

Periprocedural Coagulation Status in Percutaneous Interventions

Soumil Singhal¹ Mangerira Chinnappa Uthappa¹

¹Department of Intervention Radiology and Intervention Oncology, BGS Gleneagles Global Hospital, Kengeri, Bangalore, India

Address for correspondence Soumil Singhal, MD, Department of Intervention Radiology and Intervention Oncology, BGS Gleneagles Global Hospital, 67, Uttarahalli Main Rd, Sunkalpalya, Kengeri, Bangalore 560060, India (e-mail: drsoumilsinghal75@gmail.com).

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Abstract

Keywords

- ▶ hemostasis
- ▶ hemorrhage
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- ▶ blood coagulation tests
- ▶ partial thromboplastin time
- ▶ prothrombin time

Hemostasis is a very elaborate process, and its knowledge is essential for every interventional radiologist. Abnormal coagulation parameters are associated with an increased risk of bleeding and require appropriate management. This review aims to briefly discuss the pathophysiology of hemostasis, the role of currently available pharmacological agents affecting hemostasis, and the management of hemostasis during various percutaneous interventional procedures. A preprocedure proforma, when used as a checklist, can reduce procedure-related complications.

Introduction

Hemostasis (from the Greek “haimatos” meaning blood and “stasis” meaning stop) is a complex physiological process first described as a cascade of several enzymes in the 1960s.¹ Normal hemostasis involves four tightly integrated steps: (1) vasoconstriction, (2) platelet adhesion and activation, (3) coagulation cascade activation, and (4) permanent plug formation secondary to counterregulatory mechanism.² The thrombosis–hemorrhage balance between the coagulation cascade and the fibrinolytic system is very crucial and is always kept in check in a physiologically normal individual. Because of this complex multistep process, coagulation dysfunction is not surprisingly uncommon.

Every interventional radiologist must possess a deep understanding of hemostasis as multiple factors may result in alterations of the coagulation parameters. Many percutaneous interventional procedures have an inherent, albeit to a varying degree, risk of vascular injury and subsequent bleeding. The assessment and management of bleeding may often be delayed if the bleeding occurs in the deep tissues. A proper understanding of the coagulation pathway and the effect of various pharmacological agents on hemostasis is required for periprocedure planning and management of these patients. This article

summarizes the underlying pathophysiology of hemostasis, laboratory methods for evaluation of the coagulation system, the currently available anticoagulants and antiplatelet drugs, and risk assessment of various interventional procedures.

Pathophysiology

Hemostasis involves two main steps: (1) primary hemostasis and (2) secondary hemostasis. The initial plug formation mainly characterizes primary hemostasis. It is a multifactorial process with a complex relationship between the platelets, vessel wall, and adhesive proteins. Vascular injury induces reflexive vasoconstriction following which platelets adhere to the exposed subendothelial tissue through a bridge formed between the collagen–platelet surface glycoprotein (GP) IV and von Willebrand factor (vWF)–platelet surface GP Ib. Following adhesion, platelets get activated and facilitate further adhesion and aggregation through activation of several surface receptors and the secretion of α -granules as well as other dense granules. Once formed, the platelet plug is further stabilized by insoluble fibrin that is generated by the coagulation pathway.

Secondary hemostasis involves two main pathways including an extrinsic path and an intrinsic path. It has been

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well understood by the cell-based model, which suggests that extrinsic path plays the primary role in fibrin clot formation and includes initiation, amplification, propagation, and stabilization.³ Injury to the blood vessel starts the initiation phase that is characterized by blood getting exposed to extravascular tissue, which is rich in a lipoprotein seen in the fibroblast, smooth muscle, and the leukocyte, which is known as tissue factor (TF). Once the TF is activated by blood, it binds and activates factor VII. Activated factor VII further activates both factors X and IX, and activated factor X activates factor V and they together convert prothrombin to thrombin. Thrombin accelerates platelet adhesion and aggregation along with activation of factors VIII, V, and XI. The propagation phase is characterized by further thrombin activation. Thrombin then converts fibrinogen to fibrin (► Fig. 1).

