays an essential role in decreasing the risk of developing CIN [27]. The minimum and the optimum effective regimens are not yet clearly identified and might vary depending on the patient's medical condition [5]. In addition, the effectiveness of oral compared to intravenous hydration has to be further investigated, as there is no sufficient evidence to date [4]. Some authors advocate the use of sodium bicarbonate and *N*-acetylcysteine to decrease the risk, while others showed

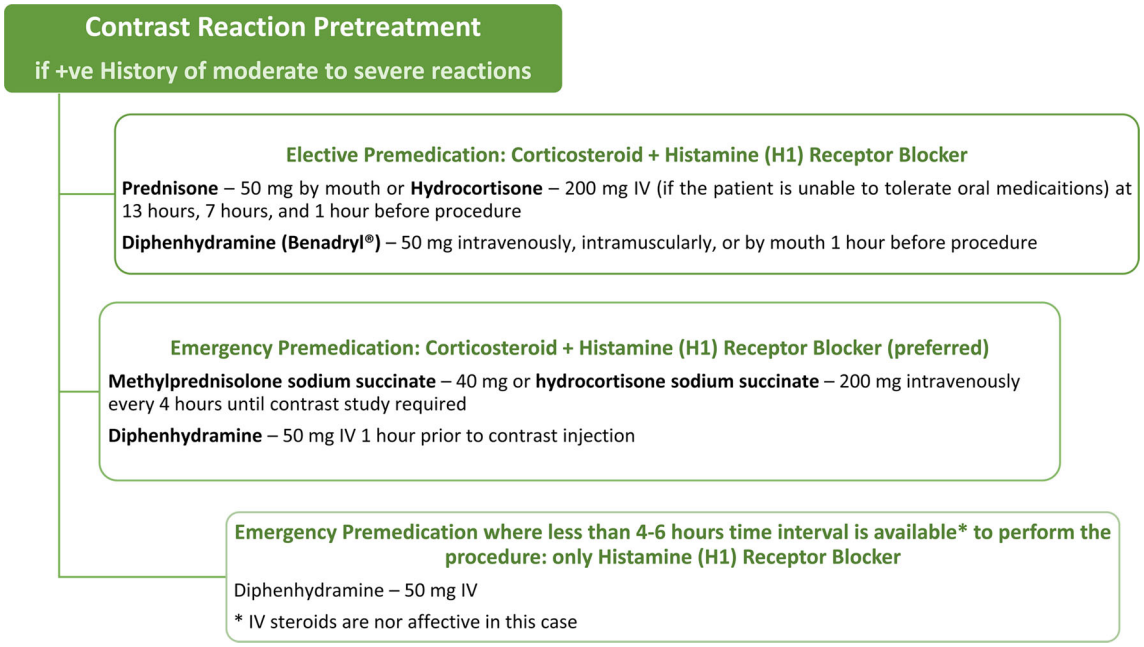

Fig. 3 Contrast reaction pretreatment guidelines [4]

no evidence of significant benefit [5]. Therefore, the efficacy of pretreatment with *N*-acetylcysteine and use of sodium bicarbonate is controversial, and left for the physician preference.

Adverse Contrast Media Reactions: Need for Prevention

Adverse reaction to contrast media is one of the serious complications of intravascular ICM. Unlike CIN, it is independent to dose and concentration above a certain threshold [32]. Although most of these reactions are mild, some patients can experience significant life-threatening reactions. Therefore, it is imperative that interventional radiologists be aware that adverse contrast media reactions continue to occur unpredictably and identifying patients at high risk for adverse reactions and taking the appropriate measures is crucial. The risk of adverse reaction to ICM has significantly decreased with the use of non-ionic low-osmolality contrast agents (0.2–0.7 %) compared to older, cheaper ionic high-osmolality agents (5–15 %) [4]. Risk factors include a history of prior allergic-like reaction to intravascular ICM injection, atopic patients particularly those with a pervious history of multiple severe allergic reactions and asthmatic patients [4, 32]. On the other hand, specific allergies to shellfish, dairy products, or iodine are not considered a reliable predictor [33]. In addition, it is important to be aware that the presence of pre-existing medical conditions, such as significant pulmonary and cardiovascular diseases, may worsen the consequences of adverse contrast media reaction and render the management more challenging should any reaction occur [4]. Therefore, interventional radiologist should carefully acquire information about the allergen, as well as type and severity of prior allergic reactions. The sensation of heat, flushing, pain, or warmth upon injection of contrast material represents physiologic responses that are dependent to dose and osmolality of ICM and do not indicate an increased risk of adverse reactions [4]. Several strategies have been proposed for the prevention of contrast-related adverse reactions in "at risk" patients, based on the urgency of the procedure during which intravascular contrast material injection is required (Fig. 3) [4, 34, 35].

