



EDUCATIONAL OBJECTIVE: Readers will assess their patients' risk of bleeding and consider adjusting their treatment accordingly

ANTONIO GUTIERREZ, MD
Duke University Medical Center,
Durham, NC

SUNIL V. RAO, MD*
Duke Clinical Research Institute,
Durham, NC

Incidence, outcomes, and management of bleeding in non-ST-elevation acute coronary syndromes

ABSTRACT

Antithrombotic and antiplatelet drugs and percutaneous interventions have decreased the ischemic outcomes of non-ST-elevation acute coronary syndromes, but they pose risks of bleeding. The authors review the scope of the problem and ways to prevent and manage bleeding in this situation.

KEY POINTS

The reported incidence of bleeding after treatment for non-ST-elevation acute coronary syndromes ranges from less than 1% to 10%, depending on a number of factors.

Bleeding is strongly associated with adverse outcomes, although a causal relationship has not been established.

Patients should be assessed for risk of bleeding so that the antithrombotic and antiplatelet regimen can be adjusted, safer alternatives can be considered, and percutaneous interventions can be used less aggressively for those at high risk.

If bleeding develops and the risk of continued bleeding outweighs the risk of recurrent ischemia, antithrombotic and antiplatelet drug therapy can be interrupted and other agents given to reverse the effects of these drugs.

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THE MEDICAL MANAGEMENT OF non-ST-elevation acute coronary syndromes focuses on blocking the coagulation cascade and inhibiting platelets. This—plus diagnostic angiography followed, if needed, by revascularization—has reduced the rates of death and recurrent ischemic events.¹ However, the combination of potent antithrombotic drugs and invasive procedures also increases the risk of bleeding.

This review discusses the incidence and complications associated with bleeding during the treatment of acute coronary syndromes and summarizes recommendations for preventing and managing bleeding in this setting.

THE TRUE INCIDENCE OF BLEEDING IS HARD TO DETERMINE

The optimal way to detect and analyze bleeding events in clinical trials and registries is highly debated. The reported incidences of bleeding during antithrombotic and antiplatelet therapy for non-ST-elevation acute coronary syndromes depend on how bleeding was defined, how the acute coronary syndromes were treated, and on other factors such as how the study was designed.

How was bleeding defined?

The first bleeding classification schemes were the GUSTO² and the TIMI³ scales (TABLE 1), both of which were developed for studies of thrombolytic therapy for ST-elevation myocardial infarction. The GUSTO classification is based on clinical events and catego-

Glossary of studies discussed in this article

ACUITY—Acute Catheterization and Urgent Intervention Triage Strategy¹⁶

CRUSADE—Can Rapid Risk Stratification of Unstable Angina Patients Suppress Adverse Outcomes With Early Implementation of the ACC/AHA Guidelines^{8,11}

CURE—Clopidogrel in Unstable Angina to Prevent Recurrent Events^{34–36}

GRACE—Global Registry of Acute Coronary Events¹⁰

GUSTO—Global Use of Strategies to Open Occluded Coronary Arteries²

HORIZONS-AMI—Harmonizing Outcomes With Revascularization and Stents in Acute Myocardial Infarction⁴¹

ISAR—Intracoronary Stenting and Antithrombotic Regimen¹⁹

OASIS—Organization to Assess Ischemic Syndromes³⁸

PARAGON—Platelet IIb/IIIa Antagonism for the Reduction of Acute Coronary Syndrome Events in a Global Organization Network⁴

PURSUIT—Platelet Glycoprotein IIb/IIIa in Unstable Angina: Receptor Suppression Using Integrilin Therapy⁴

REPLACE-2—Randomized Evaluation in PCI Linking Angiomax to Reduced Clinical Events-2²⁰

TIMI—Thrombolysis in Myocardial Infarction³

Registries often include older and sicker patients, who are excluded from clinical trials

rizes bleeding as severe, moderate, or mild. In contrast, the TIMI classification is based on laboratory values and categorizes bleeding as major, moderate, or minor.