Uncontrolled coagulation is prevented by downregulation of the coagulation cascade. Thrombomodulin, an endothelial protein, along with thrombin activates protein C, which along with a cofactor, protein S, inactivates activated factors V and VIII. Antithrombin inactivates activated factors II, X, XI, and XII. TF pathway inhibitor also plays a significant role in downregulation. The fibrinolytic system is activated to prevent unnecessary clotting during wound healing. Plasminogen, which is a proenzyme, gets activated by tissue plasminogen activator (tPA) to form plasmin, which cleaves the fibrin clot. Urokinase acts through the urokinase-type plasminogen activator receptors to activate plasminogen causing fibrinolysis.

Evaluation of Various Coagulation Parameters

The various coagulation parameters that need to be evaluated before a percutaneous procedure include (1) platelet count, (2) prothrombin time (PT), (3) international normalized ratio

(INR), and (4) activated partial thromboplastin time (aPTT) (► Table 1). Correction of coagulation parameters may be required in a periprocedure setting based on the category of the procedure (► Table 2).

Platelet Count

The fragmentation of megakaryocytes forms platelets. The life cycle of platelets lasts for 10 days. They play an essential role in the hemostasis by both creating a primary plug and providing a scaffold for clotting reaction. Platelet count refers to the number of platelets in circulation. The average adult range is 150,000 to 450,000 platelets per microliter of blood. Platelet count of less than 20,000/ μ L is associated with a high risk of spontaneous bleeding.⁴

A platelet transfusion may be required when there is either platelet dysfunction or reduction in number. Platelet transfusion is performed either in the form of a single donor unit or from a concentrated pool of four to eight donors.⁵ A single donor unit corrects platelet count by around 30,000/ μ L, whereas a random donor unit corrects by around 5,000 to 10,000/ μ L. Post transfusion, a repeat platelet count is necessary before the procedure.⁶ Repeated platelet transfusion reduces the effectiveness, warranting a more reasonable and calculated use along with the use of leucocyte-reduced platelets.⁷ In cases of complete refractiveness to the transfusion, human leucocyte antigen matching can be considered to plan transfusion.⁸

Platelet function defect can be either inherited or acquired; von Willebrand's disease is most common among the rare inherited platelet function defect. Acquired function defect is noted because of a medical condition or secondary to drug intake (e.g., aspirin). Platelet function analyzer is used to screen platelet dysfunction. Desmopressin, which is a synthetic analog of vasopressin hormone, has been found to increase the serum concentration of vWF, factor VIII, and tPA levels.⁹ It can be administered by various routes including subcutaneous, intranasal, or intravenous (IV), with IV being the route of choice. It is administered at 0.3 μ g/kg, which is infused slowly over 30 minutes, with maximum drug effect at around 30 to 60 minutes. Multiple treatments can lead to tachyphylaxis. It is indicated in conditions such as liver disease, uremia, hemophilia, and von Willebrand's disease.¹⁰

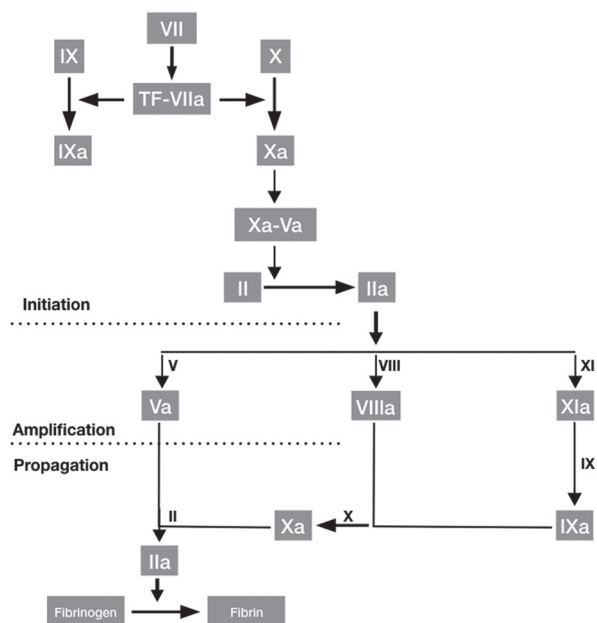


Fig. 1 Cell-based model of coagulation.

