

Patient Evaluation and Preparation in Vascular and Interventional Radiology: What Every Interventional Radiologist Should Know (Part 1: Patient Assessment and Laboratory Tests)

Bedros Taslakian¹ · Mikhael Georges Sebaaly² · Aghiad Al-Kutoubi²

Received: 26 June 2015 / Accepted: 11 September 2015 / Published online: 22 October 2015

© Springer Science+Business Media New York and the Cardiovascular and Interventional Radiological Society of Europe (CIRSE) 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 after the procedure is completed. After patient referral, contact with the referring physician and multidisciplinary team approach is vital. In addition, clinical history, physical examination, as well as full understanding of the pre-procedural laboratory results and imaging findings can guide the interventional radiologist to implement the most appropriate management plan, avoid unnecessary procedures, and prevent complications to achieve a successful outcome. We provide a comprehensive, methodical review of pre-procedural care and management in patients undergoing vascular and interventional radiology procedures.

Abbreviations

aPTT	Activated partial thromboplastin time
CIN	Contrast-induced nephropathy
CIRSE	Cardiovascular and Interventional Radiology Society of Europe
FFP	Fresh frozen plasma

GFR	Glomerular filtration rate
ICM	Iodinated contrast medium
PT	Prothrombin time
INR	International normalized ratio
SIR	Society of Interventional Radiology
VIR	Vascular and interventional radiology

Introduction

Since 1967, when Dr. Alexander Margulis proposed a new subspecialty within the family of imaging [1], interventional radiology has been transformed into a fully fledged clinical specialty. Successful interventional radiologists in this new era must have strong clinical skills and be familiar with relevant diseases, procedure techniques, and possible complications. Adverse events that occur during vascular and interventional radiology (VIR) procedures are frequently related to poor pre-procedural planning and ineffective communication between healthcare team members and operator or patient and operator.

Interventional care is a longitudinal continuum, beginning with an initial consultation (Fig. 1). Advance planning, which starts at that point, is the key for success and provides the cornerstone for a safe procedure and subsequently the desirable outcome. Key questions address the preparedness of the interventional team in general and the operator specifically to perform a procedure (Fig. 2).

The aim of this review, in conjunction with its second part, is to provide a comprehensive systematic approach to the essential steps in pre-procedural care, emphasize the importance of advance planning in achieving good outcome, review key history and physical examination findings, and discuss the essential laboratory tests required in

✉ 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, PO Box: 11-0236, 1107 2020 Beirut, Lebanon

Fig. 1 Comprehensive and systematic approach to the essential steps in pre-procedural care