On the Day of the Procedure

Before starting the procedure, interventional radiologists should ensure the preparedness of the team, availability of all required equipment, and the presence of a support team and anesthetists if needed. The procedure plan should be discussed with the interventional team, including assistants, technologists, and nurses. Consent re-affirmation might be necessary in certain situations as previously discussed. Pre-procedural sedation, using lorazepam [0.5–2.0 mg orally], can be administered to reduced patient's anxiety. The patient should be quickly reevaluated in the interventional suite. Routine pre-procedural vital signs need to be obtained, and IV fluids started. Immediately before starting the procedure, and with the entire interventional team present, the Joint Commission

mandates a "pre-operative verification process" or a "time out," as a final verification of the correct patient, procedure, and site [36]. "Time out" secures active communication and collaboration among all peri-procedural team members in the location where the procedure is to be done. Identity should be confirmed by announcing the name, medical record number, and birthdate on the patient's wrist band. The planned procedure then must be verbalized along with the site and side of intervention, along with reconciliation of the signed consent form and confirmation of on-site existence of any specialized equipment necessary for the procedure. Finally, any known drug allergies or required prophylactic antibiotics are stated.

Conclusion

Every successful invasive procedure begins with a meticulous patient evaluation, determination of the appropriateness of the procedure, and formulation of a procedural plan. Interventional radiologists performing the procedure should assume primary responsibility for management of the disease. Knowledge of pre-procedural preparation steps and optimal work habits in the interventional suite provide the best balance for a better patient care.

Compliance with Ethical Standards

Conflict of Interest None.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent Does not apply.

References

1. American Society of Anesthesiologists Committee. Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures: an updated report by the American Society of Anesthesiologists Committee on Standards and Practice Parameters. Anesthesiology. 2011;114(3):495–511.
2. American Society of Anesthesiologists Task Force on Sedation, Analgesia by Non-Anesthesiologists. Practice guidelines for sedation and analgesia by non-anesthesiologists. Anesthesiology. 2002;96(4):1004–17.
3. Moran TC, Kaye AD, Mai AH, Bok LR. Sedation, analgesia, and local anesthesia: a review for general and interventional radiologists. Radiographics. 2013;33(2):E47–60.
4. American College of Radiology. ACR manual on contrast media. Reston: American College of Radiology; 2012.
5. Davenport MS, Cohan RH, Ellis JH. Contrast media controversies in 2015: imaging patients with renal impairment or risk of contrast reaction. Am J Roentgenol. 2015;204(6):1174–81.
6. Parra D, Legreid AM, Beckey NP, Reyes S. Metformin monitoring and change in serum creatinine levels in patients undergoing radiologic procedures involving administration of intravenous contrast media. Pharmacotherapy. 2004;24(8):987–93.
7. Nawaz S, Cleveland T, Gaines PA, Chan P. Clinical risk associated with contrast angiography in metformin treated patients: a clinical review. Clin Radiol. 1998;53(5):342–4.
8. Patel IJ, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, et al. Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. J Vasc Interv Radiol. 2012;23(6):727–36.
9. Hall R, Mazer CD. Antiplatelet drugs: a review of their pharmacology and management in the perioperative period. Anesth Analg. 2011;112(2):292–318.
10. Patel IJ, Davidson JC, Nikolic B, Salazar GM, Schwartzberg MS, Walker TG, et al. Addendum of newer anticoagulants to the SIR consensus guideline. J Vasc Interv Radiol. 2013;24(5):641–5.
11. Ageno W, Gallus AS, Wittkowsky A, Crowther M, Hylek EM, Palareti G. Oral anticoagulant therapy: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2012;141(2 Suppl):e44S–88S.
12. Holbrook A, Schulman S, Witt DM, Vandvik PO, Fish J, Kovacs MJ, et al. Evidence-based management of anticoagulant therapy: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2012;141(2 Suppl):e152S–84S.
13. Douketis JD, Spyropoulos AC, Spencer FA, Mayr M, Jaffer AK, Eckman MH, et al. Perioperative management of antithrombotic therapy: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2012;141(2 Suppl):e326S–50S.
14. Woods K, Douketis JD, Kathirgamanathan K, Yi Q, Crowther MA. Low-dose oral vitamin K to normalize the international normalized ratio prior to surgery in patients who require temporary interruption of warfarin. J Thromb Thrombolysis. 2007;24(2):93–7.
15. McAvoy TJ. The biologic half-life of heparin. Clin Pharmacol Ther. 1979;25(3):372–9.
16. Garcia DA, Baglin TP, Weitz JI, Samama MM. Parenteral anticoagulants: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2012;141(2 Suppl):e24S–43S.
17. Weitz JI, Crowther M. Direct thrombin inhibitors. Thromb Res. 2002;106(3):V275–84.
18. Depta JP, Bhatt DL. New approaches to inhibiting platelets and coagulation. Annu Rev Pharmacol Toxicol. 2015;55:373–97.
19. Burch JW, Stanford N, Majerus PW. Inhibition of platelet prostaglandin synthetase by oral aspirin. J Clin Invest. 1978;61(2):314–9.
20. Lippi G, Montagnana M, Danese E, Favaloro EJ, Franchini M. Glycoprotein IIb/IIIa inhibitors: an update on the mechanism of action and use of functional testing methods to assess antiplatelet efficacy. Biomark Med. 2011;5(1):63–70.
21. Jones RN, Pfaller MA. Bacterial resistance: a worldwide problem. Diagn Microbiol Infect Dis. 1998;31(2):379–88.
22. Spies JB, Rosen RJ, Lebowitz AS. Antibiotic prophylaxis in vascular and interventional radiology: a rational approach. Radiology. 1988;166(2):381–7.
23. McDermott VG, Schuster MG, Smith TP. Antibiotic prophylaxis in vascular and interventional radiology. Am J Roentgenol. 1997;169(1):31–8.
24. Sutcliffe JA, Briggs JH, Little MW, McCarthy E, Wigham A, Bratby M, et al. Antibiotics in interventional radiology. Clin Radiol. 2015;70(3):223–34.