Table 1 Coagulation parameters and factors affecting them

Test	Normal range	When to check?
Platelet count	150,000–450,000/L	Thrombocytopenia
PT/INR	0.9–1.1	Liver disease oral anticoagulant therapy
aPTT	25–35 s	Von Willebrand's disease Factor VIII, IX, or XI deficiency Intravenous heparin therapy

Abbreviations: aPTT, activated partial thromboplastin time; PT/INR, prothrombin time/international normalized ratio.

Table 2 Adaptation of Society of Interventional Radiology/Cardiovascular and Interventional Radiological Society of Europe consensus guidelines on periprocedural hematological management of image-guided procedures according to the category of bleeding risk²²

	Category I	Category II	Category III
Nonvascular	Thoracentesis Paracentesis Superficial aspiration or biopsy from thyroid, superficial lymph node Superficial abscess drainage All drainage catheter exchange	Lung biopsy Transabdominal liver biopsy Percutaneous cholecystostomy Intra-abdominal, chest wall, or retroperitoneal abscess drainage or biopsy Gastrostomy tube Radiofrequency ablation (easy access) Spine procedures (vertebroplasty, kyphoplasty, lumbar puncture, epidural injection, facet block)	Biliary interventions Renal biopsy Nephrostomy tube placement Difficult area: radiofrequency ablation
Vascular	PICC placement Dialysis access interventions Venography IVC filter placement Central line removal	Tunneled central venous catheter Subcutaneous port device Arterial intervention (access size up to 7 F) Chemoembolization Uterine fibroid embolization Venous interventions Transjugular liver biopsy	TIPS
Routinely recommended laboratory testing	INR ^a aPTT ^b	INR aPTT ^b	INR aPTT ^b Platelet count Hematocrit
Correction	INR > 2.0: correct Platelets count < 50,000/ μ L: platelet transfusion Clopidogrel: withhold for 5 d before procedure Aspirin: do not withhold LMWH: withhold one dose prior to procedure	INR: correct to < 1.5 Platelets count < 50,000/ μ L: platelet transfusion Clopidogrel: withhold for 5 d before procedure Aspirin: do not withhold LMWH: withhold one dose prior to procedure	INR: Correct to < 1.5 aPTT: stop or reverse heparin for values > 1.5 times the control value Platelets count < 50,000/ μ L: platelet transfusion Clopidogrel: withhold for 5 d before procedure Aspirin: withhold for 5 d before procedure LMWH: withhold two doses prior to procedure

Abbreviations: aPTT, activated partial thromboplastin time; INR, international normalized ratio; IVC, inferior vena cava; LMWH, low molecular weight heparin; PICC, peripherally inserted central catheter; TIPS, transjugular intrahepatic portosystemic shunt.

^aFor patients receiving warfarin anticoagulation for known or suspected liver disease

^bFor patients receiving intravenous unfractionated heparin.

Prothrombin Time/International Normalized Ratio

In vitro evaluation of the extrinsic pathway and fibrinogen integrity and stability can be made using the PT. It is converted and reported as the INR. INR is calculated as (patient PT/control PT) ISI, where ISI is the international sensitivity index of the thromboplastin reagent used. INR is used as a standardized parameter for patients on anticoagulant therapy. PT in an average healthy human ranges from 11 to 14 seconds and can vary based on the reagent used for testing.¹¹ INR in a healthy patient ranges from 0.9 to 1.1. Prolonged PT and INR are seen when there are deranged factors responsible for extrinsic and common pathways including vitamin K deficiency, warfarin therapy, liver failure, malabsorption, malnutrition among some of the conditions.