Since these classification schemes are based on different types of data, they yield different numbers when applied to the same study population. For instance, Rao et al⁴ pooled the data from the PURSUIT and PARAGON B trials (15,454 patients in all) and found that the incidence of severe bleeding (by the GUSTO criteria) was 1.2%, while the rate of major bleeding (by the TIMI criteria) was 8.2%.

What was the treatment strategy?

Another reason that the true incidence of bleeding is hard to determine is that different studies used treatment strategies that differed in the type, timing, and dose of antithrombotic agents and whether invasive procedures were used early. For example, if unfractionated heparin is used aggressively in regimens that are not adjusted for weight and with a higher target for the activated clotting time, the risk of bleeding is higher than with conservative dosing.^{5–7}

Subherwal et al⁸ evaluated the effect of treatment strategy on the incidence of bleeding in patients with non-ST-elevation acute

coronary syndromes who received two or more antithrombotic drugs in the CRUSADE Quality Improvement Initiative. The risk of bleeding was higher with an invasive approach (catheterization) than with a conservative approach (no catheterization), regardless of baseline bleeding risk.

What type of study was it?

Another source of variation is the design of the study. Registries differ from clinical trials in patient characteristics and in the way data are gathered (prospectively vs retrospectively).

In registries, data are often collected retrospectively, whereas in clinical trials the data are prospectively collected. For this reason, the definition of bleeding in registries is often based on events that are easily identified through chart review, such as transfusion. This may lead to a lower reported rate of bleeding, since other, less serious bleeding events such as access-site hematomas and epistaxis may not be documented in the medical record.

On the other hand, registries often include older and sicker patients, who may be more prone to bleeding and who are often excluded from clinical trials. This may lead to a higher rate of reported bleeding.⁹

Where the study was conducted makes a difference as well, owing to regional practice differences. For example, Moscucci et al¹⁰ reported that the incidence of major bleeding in 24,045 patients with non-ST-elevation acute coronary syndromes in the GRACE registry (in 14 countries worldwide) was 3.9%. In contrast, Yang et al¹¹ reported that the rate of bleeding in the CRUSADE registry (in the United States) was 10.3%.

This difference was partly influenced by different definitions of bleeding. The GRACE registry defined major bleeding as life-threatening events requiring transfusion of two or more units of packed red blood cells, or resulting in an absolute decrease in the hematocrit of 10% or more or death, or hemorrhagic subdural hematoma. In contrast, the CRUSADE data reflect bleeding requiring transfusion. However, practice patterns such as greater use of invasive procedures in the United States may also be responsible.

Rao and colleagues¹² examined international variation in blood transfusion rates among patients with acute coronary syndromes. Patients outside the United States were significantly less likely to receive transfusions, even after adjusting for patient and practice differences.

Taking these confounders into account, it is reasonable to estimate that the frequency of bleeding in patients with non-ST-elevation acute coronary syndromes ranges from less than 1% to 10%.¹³

■ BLEEDING IS ASSOCIATED WITH POOR OUTCOMES

Regardless of the definition or the data source, hemorrhagic complications are associated with a higher risk of death and nonfatal adverse events, both in the short term and in the long term.

Short-term outcomes

A higher risk of death. In the GRACE registry study by Moscucci et al¹⁰ discussed above, patients who had major bleeding were significantly more likely to die during their hospitalization than those who did not (odds ratio [OR] 1.64, 95% confidence interval [CI] 1.18–2.28).

TABLE 1

Popular bleeding classifications

GUSTO

Severe or life-threatening

Either intracranial hemorrhage or bleeding that causes hemodynamic compromise and requires intervention

Moderate

Bleeding that requires blood transfusion but does not result in hemodynamic compromise

Mild

Bleeding that does not meet criteria for either severe or moderate bleeding

TIMI

Major

Intracranial hemorrhage or ≥ 5 -g/dL decrease in the hemoglobin concentration or $\geq 15\%$ absolute decrease in hematocrit

Minor

Observed blood loss: ≥ 3 -g/dL decrease in the hemoglobin concentration or $\geq 10\%$ decrease in the hematocrit

No observed blood loss: ≥ 4 -g/dL decrease in the hemoglobin concentration or $\geq 12\%$ decrease in the hematocrit

Minimal

Any clinically overt sign of hemorrhage (including imaging) that is associated with a < 3 g/dL decrease in the hemoglobin concentration or a $< 9\%$ decrease in the hematocrit

