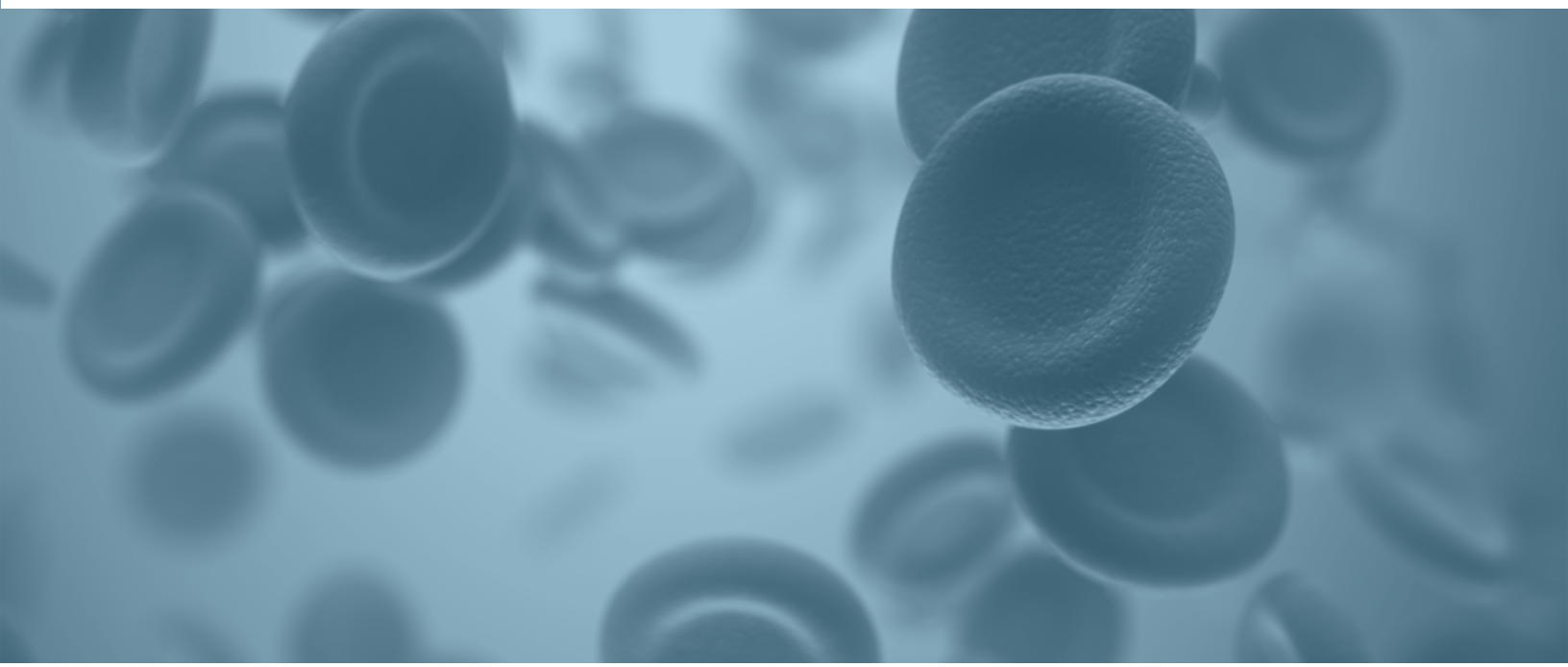
Management of Surgical Hemostasis

An Independent Study Guide



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Overview

Effective management of bleeding is critical for promoting positive outcomes in the surgical patient. Throughout a surgical procedure, bleeding must be controlled not only to provide the best view of the operative site, but also to prevent the adverse physiologic effects associated with blood loss. When the natural process of blood clotting does not occur or is adversely affected by surgery, other methods of achieving and maintaining surgical hemostasis are often indicated. The goal of this continuing education activity is to educate perioperative registered nurses (RNs) about the effective management of hemostasis in the surgical patient. Using the nursing process and evidenced-based practices, this activity will assist the perioperative RN to identify risks, benefits, indications, contraindications, and adverse effects when the various methods available for control of bleeding during surgery are used. The clinical implications of surgical bleeding and the importance of managing surgical hemostasis will be discussed, followed by a review of the normal process of coagulation. The methods currently available to effectively manage surgical hemostasis – mechanical hemostatic techniques, thermal/energy-based methods, and the various types of topical hemostatic agents – will be outlined. Perioperative nursing care considerations related to the management of surgical hemostasis, including assessment factors to determine patients at risk for prolonged or excessive bleeding and key considerations for the selection and safe use of topical hemostatic products, will be discussed.

Objectives

After completion of this continuing nursing education activity, the participant will be able to:

1. Identify the clinical implications of surgical bleeding.
2. Differentiate between mechanical, energy-based, and chemical methods of surgical hemostasis.
3. Compare the various categories of topical hemostatic products.
4. Identify key factors to consider in the selection of hemostatic products.
5. Describe perioperative nursing care for patients undergoing surgical hemostasis.

Intended Audience

This continuing education activity is intended for perioperative RNs who are interested in learning more about the importance of and methods available for the effective management of surgical hemostasis.

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Introduction*

Hemostasis is the act of restricting or stopping blood flow from a damaged vessel or organ. Adjunct hemostatic techniques are essential during surgery or other invasive procedures to provide hemostasis when the normal coagulation process may be unable to function.[1] Two types of bleeding are seen during a surgical procedure, arterial bleeding which can be seen to pulsate and venous bleeding which oozes rather than pulsates. The need to control arterial bleeding is crucial because large volumes of blood can be quickly lost, however, slower, persistent loss of venous blood can contribute to significant blood loss if uncontrolled.[2]

Maintaining hemostasis during surgery is essential to preserve physiologic functions for the patient, provide the surgeon with the ability to see the operative field, and promote successful wound management and patient outcomes.[1] In addition, effective surgical hemostasis also results in fewer blood transfusions, decreased operating time, and reduced morbidity and mortality for patients.[3] Because the elimination of risks such as bleeding are considered components of patient-centered care,[4] managing surgical hemostasis through evidence-based practices is a key role of the perioperative RN.[1]

*Note: Terms in **bold** are defined in the glossary.

Clinical Implications of Surgical Bleeding

During any surgical procedure, maintaining the delicate balance between bleeding and clotting means that blood must continue to flow to the tissues at the operative site while the surgical team prevents excessive loss of blood. Hemostasis is important to the success of the procedure, as well as to patient outcomes.[3] Therefore, a review of the clinical implications of surgical bleeding is helpful in understanding the importance of effectively managing this balance. The factors that contribute to surgical bleeding, the adverse effects of surgical bleeding, and the importance of managing hemostasis during surgery will be reviewed.

Factors that Contribute to Surgical Bleeding

Multiple factors contribute to bleeding during or after surgical intervention (Table 1) that are related to either the surgical procedure itself or the individual patient and can have a profound effect on expected outcomes.[1,3]

Table 1 – Factors that Contribute to Surgical Bleeding

Procedural Factors	Patient Factors
• Type of procedure • Patient position • Surgical incisions • Exposed bone (eg, spinal reconstructive procedures) • Large surfaces of exposed capillaries • Unseen sources of bleeding • Tissues that cannot be sutured or low-pressure suture lines • Adhesions stripped during surgery	• Specific anatomical considerations • Medications (eg, anticoagulants) • Coagulopathies o Platelet dysfunction or deficiency o Fibrinolytic activity o Coagulation factor deficiencies • Medical conditions • Nutritional status

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Adverse Effects of Surgical Bleeding

During surgery, uncontrolled or diffuse bleeding can lead to multiple clinical and economic adverse patient outcomes.[5] These adverse effects include:

- Visual obstruction of the surgical field. The significant visual complication created by uncontrolled bleeding, contributes to increases in operating time and also increases the risk of inadvertent patient and staff member injury.[3,6]
- Need for blood transfusions. If not managed properly, surgical bleeding extends the length of the surgical procedure and also can increase the patient's need for blood transfusion.[7] Serious infectious and non-infectious adverse events associated with transfusion of allogeneic blood and blood products are now recognized. While transfusion-transmitted infections have decreased, the awareness and reporting of noninfectious complications of transfusion (eg, immunological reactions, transfusion errors) have increased and noninfectious complications are now the more common and more deadly group of transfusion-related morbidities.[8] Incorrect blood component transfusion resulting in hemolytic transfusion reactions and **transfusion-related acute lung injury** (TRALI) remain major sources of morbidity and mortality.[9]
- Reduction in core temperature. Massive blood loss during trauma surgery or long surgical procedures can cause a reduction in the patient's core temperature and temperature loss has a direct effect on clotting.[1] As the core body temperature nears 34°C (93.2°F), platelets begin to lose their ability to aggregate; this is known as hypothermic **coagulopathy**.
- Thrombocytopenia. This is a common hemostatic deficiency that may develop during surgery because of massive blood loss requiring replacement or after the administration of heparin (ie, heparin-induced thrombocytopenia).[1] The effects of thrombocytopenia include hemorrhage or thrombotic events.
- Hypovolemic shock. This occurs as a result of vascular volume depletion from hemorrhage during surgery and can reduce cardiac output because the heart is unable to completely fill. After the patient loses 10% of his or her total blood volume, cardiac output and central pressure begin to fall.[1] As a result, the body compensates by causing peripheral vasoconstriction to improve cardiac output and pulmonary

gas exchange, and diaphoresis occurs. These changes can result in compensated shock, and the body is able to compensate for the volume loss. However, if the blood loss is not stopped and volume replaced, compensatory mechanisms eventually fail and the following events occur:
    - vasoconstriction reduces oxygenation of peripheral cells,
    - oxygen deprived peripheral cells begin to function anaerobically,
    - metabolic waste products build in the cells,
    - cells begin to die and release inflammatory mediators,
    - cell death and inflammatory mediators cause capillary permeability and vasodilation,
    - blood pressure falls as a result of vasodilation, and
    - the patient eventually dies.[1]
- Economic consequences. The economic effects of bleeding can be substantial, primarily because of the increased need for:
    - patient monitoring,
    - specialist consultations,
    - extended length of hospital stay,
    - further surgical intervention,
    - longer procedure times and/or a return to the OR,
    - postoperative intensive care unit (ICU) stays requiring mechanical ventilation, and
    - additional medical interventions.[5]

Importance/Benefits of Managing Hemostasis during Surgery

As discussed, effectively managing hemostasis during a procedure helps to maintain a clear field of vision for the surgeon; this is especially important as it may help to reduce time in the OR and the need for blood transfusions. Minimizing blood loss and reducing the need for blood transfusions during surgery are associated with beneficial outcomes for the patient, such as shorter stays in the ICU and the hospital and lower risks for infection and postoperative complications.[10,11] All of these benefits translate to a decrease in health care costs for both patients and health care facilities.

Normal Coagulation Process

To understand the effect of surgical bleeding, as well as the means to control bleeding, it is helpful to understand **coagulation**, the body's mechanism to control bleeding. "Coagulation is a process that changes compounds circulating in the blood into an insoluble gel, which is able to plug leaks in the blood vessels and thus stop the loss of blood. Injury to a blood vessel causes the recruitment and activation of platelets, which adhere to each other at the injury site; this leads to the initial formation of a platelet plug and eventually, the formation of a fibrin clot."[1(p139)] The following three components are required for this process:

- **coagulation factors**, which are produced by the liver;
- calcium, which is recruited from intracellular sources in the blood; and
- phospholipids, which are components of platelets.[1]

Platelets are required in the coagulation process because their aggregation begins the initial formation of a platelet plug.[1]

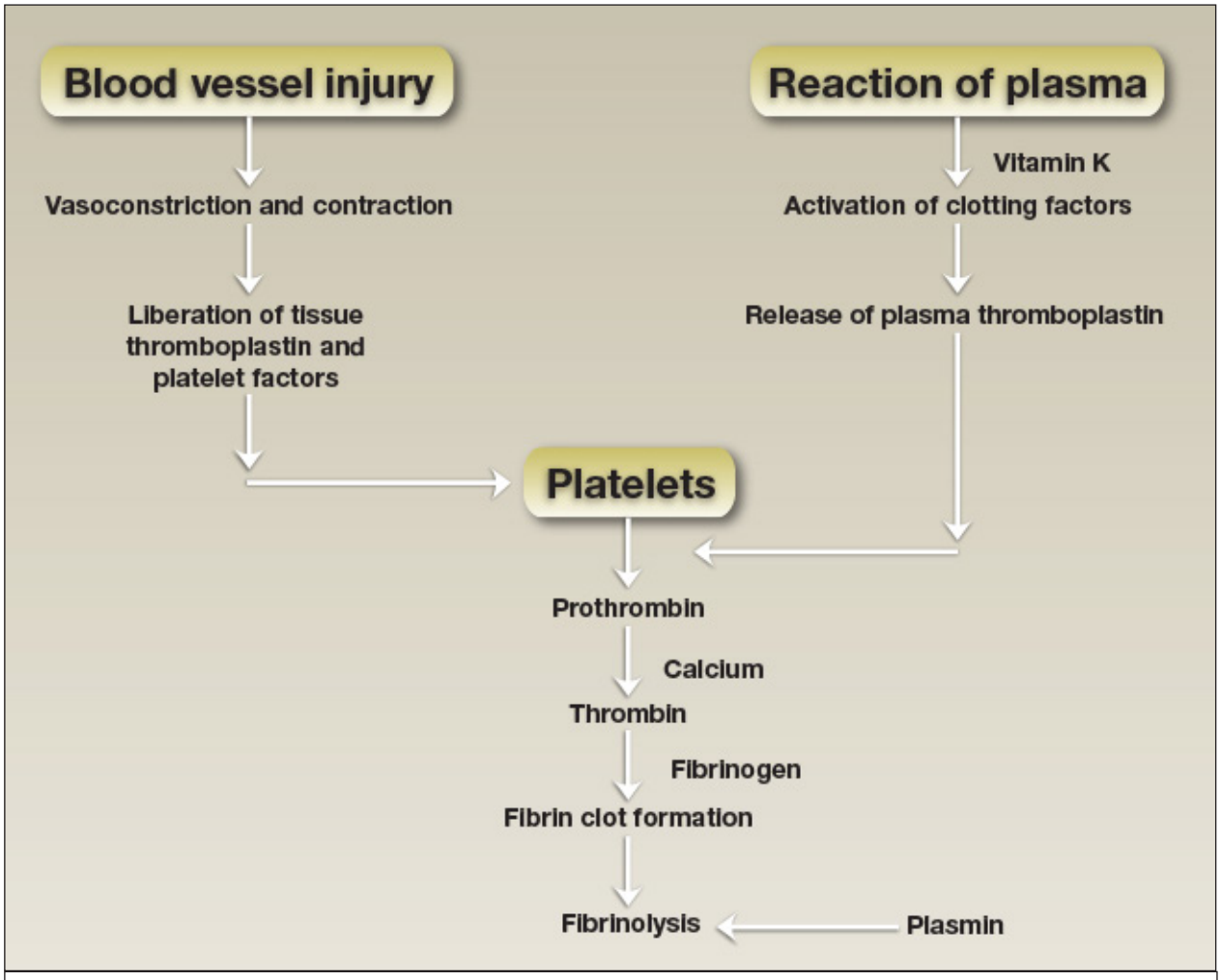
After a loss of vascular integrity (eg, an injury to a vessel), four major events occur in the following sequence:

1. Vasoconstriction. This initial phase limits the flow of blood to the area.
2. Platelet plug formation. After vasoconstriction, platelets are activated by **thrombin** and aggregate at the site of injury to form a temporary, loose platelet plug. This clumping activity is stimulated by the protein **fibrinogen** and by platelets binding to **collagen** exposed following rupture of the endothelial lining of vessels when injured. Activated platelets release serotonin, phospholipids, lipoproteins, and other proteins important for the **coagulation cascade**. In addition to induced secretion, activated platelets also change their shape to aid in the formation of the hemostatic plug.
3. Fibrin clot formation. To stabilize the initially loose platelet plug, a fibrin clot or mesh forms to trap the plug. A plug made up of only platelets, is called a **white thrombus**, whereas one made of red blood cells is termed a **red thrombus**.