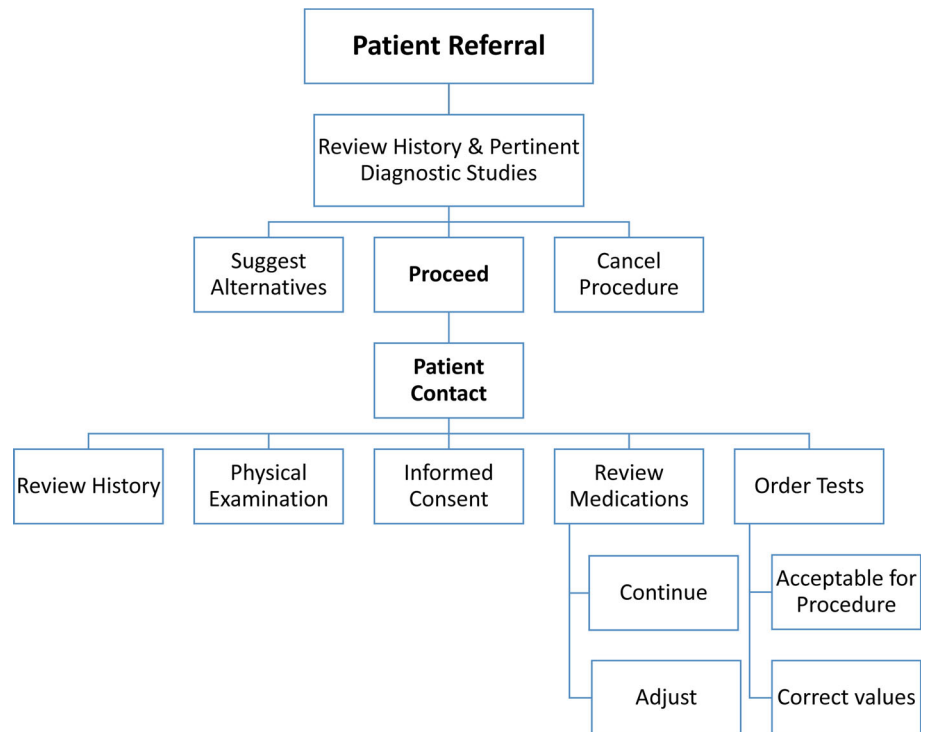


Fig. 2 Key questions in advance planning

the pre-procedural period. We also stress the importance of reviewing previous imaging studies and clinical data in planning the procedure, suggesting an alternative approach and avoiding potential complications. We provide a step-wise approach for patient preparation before VIR procedures based on the latest guidelines in the literature. Details may vary among institutions, but the principles are

universal. It is the practice in many institutions that a pre-procedural form is filled out.

Patient Referral and Contact

Patient Referral

Decision making after patient referral is largely related to effective communication between the interventional radiologist and the referring physician for straightforward cases, whereas multidisciplinary team approach is essential when discussing complex procedures, and can significantly affect the quality of care delivered to patients. This ensures that the appropriate procedure is performed, the potential risks and benefits for the individual patient are discussed, and the likely outcome is understood. A multidisciplinary team discussion is a basic tool for consensus building on the primary therapy and to have an alternative plan of management, should any failure or complication occur during the course of therapy. The operator must review the appropriate indications for the proposed intervention based on the criteria established in the medical literature or guidelines published by bodies such as the Society of Interventional Radiology (SIR) [2–4] and the Cardiovascular and Interventional Radiology Society of Europe (CIRSE). Risk factors that may require a delay or modification of the proposed procedure or adaptation of an

alternative therapeutic approach should also be taken into consideration.

Patient Contact

Reviewing the medical history and all pertinent diagnostic tests and imaging studies before seeing the patient ensures that the appropriate procedure is selected and is indicated (Table 1). Reviewing previous imaging studies leads to avoidance of complications and decreased procedure time and consequently the radiation exposure. It helps in planning complex procedures in advance (Fig. 3), selecting the appropriate interventional device (Fig. 4), suggesting an alternative approach (Figs. 5, 6), choosing a safer alternative treatment (Fig. 7), and adjusting for specific predisposing factors (Fig. 8). The initial consultation between the patient and interventional radiologist establishes rapport, allows review of the history firsthand, and provides an opportunity to explain the procedure in detail and thus reduce anxiety. Patient contact should ideally occur at a time and place remote from the procedure, to help the patient or decision-maker to be more relaxed and attentive. Inpatients are assessed during a bedside visit the day before the procedure and outpatients are preferably evaluated in a dedicated interventional clinic, with special measures in pediatric patients [3, 4]. Need for anesthetic support/requirement may also be addressed at this point.

The pre-procedural clinical evaluation includes obtaining the history of current problem and pertinent medical/surgical history, review of organ systems and current medications, as well as any history of adverse reactions specifically to anesthetics and contrast material. Directed physical examination is essential with special considerations in vascular procedures for which the interventional radiologist should evaluate and document the proposed puncture site, all extremity pulses, and the condition of extremities. In patients with local infection, preexisting pseudoaneurysm, hematoma, inguinal hernias, fresh incisions, and recent injuries to the site of puncture, an

alternative access site should be selected [5, 6]. Special attention is required to the risk factors of contrast-induced nephropathy (CIN) and contrast allergy [7, 8].

The informed consent should be obtained by a qualified doctor, usually the operator, who fully understands the procedure, its risks and benefits, as well as the alternatives and is able to explain the proposed intervention to the patient, the legal representative or to the parent of a minor [9, 10]. The physician should provide relevant and sufficient information regarding the procedure and the expected immediate and long-term outcomes, basic explanation of the medical condition and its prognosis, and a balanced explanation of the treatment and management options along with the risks and benefits of the procedure and its alternatives [9]. Risks of not performing the procedure should be discussed with the consentor [9]. It is also recommended to discuss the risks of radiation exposure for procedures that require ionizing radiation for guidance [11]. The consenting individual should have full access to all relevant information in a sensitive way to their language and comprehension. If the patient is not fluent in the native language of the health care team, assistance from a certified medical interpreter is required. When an over-the-phone consent is required from a family member or the patient's legal representative, a witness must document the conversation [10]. Many consent forms have a section to allow reaffirmation of consent and review the patient's decision close to the time of treatment. This might be necessary when significant time elapses since consent was obtained; when a different health care member obtains consent in an outpatient clinic or on the floor; or when changes to the treatment plan are made after the initial consent is obtained.