ACUITY

Major

Intracranial bleeding; intraocular bleeding

Access site hemorrhage requiring intervention

Hematoma ≥ 5 cm in diameter

Reduction in hemoglobin concentration of ≥ 4 g/dL without an overt source of bleeding

Reduction in hemoglobin concentration of ≥ 3 g/dL with an overt source of bleeding

Reoperation for bleeding

Transfusion of any blood products

REPLACE-2

Major

Intracranial, intraocular, or retroperitoneal

Overt blood loss with hemoglobin decrease > 3 g/dL

Any hemoglobin decrease > 4 g/dL

Transfusion of ≥ 2 U of blood products

Minor

Overt bleeding not meeting the above criteria

GUSTO = Global Use of Strategies for Opening Occluded Coronary Arteries;

TIMI = Thrombolysis in Myocardial Infarction; ACUITY = Acute Catheterization and

Urgent Intervention Triage Strategy; REPLACE-2 = Randomized Evaluation in PCI Linking Angiomax to Reduced Clinical Events-2

Rao et al¹⁴ evaluated pooled data from the multicenter international GUSTO IIb, PURSUIT, and PARAGON A and B trials and found that the effects of bleeding in non-ST-elevation acute coronary syndromes extended beyond the hospital stay. The more severe the bleeding (by the GUSTO criteria), the greater the adjusted hazard ratio (HR) for death within 30 days:

- With mild bleeding—HR 1.6, 95% CI 1.3–1.9
- With moderate bleeding—HR 2.7, 95% CI 2.3–3.4
- With severe bleeding—HR 10.6, 95% CI 8.3–13.6.

The pattern was the same for death within 6 months:

- With mild bleeding—HR 1.4, 95% CI 1.2–1.6
- With moderate bleeding—HR 2.1, 95% CI 1.8–2.4
- With severe bleeding, HR 7.5, 95% CI 6.1–9.3.

These findings were confirmed by Eikelboom et al¹⁵ in 34,146 patients with acute coronary syndromes in the OASIS registry, the OASIS-2 trial, and the CURE randomized trial. In the first 30 days, five times as many patients died (12.8% vs 2.5%; $P < .0009$) among those who developed major bleeding compared with those who did not. These investigators defined major bleeding as bleeding that was life-threatening or significantly disabling or that required transfusion of two or more units of packed red blood cells.

A higher risk of nonfatal adverse events. Bleeding after antithrombotic therapy for non-ST-elevation acute coronary syndromes has also been associated with nonfatal adverse events such as stroke and stent thrombosis.

For example, in the study by Eikelboom et al,¹⁵ major bleeding was associated with a higher risk of recurrent ischemic events. Approximately 1 in 5 patients in the OASIS trials who developed major bleeding during the first 30 days died or had a myocardial infarction or stroke by 30 days, compared with 1 in 20 of those who did not develop major bleeding during the first 30 days. However, after events that occurred during the first 30 days were excluded, the association between major bleeding and both myocardial infarction and

stroke was no longer evident between 30 days and 6 months.

Manoukian et al¹⁶ evaluated the impact of major bleeding in 13,819 patients with high-risk acute coronary syndromes undergoing treatment with an early invasive strategy in the ACUITY trial. At 30 days, patients with major bleeding had higher rates of the composite end point of death, myocardial infarction, or unplanned revascularization for ischemia (23.1% vs 6.8%, $P < .0001$) and of stent thrombosis (3.4% vs 0.6%, $P < .0001$).

Long-term outcomes

The association between bleeding and adverse outcomes persists in the long term as well, although the mechanisms underlying this association are not well studied.

Kinnaird et al¹⁷ examined the data from 10,974 unselected patients who underwent percutaneous coronary intervention. At 1 year, the following percentages of patients had died:

- After TIMI major bleeding—17.2%
- After TIMI minor bleeding—9.1%
- After no bleeding—5.5%.

However, after adjustment for potential confounders, only transfusion remained a significant predictor of 1-year mortality.