Deranged INR is frequently noted in a periprocedure setting. The American College of Chest Physicians guidelines¹² suggests that in case of an elective procedure, vitamin K

antagonist anticoagulant should be stopped 5 days before the procedure to facilitate the reduction of therapeutic INR value to around 1.5. If the procedure is planned within 1 to 2 days, 1 to 2 mg of oral vitamin K should be administered. In case of an urgent procedure (within 12 hours), 2.5 to 5 mg of vitamin K should be administered either orally or intravenously. However, in case of an emergency, vitamin K is given in combination with 10 to 15 mL/kg of fresh frozen plasma (FFP).¹³ FFP has a half-life of 4 to 6 hours and can be associated with transfusion-related complication including anaphylaxis, transfusion-induced acute lung injury, and urticaria. Newer agents such as prothrombin complex concentrates and recombinant factor VIIa can be used for the rapid correction of altered INR.

Prothrombin complex concentrates are plasma products that are vitamin K related factors and are formed by viral modification. They are 25 times richer than the normal

plasma and have a half-life of 24 to 32 hours.¹⁴ Recombinant factor VIIa is found to be efficacious for various bleeding disorders.¹⁵ It has a half-life ranging from 1.7 to 3.1 hours and is administered between 15 µg/kg to 90 µg/kg.

Activated Partial Thromboplastin Time

Activated partial thromboplastin time is the time taken for clot formation after activation of the intrinsic pathway. aPTT in an average healthy human ranges from 25 to 33 seconds. Isolated deranged aPTT values can sometimes be seen, which may be normal on repeat testing.¹⁶ Altered aPTT can occur because of intrinsic factor deficiency, vitamin K deficiency, heparin therapy, liver failure, and lupus anticoagulant. aPTT in patients on heparin therapy is maintained at 1.5 to 2.5 times the control value.

Anticoagulants

Anticoagulants inhibit the coagulation pathway and prevent normal clot formation. These include warfarin, heparin, factor Xa inhibitors, and direct thrombin inhibitors. A clear understanding of various anticoagulants, their mechanism of action (described in ►Fig. 2), and the antidote is needed in a periprocedure setting to reduce procedure-related complications (►Table 3).

Warfarin

Warfarin is an oral anticoagulant that was first discovered in sweet clover. It competitively inhibits vitamin K epoxide reductase complex 1, which prevents activation of vitamin K and hence antagonizes the production of clotting factors II, VII, IX, and X, protein C, and protein S. Warfarin has a mean half-life of around 40 hours. Its effect can be monitored by evaluating the INR. Phytonadione (vitamin K) is a reversal agent and can be administered orally or through

the subcutaneous or IV route. When given orally, it takes around 24 hours to act, and when given intravenously, it takes around 4 to 6 hours. Guidelines have been set by the American College of Chest Physicians in patients with a risk of bleeding.¹⁷ In adult patients posted for elective procedure, 2 to 5 mg can be administered orally. The IV route is very effective and should be considered only during an emergency as it is associated with an anaphylactoid reaction. The subcutaneous route is not considered because of an erratic, unpredictable absorption.

Heparin

Heparin is a sulfated glycosaminoglycan that is produced by mast cells. It is available in two forms: (1) unfractionated form and (2) low molecular weight form.

Unfractionated Heparin

Unfractionated heparin has a mean molecular weight of 15,000 Da. It acts by potentiating the antithrombin effect, which inhibits factor Xa and thrombin by forming an equimolar stable complex which, in turn, inhibits coagulation. It is administered through the IV route. It has a half-life ranging from 23 minutes to 2.4 hours.¹⁸ The therapeutic response is kept in check by assessing the aPTT. A note of the patient's platelet count has to be maintained to prevent heparin-induced thrombocytopenia, which is characterized by a 50% reduction in platelet count 5 to 10 days following the initiation of heparin. Protamine sulfate is a reversal agent of choice in an emergency setting. It has a rapid mechanism of action (10 min) and a half-life of 5 to 7 minutes. It is administered as a slow infusion dose calculated as 1 mg of protamine per 100 U of heparin. It is associated with complications such as anaphylactoid reaction, hypotension, and bradycardia.¹⁹⁻²¹

Low Molecular Weight Heparin

Low molecular weight heparin (LMWH) is a depolymerized form of heparin, with a mean molecular weight of 5,000 Da. Because of the smaller fragment size and lower binding property, it inhibits factor Xa only and has several advantages including predictable dose response, longer half-life, and less risk of heparin-induced thrombocytopenia. Dalteparin, enoxaparin, and tinzaparin are various types of LMWHs. LMWHs are mainly administered by the subcutaneous route. Protamine is less effective in the reversal of LMWH as it reverses the anti-factor IIa more than factor Xa activity, which is the primary target of LMWH. LMWH activity can be assessed by antifactor Xa activity; however, it is not well reported because of lack of standardization.