Laboratory Testing and Correction

Laboratory testing is of paramount importance when preparing patients for VIR procedures. It minimizes procedural risk and reduces complications by detecting, and

Table 1 Essential Steps in the Pre-procedural Clinical Evaluation

General procedures	Additional steps for vascular procedures
History of current problem	Evaluate the proposed puncture site
Pertinent medical history	Evaluate and document extremity pulses
Pertinent surgical history	Evaluate risk of contrast-induced nephropathy
Review of organ systems	History of allergy to contrast material
Review of current medications	
Review of previous laboratory results	
Review of previous imaging studies	
History of allergy	
Directed physical examination	
Order directed laboratory tests	

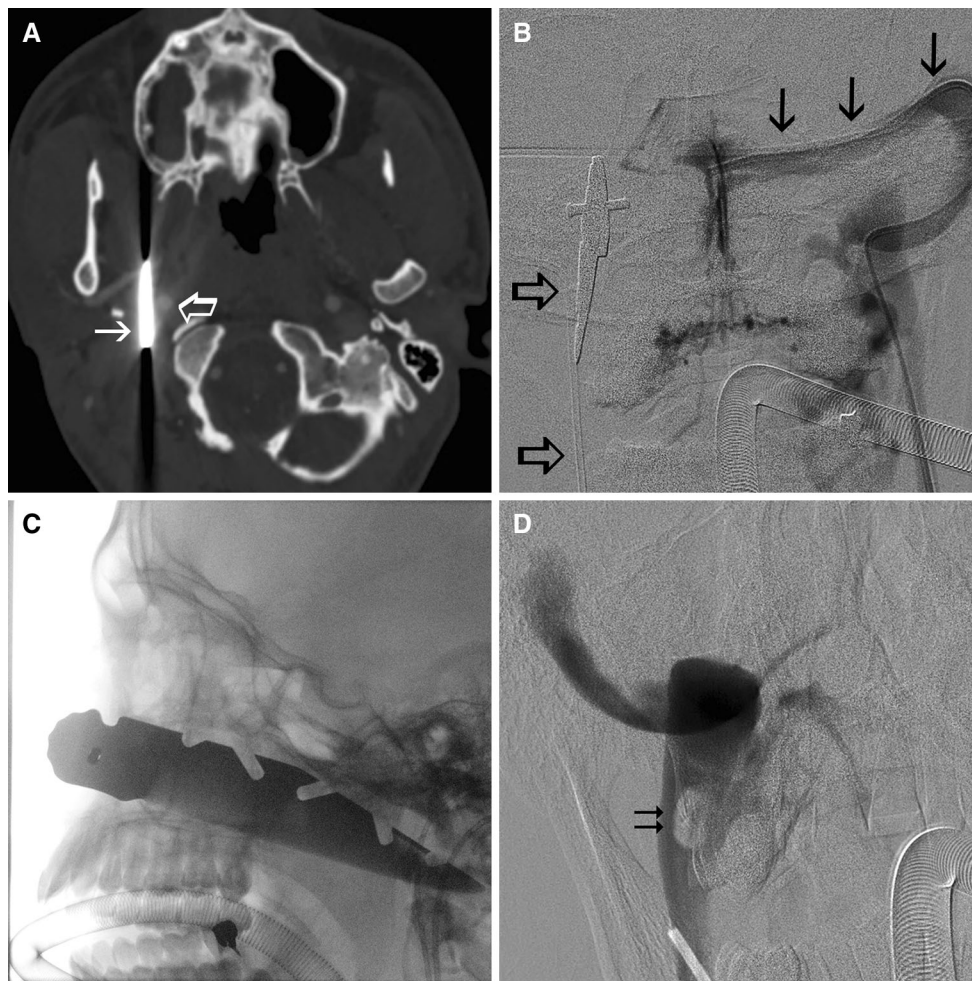


Fig. 3 20 year-old male patient presented with penetrating stab wound injury to the anatomic Zone III of the right neck, with a 12 cm serrated knife blade retained in the skull. **a** Axial contrast-enhanced CT image showing the blade apparently traversing the right internal jugular vein (arrow), and retained in a very close proximity to the right internal carotid artery (open arrow) with no significant surrounding hematoma. Removal of the blade under fluoroscopy guidance and angiographic control was planned. Carotid and vertebral angiography and internal jugular venography was performed to rule out active extravasation or arterial dissection. Balloon catheters were introduced in the right internal carotid artery to occlude the artery should any bleeding occur while retrieving the blade. **b** The contralateral left internal jugular vein was catheterized (arrows) to