Mehran et al¹⁸ evaluated 1-year mortality data from the ACUITY trial. Compared with the rate in patients who had no major bleeding and no myocardial infarction, the hazard ratios for death were:

- After major bleeding—HR 3.5, 95% CI 2.7–4.4
- After myocardial infarction—HR 3.1, 95% CI 2.4–3.9.

Interestingly, the risk of death associated with myocardial infarction abated after 7 days, while the risk associated with bleeding persisted beyond 30 days and remained constant throughout the first year following the bleeding event.

Similarly, Ndrepepa and colleagues¹⁹ examined pooled data from four ISAR trials using the TIMI bleeding scale and found that myocardial infarction, target vessel revascularization, and major bleeding all had similar discriminatory ability at predicting 1-year mortality.

In patients undergoing elective or urgent percutaneous coronary intervention in the

Bleeding is associated with poor outcomes, both short-term and long-term

REPLACE-2 trial,²⁰ independent predictors of death by 1 year were²¹:

- Major hemorrhage (OR 2.66, 95% CI 1.44–4.92)
- Periprocedural myocardial infarction (OR 2.46, 95% CI 1.44–4.20).

THEORIES OF HOW BLEEDING MAY CAUSE ADVERSE OUTCOMES

Several mechanisms have been proposed to explain the association between bleeding during treatment for acute coronary syndromes and adverse clinical outcomes.^{13,22}

The immediate effects of bleeding are thought to be hypotension and a reflex hyperadrenergic state to compensate for the loss of intravascular volume.²³ This physiologic response is believed to contribute to myocardial ischemia by further decreasing myocardial oxygen supply in obstructive coronary disease.

Trying to minimize blood loss, physicians may withhold anticoagulation and antiplatelet therapy, which in turn may lead to further ischemia.²⁴ To compensate for blood loss, physicians may also resort to blood transfusion. However, depletion of 2,3-diphosphoglycerate and nitric oxide in stored donor red blood cells is postulated to reduce oxygen delivery by increasing hemoglobin's affinity for oxygen, leading to induced microvascular obstruction and adverse inflammatory reactions.^{15,25}

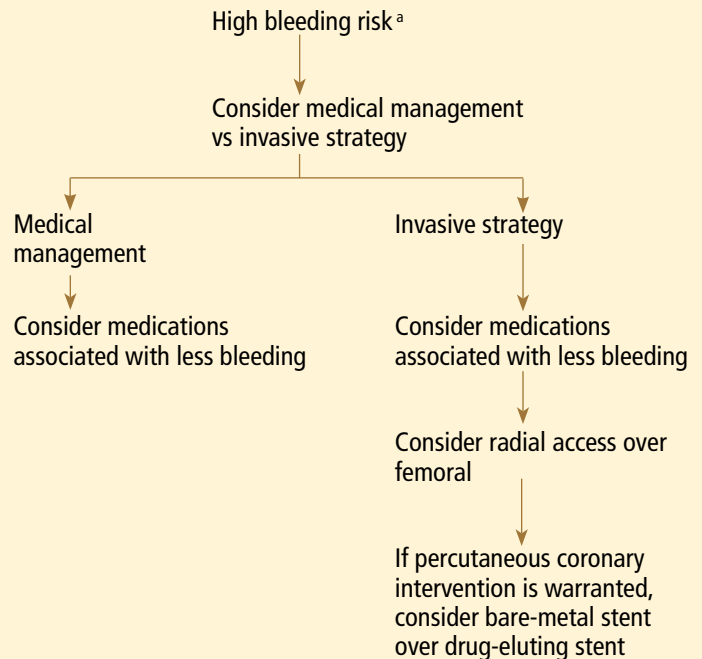
Recent data have also begun to elucidate the long-term effects of bleeding during acute coronary syndrome management. Patients with anemia during the acute phase of infarction have greater neurohormonal activation.²⁶ These adaptive responses to anemia may lead to eccentric left ventricular remodeling that may lead to higher oxygen consumption, increased diastolic wall stress, interstitial fibrosis, and accelerated myocyte loss.^{27–30}

Nevertheless, we must point out that although strong associations between bleeding and adverse outcomes have been established, direct causality has not.