Fondaparinux

Fondaparinux is a selective indirect factor Xa inhibitor. It is a synthetic pentasaccharide, which is similar to LMWH in its mode of use. It has a longer half-life and a lesser rate of complications. It is administered subcutaneously at a daily dose of 1.5 to 10 mg based on a patient's weight, renal function, and indication. It has a lower risk of heparin-induced thrombocytopenia. There is no specific reversal agent, but FFP or cryoprecipitate can be given to control bleeding.

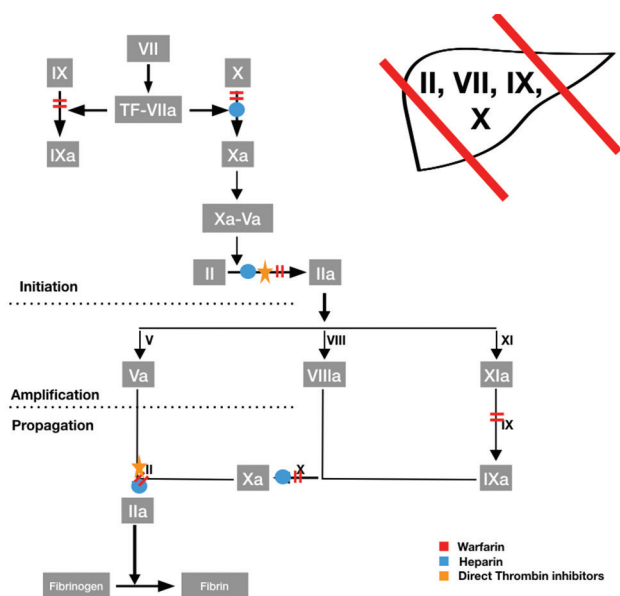


Fig. 2 Anticoagulants affecting various levels in the coagulation pathway.

Table 3 Recommendations for the management of anticoagulants and reversal agent

Medication	Category I	Category II	Category III	Reversal agent
	Anticoagulant drugs			
Warfarin	Withhold 5 d prior	Withhold 5 d prior	Withhold 5 d prior	Vitamin K Fresh frozen plasma Prothrombin complex concentrate
LMWH	Withhold 12 h prior	Withhold 12 h prior	Withhold 12 h prior	Partial: protamine
Unfractionated heparin (subcutaneous)	Withhold 4 h prior	Withhold 4 h prior	Withhold 6 h prior	Protamine
Unfractionated heparin (IV)	Withhold 1 h prior	Withhold 4 h prior	Withhold 6 h prior	Protamine
Fondaparinux	Withhold 24 h prior	Withhold 36 h prior	Withhold 48 h prior	None
Dabigatran	Withhold 24 h prior	Withhold 48 h prior	Withhold 72 h prior	Idarucizumab
Rivaroxaban	Withhold 24 h prior	Withhold 48 h prior	Withhold 48 h prior	Under trial
Apixaban	Withhold 24 h prior	Withhold 48 h prior	Withhold 72 h prior	Under trial

Abbreviations: IV, intravenous; LMWH, low molecular weight heparin.