reach the right internal jugular vein above the site of injury for balloon occlusion. The ipsilateral internal jugular vein was also catheterized (open arrows), passing the catheter over a hydrophilic wire across the site of injury for possible stenting in case any bleeding occurs. **c** Lateral spot image of the head after catheterizing the internal jugular veins, showing the blade adjacent to the major vascular structures and the catheters in the internal jugular veins. **d** Internal jugular venography after removal of the blade, showing a filling defect at the site of the injury (double arrow) probably due to intramural hematoma with no evidence of contrast extravasation. No arterial injuries were detected and the patient was discharged from the hospital after few days of uneventful hospitalization on antibiotics

when necessary correcting, relevant abnormalities. Based on the pre-procedural laboratory results, altering the procedure technique, canceling the procedure, and choosing a safer treatment option decrease the rate of complications. In addition, testing provides a baseline to direct and follow response to treatment in specific cases, such as urinalysis, urine culture, and sensitivity before nephrostomy, white blood cell count before abscess drainage, and liver function tests before biliary drainage. Pre-procedural laboratory testing may be routinely performed on all patients or

selective testing directed to detect suspected abnormalities [12]. Routine pre-procedural screening has proved to be of little value [13, 14], and is generally unnecessary in an otherwise healthy young patients. On the other hand, selective testing is warranted and directed to detect specific abnormalities based on the proposed procedure, patient age, and risk factors. The acceptable threshold of laboratory tests that warrants correction or cancellation of the procedure varies among hospitals and clinical situations and therefore cannot be generalized. However, specific



Fig. 4 A 45-year-old male presented with traumatic liver injury referred for embolization of the hepatic artery. Review of enhanced CT scan showed severely narrowed celiac trunk (*arrow*) due to arcuate ligament syndrome at the level of T12. Selecting the optimal catheter type before starting the procedure and catheterizing the celiac trunk at the correct location (T12) saves time and reduces radiation dose to the patient and operators

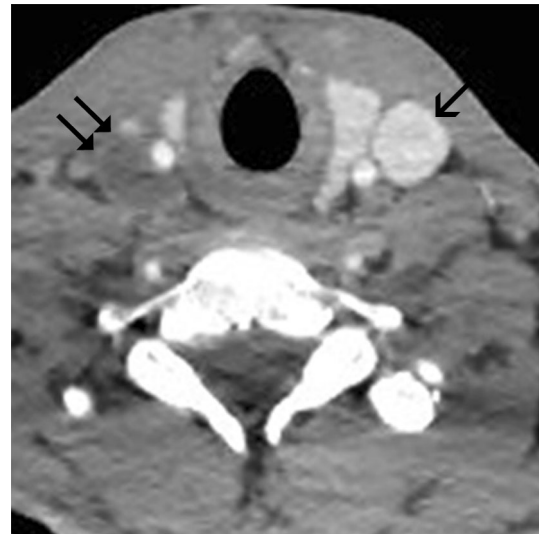


Fig. 6 A 30-year-old male patient, known to have testicular cancer with lung and liver metastases, was referred for subcutaneous port insertion. Review of previous CT images showed a thrombosed *right* jugular vein (*double arrow*) and right subclavian vein, with a patent superior vena cava. The patent *left* internal jugular vein (*arrow*) was selected in advance for port insertion, decreasing the likelihood of procedure failure and reducing potential radiation exposure

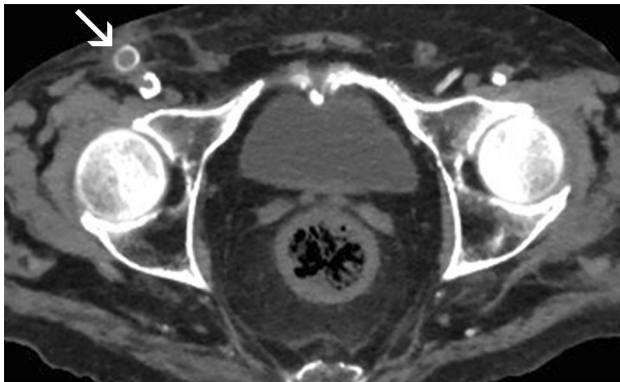


Fig. 5 A 70-year-old male patient presented with acute gastrointestinal bleeding, referred for angiography and embolization of the bleeder. Review of the previous CT showed a *right* femoral artery graft (*arrow*). A *left* femoral artery access was selected

criteria have been established in the medical literature or endorsed by the specialty societies and can be used when setting hospital or departmental policies. These are discussed below.