4. Fibrinolysis. Eventually, a clot must dissolve to allow the normal flow of blood after the tissue repair occurs. The occurs through the action of **plasmin**.[12]

The normal process of hemostasis is outlined in greater detail in Figure 1.

Figure 1 – The Coagulation Sequence[1,2]



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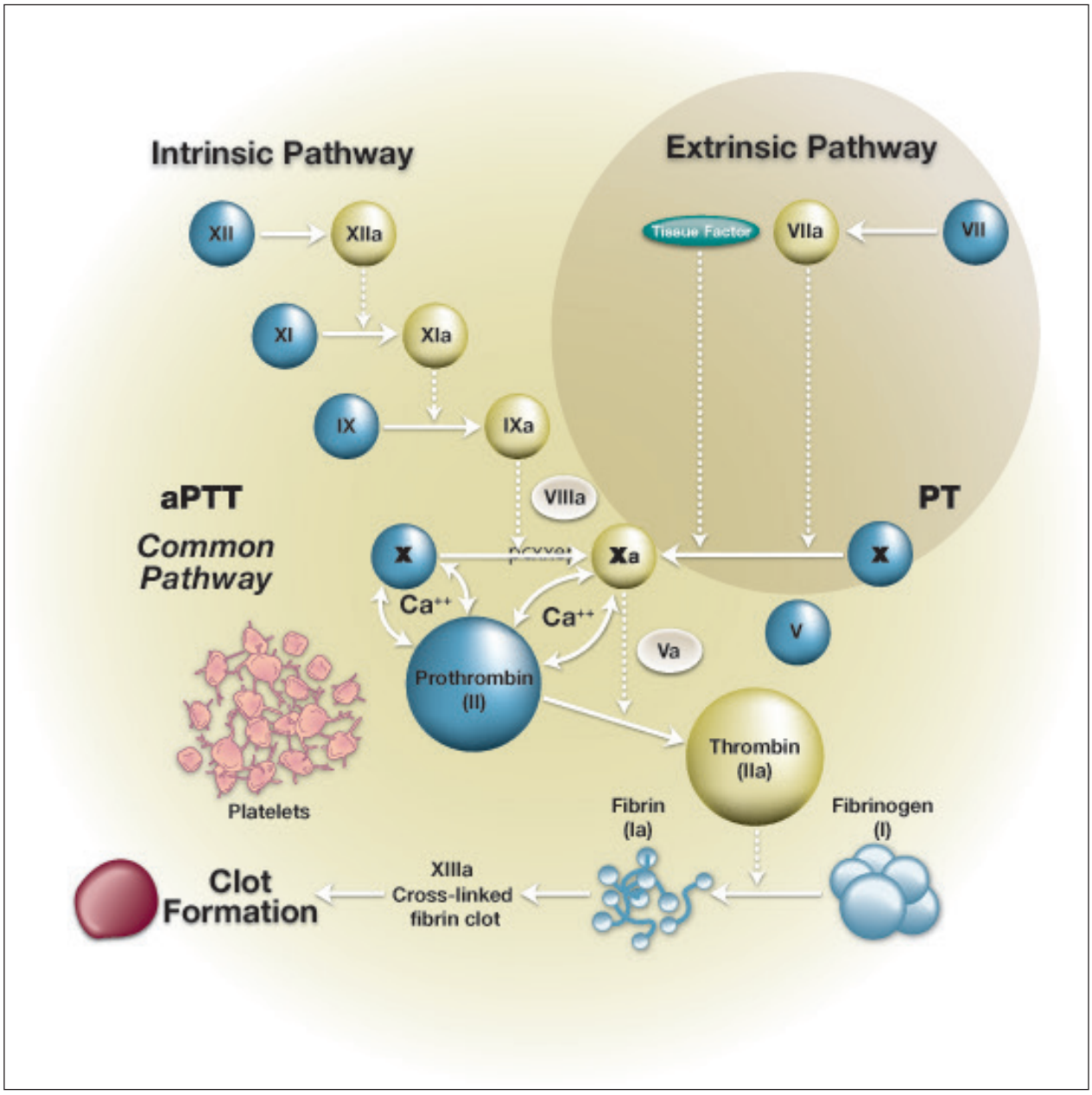
Intrinsic and Extrinsic Pathways

The body's response to bleeding is a sequence of physiologic interactions described as the coagulation cascade. During this process, coagulation occurs via intrinsic or extrinsic pathways, which are triggered by different events but are interrelated and complete the process through a common pathway (Figure 2).[1]

Figure 2 – Coagulation Cascade (Intrinsic and Extrinsic Pathways)



The intrinsic pathway is triggered by events that occur within a blood vessel (ie, damage to the vessel's endothelium), while the extrinsic pathway is triggered when an injury to a vessel occurs (ie, a vessel is cut during surgery). Both pathways begin within seconds after platelets are exposed to and activated by collagen. This causes them to form the initial platelet plug. When an injury to a vessel occurs and initiates the extrinsic pathway, the clotting cascade occurs more quickly because some of the steps necessary for the intrinsic pathway are bypassed. In both pathways, thrombin is required to form a hemostatic plug. Thrombin generation occurs after an injury to a blood vessel. Injury to a vessel exposes tissue factor, which then interacts with activated factor VII to produce thrombin. Thrombin is important because it helps convert fibrinogen to fibrin. It also activates factors V, VIII, and XI, which are needed to stimulate the production of more thrombin molecules. The additional production of thrombin increases the **cross-linkage** of fibrin strands and formation of a hemostatic plug.[1]

Coagulation Factors

Coagulation factors (Table 2) are proteins that cause successive reactions in the clotting process in a cascade-like sequence (ie, one factor is required for the activation of the next factor).[1] The number associated with the factor, however, does not reflect the order in which it is involved in the coagulation cascade. The lack of any coagulation factor can impair the clotting process.[1]

Table 2 – Coagulation Factors

Number (Name/Substance)	Function(s)
Factor I (Fibrinogen)	Converted to fibrin by thrombin.
Factor II (Prothrombin)	Converted to thrombin by Factor X. After activation thrombin converts to fibrinogen (factor 1); its synthesis is vitamin K dependent.
Factor III (Tissue factor or tissue thromboplastin)	Interacts with Factor VII; is the primary reaction that initiates the extrinsic pathway.
Factor IV (Calcium)	Enhances platelet aggregation and red blood cell clumping along with Factors VII, IX, X, and XIII, which require calcium to be activated.
Factor V Leiden (Proaccelerin, accelerator globulin, labile factor)	Essential for converting prothrombin to thrombin.
Factor VI (Accelerin)	A subset of Factor V; also known as Factor Va (there is no actual Factor VI in blood coagulation).
Factor VII (Proconvertin, cothromboplastin, Serum prothrombin conversion accelerator)	Binds to Factor III (tissue factor), then activates Factors IX and X. Essential for the conversion of prothrombin to thrombin; its synthesis is vitamin K dependent.
Factor VIII (Antihemophilic globulin)	A substance similar to Factor V that activates other steps in the coagulation process. The lack of this factor is the cause of hemophilia A.
Factor IX (Christmas factor)	Reacts with other factors to activate Factor X. Essential in the common pathway between the intrinsic and extrinsic pathways. The lack of this factor is the cause of hemophilia B.
Factor X (Stuart-Prower factor)	Reacts with other factors to activate the conversion of prothrombin to thrombin.
Factor XI (Plasma thromboplastin antecedent, Fletcher factor [or prekallikrein] and high-molecular-weight kininogen)	Part of a complex chain reaction that catalyzes other parts of the coagulation proce (activation of Factor IX). Patients deficient in Factor XI often have mild bleeding problems postoperatively.
Factor XII (Hageman factor or contact factor)	A substance that reacts with other factors to activate Factor XI in the intrinsic pathway.
Factor XIII (Fibrin-stabilizing factor and protein C)	Aids in the formation of cross-links among fibrin threads to form fibrin clot.

Adapted with permission from: McCarthy JR. Methods for assuring surgical hemostasis. In: Assisting in Surgery: Patient-Centered Care. *JC Rothrock, PC Seifert, eds. Denver, CO: CCI; 2009:140.*

Surgical Hemostasis Techniques

There are several methods available to manage bleeding in the OR including mechanical hemostatic techniques, thermal/energy-based methods, and chemical methods, which include the use of topical hemostatic products (Table 3).[1]

Table – 3 Methods to Achieve Surgical Hemostasis	
Mechanical methods	• Direct pressure • Fabric pads/gauze sponges/sponges • Sutures/staples/ligating clips

Thermal/energy-based methods	• **Electrosurgery**
	  ○ **Monopolar**
	  ○ **Bipolar**
	  ○ Bipolar vessel sealing device
	  ○ **Argon enhanced coagulation**
	• **Ultrasonic device**
	• **Laser**

Chemical methods
• **Pharmacological agents**
 	
• **Topical hemostatic agents**
	
	• Epinephrine
	• Vitamin K
	• Protamine
	• Desmopressin
	• Lysine analogues (eg, aminocaproic acid, tranexamic acid)
	• Passive (ie, mechanical) agents
	  ○ Collagen-based products
	  ○ Cellulose
	  ○ Gelatin
	  ○ Polysaccharide spheres
	• Active agents
	  ○ Thrombin products
	• Flowables
	• Sealants
	  ○ Fibrin sealants
	  ○ Polyethylene glycol (PEG) polymers
	  ○ Albumin and glutaraldehyde
	  ○ Cyanoacrylate

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Mechanical Methods

A surgeon can use direct pressure; fabric pads, gauzes, or sponges; sutures; staples; or clips to mechanically control bleeding.[13]

- Direct pressure. The use of direct pressure or compression with one or more fingers at a bleeding site is typically a surgeon's first choice to attempt to control bleeding, as this may be the simplest and fastest method.[3] Arterial bleeding is more easily controlled with direct pressure than venous bleeding.[1] Venous bleeding may not always be controlled with direct pressure, and in some cases, direct pressure can increase a vascular injury and bleeding. In general, maintaining pressure for 15 to 20 seconds will cause small clots to form at the end of blood vessels.[13] If a major artery or vein has been injured, however, direct pressure should only be used until the proximal and distal ends of the vessel have been controlled or ligated.[1]
- Fabric pads/gauzes/sponges. These materials may also be used in applying direct pressure and packing a body cavity. Sponge sticks are often used to apply pressure in deep body cavity recesses; care should be taken when removing the sponge stick to avoid dislodging fresh clots.[13] Packing an area of venous bleeding can help to reduce blood loss when direct pressure control is not an option or when there is generalized bleeding from systemic coagulopathy that has occurred as a result of infection, trauma, massive blood loss, or platelet dysfunction.[1] When sponges are used to pack a cavity the team member who places them should communicate the number of sponges that have been packed to ensure all items used are retrieved before wound closure and to prevent a retained surgical item. Removal of packing should also be reported.[1,3,13] Compression or other mechanical methods may not always be

appropriate;[3] in cases of extreme bleeding, pressure may only be a temporary measure and the use of sutures, staples, or ligating clips may be needed to achieve adequate hemostasis.[13]

- Sutures/staples/ligating clips. These mechanical methods are useful if the source of bleeding is easily identifiable and able to be sealed.[3]
    - Sutures.[14] Sutures and ties are used during operative procedures as ligatures to tie off blood vessels and control bleeding. The three primary characteristics of suture material are physical configuration (eg, single- or multi-strand; diameter, tensile strength, elasticity; memory), handling (eg, pliability, tissue drag, knot tying capability, slippage qualities), and the tissue reaction it causes (eg, inflammatory reactions, absorption effects, potentiation of infection, allergic reactions). Because allergic reactions to suture material have been reported, the perioperative team should assess if the patient is allergic to certain suture materials. Considerations when using suture include the type of tissue it will be used on, its tensile strength and whether it is as strong as the tissue it must approximate, and whether it will last (ie, not resorb) until the tissue is healed. The smallest diameter suture possible should be used to minimize tissue reaction and injury.[14]
    - Staples.[1,13] Sterile, disposable stapling devices place staggered rows of titanium staples and then divide the tissue located between the rows of staples. These devices may be used in both open and minimally invasive procedures and are a safe and efficient method to achieve hemostasis when dividing tissue. The manufacturer's instructions should be followed for the proper use of any stapling device.[1,13]
    - Ligating clips.[1,13] Ligating, or hemostatic, clips are used to ligate blood vessels. Because they are quick and easy to apply, they achieve hemostasis efficiently and also reduce the risk of foreign body reaction that may occur with suture material. Ligating clips are available in various sizes and must be used with the corresponding size applier. Before the application of clips, the surgeon must determine the appropriateness of using clips. The scrub person should check the clip appliers to ensure that they are functioning properly. The jaws should be symmetrical and they should hold the clip securely and close without overlapping. Before application, the surgeon or assistant should blot the bleeding site with a sponge and apply direct pressure if necessary to make the site more visible.[1,13]

Thermal/Energy-Based Methods

Over the last several decades, thermal means to achieve hemostasis (eg, heat generated from electrosurgery, ultrasonic devices, lasers) have become feasible options to control surgical bleeding.[1] When any energy-based tool is used for hemostasis, all members of the perioperative team should understand the underlying principles of the modality and use safety precautions during its use.

