# Educating the Educator: Use of Advanced Bleeding Control Mechanisms in Athletic Training: A Shift in the Thought Process of Prehospital Care—Part 2: Hemostatic Agents

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## INTRODUCTION

Part 1 of this series reviewed the concepts of hemorrhaging, shock, and controlling bleeding as they relate to athletic training and prehospital emergency care. Part 1 focused on the use of tourniquets in the prehospital setting along with a method for athletic training educators (ATEs) to teach the skill in the classroom. Part 2 of advanced bleeding control will provide ATEs with evidence regarding the use of topical hemostatic agents in the prehospital setting as well as how to use and teach managing external hemorrhage using hemostatic agents within their educational programs where applicable.

### CONTROL BLEEDING

The objectives of care are well defined to limit blood loss, prevent and maintain a level of critical tissue perfusion pressure, and bring the patient as quickly as possible to an appropriate receiving facility to further control blood loss.<sup>1</sup> All methods of controlling hemorrhage serve to restrict blood flow and augment the body's response to blood loss-vascular constriction, platelet aggregation, and coagulation. In the presence of shock (see Part 1)<sup>2</sup> and uncontrollable bleeding, athletic trainers may consider the use of a tourniquet,<sup>2</sup> while paramedics in the prehospital setting may implement invasive treatments to include intravenous fluid resuscitation and vasoactive therapies. Failure to manage blood loss may result in an individual becoming hemodynamically unstable. This condition, known as shock, is often defined as inadequate tissue perfusion.<sup>2,3</sup> The inability of the body to perfuse oxygen to the cellular tissues and remove waste products may occur with as little as 15 to 20% loss of the total blood volume in adults.<sup>4-6</sup>

## **Current Practice**

Controlling external bleeding is a skill taught in all basic and advanced first aid courses and one of the few actions in which

the initial care can critically influence a patient's outcome.<sup>7</sup> "Bleeding is best controlled by applying pressure until bleeding stops<sup>47–53</sup> or EMS rescuers arrive (Class I, LOE A)." $^{7(pS936)}$  Direct (fingertip or whole hand) or manual pressure requires placing sterile gauze or other cloth dressing over the source of bleeding with a gloved hand (Figure).<sup>3,7</sup> To facilitate natural clotting mechanisms, firm pressure is applied against the soft tissue and maintained until bleeding is controlled. In fact, "the amount of pressure applied and the time the pressure is held are the most important factors affecting successful control of bleeding."7(pS936) Should the dressing rapidly become blood soaked, consider adding additional dressings. In some instances, it may be necessary to remove the blood-soaked dressings and locate the source of the bleeding. Reapply the dressing, ensuring the application of direct pressure to the source of the bleeding. When continuous direct/manual pressure is warranted to provide additional care, a pressure bandage (elastic or roller bandage) firmly applied over the dressing may be utilized. Continuous monitoring to ensure bleeding remains controlled is paramount.

When direct/manual pressure fails to control external bleeding or is not possible and access to medical resources is not immediately available, the immediate application of a tourniquet by a properly trained responder should be considered.<sup>7</sup> A tourniquet is a tight band (commercial or improvised) placed around an arm or leg to constrict blood vessels to stop blood flow to a wound.<sup>2</sup> In some instances, the presence of excessive soft tissue or proximity of blood vessels within soft tissue may necessitate the application of multiple tourniquets. Subsequent applications of additional tourniquet (based on the severity of the injury) must be applied proximal to the initial tourniquet as practically close as possible to the injury. More information regarding tourniquet usage and teaching strategies in athletic training can be found in Part 1

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#### Figure. Direct fingertip pressure.



of this 2-part series (Use of Advanced Bleeding Control Mechanisms in Athletic Training: A Shift in the Thought Process of Prehospital Care—Part 1: Tourniquets).<sup>2</sup>

When presented with trauma situations where massive external bleeding cannot be controlled by direct pressure and/or with the use of a tourniquet (ie, hemorrhaging occurring in sites not amenable to tourniquet placement such as the abdomen, groin, or chest), the application of a topical hemostatic agent is warranted.<sup>7–10</sup>

## Hemostasis

The body's physiologic response (hemostasis) to blood loss from trauma, platelet abnormalities or deficiencies in coagulation factors, or vascular defects includes a complex 3-phase process to facilitate the cessation of hemorrhage. Coordinated activation of platelets and plasma clotting factors to form a platelet-fibrin plug depends upon the primary (formation of soft platelet plug) and secondary (stabilization and cross linkage) hemostatic phases. Of central importance in both primary and secondary hemostasic phases is the activation of the clotting cascade, which is broken down into 2 basic pathways; the intrinsic (activated by collagen, which is exposed when a blood vessel is damaged) and the extrinsic (activated by tissue damage and the resultant release of tissue factor) pathway.