TO PREVENT BLEEDING, START BY ASSESSING RISK

Preventing bleeding is a key step in balancing the safety and efficacy of aggressive manage-

Bleeding reduction algorithm



Regardless of baseline bleeding risk, dosing of antithrombotic agents should take into account age, weight, and renal function (on admission and throughout the hospital course).

^a See www.crusadebleedingscore.org.

FIGURE 1

ment of non-ST-elevation acute coronary syndromes. Current guidelines^{1,31} call for assessing the risk of both thrombosis and bleeding in patients presenting with these syndromes (FIGURE 1). Doing so may allow clinicians to tailor therapy by adjusting the treatment regimen in patients at risk of bleeding to include medications associated with favorable bleeding profiles and by using radial access as the point of entry at the time of coronary artery angiography.

The CRUSADE bleeding risk score

The CRUSADE bleeding score (calculator available at <http://www.crusadebleedingscore.org/>) was developed and validated in more than 89,000 community-treated patients with non-ST-elevation acute coronary syndromes.⁸ It is based on eight variables:

- Sex (higher risk in women)
- History of diabetes (higher risk)
- Prior vascular disease (higher risk)

- Heart rate (the higher the rate, the higher the risk)
- Systolic blood pressure (higher risk with pressures above or below the 121–180 mm Hg range)
- Signs of congestive heart failure (higher risk)
- Baseline hematocrit (the lower the hematocrit, the higher the risk)
- Creatinine clearance (by the Cockcroft-Gault formula; the lower the creatinine clearance, the higher the risk).

Patients who are found to have bleeding scores suggesting a moderate or higher risk of bleeding should be considered for medications associated with a favorable bleeding profile, and for radial access at the time of coronary angiography. Scores are graded as follows⁸:

- < 21: Very low risk
- 21–30: Low risk
- 31–40: Moderate risk
- 41–50: High risk
- > 50: Very high risk.

The CRUSADE bleeding score is unique in that, unlike earlier risk stratification tools, it was developed in a “real world” population, not in subgroups or in a clinical trial. It can be calculated at baseline to help guide the selection of treatment.⁸

Adjusting the heparin regimen in patients at risk of bleeding

Both the joint American College of Cardiology/American Heart Association¹ and the European Society of Cardiology guidelines³¹ for the treatment of non-ST-elevation acute coronary syndromes recommend taking steps to prevent bleeding, such as adjusting the dosage of unfractionated heparin, using safer drugs, reducing the duration of antithrombotic treatment, and using combinations of antithrombotic and antiplatelet agents according to proven indications.³¹

In the CRUSADE registry, 42% of patients with non-ST-elevation acute coronary syndromes received at least one initial dose of antithrombotic drug outside the recommended range, resulting in an estimated 15% excess of bleeding events.³² Thus, proper dosing is a target for prevention.

Appropriate antithrombotic dosing takes into account the patient’s age, weight, and re-

nal function. However, heparin dosage in the current guidelines¹ is based on weight only: a loading dose of 60 U/kg (maximum 4,000 U) by intravenous bolus, then 12 U/kg/hour (maximum 1,000 U/hour) to maintain an activated partial thromboplastin time of 50 to 70 seconds.¹

Renal dysfunction is particularly worrisome in patients with non-ST-elevation acute coronary syndromes because it is associated with higher rates of major bleeding and death. In the OASIS-5 trial,³³ the overall risk of death was approximately five times higher in patients in the lowest quartile of renal function (glomerular filtration rate < 58 mL/min/1.73 m²) than in the highest quartile (glomerular filtration rate ≥ 86 mL/min/1.73 m²).

Renal function must be evaluated not only on admission but also throughout the hospital stay. Patients presenting with acute coronary syndromes often experience fluctuations in renal function that would call for adjustment of heparin dosing, either increasing the dose to maximize the drug’s efficacy if renal function is recovering or decreasing the dose to prevent bleeding if renal function is deteriorating.

Clopidogrel vs prasugrel

Certain medications should be avoided when the risk of bleeding outweighs any potential benefit in terms of ischemia.