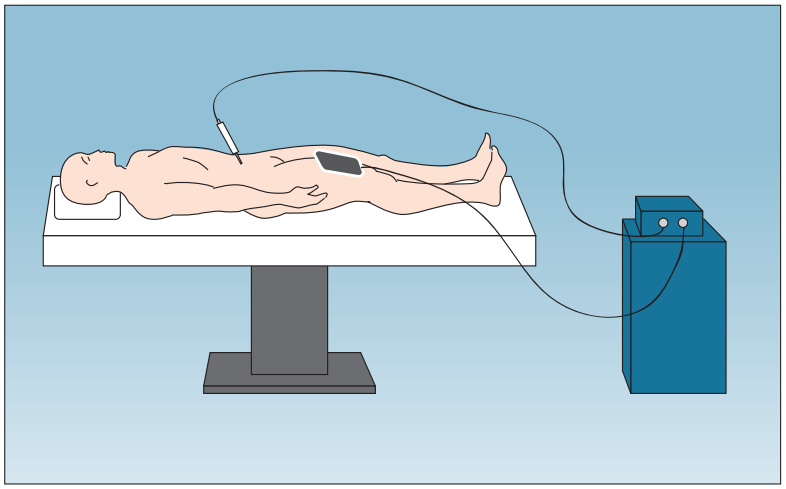
- Electrosurgery. Electrosurgery, developed in the 1930s, is the use of high-frequency (eg, radio frequency) alternating current for cutting, coagulating, and vaporizing tissues in both open and laparoscopic procedures.[13,15] Electrosurgical energy is delivered in two modes: monopolar and bipolar; a complete electrical circuit is necessary for current to flow when using either of these modes, however, the circuits are different.[16] Electrosurgical units are considered high-risk equipment.[17]

  The potential risks of electrosurgery use include patient injuries, user injuries, fires, and electromagnetic interference with other medical equipment and internal electronic devices. Electrosurgery safety is heightened by adhering to good practices, and adverse events (eg, patient burns and fires) associated with electrosurgery use may be reduced by adhering to basic principles of electrosurgery safety. Perioperative personnel should follow the manufacturer's instructions for the specific electrosurgery system being used and follow current AORN "Recommended practices for electrosurgery"[17] to promote patient safety.
    - Monopolar electrosurgery. Monopolar electrosurgery is the most frequently used electrosurgical method of hemostasis.[13] In a monopolar circuit, electrical current flows from the generator through an active electrode to the patient (Figure 3).[16] If the electrical energy concentrates in a small area and the tissue provides increased resistance, controlled heat is produced, which results in either cutting or coagulation of the tissue. When an electrosurgery unit is activated, electrical energy passes from the unit through the pencil to the patient and then to the dispersive elec-

trode placed on the patient's body. The energy then returns to the generator to complete the circuit. Because electricity will follow the path of least resistance when returning to the generator, if a dispersive electrode is tented or only a small portion of it is in contact with the patient's body, electrical energy can concentrate at that site and result in a burn. The surface area of the dispersive electrode also should be large enough to prevent the energy from becoming concentrated enough at that area to generate significant heat.[16]

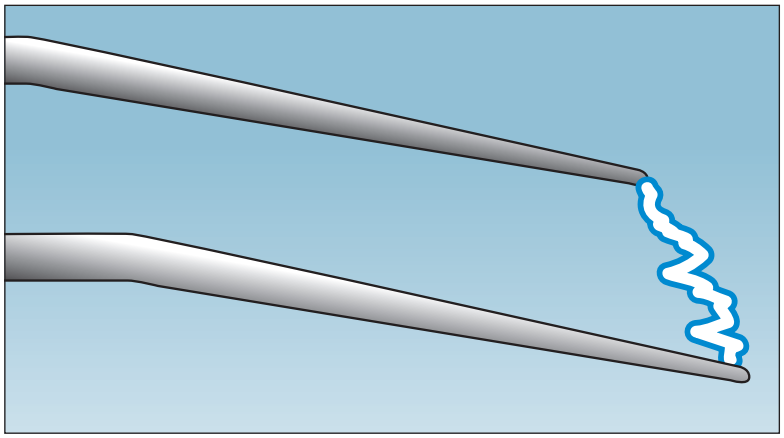
Monopolar electrosurgery delivers current using different types of waveforms or modes. The coagulation mode produces an interrupted waveform that creates heat, thereby coagulating a cell, also referred to as fulguration. The cutting mode is a continuous current at lower energy, which produces a cutting effect to vaporize tissue with little or no hemostasis. The blend mode simultaneously cuts tissue and coagulates bleeding.[1,16]

Figure 3 – Monopolar Electrosurgery Circuit



- Bipolar electrosurgery. In a bipolar electrosurgery circuit, current does not flow through the patient to complete the circuit. The circuit is completed between the two tines (or prongs or blades) of the bipolar forceps. The distance between the active and ground electrode is very small and current flows only between the two tines (Figure 4); therefore, a dispersive electrode is not needed.[16] As with monopolar electrosurgery, heat is generated in the tissue as the current flows from one bipolar tip through the tissue and back to the other tip; therefore, the electrode tips need to be near each other and the tissue should be in contact with the electrodes.[16]

Figure 4 – Bipolar Electrosurgery Circuit

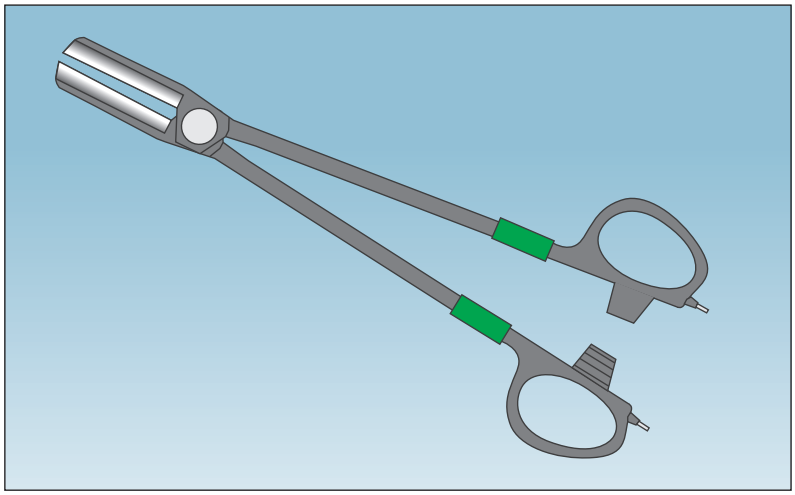


Bipolar electrosurgery works well for procedures in which the surgeon needs to limit thermal spread (eg, delicate tissue and/or on small anatomical structures).[13] Bipolar electrosurgery uses lower voltage to deliver the current, making it a safer option when the potential for electromag-

netic interference with implanted medical devices (eg, pacemakers, internal cardioverter-defibrillators) exists.[16]

- Bipolar electrosurgery **vessel sealing technology** is an advanced electrosurgical modality in which the intimal layers of a vessel are fused and a permanent seal is formed.[13] This device (Figure 5) applies heat over time with high compression. Other energy-based hemostatic methods shrink the vessel walls and rely on the formation of a thrombus to occlude the vessel; with bipolar sealing technology, the lumen of the vessel is obliterated. These systems are capable of simultaneously sealing and transecting vessels up to 7 mm in diameter, large tissue pedicles, and vascular bundles by using a combination of pressure and energy.[13]

Figure 5 – Bipolar Vessel Sealing Device



- Argon-enhanced coagulation technology.[13] Argon-enhanced electrosurgery uses a stream of inert, noncombustible argon gas to conduct the electrosurgical current. Argon gas is heavier than air and displaces nitrogen and oxygen; the electrosurgical current ionizes the argon gas, which makes it more conductive than air and creates a bridge between the electrode and the tissue.[13]

- Ultrasonic devices.[1,13] An ultrasonic device converts electrical energy into mechanical energy that oscillates longitudinally at the point of contact; vibrating at 55,500 times per second, it simultaneously cuts and coagulates and can seal vessels up to 5 mm in diameter and offers an alternative to electrosurgery for some surgical procedures. Because this device generates lower temperatures and there is no dispersed current, it cuts or coagulates only the tissue with which it is in contact and this limits thermal damage to surrounding tissues. A dispersive electrode should not be used because no electrical current enters the tissue and, therefore, does not need to be returned to a generator through a dispersive electrode.[1,13]

  Ultrasonic devices should be used in a manner that minimizes the potential for injuries to patients and staff members.[17] Inhalation of aerosols generated by an ultrasonic electrosurgical device should be minimized by the use of smoke evacuation systems and wall suction with an in-line, ultra-low penetration air filter.

- **Lasers**. Lasers are a common heat-generating device used by surgeons to provide hemostasis.[13] Laser is an acronym that stands for light amplification by stimulated emission of radiation, and describes the process in which laser light energy is produced.[16] Laser light differs from ordinary light in that it is monochromatic (ie, composed of photons of the same wavelength or color); it is collimated (ie, it consists of waves parallel to each other that do not diverge significantly) which minimizes loss of power and allows light to be focused into a tiny spot of highly concentrated energy; and it is coherent (ie, all light waves are orderly, in phase with each other, and travel in the same direction).[16] Laser energy delivered to a targeted site can be reflected, scattered, transmitted, or absorbed. The extent of the tissue reaction depends on the "laser wavelength, power settings, spot size, length of contact time with the

targeted tissue, and tissue characteristics."[16(p228)]

- Laser safety. Medical laser systems (eg, class 3 and class 4 lasers) are classified by how hazardous they are and the controls required. The dangers of using a class 3 laser are related to direct exposure or exposure to mirror-like light reflection, also known as specular reflection. Eye and skin exposure to class 4 lasers may be hazardous, and these lasers may present a potential fire risk. Perioperative personnel should establish a formal laser safety program and follow the current AORN's "Recommended practices for laser safety in perioperative practice"[18] settings to promote patient safety during laser use.

Chemical Methods/Topical Hemostatic Products

"Depending on the procedure and location of the bleeding tissue, it may be impractical or impossible to effectively control bleeding with mechanical or thermal hemostatic techniques. For example, in bony surfaces, parenchymal tissues, inflamed or friable vessels, or tissues with multiple and diffuse capillaries, it is extremely difficult to maintain hemostasis with these methods." [3(pS5)] In these cases, using pharmacological methods to obtain hemostasis or an adjunct to other hemostatic methods may be helpful.

Chemical methods available today (eg, pharmacological agents, various topical hemostatic agents) enhance the natural coagulative mechanisms. It is important to note that the surgeon or licensed independent practitioner selects the hemostatic agent to be used and all of the agents and products discussed here require a physician's order.

- Pharmacological agents
  - Pharmacological agents are used primarily to improve clot formation through several mechanisms including increasing platelet function and reversing anticoagulation.[19] These agents used during surgery to control bleeding by enhancing the natural mechanisms of coagulation may include use of the following agents:[3]
    - Epinephrine.[1] This hormone causes direct vasoconstriction and acts on the heart by increasing the heart rate. This vasoconstrictive property makes epinephrine useful during surgery, because it can be applied topically or injected in combination with a local anesthetic agent. When combined with a local anesthetic, epinephrine reduces bleeding, slows the absorption of the local anesthetic, and prolongs the analgesic effect.
    - Vitamin K. Vitamin K plays a role in the coagulation process and may be administered preoperatively to reverse the effects of warfarin and to potentially avoid the need for transfusion of fresh frozen plasma.[20] The lowest possible dose should be used and vitamin K should be given orally because this route provides the most predictable response. Intravenous (IV) vitamin K should be administered slowly (ie, over 30 minutes) to prevent the possibility of anaphylactic reactions, and it should not be given subcutaneously or intramuscularly because of erratic absorption.[21] Reversal of elevated international normalized ratios with Vitamin K takes approximately 24 hours for maximum effect, regardless of the route of administration.[21]
    - Protamine.[19,22] Protamine is the only current agent that is able to reverse heparin anticoagulation.[19] "One milligram of IV protamine will neutralize 100 units of heparin administered in the previous four hours."[22] However, protamine does not reverse low-molecular-weight heparin. "Protamine is associated with adverse events, including anaphylaxis, acute pulmonary vasoconstriction, and right ventricular failure."[19(pS18)] Patients at risk for protamine reactions include diabetic patients, patients who have undergone a vasectomy, or those who have multiple drug allergies or have had previous protamine exposure.[19]
    - Desmopressin.[19,23] Desmopressin is a synthetic analogue of arginine vasopressin. It stimulates the release of von Willebrand factor (vWF) from endothelial cells, which leads to an increase in plasma levels of vWF and enhances primary hemostasis. "Desmopressin should be administered by slow IV infusion at a dose of 0.3 μg/kg to prevent hypotension."[19(pS18)] While it assists in reducing perioperative bleeding, the effect of desmopressin is too small to influence other, more clinically relevant outcomes, such as the need for blood transfusion and repeat procedures.[19]
    - Lysine analogues (ie, aminocaproic acid, tranexamic acid).[19] "Synthetic lysine analogues

are antifibrinolytic agents that competitively inhibit activation of plasminogen, thereby reducing the conversion of plasminogen to plasmin, the enzyme that degrades a fibrin clot."[19(pS17)] These agents have variable effects in reduction of bleeding; in addition, published safety data on these agents is limited.

Lysine analogues also may also be used for cardiac surgery patients.[23] A loading dose of 1 to 15 grams of aminocaproic acid, for example, is administered at induction of anesthesia, followed by a maintenance dose of 1 to 2 grams per hour as a continuous infusion during surgery, with a total dose of 10 to 30 grams. Tranexamic acid is administered as a loading dose of 2 to 7 grams at induction of anesthesia, followed by a maintenance dose of 20 to 250 milligrams per hour as a continuous infusion during the procedure, with a total dose of 3 to 10 grams.[19,23]

- Topical Hemostatic Products
  Today, there is a wide range of topical hemostatic products available for use in the OR. To understand their mechanisms of action and use them appropriately and safely, the reader must understand the processes of passive and active hemostasis.
    - Passive versus active hemostasis.[3,5] Topical hemostatic agents currently available for use in surgery can be divided into two primary categories: passive and active. These classifications refer to the mechanism of action provided by the agent during surgery. Passive, or mechanical, agents act passively through contact with bleeding sites and promotion of platelet aggregation; active agents act biologically on the clotting cascade. Passive topical hemostatic products include collagens, cellulose, gelatins, and polysaccharide spheres. Active agents include thrombin and those products in which thrombin is combined with a passive agent to provide an active overall product. Two other categories are flowable agents and sealants, which include fibrin sealants, polyethylene glycol (PEG) polymers, albumin and glutaraldehyde, and cyanoacrylate.[3,5]
- Passive hemostasis. Passive or mechanical topical hemostatic agents conserve blood by accelerating the coagulation cascade and reducing blood loss. The central mechanism of passive hemostatic agents is to form a physical, lattice-like matrix that adheres to the bleeding site; this matrix activates the extrinsic clotting pathway and provides a platform around which platelets can aggregate to form a clot. Because passive hemostats rely on fibrin production to achieve hemostasis, they are only appropriate for use in patients who have an intact coagulation cascade. For example, a hemorrhaging patient with a significant coagulopathy would not be an appropriate candidate.[3,5]

  Passive hemostatic agents used during surgery are available in many forms and methods of application (eg, bovine collagen, cellulose, porcine gelatins, polysaccharide spheres) that integrate an absorbable sponge, foam, pad, or other material with a topical hemostatic agent, which is then applied to the bleeding site. Passive hemostats are generally used as first-line agents because they are immediately available, require no special storage or preparation, and are relatively inexpensive.