The clotting cascade includes a series of dependent reactions following trauma that involves several plasma proteins, calcium ions, and blood platelets that lead to the conversion of fibrinogen to fibrin and an eventual soft platelet plug.<sup>11</sup> In the initial phase, the muscular wall of a blood vessel contracts to reduce the amount of blood flow and creates a turbulent flow of blood. This turbulent flow initiates the second phase of response by attracting platelets which adhere in the presence of collagen to the lining of the vessel, surrounding tissue and each other; further reducing blood flow through the vessel. While the initial clot formed in the vessels (ie, capillaries, small veins, and arteries) greatly decreases the loss of blood, it is extremely unstable.

The third phase of coagulation strengthens the clot through the incorporation of fibrin and red blood cells, resulting in the expansion and strengthening of the clot. When bleeding is uncontrollable (by the previously recommend methods), a number of topical hemostatic agents are available to actively affect the biological mechanism of action of the clotting cascade and, passively, through contact activation and promotion of platelet aggregation.<sup>11</sup> A fourth and final stage in the process is where the dissolving of the clot by enzyme plasmin occurs.

## TOPICAL HEMOSTATIC AGENTS

Hemostatic agents are antihemorrhagic substances that promote hemostasis by controlling bleeding<sup>8,9</sup> and therefore prevent possible shock or death. Approved for human use by the Food and Drug Administration (FDA), these agents are used when severe or uncontrollable bleeding occurs in areas not accessible to a tourniquet.<sup>8,12</sup> These antihemorrhagic substances produce hemostasis when placed in bleeding wounds by (1) "physically adhering to damaged tissues in the wound and sealing injured blood vessels to prevent further blood loss,"<sup>9(p26)</sup> and (2) "accelerating and strengthening the clotting of blood present in the wound by incorporating into the developing clot and producing hemostasis."<sup>9(p26)</sup>

## History

The use of agents for control of bleeding is documented by the ancient Egyptian culture with the use of fresh meat being utilized as an "efficient hemostatic and mechanical agent."13 In 1966, the National Academy of Sciences identified deficiencies in providing emergency medical care in the United States and released a White Paper entitled Accidental Death and Disability: The Neglected Disease of Modern Society.<sup>14</sup> The foundation for the White Paper originated from comparisons of statistics which identified that more civilians died on the roadways of the United States from traumatic injury than soldiers injured in the Korean War. Methodologies for treating the wounded during the Korean War took tremendous strides forward with the increased utilization of mobile army surgical hospitals and rapid evacuation of the injured to these facilities.

Care of both military and civilian personnel has evolved over the past several decades. The control of external hemorrhage gained increasing attention during the 1990s when a retrospective analysis indicated care provided by Emergency Medical Services (EMS) using a "scoop and run" approach in the 1970s had a higher survival rate than those in the early 1980s. By 1982, EMS providers were receiving focused education on how to rapidly assess, intervene, and transport injured patients to hospitals. Between 1976 and 1995, a concerted effort to increase organized resources within hospitals and align prehospital care has transformed into what we know today in the United States as the current trauma system. These systems coordinate the education, implementation, and transportation of out-of-hospital EMS systems with consolidated resources within specific centers to treat the injured patient immediately. Today, military medicine continues to be the leader in investigating and using topical hemostatic agents. What has been learned on the battlefield has certainly been the driving force behind the increased interest in the use of topical hemostatic agents in the prehospital setting.

## Table 1. Characteristics of an Ideal Hemostatic Agent<sup>a</sup>

Approved or cleared by the US Food and Drug Administration.

- Effective in stopping hemorrhaging (ie, hemostatic efficacy).
- No patient side effects (ie, burns, toxicity, allergic reactions).
- No responder side effects or risks.
- Simple, ready to apply and remove (with no residue) and reapply if necessary.
- Applied quickly to a number of different patients by provider.

Shelf-life (>2 years desirable).

Stable in multiple environmental conditions.

Inexpensive, small, with a low carry weight and easily stored.