For example, in a randomized trial,³⁴ prasugrel (Effient), a potent thienopyridine, was associated with a significantly lower rate of the composite end point of stroke, myocardial infarction, or death than clopidogrel (Plavix) in patients with acute coronary syndromes undergoing percutaneous coronary interventions. However, it did not seem to offer any advantage in patients 75 years old and older, those with prior stroke or transient ischemic attack, or those weighing less than 60 kg, and it posed a substantially higher risk of bleeding.

With clopidogrel, the risk of acute bleeding is primarily in patients who undergo coronary artery bypass grafting within 5 days of receiving a dose.^{35,36} Therefore, clopidogrel should be stopped 5 to 7 days before bypass surgery.¹ Importantly, there is no increased risk of recurrent ischemic events during this 5-day waiting period in patients who receive clopidogrel early. Therefore, the recommen-

dation to stop clopidogrel before surgery does not negate the benefits of early treatment.³⁶

Lower-risk drugs:

Fondaparinux and bivalirudin

At this time, only two agents have been studied in clinical trials that have specifically focused on reducing bleeding risk: fondaparinux (Arixtra) and bivalirudin (Angiomax).^{20,37–39}

Fondaparinux

OASIS-5 was a randomized, double-blind trial that compared fondaparinux and enoxaparin (Lovenox) in patients with acute coronary syndromes.³⁸ Fondaparinux was similar to enoxaparin in terms of the combined end point of death, myocardial infarction, or refractory ischemia at 9 days, and fewer patients on fondaparinux developed bleeding (2.2% vs 4.1%, HR 0.52; 95% CI 0.44–0.61). This difference persisted during long-term follow-up.

Importantly, fewer patients died in the fondaparinux group. At 180 days, 638 (6.5%) of the patients in the enoxaparin group had died, compared with 574 (5.8%) in the fondaparinux group, a difference of 64 deaths ($P = .05$). The authors found that 41 fewer patients in the fondaparinux group than in the enoxaparin group died after major bleeding, and 20 fewer patients in the fondaparinux group died after minor bleeding.³⁸ Thus, most of the difference in mortality rates between the two groups was attributed to a lower incidence of bleeding with fondaparinux.

Unfortunately, despite its safe bleeding profile, fondaparinux has fallen out of favor for use in acute coronary syndromes, owing to a higher risk of catheter thrombosis in the fondaparinux group (0.9%) than in those undergoing percutaneous coronary interventions with enoxaparin alone (0.4%) in the OASIS-5 trial.⁴⁰

Bivalirudin

The direct thrombin inhibitor bivalirudin has been studied in three large randomized trials in patients undergoing percutaneous coronary interventions.^{20,37,41}

The ACUITY trial³⁷ was a prospective, open-label, randomized, multicenter trial that compared three regimens in patients with moderate or high-risk non-ST-elevation acute

coronary syndromes:

- Heparin plus a glycoprotein IIb/IIIa inhibitor
- Bivalirudin plus a glycoprotein IIb/IIIa inhibitor
- Bivalirudin alone.

Bivalirudin alone was as effective as heparin plus a glycoprotein IIb/IIIa inhibitor with respect to the composite ischemia end point, which at 30 days had occurred in 7.8% vs 7.3% of the patients in these treatment groups ($P = .32$, RR 1.08; 95% CI 0.93–1.24), and it was superior with respect to major bleeding (3.0% vs 5.7%, $P < .001$, RR 0.53; 95% CI 0.43–0.65).

The HORIZONS-AMI study⁴¹ was a prospective, open-label, randomized, multicenter trial that compared bivalirudin alone vs heparin plus a glycoprotein IIb/IIIa inhibitor in patients with ST-elevation acute coronary syndromes who were undergoing primary percutaneous coronary interventions. The two primary end points were major bleeding and net adverse events.

At 1 year, patients assigned to bivalirudin had a lower rate of major bleeding than did controls (5.8% vs 9.2%, HR 0.61, 95% CI 0.48–0.78, $P < .0001$), with similar rates of major adverse cardiac events in both groups (11.9% vs 11.9%, HR 1.00, 95% CI 0.82–1.21, $P = .98$).⁴¹

Both OASIS 5 and HORIZONS-AMI are examples of clinical trials in which strategies that reduced bleeding risk were also associated with improved survival.