25. Venkatesan AM, Kundu S, Sacks D, Wallace MJ, Wojak JC, Rose SC, et al. Practice guidelines for adult antibiotic prophylaxis during vascular and interventional radiology procedures. J Vasc Interv Radiol. 2010;21(11):1611–30.
26. Ryan JM, Ryan BM, Smith TP. Antibiotic prophylaxis in interventional radiology. J Vasc Interv Radiol. 2004;15(6):547–56.
27. Pucelikova T, Dangas G, Mehran R. Contrast-induced nephropathy. Catheter Cardiovasc Interv. 2008;71(1):62–72.
28. Katzberg RW, Newhouse JH. Intravenous contrast medium-induced nephrotoxicity: is the medical risk really as great as we have come to believe? Radiology. 2010;256(1):21–8.
29. Hall KA, Wong RW, Hunter GC, Camazine BM, Rappaport WA, Smyth SH, et al. Contrast-induced nephrotoxicity: the effects of vasodilator therapy. J Surg Res. 1992;53(4):317–20.
30. Ajami G, Derakhshan A, Amoozgar H, Mohamadi M, Borzouee M, Basiratnia M, et al. Risk of nephropathy after consumption of nonionic contrast media by children undergoing cardiac angiography: a prospective study. Pediatr Cardiol. 2010;31(5):668–73.
31. Younathan CM, Kaude JV, Cook MD, Shaw GS, Peterson JC. Dialysis is not indicated immediately after administration of nonionic contrast agents in patients with end-stage renal disease treated by maintenance dialysis. Am J Roentgenol. 1994;163(4):969–71.
32. Bush WH, Swanson DP. Acute reactions to intravascular contrast media: types, risk factors, recognition, and specific treatment. Am J Roentgenol. 1991;157(6):1153–61.
33. Beaty AD, Lieberman PL, Slavin RG. Seafood allergy and radiocontrast media: are physicians propagating a myth? Am J Med. 2008;121(2):158.e1–4.
34. Greenberger PA, Halwig JM, Patterson R, Wallemark CB. Emergency administration of radiocontrast media in high-risk patients. J Allergy Clin Immunol. 1986;77(4):630–4.
35. Lasser EC, Berry CC, Talner LB, Santini LC, Lang EK, Gerber FH, et al. Pretreatment with corticosteroids to alleviate reactions to intravenous contrast material. N Engl J Med. 1987;317(14):845–9.
36. Angle JF, Nemcek AA Jr, Cohen AM, Miller DL, Grassi CJ, D'Agostino HR, et al. Quality improvement guidelines for preventing wrong site, wrong procedure, and wrong person errors: application of the joint commission "universal protocol for preventing wrong site, wrong procedure, wrong person surgery" to the practice of interventional radiology. J Vasc Interv Radiol. 2009;20(7 Suppl):S256–62.