  These agents can absorb several times their own weight in fluid. For example, oxidized cellulose can absorb seven times its own weight in normal saline, whereas cotton-type collagen can absorb 32 times its own weight. However, this expansion can result in complications, such as pressing nerves in the surrounding tissue against bone or hard tissue. For example, Broadbelt et al [24] reported three cases of patients with paraplegia following thoracic surgery where oxidized cellulose was used for hemorrhage control and which was later found to have passed through the intervertebral foramen causing spinal cord compression. Therefore, when a passive topical hemostatic agent is used on or near bony or neural spaces, it is recommended that the surgeon use the minimum amount of the agent required to achieve hemostasis and remove as much of the agent as possible once hemostasis has been achieved.[1,24] Passive topical hemostatic agents do not adhere strongly to wet tissue and thus have little effect on actively bleeding wounds; however, they can be effective in the presence of heavier bleeding because of their larger absorption capacity and the greater mass provided by their more fibrous/dense structures.[24]
- Active hemostasis. Active hemostatic agents such as topical thrombins (eg, bovine, pooled human plasma, recombinant), have biological activity and directly participate at the end of the coagulation cascade to stimulate fibrinogen at the bleeding site to produce a fibrin clot.[3,5] Because thrombin acts at the end

of the clotting cascade, its action is less affected by coagulopathies from clotting factor deficiencies or platelet malfunction, and thrombin is a logical and useful choice for patients who are receiving antiplatelet and/or anticoagulation medications. Because thrombin relies on the presence of fibrinogen in the patient's blood, however, it is ineffective in patients who have afibrinogenemia. In addition, thrombin itself does not need to be removed from the site of bleeding before wound closure. Degeneration and reabsorption of the resulting fibrin clot occur during the normal wound healing process.[3,5]

Active topical hemostatic agents typically provide hemostasis within 10 minutes in most patients. In addition, they control local bleeding more effectively than passive hemostats, although they are usually more costly. Active hemostatic agents are available in various forms and can be applied using pump or spray kits when large wound areas need to be evenly covered. The surgeon can also apply them directly to the bleeding site using a saturated, kneaded, absorbable gelatin sponge. In many cases, the surgeon may choose to combine an active agent with a passive agent to improve overall hemostasis.[3,5]

- General considerations for the use of topical hemostatic agents.[1,13] Topical hemostatic agents are used as an adjunct method to control bleeding when standard methods are ineffective or impractical; that is, if the use of direct pressure, suture, or electrosurgery can safely achieve and maintain hemostasis, then one of these techniques should be the first choice for control of bleeding. Before using a chemical hemostatic agent, the surgeon or first assistant should:
  - determine the appropriateness of using a chemical agent in the area requiring hemostasis,
  - evaluate the wound classification because use of most topical hemostatic agents is contraindicated in contaminated wounds,
  - understand that chemical agents are not intended to act to tamponade or plug a bleeding site, and
  - assess the patient for allergies to the agent being considered for use or to the product's constituents.[13]

When a topical hemostatic agent is selected to help manage surgical bleeding, team members should follow AORN's "Recommended practices for medication safety" for safe management on the sterile field.[1,25] The manufacturer's instructions for use (ie, the package insert regarding approved indications for use; level of bleeding; contraindications; specific storage, preparation, and application instructions; safety considerations) should always be followed. Before providing any topical hemostatic agent to the sterile field, the perioperative RN should check its expiration date, inspect the product for sterility compromise, and transfer it to the sterile field using aseptic technique. The scrub person should label the syringe or container, if applicable, and the surgeon or first assistant should verbally confirm and acknowledge the scrub person's announcement of the topical agent provided for use.[25]

Each category of passive and active topical hemostatic products is described in greater detail below.

Passive Hemostatic Agents

The products in the passive or mechanical category of hemostatic agents act by forming a barrier to stop the flow of blood and by providing a surface that allows blood to more rapidly clot.[26] This category includes collagen-based products, oxidized regenerated cellulose, gelatin-based products, and polysaccharide hemospheres; each of these product categories is described below.

- *Collagen-based products*. Collagen-based products are activated on contact with bleeding and provide a scaffold to which platelets can adhere. This stimulates the body's normal coagulation mechanism. These products provide a stable matrix for clot formation, but also enhance platelet aggregation, degranulation, and release of clotting factors, which further promotes clot formation.[27] Hemostatic collagen products are derived from either bovine tendon or bovine dermal collagen and may be further divided into microfibrillar and absorbable collagen products.
  - *Microfibrillar collagen hemostat* (eg, *Avitene*™ and *Avitene*™ *Ultrafoam*™, [http://www.davol.com/products/srugical-specialties/hemostasis/avitene-ultrafoam-collagen-sponge/][28], Instat®MCH[29] [http://www.ethicon360.com/products/instat-mch-microfibrillar-collagen-hemostat])[1,5,13]

    This type of product is derived from purified bovine dermal collagen; it is a fibrous, water-insoluble partial hydrochloric salt. Microfibrillar collagen hemostats are available in a loose fibrous

form and also as sheets or sponges. These products are stored at room temperature, are immediately available for use, and should not be resterilized. When a microfibrillar collagen hemostat comes in contact with a bleeding site, the platelets are attracted to it, adhere to the fibrils, and then aggregate, thus initiating the clotting cascade.[13]

Microfibrillar collagen hemostats are effective agents when there is capillary, venous, or small arterial bleeding.[5] Collagen inherently adheres to tissue, and when used as a hemostatic agent it should be applied directly to the source of bleeding. Because moisture activates microfibrillar collagen products, they should be used dry (ie, not combined with saline or thrombin) and applied with dry, smooth forceps to the bleeding site. Sheets work best on flat surfaces or when wrapping vessels and anastomosis sites is needed; sponges should only be used in ophthalmic or urologic procedures.[5] The presence of a firm, adherent coagulum with no breakthrough bleeding from the surface or edges indicates that the collagen has been successfully applied. The surgeon or first assistant should remove any excess product from the application site and irrigate before the wound is closed. Microfibrillar collagen hemostat is a foreign substance, therefore, its presence may potentiate wound infections and abscess formation.[13]

Microfibrillar collagen hemostats should not be used:

- in patients with known allergies or sensitivities to materials of bovine origin;
- when a blood scavenging system is used because fragments can pass through the system's filters. Scrubbed team members should notify the RN circulator to discontinue the use of blood scavenging equipment after microfibrillar collagen hemostat is used;
- for skin closure, as it may interfere with healing of the skin edges;
- on bony surfaces because it interferes with methyl methacrylate adhesives by filling porosities of cancellous bone; or
- in any area where it may exert pressure on adjacent structures because of fluid absorption and expansion.[1,5,13]

These products potential adverse effects include: allergic reaction, adhesion formation, inflammation, foreign-body reaction, and potentiation of wound infections and abscess formation.[1,5,13]

◦ *Absorbable collagen hemostat sponge* (eg, *Helistat*® [http://www.integralife.com/products/pdfs/helitene-helistat-sellsheet%20final[1]_674.pdf])[1,13,30]

These agents consist of collagen derived from purified and **lyophilized** (ie, freeze dried) bovine flexor tendon and is available as a lightly cross-linked sponge-like pad or felt. These products are supplied sterile and should not be resterilized. When the product comes in contact with blood, it activates the coagulation mechanism causing platelet aggregation and accelerating the formation of a clot within two to four minutes.[13]

Like microfibrillar collagen, moisture activates absorbable collagen hemostatic products; therefore, the surgeon should cut them to the appropriate size and apply them dry to the bleeding surface using dry gloves or instruments and only use the amount needed. Excess product should be removed before wound closure. Because absorbable collagen hemostatic sponges do not disperse like microfibrillar collagen does, these products are easier to handle and place. The product should be packed loosely in closed spaces or cavities because it swells as it absorbs fluid. The body absorbs collagen sponge in eight to 10 weeks.[1,13]

Absorbable collagen hemostats should not be used:

- in patients with known allergy or sensitivity to materials of bovine origin;
- in areas that are infected or contaminated;
- for skin incision closure, because they will create a mechanical barrier to healing;
- in areas where blood or other body fluids have pooled;
- on bony surfaces where methyl methacrylate adhesives will be needed, as it may substantially decrease the bonding strength of the methyl methacrylate; or
- in urological, neurological, or ophthalmological procedures because the product absorbs fluid and may expand and exert pressure on adjacent structures.[1,13,30]

Potential adverse reactions include allergic reaction, adhesion formation, foreign body reaction, and hematoma. [1,13,30]

- *Oxidized regenerated cellulose* (eg, *Surgicel®; Surgicel Nu-Knit® [low-density]* [http://www.ethicon360.com/products/surgical-family-absorbable-hemostats])[1,5,13,31]

  Oxidized regenerated cellulose (ORC) products are available in an absorbable white, knitted, fabric (single or multiple sheets) that is either high- or low-density. It does not fray when sutured or cut and its performance is not affected by age; however, aging may result in discoloration. It is stored at room temperature and is immediately available for use. Autoclaving causes physical breakdown of the product; therefore, it should not be resterilized.[1,5,13,31]

  An ORC product can absorb seven to 10 times its own weight; however, the rate at which the body absorbs it depends on the amount used, the extent of blood saturation, and the tissue bed. As ORC reacts with the blood, it increases in size and forms a gelatinous mass, which aids in the formation of a clot. Adding thrombin for additional hemostasis does not affect the action of oxidized cellulose; however, the activity of thrombin is destroyed by the low pH of oxidized cellulose.[13] The hemostatic effect of ORC also is reduced if it is moistened with saline, water, other hemostatic agents, or anti-infective agents; therefore these products should be used dry and not in combination with saline or thrombin.[1,5,13,31]

  These products are used to control capillary, venous, and small arterial bleeding. The surgeon can cut the product into sheets, smaller pieces, or strips for placement and smaller pieces can be easily manipulated into place. Excess product should be removed with irrigation before closure, but small amounts may be left in place. If used around the optic nerve or spinal cord, the surgeon must remove excess product because of the potential harm that can be caused from the product swelling and placing pressure on nerves.[1,5,13,31]

  Similar to other hemostatic agents discussed, ORC products should not be used
    - in closed spaces because of swelling;
    - on bony defects (eg, fractures), as it may interfere with bone regeneration unless it is removed after hemostasis is achieved;
    - for control of hemorrhage from large arteries;
    - on surfaces oozing serous nonhemorrhagic fluid, because body fluids other than whole blood (eg, serum) do not react well with the product to achieve hemostasis; or
    - for adhesion prevention.[1,5,13,31]

  The potential adverse reactions include
    - encapsulation of fluid and foreign body reaction, if the product is left in the wound;
    - stenosis of vascular structures if ORC is used to wrap a vessel tightly;
    - burning or stinging sensations, headaches, and sneezing when used as a packing for epistaxis because of its low pH; and
    - burning or stinging when used after nasal polypectomy or hemorrhoidectomy, or when applied to open wound surfaces (eg, donor sites, venous stasis ulcerations, dermabrasions).[11,5,13,31]

- *Gelatins* (eg, *Gelfoam®, Gelfoam® Plus [Gelfoam® sponges combined with thrombin], Surgifoam®*[1,5,13,32] [http://www.baxter.com/healthcare_professionals/products/Gelfoam.html])

  "Absorbable porcine gelatin hemostatic agents are prepared from a purified gelatin solution that has been whipped into foam, dried, and then sterilized."[1(p189)] This type of product is available as a sponge or powder and is stored at room temperature as a single-use product that is immediately available. The product should not be resterilized. It is pliable and can absorb several times its weight. It assists with hemostasis by providing a matrix for clot formation, by creating a mechanical barrier to bleeding, and is generally used in cases of minimal bleeding. Clotting is initiated by contact with bleeding. When the surgeon places it on areas of capillary bleeding, the product absorbs fibrin into its interstices and then swells. The swollen gelatin particles restrict blood flow and provide a stable matrix for clot formation.[1,5,13,32]

  A surgeon can apply a gelatin sponge dry or can moisten it with sterile saline before application. Frequently surgeons add thrombin or epinephrine to the saline they soak the gelatin foam in to augment its hemostatic effect. Gelatin conforms easily to wounds making it suitable for use in

irregular wounds. It liquefies within two to five days after application and is absorbed completely in four to six weeks. Absorbable gelatin sponges do not need to be removed before wound closure, however, surgeons often remove them when possible to prevent compression of adjacent structures from the gelatin's swelling.[1,5,11,13,32]

Absorbable gelatin hemostatic products should not be used

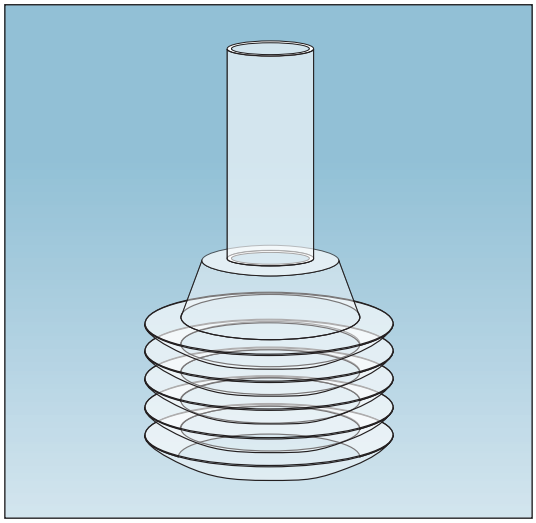
- for patients with known allergies or sensitivities to porcine products;
- for skin incision closure;
- in intravascular compartments because of embolization risk;
- in the presence of infection or areas of gross contamination because bacteria can become enmeshed in the sponge, leading to the formation of an abscess; or
- around nerves because of the risk of swelling and nerve compression.[1,5,13,32]

Potential adverse reactions to absorbable gelatin hemostatic products include abscess formation, foreign body reactions, encapsulation of fluid, hematoma, and localized infection.[1,5,13,32]

- ***Polysaccharide Hemospheres*** *(eg, Arista®AH*[33] [http://medafor.com/products-and-technology/arista-ah]; *Hemostase MPH®*[34] [http://www.planned.hu/userfiles/file/Hemostase%20%20Bio-Glue%20Perfect%20Partnership%20Brochure%20-%20Europa%20-%20ML0278_000.pdf]; *Vitasure™*[35] [http://www.orthovita.com/vitasure/pdf/applicatorIFU.pdf])[1,5]

This is a relatively new type of topical hemostatic agent derived from vegetable starch and contains no human or animal components. It is available in powder form with a bellows applicator (Figure 6).