For cardiac catheterization, inserting the catheter in the wrist poses less risk

Bleeding is currently the most common non-cardiac complication in patients undergoing percutaneous coronary interventions, and it most often occurs at the vascular access site.¹⁷

Rao et al¹² evaluated data from 593,094 procedures in the National Cardiovascular Data Registry and found that, compared with the femoral approach, the use of transradial percutaneous coronary intervention was associated with a similar rate of procedural success (OR 1.02, 95% CI 0.93–1.12) but a significantly lower risk of bleeding complications (OR 0.42, 95% CI 0.31–0.56) after multivariable adjustment.

Renal function must be evaluated not only on admission, but also throughout the hospital stay

The use of smaller sheath sizes (4F–6F) and preferential use of bivalirudin over unfractionated heparin and glycoprotein IIb/IIIa inhibitor therapy are other methods described to decrease the risk of bleeding after percutaneous coronary interventions.^{20,41–49}

■ IF BLEEDING OCCURS

Once a bleeding complication occurs, cessation of therapy is a potential option. Stopping or reversing antithrombotic and antiplatelet therapy is warranted in the event of major bleeding (eg, gastrointestinal, retroperitoneal, intracranial).³¹

Stopping antithrombotic and antiplatelet therapy

Whether bleeding is minor or major, the risk of a recurrent thrombotic event must be considered, especially in patients who have undergone revascularization, stent implantation, or both. The risk of acute thrombotic events after interrupting antithrombotic or antiplatelet agents is considered greatest 4 to 5 days following revascularization or percutaneous coronary intervention.¹⁵ If bleeding can be controlled with local treatment such as pressure, packing, or dressing, antithrombotic and antiplatelet therapy need not be interrupted.⁵⁰

Current guidelines recommend strict control of hemorrhage for at least 24 hours before reintroducing antiplatelet or antithrombotic agents.

It is also important to remember that in the setting of gastrointestinal bleeding due to peptic ulcer disease, adjunctive proton pump inhibitors are recommended after restarting antiplatelet or antithrombotic therapy or both.

Importantly, evidence-based antithrombotic medications (especially dual antiplatelet therapy) should be restarted once the acute bleeding event has resolved.³¹

Reversal of anticoagulant and antiplatelet therapies

Reversal of antithrombotic therapy is occasionally necessary (TABLE 2).

Unfractionated heparin is reversed with infusion of protamine sulfate at a dose of 1 mg per 100 U of unfractionated heparin given over the previous 4 hours.^{51,52} The rate of prot-

amine sulfate infusion should be less than 100 mg over 2 hours, with 50% of the dose given initially and subsequent doses titrated according to bleeding response.^{52,53} Protamine sulfate is associated with a risk of hypotension and bradycardia, and for this reason it should be given no faster than 5 mg/min.

Low-molecular-weight heparin (LMWH) can be inhibited by 1 mg of protamine sulfate for each 1 mg of LMWH given over the previous 4 hours.^{51,52}

However, protamine sulfate only partially neutralizes the anticoagulant effect of LMWH. In cases in which protamine sulfate is unsuccessful in abating bleeding associated with LMWH use, guidelines allow for the use of recombinant factor VIIa (NovoSeven).³¹ In healthy volunteers given fondaparinux, recombinant factor VIIa normalized coagulation times and thrombin generation within 1.5 hours, with a sustained effect for 6 hours.⁵²

It is important to note that the use of this agent has not been fully studied, it is very costly (a single dose of 40 µg/kg costs from \$3,000 to \$4,000), and it is linked to reports of increased risk of thrombotic complications.^{54,55}

Antiplatelet agents are more complex to reverse. The antiplatelet actions of aspirin and clopidogrel wear off as new platelets are produced. Approximately 10% of a patient's platelet count is produced daily; thus, the antiplatelet effects of aspirin and clopidogrel can persist for 5 to 10 days.^{31,56}

If these agents need to be reversed quickly to stop bleeding, according to expert consensus the aspirin effect can be reversed by transfusion of one unit of platelets. The antiplatelet effect of clopidogrel is more significant than that of aspirin; thus, two units of platelets are recommended.⁵⁶