Coagulation Parameters Simplified

Detection and control of bleeding during or after percutaneous procedures is more challenging compared to open surgical cases during which any bleeding complications are typically directly visualized and immediately controlled by

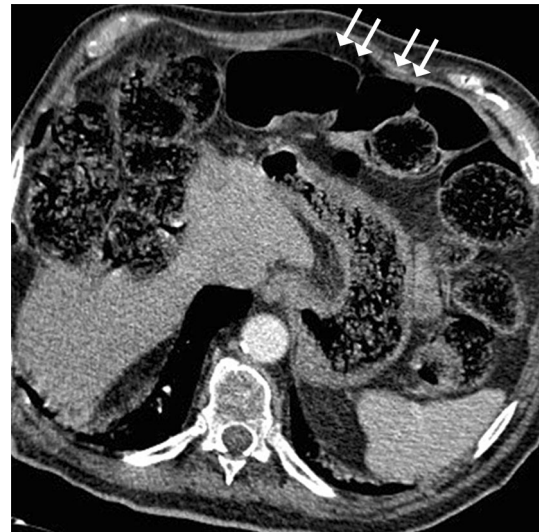


Fig. 7 A 75-year-old male with history of stroke referred for percutaneous gastrostomy tube placement. Review of the previous CT images showed interposition of the transverse colon (*arrows*) between the stomach and anterior abdominal wall precluding safe percutaneous gastrostomy insertion. The patient was referred for surgical gastrostomy

the surgeon. Pre-procedural assessment and correction of coagulation parameters vary according to the institutional policies, personal preferences of interventionalists, and the type of the procedure in conjunction with a comprehensive assessment of different patient's comorbidities. Routine

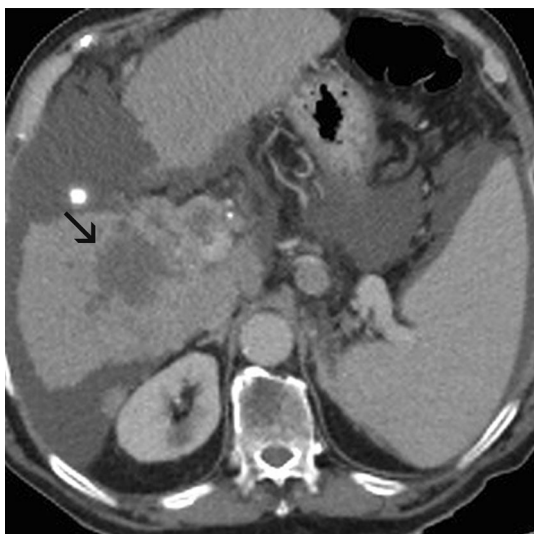


Fig. 8 A 69-year-old male, known to have liver cirrhosis, referred for targeted biopsy of a hepatic lesion (*arrow*). Review of recent CT images showed moderate amount of ascites. Persistent ascites was confirmed by ultrasound and the patient was scheduled for percutaneous ascites drainage prior to the biopsy to decrease the risk of uncontrolled bleeding

testing is the practice in many institutions, with many differences regarding the pre-procedural testing of the coagulation parameters and the threshold set for correcting abnormal values. In fact, there are equivocal data regarding the accepted values of coagulation tests in predicting the likelihood of bleeding from invasive procedures [15, 16]. The use of coagulation tests should be dictated by the indication for the procedure, location and type of target lesion or organ, the size of interventional devices used, and findings from the patient history and physical examination that are suggestive of an increased risk of uncontrollable bleeding. Thus, pre-procedural assessment of the coagulation status is vital whenever the patient has known or suspected risk factors for bleeding (e.g., liver disease, renal failure, thrombocytopenia, disseminated intravascular coagulation, etc.), when the procedure involves traversing, or a possibility of inadvertent entry, into a vascular structure with significantly sized interventional devices, or when the resulting bleeding is only detectable after significant blood loss has occurred and when the bleeding is difficult to control [17, 18]. In the absence of strong evidence regarding pre-procedural management of coagulation parameters in patients undergoing VIR procedures, a panel of experts in the field of VIR published a set of consensus guidelines as a reference for interventionalists [17, 18]. VIR procedures were classified into three different categories (Fig. 9): procedures with low bleeding risk, procedures with moderate bleeding risk, and procedures with significant bleeding risk [17, 18]. This classification is