Figure 6 – Bellows applicator



It has a flexible storage temperature (- 40.6° C [- 41° F] to 60° C [140° F]) and is immediately available for use, as it requires no additional components or mixing. The product should not be resterilized.[1,5,33-35]

Polysaccharide hemospheres are used to control capillary, venous, and small arterial bleeding by producing a hydrophilic effect, dehydrating the blood, and concentrating its solid components thereby increasing barrier formation. Because the hemospheres are composed of sugars, the amount used should not exceed 50 g in patients with diabetes. Excess product should be removed with irrigation.[1,5,33-35]

This type of product should not be used in closed spaces (eg, neurologic, urologic, ophthalmic areas) because of swelling. This type of agent presents little risk to the patient because it contains no human or animal components; however, pressure from swelling may be exerted on adjacent structures.[1,5,33-35]

The efficacy of passive hemostats varies among products.[5] Research found that microfibrillar

collagen was the most effective of the passive topical hemostatic agents, followed by collagen sponge, gelatin sponge, and then oxidized regenerated cellulose.[10,36] Polysaccharide hemospheres have also demonstrated efficacy. In a recent preliminary study of 10 patients undergoing cerebral procedures, the direct application of absorbable hemospheres helped to effectively manage superficial cerebral bleeding, reducing the use of bipolar coagulation and shortening surgical time.[37] However, researchers have not been able to conduct surgeon-blinded trials; therefore, studies comparing the efficacies of the various topical hemostatic agents in situ are open to bias and should be evaluated with caution.[3]

Active Hemostatic Agents

Active hemostatic agents are those that contain thrombin. Thrombin is a naturally derived enzyme that plays a role in hemostasis, inflammation, and cell signaling.[38] Thrombin is formed from prothrombin as a result of activation of the intrinsic and extrinsic coagulation pathways; it forms the basis of a fibrin clot by promoting the conversion of fibrinogen to fibrin.

In the late 1970s, the US Food and Drug Administration (FDA) approved topical bovine thrombin as an aid to hemostasis in surgery.[3] Since then, thrombin has demonstrated a long history of clinical efficacy and safety in various surgical procedures.[3,39] Thrombin has been purified from numerous sources and used as a clinical aid for topical hemostasis for more than 60 years.[38] Although thrombin has been effective in the control of bleeding, bovine-derived thrombin has been shown to induce an immune response following human exposure; numerous reports have documented a number of clinical events that follow bovine thrombin exposure, including the development of antibodies against thrombin, prothrombin, factor V, and cardiolipin.[40,41] These concerns led to the development of human plasma derived thrombin and recombinant human thrombin.

Current data indicate that topical recombinant human thrombin is as effective as bovine thrombin for hemostasis and causes significantly less immunogenic responses.[42] In one study, researchers randomly assigned 401 patients to receive either recombinant or bovine thrombin as adjuncts to hemostasis during liver resection or spine, peripheral arterial bypass, or dialysis access surgery.[43] They report the time frame for thrombin hemostasis is within 10 minutes. The development of antibodies to recombinant human thrombin or to the bovine product was also evaluated. The results demonstrated that hemostasis was achieved at the evaluation site within 10 minutes in 95% of patients in each treatment group. Overall complications, including mortality, adverse events, and laboratory abnormalities, were similar between groups. Forty-three patients (21.5%) receiving bovine thrombin developed antibodies to the product. Only three patients (1.5%) in the recombinant human thrombin group developed antibodies to the product; none of the three patients had abnormal coagulation laboratory results or bleeding, thromboembolic, or hypersensitivity events. The results of this trial suggest that recombinant human thrombin has comparable efficacy, a similar safety profile, and is considerably less immunogenic than bovine thrombin when used for surgical hemostasis.[43]

- *Clinical Considerations*[1,3,5,13]

  Thrombin requires no intermediate physiological agent for its actions, but it does require the presence of circulating fibrinogen to actively convert fibrinogen to fibrin at the bleeding site to produce a clot.[3,5] Topical thrombin products are indicated for broad surgical use to help control minor bleeding from accessible capillaries and small venules. As previously discussed, thrombin is commonly used in combination with certain passive topical hemostatic agents (eg, a gelatin sponge) to increase both the usefulness and effectiveness of the final product. In neurosurgical procedures, thrombin is applied to small cottonoid sponges that are placed on the brain and/or nerve structures for their protection.[3,5]

  The surgeon must assess the use of thrombin to provide hemostasis. Depending on the product used any patient allergy or sensitivity to bovine materials or human blood product allergies must be verified. Before applying thrombin, the surgeon should remove any excess blood from the operative site by suctioning or sponging the area. He or she can then use a spray or flood the surface with a syringe containing the hemostatic agent. If absorbable gelatin sponges soaked in thrombin are used, it is important for the surgeon to squeeze the sponge gently to remove any trapped air and completely saturate the sponge with thrombin to promote more effective hemostasis. When using thrombin in conjunction with an absorbable gelatin sponge, periop-

erative personnel should ensure that the concentration of the thrombin product is appropriate and that the sponge is held in place for 10 to 15 seconds with a gauze sponge. After an area has been treated, scrubbed team members should not sponge it to avoid removing or dislodging the clots.[1,3,5,13]

Thrombin should never be injected into the bloodstream or allowed to enter the bloodstream through large, open blood vessels, because it can cause extensive intravascular clotting, which can be fatal. Repeated surgical applications of thrombin increase the likelihood that the patient may form antibodies against thrombin and/or factor V, which interfere with hemostasis. In addition, the use of topical thrombin has occasionally been associated with clotting abnormalities ranging from asymptomatic alterations in prothrombin times and partial thromboplastin times, to mild or severe bleeding or thrombosis, which have rarely been fatal.[1,3,5,13]

Active topical hemostatic agents have a rapid onset of action (eg, within 10 minutes) in most patients. Topical thrombin products are derived from either bovine or human plasma, or they are manufactured using recombinant DNA techniques (ie, recombinant thrombin). Thrombin may be used topically as a dry powder, as a solution for use with gelatin sponges, mixed with a gelatin matrix, or as a spray. The best form of thrombin to use is typically determined by personal surgeon preference, cost considerations, and availability. The three types of topical thrombin products are discussed in greater detail below.[1,3,5,13]

- *Thrombin Products*[1,26]

There are three forms of thrombin products; each of which function by providing concentrated thrombin that rapidly converts fibrinogen into a fibrin clot, with the rate of clot formation being proportional to the thrombin concentration. These products are differentiated based on the type of plasma used to create them (eg, bovine, human, recombinant). No thrombin product should ever be injected intravascularly.

- *Bovine thrombin* (eg, Thrombin-JMI®[44] [http://www.pfizerinjectables.co/factsheets/Thrombin-JMI_all%20SJUs.pdf]) is available as a powder in vial form that can be used dry or reconstituted with sterile saline. It should be used within three hours of reconstitution, and it is applied using a pump or spray kit, or in a saturated, kneaded, absorbable gelatin sponge. The product should be stored at room temperature.[44]

  Bovine thrombin is available in several concentrations:
  - 5,000 IU per vial with 5mL diluent;
  - 20,000 IU per vial with 20 mL diluents;
  - 20,000 IU per vial with 20 mL diluent, spray pump, and actuator; and
  - 20,000 IU per vial with 20 mL diluent, spray tip, and syringe.

  The perioperative RN should verify with the scrub person and the surgeon that the correct concentration of the product has been prepared, and follow safe medication practices by verbally confirming the prepared concentration with the scrub assistant and the surgeon by reading the solution label.[25]

  When spraying bovine thrombin, the surgeon should flood the surface with the product. He or she should not suction or sponge the area dry because thrombin is most effective when it mixes with blood. When using thrombin-soaked sponges, the surgeon or assistant should use dry forceps to apply the appropriately-sized piece of sponge and hold it in place with a surgical sponge (eg, gauze sponge, cottonoid) for 10 to 15 seconds.[44]

  Antibody formation associated with the use of bovine thrombin can potentially result in coagulopathy and, in rare cases, death. This has resulted in a black box warning, the FDA's highest level of concern, being placed on the material's package insert. As a result, use of bovine thrombin is contraindicated in patients with allergies or known sensitivities to components or materials of bovine origin, because fever or allergic-type reactions may occur. Bovine thrombin product should not be used in patients who have developed coagulopathies from previous exposure to bovine thrombin.[44]

- *Pooled human plasma thrombin* (eg, Evithrom®[45] [http://www.ethicon360.com/products/Evithrom-thrombin-topical-human]) is available as a frozen liquid in vial form. It may be stored frozen (-18° C [-40° F]) for two years; refrigerated (2° C to 8° C [35.6° F to 46.4° F]) for 30 days; or stored at room temperature (20° C to 25° C [68° F to 77° F]) for 24 hours or stored at 37° C (98.6° F) for one hour. The product must be used within 24 hours of reconstitution. The product is delivered via a saturated, kneaded, absorbable gelatin sponge.[45]

  Pooled human plasma thrombin has a potential risk of viral or prion (eg, the agent responsible for Creutzfeldt-Jakob disease) disease transmission because multiple units of blood are used to manufacture of each lot of product. Pooled human plasma thrombin products are contraindicated in patients with human blood product allergies, and they should not be used in combination with blood salvage or cardiopulmonary bypass systems.[45]

- *Recombinant thrombin* (eg, *Recothrom*®[46] [http://www.reconthrom.com/about_recothrom/default.aspx). Genetically engineered recombinant products are relatively new hemostatic options on the US market. Recombinant thrombin is a lyophilized powder in vial form and can be stored at room temperature. The product is reconstituted with sterile saline and should be used within 24 hours of reconstitution. It is applied either by using a pump or spray kit, or it also comes as a saturated, kneaded, absorbable gelatin sponge.[46]

  The use of genetic engineering to produce the product reduces the risks of antibody formation and eliminates the risk of known viral or prion disease transmission. Recombinant thrombin use is contraindicated in patients with hypersensitivity to hamster and snake proteins and should not be used in combination with blood salvage or cardiopulmonary bypass systems.[46]

Flowable Hemostatic Agents[1,5,11,26]

The flowable hemostatic agents combine a passive and active hemostatic agent into a single application product. As a result, these products work by blocking blood flow and actively converting fibrinogen in blood into fibrin at the site of bleeding.[26] This category includes two types of products a combination of absorbable bovine gelatin particles and pooled human thrombin (FloSeal® hemostatic matrix [47] [http://www.floseal.com/us/preparation.html]) and a product that consists of absorbable porcine gelatin particles that may be combined with any of the three stand-alone thrombins described above (Surgiflo®[48] [http://www.ethicon360.com/products/Surgiflo-hemostatic-matrix]).[1,5,11,26]

When combined with a gelatin, human plasma thrombin is typically reconstituted as a liquid and can run off a bleeding surface. It has a solid or pasty consistency. For this reason, flowable hemostatic agents remain in place more effectively than does the liquid thrombin alone, and this allows the surgeon to more accurately administer it. In addition, both of these products only require two to three minutes of preparation time and are applied with a syringe-like applicator. As previously noted, perioperative RNs should refer to the package insert for product-specific instructions regarding proper preparation, application, and use.[1,5,11,26]

"Because these products contain thrombin without fibrinogen, they require direct contact with blood as a fibrinogen source for conversion into fibrin. Pressure may be rapidly placed directly onto the flowable at the bleeding site by the surgeon using a moist saline (nonbloody) gauze or pad for a period of 2 minutes."[26(p499)] The product does not stick to the nonbloody saline-soaked gauze or pad; therefore removal of the gauze or pad will not disrupt the clot. Because these products may swell, excess product should be removed, especially from confined spaces (eg, spinal cord, optic chiasm, foramina in bone).

Products composed of bovine gelatin are approved for use in all surgical specialties except ophthalmic surgery.[47] They can be used in irregular wounds or bleeding cavities.[5] This type of product should not be:

- used in patients with allergies or known sensitivities to materials of bovine origin;
- injected or compressed in to blood vessels or tissue;
- applied in the absence of active blood flow (eg, to clamped or bypassed vessels) because extensive intravascular clotting resulting in death may occur;
- used in combination with blood salvage or cardiopulmonary bypass systems; or

- used for closure of skin incisions because it may interfere with the healing of the skin edges.[5,11,26]

Products composed of porcine gelatin are approved for use in all surgical specialties except ophthalmic; its safety and efficacy for use in urology have not been established.[48] They can be used in irregular wounds or bleeding cavities.[5] Obviously, this type of product should not be used on patients with allergies or known sensitivities to materials of porcine origin.[5,11,26]

Adverse reactions to flowable hemostatic agents include anemia, arrhythmia, arterial thrombosis, atelectasis, atrial fibrillation, confusion, edema, fever, hemorrhage, hypotension, infection, pleural effusion, respiratory distress, and right heart failure.[5,11,26]

Clinical trials have demonstrated the efficacy of flowable hemostatic agents. Researchers conducted a multicenter, prospective, single-arm study to evaluate the clinical performance of Surgiflo® in achieving hemostasis within 10 minutes of application in patients undergoing endoscopic sinus surgery and to evaluate patient satisfaction and postoperative healing.[49] Researchers report that the product achieved hemostasis within 10 minutes of product application in 96.7% of patients.[49] The results of a multicenter trial of 93 cardiac surgery patients demonstrated that the efficacy of FloSeal® was superior to that of Gelfoam® plus thrombin. FloSeal® stopped bleeding in 94% of the patients (at the first bleeding site only) within 10 minutes, compared to 60% in the patients receiving Gelfoam® plus thrombin.[50]

Sealants

Sealants work by forming a barrier that is impervious to the flow of most liquids.[26] There are four types of materials approved for use as sealants to manage surgical hemostasis: fibrin sealants; PEG polymers; albumin with glutaraldehyde; and the new cyanoacrylate sealant.[26,51]

- Fibrin sealants. Fibrin sealants consist of concentrated fibrinogen and thrombin which, upon mixing with blood, create a stable fibrin clot.[26,38] Fibrin sealants increase the rate of blood clot formation by providing higher concentrations of both fibrinogen and thrombin at a bleeding site than would normally occur. The concentration of fibrinogen is proportional to clot strength, while the concentration of thrombin is proportional to the rate of clot formation.[26,38]

  There are three types of fibrin sealants available:[26,51]
  - pooled human plasma (eg, Tisseel®[52] [http://tisseel.com/us/pdf/2012-0125_PI_TISSEEL_.pdf], Evicel®[53] [http://www.ethicon360.com/products/evicel-fibrin-sealant-human);
  - individual human plasma with bovine collagen and bovine thrombin (eg, Vitagel® surgical hemostat[54] [http://www.orthovita.com/pdfs/Vitagel_Brochure.pdf]); the patient's plasma provides the source of fibrinogen that combines with bovine collagen and bovine thrombin to create a collagen-enhanced sealant; and
  - pooled human plasma and equine collagen (eg, TachoSil®[55] [http://www.tachosil.com]); pooled human plasma fibrinogen and thrombin are embedded in an equine collagen patch.