Glycoprotein IIb/IIIa inhibitors. If a major bleeding event requires the reversal of glycoprotein IIb/IIIa inhibitor therapy, the treatment must take into consideration the pharmacodynamics of the target drug. Both eptifibatide (Integrilin) and tirofiban (Aggrastat) competitively inhibit glycoprotein IIb/IIIa receptors; thus, their effects depend on dosing, elimination, and time. Due to the stoichiometry of both drugs, transfusion of platelets is ineffective. Both eptifibatide and tirofiban are eliminated by the kidney; thus,

Clopidogrel should be stopped 5 to 7 days before bypass surgery

TABLE 2

Reversal of common medical therapies for acute coronary syndromes

AGENT	ANTIDOTE	CONCERNS
Anticoagulants		
Unfractionated heparin	Stop therapy Protamine sulfate (1 mg per 100 U of unfractionated heparin given over previous 4 hours; total dose < 100 mg over 2 hours; 50% of total dose given initially; administration rate ≤ 5 mg/min)	Hypotension and bradycardia with rapid infusion
Low-molecular-weight heparins	Stop therapy Protamine sulfate (1 mg per 1 mg of low-molecular-weight heparin given over previous 4 hours; total dose < 100 mg over 2 hours; 50% of total dose given initially; administration rate ≤ 5 mg/min) Recombinant factor VIIa (NovoSeven) (20–30 µg/kg)	Hypotension and bradycardia with rapid infusion Costly Reports of thrombotic complications
Antiplatelet drugs		
Aspirin	Stop therapy Platelets (1 unit) Desmopressin (DDAVP) (0.3–0.4 µg/kg)	Transfusion reaction
Clopidogrel (Plavix)	Stop therapy Platelets (2 units)	Transfusion reaction
Glycoprotein IIb/IIIa inhibitors		
Eptifibatide (Integrilin)	Stop therapy; half-life is 2.5 hours; hemostasis occurs 4 hours after stopping infusion	
Tirofiban (Aggrastat)	Stop therapy; plasma half-life is 2 hours	
Abciximab (ReoPro)	Stop therapy Platelet transfusion (1 unit)	Transfusion reaction

normal renal function is key to the amount of time it takes for platelet function to return to baseline.⁵⁷ Evidence suggests that fibrinogen-rich plasma can be administered to restore platelet function.^{31,58,59}

Abciximab (ReoPro). Whereas reversal of eptifibatide and tirofiban focuses on overcoming competitive inhibition, neutralization of abciximab involves overcoming its high receptor affinity. At 24 hours after abciximab in-

fusion is stopped, platelet aggregation may still be inhibited by up to 50%. Fortunately, owing to abciximab's short plasma half-life and its dilution in serum, platelet transfusion is effective in reversing its antiplatelet effects.^{31,57}

Blood transfusion

Long considered beneficial to critically ill patients, blood transfusion to maintain hematocrit levels during acute coronary syndromes

has come under intense scrutiny. Randomized trials have shown that transfusion should not be given aggressively to critically ill patients.⁶⁰ In acute coronary syndromes, there are only observational data.

Rao et al⁶¹ used detailed clinical data from 24,112 patients with acute coronary syndromes in the GUSTO IIb, PURSUIT, and PARAGON B trials to determine the association between blood transfusion and outcomes in patients who developed moderate to severe bleeding, anemia, or both during their hospitalization. The rates of death in the hospital and at 30 days were significantly higher in patients who received a transfusion (30-day mor-

tality HR 3.94; 95% CI 3.36–4.75). However, there was no significant association between transfusion and the 30-day mortality rate if the nadir hematocrit was 25% or less.

Of note: no randomized clinical trial has evaluated transfusion strategies in acute coronary syndromes at this time. Until such data are available, it is reasonable to follow published guidelines and to avoid transfusion in stable patients with ischemic heart disease unless the hematocrit is 25% or less.³¹ The risks and benefits of blood transfusion should be carefully weighed. Routine use of transfusion to maintain predefined hemoglobin levels is not recommended in stable patients. ■

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ADDRESS: Antonio Gutierrez, MD, Duke University Medical Center, 2301 Erwin Road, Durham, NC 27710; e-mail antonio.gutierrez@duke.edu.