In patients undergoing category I or II procedures, one dose of LMWH has to be withheld, whereas in a category III procedure, patients with an aPTT value of more than 1.5 times the control value need to undergo a reversal and up to two doses of LMWH should be withheld before the procedure.²² Antifactor Xa assay can monitor patients on LMWH and fondaparinux. In a small series, protamine was found to be unable to stopping bleeding in two-third cases on LMWH.²³ Factor VIIa has shown promising results in such a scenario and can be used as an antidote in patients on LMWH and fondaparinux.²⁴

Direct Thrombin Inhibitors

The direct thrombin inhibitors act by directly inhibiting the activity of thrombin. They can be administered through the oral or parenteral route. They are either bivalent or univalent based on the sites blocked on thrombin. Bivalirudin, hirudin, lepirudin, and argatroban are few of the various inhibitors. The dose can be monitored by measuring the clotting time. They have a relatively short half-life (40-80 minutes); however, they do not have any proven reversal agent.

Novel Oral Anticoagulants

Novel oral anticoagulants (NOACs) are fast acting and have a specific target in the coagulation cascade as compared to their predecessors. These include rivaroxaban, edoxaban, betrixaban, apixaban, and dabigatran. Thrombin is targeted explicitly by dabigatran, and the rest target the activated factor X.^{25,26}

Dabigatran acts by directly inhibiting both the free and bound forms of thrombin, which prevents further activation of fibrinogen. Dabigatran is unique as it has pH-dependent absorption due to which both proton pump inhibitors and antacids reduce its absorption. It has the longest half-life ranging from 12 to 17 hours. As the kidneys clear it, the

pharmacokinetics is affected by kidney function. Dabigatran should be withheld for 3 days in patients with creatinine clearance less than 50 mL/minute and 5 days in patients with creatinine clearance less than 30 mL/minutes.

Rivaroxaban selectively and reversibly inhibits activated Xa, which prevents platelet activation and clot formation. It has the shortest half-life and is cleared by the kidneys. The cytochrome P450 system metabolizes it. The anticoagulant effect is increased in patients on vitamin E, omega 3 fatty acid, erythromycin, and clarithromycin. Its effect is reduced in patients takingazole antibiotic or protease inhibitors.²⁷⁻²⁹

In patients planned for category I procedure, NOACs are not withheld before the procedure. In category II and III procedures, the drug needs to be held according to its half-life. Edoxaban and rivaroxaban should be withheld at least 24 hours before both category II and III interventions. Apixaban and dabigatran should be withheld 24 hours before category II and 48 before category III interventions.

As dabigatran has minimal protein-binding property, hemodialysis remains an option for reversal. Hemodialysis is not effective in patients using direct Xa inhibitors. Idarucizumab is an FDA (U.S. Food and Drug Administration) approved, target-specific, reversal agent against dabigatran. Idarucizumab is a monoclonal antibody with very high affinity to dabigatran. It is administered as two 2.5-g injections or 50-mL IV infusion not more than 15 minutes apart.³⁰⁻³⁴ Andexanet alfa is an activated factor X inhibitor, which is still under trial. It is a recombinant human factor that acts as a decoy and inhibits both indirect and direct activated factor X inhibitors. Aripazine is a promising new agent under trial; it has shown potential reversal effect against several anticoagulants. It is a water-soluble molecule with many binding sites, which interact with various anticoagulants. It has a short half-life, no protein binding, rapid action, and no other drug interactions.³⁵

Antiplatelets

Antiplatelet agents act by inhibiting both platelet aggregation and platelet plug formation. These include aspirin, thienopyridines, nonsteroidal anti-inflammatory drugs (NSAIDs), and GP IIb/IIIa inhibitors (► **Table 4**).

Aspirin

Aspirin or acetylsalicylic acid is a commonly used first-generation antiplatelet agent that has been used for more than a century in the prevention and treatment of various vascular diseases. Aspirin acts by inhibiting the platelet cyclooxygenase enzyme 1, which inhibits platelet aggregation by reducing the production of prostaglandin precursors. It is metabolized into salicylic acid. It has a short half-life, with a peak antiplatelet effect by 40 to 60 minutes. Low-dose aspirin (75–162 mg) is an effective long-term antiplatelet regimen.³⁶ In case of an emergency, a high dose of aspirin (300–325 mg) is administered as a loading dose. The CURE (Clopidogrel in Unstable angina to prevent Recurrent Events) trial found an advantage when clopidogrel was given along with aspirin.³⁷ Desmopressin acetate, which is a vasopressin antagonist, can be infused slowly (over more than 30 minutes) in 0.2 to 0.4 µg/kg body weight concentration. Platelet infusion can also be used to reverse the aspirin's effect. Aspirin is not withheld in patients on low-dose aspirin, whereas patients who are on high-dose aspirin are advised to withhold the drug at least

5 days prior in case of category II and III interventions. It is resumed immediately postprocedure.