  Clinical Considerations[11,26,38,51]
  Fibrin sealants control local as well as diffuse bleeding, however, they do not control vigorous bleeding. These products can be applied using a syringe-like applicator or sprayed over a larger area using a gas-driven device.[11,26,38,51]

  Fibrin sealants can be used in patients with coagulopathies who have insufficient fibrinogen to form a clot, and can also be used on patients who are receiving heparin. They can be used for skin grafting, dural sealing, bone repair, splenic injuries, closure of colostomies, and in re-operative cardiac surgery as well as during urologic procedures. The two pooled human plasma products (ie, Tisseel®, Evicel®) are useful for controlling venous oozing from raw surfaces. The surgeon should clean wounds of antiseptics containing alcohol, iodine, or heavy metal ions that can denature applied thrombin and fibrinogen before applying these products.[11,26,38,51]

  The fibrin sealant product containing equine collagen (ie, TachoSil®) is approved for hemostasis in cardiac surgical procedures. Because this product is derived from human blood, the transmission of infectious agents may be a risk. The risk of disease transmission is reduced through donor screening for viral disease risk factors; serologic and nucleic acid testing for viral antigens and antibodies; and pathogen reduction using pasteurization (ie, heating to inactivate virus), precipitation (ie, chemical

clumping of viruses), and specialized filtering of plasma. Use of excessively tight packing or the use of too many sponges of this product, may cause tissue compression leading to injury. This product should not be used intravascularly, in neurosurgical procedures, or for procedures on the renal pelvis or ureter, for the closure of skin incisions; it should not be left in infected spaces.[55] The number of patches that can be used on each patient may be limited, based on which size patch is used. The entire patch is designed to be left in place as it becomes firmly incorporated into the newly formed clot at the point of application. It biodegrades within 13 weeks.[11,26,38,51]

Clinical concerns about fibrin sealants use primarily concern the difficulty of reconstitution, as well as the time it takes for the surgeon to learn application techniques. For example, pooled human plasma fibrin sealants may require thawing or mixing and individual human plasma products require processing the patient's own blood.[11,26,38,51]

Adverse reactions and safety concerns associated with fibrin sealants include viral or prion disease transmission with pooled human plasma derivatives; antibody formation with bovine thrombin; swelling associated with collagen use; the need for the patient to have a functional coagulation system; and the need to avoid using any type of anticoagulant with individual human plasma. Products derived from pooled human plasma should not be used in patients who have experienced anaphylactic or severe systemic reactions to human blood products, and products derived from bovine components should not be used in patients with allergies or known sensitivities to materials of bovine origin.[11,26,38,51]

- *Clinical Evidence*

  The safety and effectiveness of fibrin sealants have been demonstrated in clinical trials. A prospective randomized controlled trial compared the hemostatic effectiveness of a fibrin sealant (Evicel®) in 75 patients to manual compression in 72 patients undergoing the insertion of polytetrafluoroethylene (PTFE) arterial anastomoses.[56] The results of this study demonstrated that a higher percentage of patients who received fibrin sealant achieved hemostasis at four minutes (ie, 85% versus 39% respectively) versus patients upon whom manual compression was used; likewise, a higher percentage of patients who received the fibrin sealant achieved hemostasis at seven and 10 minutes. Treatment failure was lower in the fibrin sealant group, while the rate of complications potentially related to bleeding was similar; 64% of patients who received fibrin sealant experienced at least one adverse event, compared with 7% in the manual compression group.[56]

  Researchers conducted a prospective study of 78 patients to evaluate and compare the efficacy of topical autologous platelet-enriched plasma combined with bovine collagen and thrombin to Gelfoam/thrombin regarding hemostatic control/blood transfusion requirements and subsequent outcome. These outcomes were measured by the patient's length of stay in the ICU and the hospital, as well as mortality rates.[57] Patients who received Gelfoam/thrombin had a significantly greater number of early postoperative transfusions and longer ICU and hospital lengths of stay; there was no difference in mortality between the two groups. The authors concluded that PCT is a rapidly available topical hemostat that is associated with a significant decrease in the need for postoperative blood transfusions and ICU and hospital length of stay.[57] A randomized prospective trial to confirm these results is warranted.

  Another clinical trial evaluated the efficacy and safety of a pooled human plasma and equine collagen patch (TachoSil®) in comparison to the use of standard hemostatic fleece for the control of bleeding in 120 patients undergoing cardiovascular surgery.[58] The results demonstrated that TachoSil® was significantly superior to standard hemostatic fleece in controlling bleeding after insufficient primary hemostasis (ie, 75% of the TachoSil® patients achieved hemostasis at three minutes, compared with only 33% of the standard treatment group). This difference persisted at six minutes, with 95% of patients achieving hemostasis in the TachoSil® group compared with 72% in the standard treatment group. Only three TachoSil® patients (5%) compared with 17 standard treatment patients (28%) failed to achieve hemostasis at six minutes and received rescue treatment. TachoSil® was well tolerated with adverse events generally similar in the two treatment groups.[58]

- Polyethylene glycol polymers CoSeal™[11,26,38,51,59] [http://www.baxterbiosurgery.com/us/products/coseal/mechanism.html]

  There are three types of products in this category:

  - CoSeal™ is a combination of two PEG polymers that can be sprayed on tissue to form a synthetic, **hydrogel** matrix. The polymers cross-link to each other and to the contact tissue. This cross-linked network then forms a sealant to tissue fluids as well as a barrier to cell ingrowth and adhesion formation. This product is approved for vascular sealing and is an effective agent for vascular and cardiac procedures in which swelling and expansion are not concerns.[11,26,38,51,59]

    CoSeal™ is stored at room temperature (77°F; 25°C) and must be reconstituted by mixing its liquid and powder components in the applicator system, which is designed to assure proper mixing of the appropriate components. After reconstitution, the product is stable for two hours. The surgeon should use the dual-syringe spray applicator system from a distance of approximately 3 cm in the presence of proximal and distal vascular control so that the field is dry. After application, he or she should not place pressure on the blood vessel for at least 60 seconds so that the PEG can fully polymerize. The product may be reapplied, but the applicator tip must be cleaned after each use to prevent clogging. If the sealant fails to gel after 30 seconds, the surgeon should irrigate the site and remove the components with suction and then discard the suction tip.[11,26,38,51,59]

  - DuraSeal™[60] [http://www.covidien.come/covidien/pages.aspx?page=Innovation/Detail-sealant] is a combination of a PEG polymer, trilysine amine, and blue dye; when combined, these components form a hydrogel that can help with dural closure because it forms a water tight seal. DuraSeal™ can be stored at room temperature 77°F (25°C) and is provided in a dual-syringe applicator system. With this product, the surgeon reconstitutes the PEG component powder and its liquid before attaching the reconstituted PEG and the trilysine amine solutions to one of three spray heads.[60] DuraSeal Xact™, a new synthetic absorbable spinal sealant recently been approved by the FDA, is based on modifications of the original DuraSeal™. Used to seal sutured dural repair, it provides watertight closure during spinal surgery. DuraSeal™ also contains a blue dye, which assists the surgeon with accurate product placement. However, the molecular weight of the PEG has been reduced to minimize swelling; the **polymerization** time has also been reduced to three seconds. These new characteristics are designed to improve safety by minimizing the possibility of spinal nerve compression from product swelling and provide rapid polymerization to reduce the risk of cerebrospinal fluid leakage.[60]

  - ProGel®[61] [http://www.neomend.com/progel.products/progel-pleural-air-leak-sealant/] represents a new class of PEG polymer combined with human serum albumin. It provides a strong, flexible barrier and has been approved for use on the visceral pleura to close air leaks of ≥ 2 mm during pulmonary surgery and is the only product approved by the FDA specifically for lung sealing. The product should be refrigerated (2-8°C [36-46°F]), and it requires reconstitution of the PEG polymer powder with saline no sooner than 20 minutes before use. The applicator, which delivers the product in a stream or spray depending on the plunger pressure applied (ie, less pressure creates a stream, more creates a spray), contains syringes of the PEG polymer and human serum albumin. The applicator produces 4 mL of the final product. The two components should not be allowed to come into contact with each other until ready for use, as this may cause clogging of the applicator. The surgeon should apply the product from a distance of 2 inches (5 cm) to a non-ventilated lung. If this is not possible, the anesthesia professional should inflate the patient's lung with reduced tidal volumes so the surgeon can apply the product. Recently, new longer flexible applicators have been approved (6 inches [16 cm]; 11 inches [29 cm]), which may permit easier application, including using the product during thoracoscopy. After application, the surgeon should allow the product to cure for 15 to 30 seconds; maximum strength is achieved at approximately two minutes. The material biodegrades within 28 days.[61] ProGel® should not to be used in patients who are allergic to human albumin or who have insufficient renal function to clear the PEG polymer. It should not be applied to the main stem or lobar bronchi because of a possible increased incidence of bronchopleural fistulae formation.

The safety of this agent in contaminated or infected spaces or in conjunction with the use of other hemostats, sealants, or adhesives has not been established.[61]

These PEG polymers are used most effectively when the surgical team ensures that the tissues to be sealed are as dry and free of blood or fluid as possible. The location and position of the tissue the product is applied to should be assessed because these agents are applied as liquids. They polymerize quickly, but may still tend to drip away from the intended application site.[11,26,38,51,59-61]

The primary safety concern with all of these products is swelling and the need to be used with caution in closed spaces to avoid the adverse effects of pressure, including nerve compression. CoSeal™ should not be injected or used in place of sutures, staples, or other mechanical closure; it has demonstrated skin sensitization in animals; and its safety in doses larger than 16 mL has not been validated. The blue dye in DuraSeal™ may be associated with allergic responses, and it has also been associated with wound infections, cerebrospinal fluid leaks, renal or neurologic compromise, inflammatory reactions, and delayed wound healing.[62] Absorption of this product occurs within four to eight weeks and it is cleared from the body by the kidneys. It should be used with caution in patients with compromised renal, hepatic, or immune function and when used in proximity to air sinuses or in combination with other hemostats and sealants.

The safety of DuraSeal Xact™[63] is similar to CoSeal™ and DuraSeal™, but produces less swelling. The material is excreted by the kidneys. Surgeons are cautioned not to use this product as space fillers in spinal procedures because there is some potential for swelling and nerve compression. Its safety in patients with allergy to the blue dye used in DuraSeal™ and DuraSeal Xact™ has not been established, nor has its use with the simultaneous use of nonautologous dural patches. Warnings and precautions include that the product should not be used in patients younger than 18 years of age or in pregnant or breastfeeding women, until hemostasis has been achieved, or between tissue planes to be approximated such as muscle or skin.[63] The product biodegrades in four to eight weeks.[11,26,38,51,59-61]

In a randomized controlled trial of 54 patients undergoing aortic reconstruction of nonruptured aneurysms, the effectiveness of CoSeal™ was compared to Gelfoam/thrombin for managing anastomotic bleeding.[64] The surgeons applied each product directly to the suture line after confirming the presence of anastomotic bleeding. The study demonstrated that a significantly greater proportion (ie, 81%) of bleeding suture line sites treated with CoSeal™ achieved immediate sealing following the reestablishment of blood flow compared with 37% of the control sites treated with Gelfoam/thrombin. After five minutes, 85% of the sites treated with CoSeal™ were sealed, as opposed to slightly more than half (52%) of the control sites. Additionally, researchers reported no adverse events related to the use of CoSeal.[64]

A multicenter, prospective randomized study of 237 patients undergoing elective cranial surgery demonstrated that a PEG hydrogel (DuraSeal™) was similarly safe when used with common dural sealing techniques (eg, sutures, autologous grafts, gelatin or collagen sponges, fibrin glues) or when used as dural closure augmentation in cranial surgery.[65] The incidences of neurosurgical complications, surgical site infections, and cerebrospinal fluid leaks were similar between the treatment group using the PEG hydrogel and the control group using the standard dural sealing techniques, with no statistically significant difference between them; however, the PEG hydrogel dural sealant group demonstrated faster product preparation times (ie, less than five minutes in 96.6% of the PEG hydrogel group compared with 66.4% of the control group) and product application times (ie, less than one minute in 85.7% of the PEG hydrogel group compared with 66.4% of the control group) than other commonly used dural sealing techniques.[65]

A randomized prospective multicenter trial confirmed significant reductions in air leaks with the use of ProGel®.[66] In this multicenter study, researchers randomized 161 patients in a 2:1 ratio to have at least one significant air leak (≥ 2.0 mm in size) acquired during a pulmonary resection receive the sealant or to receive standard closure methods including sutures, staples, or electrosurgery. In the sealant group, all significant air leaks underwent attempted repair by standard closure methods (ie, sutures, staples, or cautery) before the application of sealant. The control group underwent only standard methods. Researchers analyzed the patients' blood for immunologic response and followed up with patients one month postoperatively. The results demonstrated that intraoperative air leaks were sealed in 77%

of the sealant group compared with 16% in the control group. The sealant group had significantly fewer patients with postoperative air leaks compared to the control group (ie, 65% versus 86%). The average length of hospital stay was six days (range, three to 23 days) for the sealant group compared with seven days (range four to 38 days) for control group. There was no difference in mortality, morbidity, duration of chest tubes, or immune responses between the two groups.[66]

- Albumin and glutaraldehyde[26,38]

  The glutaraldehyde cross-linked albumin sealant (eg, BioGlue®[67] [http://www.cryolife.com/products/bioglue-surgical-adhesive]) available today consists of a 10% glutaraldehyde solution and a 45% bovine serum albumin solution contained in separate compartments of a dual cartridge.[67] When needed, the surgeon loads the cartridge into a single-nozzle dispenser and the components are mixed during application. The bovine serum albumin is obtained from countries that are free from bovine spongiform encephalopathy and is purified by various methods including heat precipitation, chromatography, and radiation. Glutaraldehyde cross-links the residues of proteins in the bovine albumin to cell proteins at the wound site and forms a tough scaffold to which the clot can adhere. The surgeon must prime the applicator by expressing a small amount of product outside of the surgical field to initiate the process of albumin cross-linking by the glutaraldehyde. This product can adhere to synthetic graft materials through mechanical interlocking with the graft matrix's interstices. The product has 65% binding power within 20 seconds of application and obtains full strength in two minutes, regardless of temperature or whether the product is applied in an environment of air or water.[67]

  This product has been approved for attaching the intimal and adventitial layers of the aorta during the repair of aortic dissection. It is most commonly used for sealing holes around sutures or staple lines in complex cardiovascular procedures (eg, aortic aneurysms, valve replacements, aortic dissections) and in peripheral vascular procedures (eg, carotid endarterectomy, arteriovenous access) and instances of arterial bleeding. It should not be applied circumferentially around developing structures, valve leaflets, or intracardiac structures because it bonds with the tissue and can restrict growth; it is not approved for use in neurosurgical procedures.[67,68] Critical areas within in the operative field should be protected by isolating the area with removable sponges or pads to avoid injuring delicate tissues or occluding blood vessels (eg, the coronary arteries). The use of large volumes of this product should be avoided, to reduce the risk of associated complications including tissue injury, muscle necrosis, emboli, and delayed pseudoaneurysm formation.[67,68] This product may cause sensitivity reactions and glutaraldehyde that has not reacted may have mutagenic effects. Any unwanted liquid material should be immediately removed with suction before it polymerizes and becomes adherent. After removal, the suction should be discarded.[67,68]