Biodegradable and bio-absorbable.

<sup>a</sup> Modified from Pusateri et al<sup>15</sup> and Kheirabadi.<sup>9</sup>

## **Topical Hemostatic in the Prehospital Setting**

Topical hemostatic agents are gaining popularity for use in emergency bleeding control, especially in military medicine and now in civilian agencies responsible for providing prehospital trauma care.<sup>8</sup> Pusateri et al<sup>15</sup> and Kheirabadi<sup>9</sup> outlined several characteristics for the ideal hemostatic dressing for prehospital use: (1) able to stop large-vessel arterial and venous bleeding within 2 minutes; (2) ready to use and require no mixing or special preparation; (3) easy to apply by the wounded, another solider, or medic/emergency medical technician with minimal training; (4) lightweight and durable; (5) stable and functional at room temperature for at least 2 years and capable of withstanding extreme temperatures for several weeks; (6) safe for use and to not cause additional tissue damage; and (7) inexpensive (Table 1). Stuke<sup>16</sup> also added that the dressings should not wash away during rapid bleeding from high-flow vessels, but be easy to remove from the wound.

# Agent Description and Classification

Several types of topical hemostatic agents have been developed and marketed for the military and civilian use. They can be grouped into 3 classes by mechanism of action and into 2 forms of delivery. It should be noted that hemostatic products "do not tend to have 'generic' alternative names; one manufacturer's 'Chitosan' may behave differently from another's; they are marketed under trade names and care providers need to be familiar with these."<sup>8(p448)</sup> Many, if not all of the commercially available products have undergone multiple stages of development and generations, and all must be approved by the FDA before becoming available commercially.

Currently, hemostatic agents are available in 2 forms: granular powder poured onto a wound and embedded dressings introduced into a wound. These agents use 2 mechanisms to produce hemostasis: (1) physically adhering to damaged tissues in the wound and sealing injured vessels to prevent further blood loss (eg, chitosan dressing), and (2) accelerating and strengthening the clotting of blood present in the wound by incorporating into the developing clot and producing hemostasis. The second mechanism is often achieved as a result of 2 related reactions: (1) rapid absorption of water from blood in the wound which concentrates all clotting elements on the injured tissues, and (2) a chemical reaction that activates the intrinsic coagulation pathway and platelets and promotes clot formation. Therefore, the activity of these products depends on the intact coagulation function of patients. It should be noted that the majority of hemostatic agents, including those embedded in dressings, facilitate hemostasis through the second mechanism.

## **Classes of Action**

The 3 classes of action for topical hemostatic agents include (1) factor concentrators, (2) mucoadhesive agents, and (3) procoagulant supplementors.

Factor Concentrators. Factor concentrators "work through the rapid absorption of the water content of blood; they concentrate the cellular and protein components of the blood, and so promote clot formation".8(p448) An example of this includes zeolite granular. Zeolite is an inert volcanic mineral composed of oxides of silicon, aluminum, sodium, and magnesium, and small amounts of quartz.<sup>17</sup> When introduced into a wound the mineral rapidly absorbs water in an exothermic reaction due to its large surface area found in a small volume of material. Additionally, the mineral not only adsorbs water from the blood, trapping the water held within zeolite pores, it contains cations (Ca++) that act as a cofactor in many steps of the coagulation cascade. Together, the absorption of water and the addition of cations concentrate the cellular and large protein components of the blood, further catalyzing clot formation.<sup>18</sup>

Zeolite was sold under the trade name of QuikClot beginning in 2002<sup>19</sup> and was designed to be poured directly on the wound, but was found difficult to work with in many settings due to the granules being washed away by the blood or blowing away in the wind.<sup>19</sup> The QuikClot Zeolite Granular was replaced with the "beanbag" in an effort to address product concerns from the first generation. These products, including QuikClot ACS+, QuikClot 1st Response, QuikClot Sport, and QuikClot Sport Silver, solved the delivery and application problem by having the active ingredients inside a porous mesh bag.<sup>19</sup> This change in delivery allowed for cleaner application, the ability to apply direct pressure to the wound and dressing, and reduced the exothermic reaction produced. The third generation of QuikClot products uses a kaolin impregnated gauze, which activates factors in the blood, thus triggering the body's natural coagulation cascade and resulting in rapid coagulation.<sup>19</sup> Z-Medica now produces multiple lines of products, including items marketed specifically to EMS, the military, and directly to the consumer. See Table 2 for current commercially available products.