Thienopyridines

Thienopyridine group of drugs acts by inhibiting ADP-dependent platelet aggregation through the platelet P2Y₁₂ receptor. They include clopidogrel (first generation), ticlopidine (second generation), and prasugrel (third generation).

Clopidogrel is an oral antiplatelet agent with a rapid onset of action and dose-dependent antiplatelet action. It is administered as 75 mg per day, with an initial loading dose of 300 mg. Both ticlopidine and prasugrel have a more rapid onset of action when compared with clopidogrel. No specific reversal agent is available; however, both platelet infusion and desmopressin can be helpful.³⁸ Clopidogrel is withheld five days before any category interventions. Ticlopidine and prasugrel are withheld 5 days before category I interventions and 7 days before category II and III interventions.³⁹

Nonsteroidal Anti-Inflammatory Drugs

Nonsteroidal anti-inflammatory drugs are an antithrombotic agent with a reversal antiplatelet action. They act by inhibiting both cyclooxygenase enzyme 1 and 2 enzymes. NSAIDs are classified based on the different half-life into (1) short-acting (half-life of 2–6 hours), (2) intermediate-acting (half-life of 7–15 hours), and (3) long-acting (half-life more than 20 hours). There is no specific reversal agent.

Table 4 Recommendations for the management of antiplatelets and reversal agents

Medication	Category I	Category II	Category III	Reversal agent
Antiplatelet drugs				
Aspirin				
Low dose	None	None	None	Desmopressin
High dose	None	Withhold 5 d prior	Withhold 5 d prior	Desmopressin, platelet, or both
Clopidogrel	Withhold 5 d prior	Withhold 5 d prior	Withhold 5 d prior	Desmopressin, platelet, or both
Ticlopidine	Withhold 5 d prior	Withhold 5 d prior	Withhold 7 d prior	Desmopressin, platelet, or both
Prasugrel	Withhold 5 d prior	Withhold 5 d prior	Withhold 7 d prior	Desmopressin, platelet, or both
NSAIDs				
Short acting				
Ibuprofen Diclofenac Ketoprofen Indomethacin	Do not withhold	Do not withhold	Withhold 24 h prior	None
Intermediate acting				
Naproxen Sulindac Diflunisal Celecoxib	Do not withhold	Do not withhold	Withhold 2–3 d prior	
Long acting				
Meloxicam Nabumetone Piroxicam	Do Not Withhold	Do Not Withhold	Withhold 10 days prior	
Abciximab	Withhold 12–24 h prior	Withhold 24 h prior	Withhold 24 h prior	Platelet transfusion
Eptifibatide Tirofiban	Withhold immediately before procedure	Withhold 4 h prior	Withhold 4 h prior	Desmopressin, platelet, or both

Glycoprotein IIb/IIIa Inhibitors

Glycoprotein IIb/IIIa inhibitors prevent platelet aggregation by antagonizing the GP IIb/IIIa integrin complex. It includes abciximab, eptifibatide, and tirofiban. These are fast-acting IV antiplatelet agents with a rapid onset of acting (10–15 minutes after administration). Abciximab is a monoclonal antibody with the highest affinity toward the GP IIb/IIIa receptor lasting for 24 to 48 hours, whereas tirofiban and eptifibatide have an effect lasting for up to 4 hours postinfusion. No specific reversal agent is available; however, both platelet infusion (ineffective in tirofiban) and desmopressin can be helpful.⁴⁰