  Researchers reported the initial results of a retrospective study that offers thoracic surgeons an alternative to products currently used to reduce the incidence of alveolar air leaks and bronchopleural fistulae after thoracic surgical procedures and supports the reliability of BioGlue®.[69] In 35 out of 36 patients with alveolar air leaks, surgeons were able to control the leaks at the site where BioGlue® was applied.[69] In one study, cardiac surgeons used BioGlue® as a hemostatic agent in 79 cardiac surgery patients and successfully achieved hemostasis in 78 of those cases.[70] In an earlier prospective multicenter, randomized controlled clinical trial of 151 patients researchers wanted to determine if the use of BioGlue® could reduce the rate of anastomotic bleeding in patients undergoing cardiac and vascular repair procedures when used as an adjunct to standard repair techniques (ie, lung sutures or staples used in the control group.[71] This study demonstrated that anastomotic bleeding was significantly reduced in the BioGlue® group (ie, 18.8% of anastomoses) compared with the control group (ie, 42.9% of anastomoses). Pledget use was also reduced by 26.2% in the BioGlue® group compared to 35.9% in the control group. Lengths of stay in the ICU and the hospital were slightly higher in the control group. Researchers report that adverse event profiles were similar between the two groups, except for the occurrence of neurological defects, which were reported to be three times less in the BioGlue® group.[71]

- Cyanoacrylates [51]

  A new type of octyl and butyl lactoyl cyanoacrylate sealant (eg, Omnex™[72] [http://www.ethicon360.com/products/ethicon-omnex-surgical-sealant]) is the first FDA-approved absorbable cyanoacrylate hemostatic agent approved for internal use and is indicated for vascular sealing.[71] This product consists

of two monomers of cyanoacrylate, 2-octyl cyanoacrylate and butyl lactoyl cyanoacrylate, formulated to biodegrade slowly and safely over 36 months so that only small amounts of the degraded by products (eg, formaldehyde) are produced at any given time. This product is intended to be used as a sealant and should not be used as a substitute for sutures, staples, or other methods of mechanical closure. It should only be applied after vascular control is obtained.[72]

According to the Omnex™ package insert, perioperative staff members should store the applicator kits at a controlled room temperature of between 20° to 25° C (68° to 77° F), with temporary storage periods of temperatures of 15° C (59° F) or up to 30° C (86° F) permitted.[72] The assembled applicator requires that the surgeon prime and mix the contents by depressing the applicator trigger handle several times. After that has been completed, the product has a working time of approximately five minutes. The surgeon should leave vascular clamps in place for at least two minutes to allow the anastomosis site to dry and be clear of fluids for the entire required polymerization period. A second application of the product may be used if needed, but the product should be applied sparingly. The flexible application cannula tip contains a steel wire that should not be trimmed if it becomes clogged, because this may expose the internal wire, which could potentially cause damage to the vessel. This product is capable of strongly adhering to almost any surface; therefore, the sealant should not come in contact with any unintended structures (eg, gloves, surgical instruments). If allowed to contact unintended tissues, peeling of the product from these tissues can result in tissue tearing and damage. Surgeons should not use this agent in patients sensitive or allergic to cyanoacrylate or its degraded products (eg, formaldehyde). It should not be used for intravascular injection because it has not been evaluated for use on veins or in cardiac or pediatric surgical patients.[72]

Researchers conducted a multicenter, randomized, controlled study to evaluate the safety and efficacy of a cyanoacrylate surgical sealant in establishing hemostasis of expanded polytetrafluoroethylene (PTFE) grafts to arterial vascular anastomoses in arteriovenous (AV) grafts and femoral bypass grafts.[73] They randomized a total of 151 patients scheduled to undergo femoral bypass procedures or AV shunt procedures for hemodialysis access using expanded PTFE grafts 2:1 to receive either the cyanoacrylate surgical sealant or oxidized cellulose (ie, the control group). The goal was to determine the elapsed time needed from clamp release to hemostasis; in addition, they wanted to determine the proportion of patients achieving immediate hemostasis and hemostasis at one, five, or 10 minutes after clamp release. Researchers also evaluated the need for additional adjunctive measures to achieve hemostasis and the occurrence of adverse events. The study demonstrated that the mean time from clamp release to hemostasis was 119.3 seconds with cyanoacrylate surgical sealant versus 403.8 seconds in the control group. Immediate hemostasis was achieved in 54.5% of patients receiving cyanoacrylate surgical sealant and in 10% of the control patients. The occurrence of adverse events (eg, pleural effusion, respiratory dysfunction/failure, infection, renal dysfunction or failure) was similar in both groups; however, the proportion of patients requiring additional adjunctive measures was lower with cyanoacrylate surgical sealant.[73]

Key Considerations in the Selection of Hemostatic Products

There are several factors that should be considered when selecting the most appropriate topical hemostatic agent and delivery method. The exact properties of the ideal topical hemostatic agent will vary depending on the surgical specialty, the specific patient population, procedure requirements, the type of bleeding, and the agent's specific mechanism of action.[3] Other important factors to evaluate include the agent's ability to:[3,26]

- rapidly and effectively control bleeding,
- effectively contact the bleeding surface,
- work well,
- work reliably,
- be handled easily,
- be simply prepared,
- be available in multiple delivery options,
- be compatible with the patient's physiology,
- be safely used (ie, have an acceptable adverse-event profile), and
- be cost effective.[3,26]

Perioperative Nursing Care for Management of Surgical Hemostasis: The Role of the Perioperative RN

Control of surgical bleeding is primarily a concern for the surgeon and first assistant, however, it is also an important consideration for the perioperative RN who plays a key role by monitoring surgical bleeding and also through preparing topical hemostatic agents appropriately and providing them to the surgical team.[5] Through the use of the nursing process, the perioperative RN can implement effective interventions for managing surgical hemostasis and evaluate outcomes to promote positive patient outcomes.

Preoperative Nursing Assessment[1,13]

The importance of a thorough preoperative surgical bleeding risk assessment and the need to use adjunct methods for hemostasis for all surgical patients cannot be understated. Identifying patients at risk for prolonged or excessive bleeding during a procedure begins with the preoperative nurse's patient assessment and his or her review of the patient's history and physical examination. A thorough preoperative assessment will alert the perioperative team to cardiovascular comorbidities that could predispose the patient to intraoperative bleeding problems. The history and physical examination should provide clinical data regarding the patient's present condition, past history, and current medications. A patient with a history of sepsis; allergies; coagulation deficiencies; use of anticoagulant medications; or diseases such as leukemia, thrombocytopenia, lymphoma, or multiple myeloma increase his or her risk for intraoperative bleeding. In addition, the nurse should evaluate the patient's wound classification if there is a possibility that a chemical hemostatic agent may be used. Bleeding sites must be visible if hemostatic agents are used, and most topical agents use is contraindicated in contaminated wounds. Also, it is critical that the nurse question the patient about any known allergies to the agent being used or to the substance from which the agent was derived and report the information to the surgical team.[1,13]

Another key patient consideration regarding the selection and use of topical hemostatic agents is informed consent. The perioperative RN must be aware of any patient-specific consent issues that are based on religious, social, cultural, or emotional beliefs associated with animal-derived products. Certain religious groups have beliefs related to the dietary use of both porcine and bovine products. Although dietary restrictions do not always translate into restrictions regarding the use of these products during surgery, religious and cultural beliefs can conflict with and thus limit treatment options, especially in surgery.[74] The proposed use of animal-derived surgical products should be included in the patient's informed consent process to prevent religious or cultural distress if the products are used.[75] Ignoring the patient's religious or cultural sensitivities by neglecting to include the use of animal-derived or biologic products in the informed consent process can have serious litigation implications.[76] The surgeon and perioperative RN have a duty to explain the nature and purpose of any proposed treatment, including the components of topical hemostatic products, as well as the associated risks they can present to the patient. To obtain a culturally sensitive informed consent, the surgeon and the perioperative RN must be aware of the constituents of the topical hemostatic agents that are used in the facility.[1,13] Important preoperative assessment parameters are outlined in Table 4.

Table 4 – Preoperative Assessment Considerations

Does the patient

- have allergies especially to any topical hemostatic agent or products of bovine or porcine origin?
- use anticoagulants or antiplatelet medications?
- use aspirin-containing or other non-steroidal anti-inflammatory prescription or over-the-counter medication?
- use supplements or herbs that might contribute to increased bleeding times (eg, vitamin E, bilberry, gingko biloba, garlic, cayenne, ginseng, fish or flaxseed oil, grape seed extract, dandelion root saw palmetto, quinine)?
- have a personal or family history of bleeding disorders (eg, sickle cell anemia, hemophilia)?
- report bleeding gums, easy bruising, excessive superficial bleeding, or severe nosebleeds?
- have anemia?
- have a history of renal or hepatic disease?

What is/are
- the proposed procedure and wound classification?
- the results of
  - coagulation profile?
  - blood type and cross-match, if ordered?

Has the nurse verified the presence of
- a signed consent for administration of blood/blood products or a signed refusal of blood/blood products?
- any restrictions to consent for blood or blood products or directions regarding which blood components are acceptable?
- autologous blood donation, if ordered?
- plans for perioperative blood salvage/autotransfusion?
- cultural, ethnic, or religious beliefs affecting or prohibiting blood or blood product use?

Adapted with permission from: McCarthy JR. Methods for assuring surgical hemostasis. In: Assisting in Surgery: Patient-Centered Care. *JC Rothrock, PC Seifert, eds. Denver, CO: CCI; 2009:144.*

It is also important for the perioperative RN to be aware of the clinical considerations related to the use of all topical hemostatic agents in pediatric or geriatric patients or in pregnant or breastfeeding women. The nurse should always consult the package insert of the product for the directions for use and clinical data regarding the safety and efficacy of using the agent in these patients.[1,13]

Planning

Developing a plan of care is the next step in the effective management of surgical hemostasis. Based on the preoperative assessment data, the surgical team should conduct a briefing and use a surgical safety checklist.

- *OR Briefing.* A systematic preoperative briefing protocol, when used, improves the overall briefing process and OR team interaction. This in turn enhances both teamwork and patient safety.[77] Some surgical procedures clearly pose a significantly higher risk for bleeding than others, therefore, the type and extent of the planned procedure are important to consider when determining the patient's overall risk of bleeding.[1] The OR briefing should include a review of the critical steps involved in the planned procedure and any potential problems. During the briefing, team members should review and address any potential problems the patient may have with coagulation and discuss aspects of the procedure that present substantial bleeding risks (eg, removal of an abdominal organ, tumor resection, major vessel resection, extracorporeal blood circulation). Patients who have had previous surgeries also may have adhesions, which may increase bleeding. Prolonged or difficult procedures that require extensive exposure causes the patient's core temperature to drop, which also increases the risk for extensive bleeding.
- *Surgical Safety Checklist.* The World Health Organization has developed a surgical safety checklist as part of its Safe Surgery Saves Lives initiative to reduce the number of surgical deaths.[78] This checklist divides surgical procedures into three phases, each phase corresponds to a specific time period in the normal flow of surgical patient care. The three phases and how their activities relate to surgical bleeding are outlined below.
  - Sign In - the period before induction of anesthesia.
    - The checklist coordinator asks team members whether an adult patient risks losing more than 500 mL or if a pediatric patient risks losing 7 mL/kg of blood during surgery. This ensures that team members are aware of and prepared, if this event occurs.
  - Time Out – a time out should be performed before all surgical or invasive procedures.[79]
    - Team members review anticipated critical events and possible unexpected events that could occur, the planned length of the procedure, and the anticipated blood loss. This discussion includes any events that might increase the patient's risk for rapid blood loss, injury, or other major morbidity. The anesthesia professional reviews any patient-specific concerns with team members. For patients at risk for major blood loss, hemodynamic instability, or other major morbidity as a result of the procedure, a member of the anesthesia team should review aloud the specific plans and concerns for resuscitation and whether they plan to use blood products and discuss any complicating patient characteristics or comorbidities (eg, cardiac or pulmonary disease, arrhythmias, blood disorders).

- Sign Out - the period during or immediately after wound closure, but before the patient leaves the OR.
    - The surgeon, anesthesia professional, and perioperative RN should review the patient's planned postoperative recovery and management, focusing on any intraoperative or anesthetic issues that might affect the patient to provide an efficient and appropriate transfer of care. Events that present a specific risk to the patient during recovery and that may not be evident to all involved are particularly relevant.

Research on implementation of the checklist in a diverse group of hospitals demonstrated that its use was associated with reductions in complications and mortality among patients at least 16 years of age who had undergone noncardiac surgical procedures.[80]

Implementation

There are several methods that can be used to control bleeding during a procedure. To help preoperatively screen patients for potential complications with these products and help the surgeon choose the most effective method(s) of hemostasis for the patient, the perioperative RN must understand their indications and contraindications and their mechanisms of action, constituents, and the potential adverse effects of the different topical hemostatic products available for use in the facility.

The perioperative RN should also be aware of the specific directions for storage and preparation of topical hemostatic products (ie, which products can be stored at room temperature, which require refrigeration or preparation, or are ready-to-use). Both the RN circulator and scrub person must prepare and use the product according to the manufacturer's instructions for use, ensure that it is prepared correctly, and that it is used within the specified time. The perioperative RN should also be aware of the clinical evidence supporting the proposed product application.

Patient Care Outcomes Related to Management of Surgical Hemostasis

To appropriately use and evaluate the effectiveness of the various methods for achieving and maintaining hemostasis during surgery, the perioperative RN should be aware of the applicable nursing diagnoses, expected outcomes, patient considerations, and evaluation of outcome indicators, as outlined in Table 5. Documentation in the patient's health care record must include the use of all administered agents because of the risk for antibody formation and anaphylaxis with repeated exposure to hemostatic agents, especially bovine thrombin agents.[81] In addition, the patient's health care record should reflect the plan of nursing care, including assessment, applicable nursing diagnoses, outcome identification, planning, implementation, and evaluation of the patient's progress.[82]

Table 5 – Nursing Diagnoses, Expected Outcomes, Patient/Nursing Considerations, and Outcome Indicators Related to Managing Surgical Hemostasis

Nursing Diagnoses	Expected Outcome/ Outcome Definition	Patient/Nursing Considerations	Outcome Indicators
Risk for fluid volume deficit Risk for imbalanced fluid volume Impaired gas exchange	The patient's fluid, electrolyte, and acid-base balance are maintained at or improved from baseline levels. • The patient's fluid, electrolyte, and acid-base balance are within expected or therapeutic range throughout the perioperative period;	• Use of anticoagulants, aspirin, nonsteroidal antiinflammatory drugs, and antihistamines • Status post bone marrow replacement • Use of incompatible blood products • Malnutrition • Mixed coagulation and platelet defects • Renal failure • Retroplacental hemorrhage	• Vital signs are within expected range. • General skin condition is smooth, intact, free from ecchymosis, cuts, abrasions, shear injury, rash, or blistering. • Patient is free from new or increasing edema in dependent areas. • Conjunctiva and/or mucous membranes are pink and free from cyanosis or pallor. • Cardiovascular status is within expected ranges. • Peripheral pulses are present and equal bilaterally.