TraumaDEX (Medafor, Inc. Minneapolis, MN) is another example of a factor concentrator topical hemostatic agent. It uses microporous polysaccharide hemospheres from potato starch to promote hemostasis through a gelling action to concentrate natural clotting components.<sup>20</sup> This product does not produce an exothermic reaction when used like the

Class	Active Agent	Product Name	Manufacturer	Retail Price
Factor concentrators	Mineral zeolite	QuikClot ACS+, QuikClot 1st Response, QuikClot Sport, QuikClot Sport Silver	Z-Medica, Wallingford, CT (http://www.z- medica.com)	\$14.95 for one 25 gram QuikClot Sport sponge
	Kaolinite	QuikClot 2 $\times$ 2 and 4 $\times$ 4	Z-Medica, Wallingford, CT (http://www.z- medica.com)	\$35.99 for a 3-pack of 4 $ imes$ 4
	Micropourus polysaccharide particles	TraumaDEX	Medafor, Inc. Minneapolis, MN (www.medafor. com)	\$20 for 5 gram single application
Mucoadhesive agents	Poly-N-acetyl glucosamine	Celox	Medtrade Products Ltd, UK (http:// www.celoxmedical. com/usa)	\$20 for 35 gram single application
	Chitosan	HemCom Bandage PRO-Patch, 2" × 2", 2" × 4", 4" × 4"	HemCon Inc, Portland, OR (http://www. hemcon.com/ Products.aspx)	\$30.06 for one 2" $ imes$ 2" bandage
	Chitosan	HemCon ChitoGauze PRO, 3" $ imes$ 4 yd	HemCon Inc, Portland, OR (http://www. hemcon.com/ Products aspx)	\$45.59
	Proprietary algae- derived polysaccharide	Rapid Deployment Hemostat (RDH)	Marine Polymer Technologies Inc, Danvers, MA	NA
	Hydrophilic polymer and potassium ferrate	StatSeal	Biolife, Sarasota, FL	NA
Procoagulant supplementors	Kaolinite	QuikClot Combat Gauze	Z-Medica, Wallingford, CT (http://www.z- medica.com)	\$56.99 for one 3"W $ imes$ 36"L gauze
	Factor XIII, fibrinogen, thombin, and Ca <sup>+2</sup>	Dry Fibrin Sealant Dressing (DFSD)	American Red Cross and the US Military, Rockville, MD	Not commercially available

### Table 2. Topical Hemostatic Agents<sup>a</sup>

Abbreviation: NA, not available.

<sup>a</sup> Adapted from Granville-Chapman et al.<sup>8</sup>

original QuikClot. While TraumaDEX is considered safe and easy to use, it has not been utilized by US military forces because the product appears more effective with minor to moderate wounds, not the severe wounds seen in combat.<sup>20</sup> This product may have more uses in civilian settings.

The fourth and final factor concentrator we will review is a newer product with little to no identifiable scientific research. Responder (Starch Medical, San Jose, CA) is a topical hemostatic agent composed of AMP or an absorbable modified polymer. This polymer is derived from purified plant starch and is reported by the manufacture to be very hydrophilic, biocompatible, nonpyrogenic.<sup>21</sup> In the presence of uncontrollable bleeding, the polymer can be deployed

directly into the wound and dissolved with a water or saline rinse.

**Mucoadhesive Agents.** Mucoadhesvise agents work through a strong adherence to tissues and physically seal bleeding wounds.<sup>16,22</sup> Chitosan-based products, available from multiple manufactures, are examples of this type of agent. HemCon (HemCon Medical Technologies, Inc, Portland, OR) is one such agent and is available in various-sized bandages with an active chitosan-containing side and nonstick side to allow the prehospital emergency care provider to apply direct pressure. This dressing works best on flat, superficial wounds since the bandage can break when forced into a wound.<sup>16</sup> In response to limited use of the HemCon bandage, the manufacturers developed ChitFlex, which uses the same active ingredient as HemCon, chitosan, but in a flexible gauze strip to allow for the material to be packed into deeper wounds.<sup>16,22</sup> The use of HemCon has expanded outside military use to civilian emergency medical personnel and is one of the few topical hemostatic agents to have research published about its use outside of the military setting. This type of product shows promise for use, as it is easy to use, has a long shelf life, and is relatively inexpensive.<sup>20</sup>