based on the organ system, the access site, and size of interventional devices used for the specific procedure. The high-risk group also included procedures that can result in hemorrhage in a “hidden” location that allows no or poor prompt control of the bleeding when it occurs [17]. However, a question that might occur is: what if stopping the antithrombotic agent or correcting a value would put the patient at an increased risk for a cardiovascular or thromboembolic event. This situation is not infrequently encountered when a patient with recent coronary or cerebrovascular stenting on anticoagulation or antiplatelet therapy needs a percutaneous intervention. The answer is very simple if we apply the basic concept in medicine: “do no harm” and always weigh risks versus benefits in any medical decision. Therefore, the operator can, with appropriate consultations, apply exceptions in cases when emergency interventional procedure is indicated or anticoagulation cannot be safely withheld [18].

A prolonged prothrombin time (PT) and elevated international normalized ratio (INR) are seen in patients with a variety of medical conditions as well as patients on anticoagulation therapy. It is recommended to correct INR values based on the procedure’s bleeding risk category, with INR of two or higher and INR of 1.5 or higher set as a threshold for correction in low-risk and moderate-to-high-risk procedures, respectively (Table 2) [17, 18]. Withholding warfarin with or without the administration of vitamin K and fresh frozen plasma (FFP) is used to correct abnormal INR values, which will be discussed later in details.

A prolonged activated partial thromboplastin time (aPTT) of different causes can be corrected by withholding the unfractionated heparin before the procedure, and/or transfusing FFP in urgent cases. Threshold value of $\leq 1.5 \times$ control for moderate and high-risk procedures is set by the SIR expert panel (Table 2) [17, 18].

The platelet count, measured as a standard part of the complete blood count, reflects the number of circulating platelets, not the platelet function. A normal adult platelet count is approximately 150,000–450,000 platelets per microliter of blood and is affected by many conditions. Platelet count is corrected when $\leq 50,000/\text{mm}^3$ by transfusion of platelet concentrates (10 units to increase count by 50,000–100,000/ mm^3) (Table 2) [17, 18].

Bleeding time, which assesses platelet function in patients with suspected qualitative platelet dysfunction, is neither a specific nor a sensitive indicator of bleeding risk in patients undergoing invasive procedures [19]. Subsequently, pre-procedural assessment of bleeding time has devalued because of discordant data on its practical importance. There are no current indications to measure bleeding time before image-guided procedures [17].

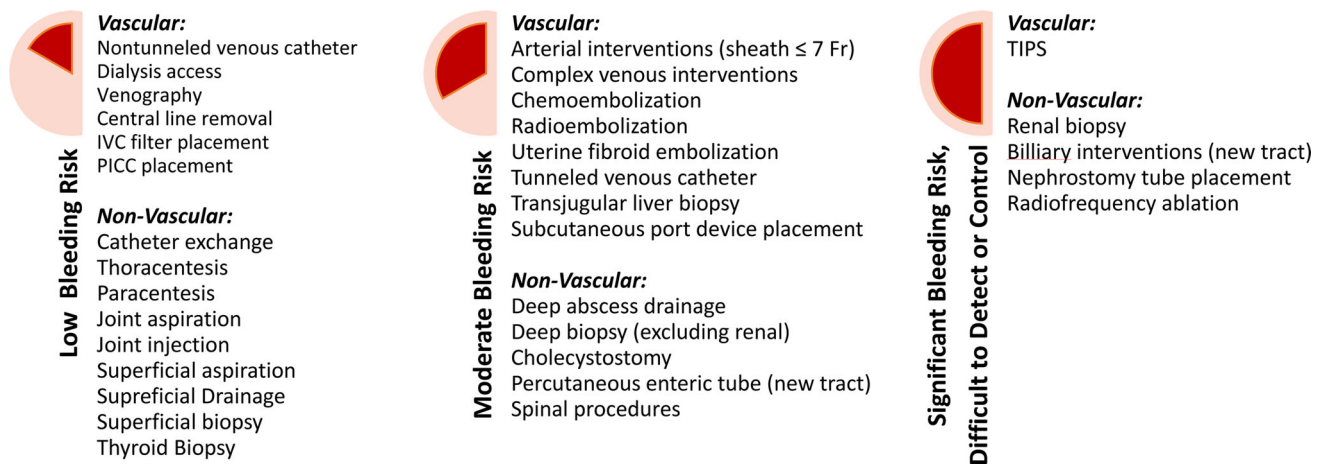


Fig. 9 Procedural bleeding risk stratification of different interventional procedures as per SIR consensus guidelines for peri-procedural management of coagulation status and hemostasis risk [18]