Chronic Liver Disease

Patients who suffer from chronic liver disease have altered hemostatic mechanism; they are classically described to be in an autoanticoagulated state due to thrombocytopenia secondary to splenic sequestration and elevated INR due to hepatic dysfunction. These patients have a rebalanced coagulation system due to cirrhosis-related deficiency of both pro- and anticoagulants.^{41,42} The rebalanced state in these patients affects both primary and secondary hemostasis. Primary hemostasis is changed because of a decrease in the number of platelets; however, this effect is compensated by elevated levels of vWF and decrease in ADAMTS13 (a disintegrin and metalloproteinase with a thrombospondin type 1 motif, member 13).^{43,44} A study showed that a platelet count of around 55,000 allows normal clot formation.⁴⁵ Secondary hemostasis is characterized by a reduction in liver-derived procoagulants, leading to an anticoagulated state; however, there is an associated compensatory decrease in anticoagulant levels (e.g., protein C, protein S, and antithrombin).^{46,47} The coagulation system remains in a steady state of balance,

preventing any spontaneous bleeding episodes. An acute episode can tip this balance, leading to either bleeding or thrombosis. Platelet count, INR, and bleeding time has shown poor correlation, and hence tests such as thromboelastography, thromboelastometry, and sonorheometry are found to be more efficacious.⁴⁸⁻⁵⁰

Categorization of Minimally Invasive Image-Guided Procedures

A Delphi panel of experts categorized minimally invasive image-guided procedures due to the lack of randomized controlled studies or reliable recommendations on periprocedure management of patients undergoing interventional procedures.⁵¹ Representative procedures were categorized on the risk of bleed, and various recommendations were made (→Table 2). However, the committee believed that there could be variability within categories due to various patient-related factors including homeostatic abnormalities and preexisting comorbidities. The panel suggested that patient management should be tailor-made keeping in mind various patient-related factors. The Delphi recommendations are for elective cases with a single homeostatic defect. They did not address emergency interventions, multiple hemostatic abnormalities, and the use of closure devices. The Delphi consensus has some limitations that include the purpose and role of bleeding time, the role of recombinant factor VIIa, and the use of NSAIDs.⁵²

Periprocedure Proforma

A periprocedure proforma (→Table 5) is a checklist tool that reduces procedure-related complications. The use of a well-devised proforma can improve patient outcomes.

Table 5 Periprocedure proforma

Periprocedure proforma			
To be filled by patients	Patient name:		Age:
Any history of blood transfusion	Yes/ No		
Any history of surgery/ procedure	Yes/ No		
Any cardiac history	Yes/ No		
Are you on blood thinning agent?	Yes/ No		
Any other drug intake	Yes/ No		
History of bleeding	Yes/ No		
Family history of bleeding disorder	Yes/ No		
To be filled by doctor			
Name of procedure			
Category	1	2	3
Type of procedure	Vascular/ nonvascular		
Laboratory values	INR: Platelet count ^a :	aPTT: Hematocrit ^a :	
Drug history			
Correction (if any)	As per Table 1		

^aOnly for category III intervention.

A well-devised periprocedure checklist includes two parts, one to be filled by the patient and the other to be filled by the physician. The questions to be answered by the patient consists of (1) prior history of surgery or any invasive procedures, (2) history of blood transfusion in the past, (3) cardiac history, (4) history of medication including blood thinning agents, (5) prior history of bleeding, and (6) any family history of bleeding disorder. The portion to be filled by the treating physician includes (1) procedure name, (2) category the procedure, (3) nature of the procedure, (4) laboratory parameters, and (5) patient drug intake history. Various checklists have been proposed in intervention radiology to improve patient safety and outcome. We recommend a preprocedure proforma of a checklist that can reduce procedure-related bleeding if executed efficiently.

Conclusion

Coagulation is a complicated process that requires thorough knowledge before performing any invasive procedure. Periprocedure protocol is essential for the planning and management of various coagulation defects. A well-devised proforma includes the procedure category, laboratory parameters, and correction (as needed) based on the precise knowledge of coagulation and the effect of anticoagulants. By including clinical parameters including the patient's history helps in the reduction of procedure-related complication.

Conflicts of Interest

None declared.

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