	these parameters are continuously monitored during the perioperative period.	• Severe hepatic or renal disease • Vitamin K deficiency • Widespread metastatic disease, massive trauma or burns, gram-negative or gram-positive sepsis • Personal or family history of bleeding disorder • Reports of easy bruising or superficial bleeding	• Skin is warm to touch; free from cyanosis or pallor. • Capillary refill time is less than three seconds. • Urinary output is greater than 30 mL/hour. • Specific gravity is 1.010 to 1.030. • Laboratory values for arterial blood gases, serum electrolytes, and hemodynamic monitoring values (if ordered or available) are within expected ranges.
Risk for injury related to the use of mechanical methods to achieve hemostasis Risk for injury as a result of environmental conditions interacting with the individual's adaptive and defensive resources	The patient is free from signs and symptoms of injury caused by extraneous objects. • The patient is free from signs or symptoms of injury from equipment or instrumentation. • There is no evidence of injury related to mechanical hemostatic techniques used during the procedure.	• Adhesions • Improper identification of anatomical structures before clipping • Poor operative exposure • Application of inappropriate-sized hemostatic clip Defective clip appliers • Obesity which may impede exposure of the operative field, which may interfere with the use of pressure or the use of sutures and hemostatic clips • Use of packs to control bleeding	• The patient did not experience hemorrhage from improper use of pressure or application of hemostatic clips during the procedure. • The patient did not experience signs and symptoms of post-procedure infection or pain related to retained packing sponges. • General skin condition is smooth, intact, free from ecchymosis, cuts, abrasions, shear injury, rash, or blistering. • Cardiovascular status is within expected ranges. • Peripheral pulses are present and equal bilaterally. • Skin is warm to touch.
Risk for injury related to the use of electrical devices to achieve hemostasis Risk for impaired skin integrity Acute pain	The patient is free from signs and symptoms of electrical injury. • The patient is free from any observable signs or reported symptoms of injury related to the use of electrical devices to achieve hemostasis.	• Bony prominence at dispersive electrode site • Inappropriate placement of the dispersive electrode • Emaciation • Excessive hair at the dispersive electrode site • Scar tissue at the dispersive electrode site • Exposed metal in contact with the patient's skin • Defective dispersive electrode • Impaired skin or tissue integrity at the dispersive electrode site • Impaired tissue perfusion at dispersive electrode site • Internal or external prosthetic device at the dispersive electrode site • Improper identification of anatomical structure(s) before activating the active electrode • Inappropriate use of electrosurgery to control bleeding	Skin condition at the dispersive electrode site and potential alternative ground injury sites (eg at the electrocardiographic lead sites) is smooth and intact and free from ecchymosis, blisters, or redness. • Cardiovascular status is within expected ranges. • Peripheral pulses present and equal bilaterally. • Skin is warm to touch; free from cyanosis or pallor. • Capillary refill is less than three seconds. • Neurovascular status is intact. The patient flexes and extends extremities without assistance and denies numbness or tingling of extremities. • The patient did not experience post-procedure impaired tissue integrity, hematoma formation due to ineffective desiccation or fulguration of blood vessels, or deep tissue burns. • The patient did not experience hemorrhage from ineffective cauterization of blood vessels during the procedure.

		• Minimally invasive procedure without the use of active electrode monitoring to reduce the hazards of insulation failure and capacitive coupling • Use of a ground-reference generator or isolated generator without return electrode monitoring • Obesity (ie, excessive subcutaneous tissue does not conduct electricity as well as muscle) • Pacemaker or implantable cardioverter-defibrillator • Poor exposure of the operative field • Use of flammable agents to prepare the operative site	• The patient denies acute pain or discomfort at the dispersive electrode site.
Risk for injury related to the use of a laser to achieve hemostasis Risk for impaired skin integrity Impaired skin integrity Disturbed sensory perception Acute pain	The patient is free from signs and symptoms of laser injury. • The patient receives the minimal laser energy exposure needed to achieve the therapeutic purpose and has no contact with the laser beam other than for the intended purpose. • The patient remains free from any observable signs or reported symptoms of laser injury.	• Exposed tissue around the operative field • Inadequate eye protection for the patient • Movement during laser operation • Poor exposure of the operative field • Use of dry sponges during laser operation • Use of flammable agents to prepare the operative site • Use of flammable draping materials • Use of non-laser safe endotracheal tube during respiratory or gastrointestinal procedures • Use of reflective instruments	• General skin condition is smooth and intact, free from unexplained edema, redness, or tenderness in non-targeted area. • Patient's postoperative vision is equal to preoperative status (in non-ophthalmologic patient). • Vision in non-operative eye is unaffected (in ophthalmologic patient). • Patient denies corneal pain or discomfort in non-targeted areas.
Risk for injury related to the use of chemical methods to achieve hemostasis Risk for injury related to the use of microfibrillar collagen hemostat, gelatin sponge,	• The patient is free from signs and symptoms of injury caused by extraneous objects (ie, the use of chemical hemostatic agents to achieve hemostasis during the procedure). • The patient is free from signs or symptoms of injury from equipment or instrumentation.	• Allergy to materials of bovine origin • Application to wound edges • Failure to remove excess amounts of the agent • Use of microfibrillar collagen hemostat in presence of methyl methacrylate • Use of blood scavenging systems • Use in the presence of methyl methacrylate • Use in urological, ophthalmological, and neurological procedures	• There is no evidence of abscess or hematoma formation. • There is no failure of an orthopedic prosthesis due to a reduction in the bonding strength of methyl methacrylate. • There is no evidence of nonhealing of wound skin edges. • There were no incidences of aspiration of microfibrillar collagen hemostat. • The patient did not experience an allergic response to microfibrillar collagen hemostat. • The patient's blood was not contaminated with microfibrillar collagen hemostat particles.

and oxidized cellulose Risk for injury related to the use of collagen sponge Risk for injury related to the use of oxidized cellulose for hemostasis	• There is no evidence of injury related to chemical hemostatic techniques used during the procedure.	• Hemorrhoidectomy, skin graft donor site, dermabrasion • Nasal procedures (eg, polypectomy when used for packing) • Orthopedic procedures • Spinal cord and optic nerve procedures • Vascular procedures	• The patient's skin condition remains unchanged. The patient did not experience hematoma formation from vascular oozing from improper application or use of gelatin sponge. • There is no evidence of adhesion formation. • The patient did not experience an allergic reaction. • The patient does not complain of post-procedure pain or have symptoms of neurological deficit. • The patient does not complain of post-procedure headaches. • The patient does not experience sneezing, burning, and stinging sensations to localized application areas. • The patient does not experience impaired bone healing. • There is no evidence of vascular stenosis.
Risk for impaired tissue integrity related to the use of a gelatin sponge to achieve hemostasis	• The patient is free from signs and symptoms of impaired skin integrity related to the use of a gelatin sponge to achieve hemostasis during the procedure. • The patient is free from observable signs or reportable symptoms of chemical injury.	• Application to wound edge • Inappropriate application of gelatin sponge, resulting in bleeding after closure • Use in presence of tissue inflammation • Use during neurosurgery and tendon repair	• The patient did not experience hematoma formation from vascular oozing from improper application or use of a gelatin sponge. • The patient does not complain of post-procedure pain or exhibit signs of neurological deficit related to the inappropriate use of a gelatin sponge.
Risk for infection related to the use of electrical devices to achieve hemostasis	• The patient is free from evidence of post-procedure infection related to thermal hemostatic techniques used during the procedure. • The patient is free from signs or symptoms of surgical site infection such as pain, induration, foul odor, purulent drainage, and/or fever through 30 days following the operative procedure.	• Charring of tissue during cauterization of blood vessels • Contaminated wound • Excessive use of electrosurgery resulting in large areas of tissue injury and necrosis, particularly in the subcutaneous layer • Presence of existing infection • Hematoma formation due to inadequate cauterization of blood vessels • Immunosuppression secondary to blood transfusions • Retained blood products in the subcutaneous layer which provide an excellent growth medium for bacteria	• The patient does not experience fever or chills. • There is no evidence of redness, warmth, or swelling around the incision or open wounds. • Wound drainage does not have an unusual appearance. • Laboratory values: white blood cell count is within normal limits; wound cultures are negative for infectious agents.

Risk for infection related to the use of microfibrillar collagen hemostat, gelatin sponge, and oxidized cellulose to achieve hemostasis	• The patient is free from evidence of post-procedure infection related to chemical hemostatic techniques used during a procedure. • The patient is free from signs or symptoms of surgical site infection such as pain, induration, foul odor, purulent drainage, and/or fever through 30 days following the operative procedure.	Microfibrillar collagen: • Retained blood products in the subcutaneous tissue which provide an excellent growth medium for bacteria • Suppressed immune system secondary to blood transfusions Gelatin sponge: • Allergy to gelatin products • Application to wound edges • Inflammation of the operative site, wound contamination, or infection Oxidized cellulose: • Contaminated wound • Retained blood products in the subcutaneous tissue which provide an excellent growth medium for bacteria • Suppressed immune system secondary to blood transfusions	• The patient does not experience fever or chills. • There is no redness, warmth, or swelling around the incision or open wounds. • There is no unusual wound drainage.

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Transfer of Care[1,83]

The perioperative RN is responsible for clear, concise, and focused communication during the transfer of care to personnel in the postanesthesia care unit or ICU. During the handoff report, the nurse should communicate all relevant information, including but not limited to the patient's:

- estimated blood loss,
- hemodynamic status,
- airway and oxygenation status,
- thermal status, and
- urinary output.[83]

In addition, the nurse should report:

- any problems with coagulation or hemostasis;
- interventions, including the administration of medications and their dose and time given;
- use of IV fluids, irrigation fluid, and blood and blood products, if applicable;
- information about the surgical site (eg, descriptions of dressings, drains, tubes, packing);
- any anticipated issues resulting from problems associated with managing hemostasis during the procedure; and
- the presence or absence of surgical complications.[83]

An additional tool for identifying patients who may be at increased risk for developing postoperative complications is a surgical Apgar score.[1] This score is calculated at the end of the procedure using the patient's estimated blood loss, his or her lowest mean arterial blood pressure reading, and the lowest heart rate rhythm recorded on the anesthesia record during the procedure.

Conclusion

The success of any surgical procedure depends on a surgeon's ability to effectively and efficiently manage hemostasis to provide an optimal view of the surgical field and to prevent the adverse physiologic effects associated with blood loss. Mechanical, thermal, and chemical methods are available for managing surgical hemostasis. However, during some procedures, the patient's normal clotting mechanisms may be insufficient and/or the use of standard methods (ie, suturing; electrosurgery) may be impractical to achieve and maintain adequate hemostasis. In these cases, the use of topical hemostatic agents may be ordered by the surgeon or licensed independent practitioner to assist in the coagulation process. The perioperative RN should understand what contributes to surgical bleeding, its associated adverse effects, the benefits of maintaining hemostasis during a procedure, the various methods available to achieve and maintain surgical hemostasis, and how the patient's religious and cultural beliefs may affect the use of certain products. Because of the wide array of topical hemostatic products available in the OR today, the perioperative RN must understand how they differ in constituents, indications, contraindications, methods of storage and preparation, efficacy, safety profile, and cost to help the surgeon use them appropriately and safely. In this way, the perioperative RN can play a vital role in helping the surgical team effectively managing surgical hemostasis and ultimately promote a positive clinical outcome for all surgical patients.

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Glossary	
Afibrinogenemia	The absence or deficiency of fibrinogen in the blood plasma.
Allogeneic	Taken from different individuals of the same species.
Argon-enhanced coagulation	Radio frequency coagulation from an electrosurgical generator; it is capable of delivering a monopolar current through a flow of ionized argon gas.
Bipolar electrosurgery	A type of electrosurgery in which current flows between two tips of a bipolar forceps that are positioned around tissue to create a surgical effect. Current passes from the active electrode of one tip of the forceps through the patient's tissue to the other dispersive electrode tip of the forceps, thus completing the circuit without entering another part of the patient's body.
Coagulation	The process that changes compounds circulating in the blood into an insoluble gel, which is able to plug leaks in the blood vessels and thus stop the loss of blood; the formation of a clot.
Coagulation cascade	A sequence of biochemical activities to stop bleeding by forming a clot.
Coagulation factors	Factors essential to normal blood clotting whose absence, diminution, or excess may lead to abnormality of the clotting process.
Coagulopathy	Any disorder of blood coagulation that results in either excessive or insufficient clotting. The presence of a high anticoagulant concentration can lead to insufficient clotting or excessive bleeding.
Collagen	The fibrous protein of tissue that provides support and gives cells structure.

Cross-linkage	A covalent bond (ie, linkage) between two polymers (ie, chains) or between different regions of the same polymer.
Electrosurgery	The cutting and coagulation of body tissue with a high-frequency (ie, radio frequency) current.
Fibrin	The insoluble protein that is essential to clotting of blood; it is formed from fibrinogen by the action of thrombin.
Fibrinogen	A high-molecular weight protein in the blood plasma that, by the action of thrombin, is converted into fibrin; also known as clotting factor I.
Fibrinolysis	The breakdown of fibrin, typically by the enzymatic action of plasmin.
Hemostasis	The process of controlling or stopping the flow of blood from a vessel or organ.
Hydrogel	A colloidal gel in which the particles are dispersed in water.
Laser	An acronym for light amplification by stimulated emission of radiation; a device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels.
Lyophilized	The creation of a stable preparation of a biological substance by a process of rapid freezing and dehydration of the frozen product under high vacuum.
Monopolar electrosurgery	Electrosurgery in which only the active electrode is in the surgical wound; the electrical current is directed through the patient's body, received by the dispersive pad, and then transferred back to the generator, completing the monopolar circuit.
Plasmin	An endopeptidase that occurs in plasma as plasminogen; it is responsible for solubilizing fibrin in blood clots and degrading other coagulation-related proteins.
Platelet	A small, disk or plate-like structure, the smallest of the formed elements in blood. Platelets, also called thrombocytes, are disc-shaped, non-nucleated blood elements with a fragile membrane. They tend to adhere to uneven or damaged surfaces.
Polymerization	The combination of two or more molecules by a chemical reaction.
Polysaccharide hemospheres	Microspheres derived from vegetable starch that have a porous surface, which effectively absorbs water and low molecular weight compounds from blood and also concentrates platelets and clotting proteins at the bead surface to enhance endogenous clotting mechanisms.
Prothrombin	A glycoprotein present in the plasma that is converted into thrombin by extrinsic thromboplastin during the second stage of blood clotting; also known as clotting factor II.
Red thrombus	A clot formed rapidly by the coagulation of blood, composed primarily of red blood cells rather than platelets.
Thrombin	An enzyme resulting from activation of prothrombin, which catalyzes the conversion of fibrinogen to fibrin. A preparation from prothrombin of bovine origin is used as a clotting agent.
Thrombocytopenia	A condition in which there is a deficient number of circulating platelets.
Thromboplastin	A plasma protein present in tissues, platelets, and white blood cells necessary for the coagulation of blood; in the presence of calcium ions, it is necessary for the conversion of prothrombin to thrombin.
Transfusion-related acute lung injury (TRALI)	A clinical syndrome characterized by the acute onset of respiratory distress typically within six hours after a transfusion; one of the most common causes of transfusion-associated major morbidity and death.
Ultrasonic device	A cutting/coagulation device that converts electrical energy into mechanical energy, providing a rapid ultrasonic motion.
Vessel sealing technology	Bipolar electrosurgery technology that fuses collagen and elastin in the vessel walls and permanently obliterates the lumen of the vessel.
White thrombus	A clot of opaque, dull, white color composed primarily of platelets.

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