Table 2 Peri-procedural coagulation parameter management based on the procedural risk for bleeding [18]

	Low risk for bleeding	Moderate risk for bleeding	High risk for bleeding
INR	Recommended correct value to ≤ 2.0	Recommended correct value to ≤ 1.5	Recommended correct value to ≤ 1.5
aPTT	Recommended no consensus on threshold	Recommended correct value to $\leq 1.5 \times \text{control}^a$	Recommended correct value to $\leq 1.5 \times \text{control}$
Platelet count	Recommended transfuse if $\leq 50,000/\mu\text{L}$	Recommended transfuse if $\leq 50,000/\mu\text{L}$	Recommended transfuse if $\leq 50,000/\mu\text{L}$

^a 73 % consensus on threshold, whereas all other values reached 80 % consensus

INR international normalized ratio, aPTT activated partial thromboplastin time

Renal Function

Pre-procedural assessment of renal function may be used to estimate the risk of CIN prior to procedures requiring intravascular iodinated contrast medium (ICM) administration. Renal function can be assessed by measuring serum creatinine concentration, which is the most widely used measure of renal function, and calculating the estimated glomerular filtration rate (GFR) [20]. Serum creatinine measurement has limitations as an accurate measure of renal function and is considerably affected by different factors other than GFR, such as the patient’s gender, muscle mass, nutritional status, and age [20]. It is clear that alterations in serum creatinine may lag several days behind actual changes in GFR [21]. Alternatively, GFR can be estimated using different formulae based on age, gender, body weight, and serum creatinine [20, 22, 23]. Different studies indicate that CIN incidence after intra-arterial injection of ICM is more common when compared to the intravenous [24–26], particularly when the arterial injection is suprarenal [27]. However, this increased risk of CIN might be partially related to microshowers of cholesterol

emboli as the catheter passes through the aorta rather than pure contrast-induced renal toxicity [24, 28]. In addition, CIN is not common in patients with normal preexisting renal function and it rarely occurs in children; rather, it occurs more frequently in patients with renal impairment and is possibly exacerbated when the impairment is due to diabetic nephropathy [29, 30]. Therefore, baseline serum creatinine level measurement is warranted before the injection of ICM in all patients considered at risk for contrast nephrotoxicity including age >60, history of renal disease (e.g., patient on dialysis, kidney transplant, single kidney, renal malignancy, proteinuria, and kidney surgery), history of hypertension requiring medical treatment, history of diabetes mellitus, and in any patient treated with metformin-containing medications [8, 31]. Although there is no consensus over the acceptable interval between the baseline serum creatinine measurement and ICM administration, 30-day interval seems to be adequate [8]. However, in patients with a new or increased risk for renal dysfunction, it is essential to shorten this interval [8]. In practice, urgent or emergent procedures may be undertaken irrespective of the levels obtained, and therefore, we stress

on the fact that, prior to ICM administration, it is essential to conduct adequate individualized risk-benefit assessment and communicate effectively with the treating physician.

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. Careful assessment and review of medical history, previous imaging studies, and laboratory tests are essential in the planning the procedure and avoiding complications to ensure good outcome.

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

- Margulis AR. Interventional diagnostic radiology—a new subspecialty. *Am J Roentgenol.* 1967;99:763–5.
- Cardella JF, Kundu S, Miller DL, Millward SF, Sacks D. Society of Interventional Radiology clinical practice guidelines. *J Vasc Interv Radiol.* 2009;20(7 Suppl):S189–91.
- Baskin KM, Hogan MJ, Sidhu MK, Connolly BL, Towbin RB, Saad WE, et al. Developing a clinical pediatric interventional practice: a joint clinical practice guideline from the Society of Interventional Radiology and the Society for Pediatric Radiology. *J Vasc Interv Radiol.* 2011;22(12):1647–55. doi:10.1016/j.jvir.2011.07.010.
- American College of Radiology; American Society of Interventional, Therapeutic Neuroradiology; Society of Interventional Radiology. Practice guideline for interventional clinical practice. *J Vasc Interv Radiol.* 2005;16(2 Pt 1):149–55.
- Heran MK, Marshalleck F, Temple M, Grassi CJ, Connolly B, Towbin RB, et al. Joint quality improvement guidelines for pediatric arterial access and arteriography: from the Societies of Interventional Radiology and Pediatric Radiology. *J Vasc Interv Radiol.* 2010;21(1):32–43.
- Principles of Arterial Access. In: Burke CT, Dixon RG, Mauro MA, Murphy KPJ, Thomson KR, Venbrux AC, Zollikofer CL, editors. *High yield imaging: interventional.* Philadelphia: Saunders Elsevier; 2010. p. 16–9.
- Corso R, Vacirca F, Patelli C, Leni D. Use of “Time-Out” checklist in interventional radiology procedures as a tool to enhance patient safety. *Radiol Med.* 2014;119(11):828–34.
- American College of Radiology. *ACR manual on contrast media.* Reston: American College of Radiology; 2012.
- Berlin L. Malpractice issues in radiology. Informed consent. *Am J Roentgenol.* 1997;169(1):15–8.
- American College of Radiology. *ACR practice guideline on informed consent for image-guided procedures.* Reston: American College of Radiology, *ACR practice guidelines and technical standards;* 2010. p. 1–4.
- Stecker MS, Balter S, Towbin RB, Miller DL, Vañó E, Bartal G, et al. Guidelines for patient radiation dose management. *J Vasc Interv Radiol.* 2009;20(7 Suppl):S263–73.
- Murphy TP, Dorfman GS, Becker J. Use of preprocedural tests by interventional radiologists. *Radiology.* 1993;186(1):213–20.
- Mantha S, Roizen MF, Madduri J, Rajender Y, Shanti Naidu K, Gayatri K. Usefulness of routine preoperative testing: a prospective single-observer study. *J Clin Anesth.* 2005;17(1):51–7.
- Smetana GW, Macpherson DS. The case against routine preoperative laboratory testing. *Med Clin N Am.* 2003;87(1):7–40.
- Segal JB, Dzik WH. Paucity of studies to support that abnormal coagulation test results predict bleeding in the setting of invasive procedures: an evidence-based review. *Transfusion.* 2005;45(9):1413–25.
- Dzik WH. Predicting hemorrhage using preoperative coagulation screening assays. *Curr Hematol Rep.* 2004;3(5):324–30.
- 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.
- 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.
- Lind SE. The bleeding time does not predict surgical bleeding. *Blood.* 1991;77(12):2547–52.
- Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D, Modification of Diet in Renal Disease Study Group. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. *Ann Intern Med.* 1999;130(6):461–70.
- Star RA. Treatment of acute renal failure. *Kidney Int.* 1998;54(6):1817–31.
- Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. *Nephron.* 1976;16(1):31–41.
- Schüick O, Smrcková J, Teplan V, Stávek P, Skibová J, Stollová M. A new method to estimate glomerular filtration rate based on serum concentration of creatinine, urea and albumin (MDRD, modification of diet in renal disease). *Vnitr Lek.* 2004;50(7):507–9.
- Katzberg RW, Barrett BJ. Risk of iodinated contrast material-induced nephropathy with intravenous administration. *Radiology.* 2007;243(3):622–8.
- Khoury GA, Hopper JC, Varghese Z, Farrington K, Dick R, Irving JD, et al. Nephrotoxicity of ionic and non-ionic contrast material in digital vascular imaging and selective renal arteriography. *Br J Radiol.* 1983;56(669):631–5.
- 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.
- Campbell DR, Flemming BK, Mason WF, Jackson SA, Hirsch DJ, MacDonald KJ. A comparative study of the nephrotoxicity of iohexol, iopamidol and ioxaglate in peripheral angiography. *Can Assoc Radiol J.* 1990;41(3):133–7.
- 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.
- 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.
30. Haight AE, Kaste SC, Golubeva OG, Xiong XP, Bowman LC. Nephrotoxicity of iopamidol in pediatric, adolescent, and young adult patients who have undergone allogeneic bone marrow transplantation. *Radiology.* 2003;226(2):399–404.
31. Pucelikova T, Dangas G, Mehran R. Contrast-induced nephropathy. *Catheter Cardiovasc Interv.* 2008;71(1):62–72.