Celox (Medtrade Products LTD, United Kingdom) is another chitosan-based preparation approved by the FDA. Responders in the prehospital setting may choose between the granular (ie, flake) preparation or an impregnated gauze (ie, bandage) preparation, depending on the size and type of the wound. When either delivery preparation makes contact with blood, the chitosan swells, gels, and sticks together to make a gel-like clot without generating an exothermic reaction.<sup>23</sup> When used with direct pressure (ie, 3 minutes for significant bleeding), the Celox only clots the blood it comes directly into contact with and does not set off the normal clotting cascade. This allows the product to work independently of blood clotting factors. Therefore, a patient on a blood thinner or who has lost a lot of blood may still be a candidate for the product.

**Procoagulant Supplementors.** Procoagulant supplementors function by delivering high concentrations of procoagulant factors to the bleeding wound. For example, dry fibrin sealant dressing (DFSD) incorporates highly purified human fibrinogen, thrombin, calcium, and coagulation factor XIII onto a polypropylene backing, thereby providing a high local concentration of coagulation factors.<sup>8,20</sup> This agent has not yet gained FDA approval, but has been reviewed, used in the military setting, and continues to be investigated in animal studies. While the research is currently favorable for the effectiveness of DFSD as a hemostatic agent, in its current form, the product has many limitations, including cost and delivery method.<sup>20</sup>

## **Clinical Evidence**

Most information about topical hemostatic agents has come from animal models and the military, and methodologies in these studies vary greatly.<sup>8,15,16</sup> Pusateri et al<sup>15</sup> presents one of the most comprehensive reviews of the literature on topical hemostatic agents. From their review, the authors recommended HemCon as the first hemostatic agent to be used in situations where bleeding can not be controlled with direct pressure or a tourniquet. QuikClot was recommended if HemCon was unavailable or failed, but it should be noted that only the first generation QuikClot product was available at the time of this article. The more recent review by Granville-Chapman et al<sup>8</sup> supports the conclusion of Pusateri et al, calling HemoCon and QuikClot (second-generation product at the time of this article) the "standards" for topical hemostatic agents.

In 2009, researchers from Israel investigated the use of QuikClot Combat Gauze during military conflict.<sup>24</sup> Medical personnel used QuikClot Combat Gauze and trained on its use prior to deployment. Data collection occurred during and after the operation through case reports and interviews with medical personnel and injured soldiers. During this conflict,

42 tourniquets and 14 hemostatic dressings were used on 35 soldiers. Most of the QuikClot Combat Gauze used was in areas a tourniquet could not be applied or after direct pressure failed to control bleeding. The success rate for use of the QuikClot Combat Gauze was reported as 79%.<sup>24</sup> In the 3 cases in which bleeding was not controlled, it was determined that the QuikClot Combat Gauze could not be applied directly to the source of the bleeding and that it was not the product that failed. No short-term complications or adverse effects were reported in any of the 14 cases. Ran et al<sup>24</sup> concluded that QuikClot Combat Gauze was an effective and safe product.

Wedmore et al<sup>25</sup> published one of the first reports on the effectiveness of the HemCon Bandage in the prehospital setting during Operation Iraqi Freedom and Operation Enduring Freedom. The retrospective study reviewed 64 case reports where HemCon was used in the field. In 66% of cases, the dressing was used after traditional gauze and pressure failed and was 100% successful in controlling bleeding. In 97% of the 64 cases, the use of the the HemCon Bandage resulted in cessation or improvement of bleeding. There were 2 reported failures that occurred in the 64 cases, which involved blind application of the bandage. The bandage was reported to be most useful on areas where tourniquets could not be applied to control bleeding (ie, neck, groin, face). The bandage was reported to be most difficult to use in extremity injuries where it could not be placed easily into the wound and the bandage had to be cut or torn to fit the wound. Wedmore et al<sup>25</sup> also reported that "in 12 extremity cases, the supervising physicians who eventually received these casualties felt the HemCon dressing may have been utilized 'overzealously' and that standard dressings alone may have been as effective as the \$90 bandage".<sup>25(p657)</sup> No complications were reported, and Wedmore et al<sup>25</sup> concluded that HemCon Bandages were beneficial for use in the prehospital military setting.

One recent study did investigate the effectiveness of the HemCon Bandage in the civilian EMS system.<sup>10</sup> The bandage was added to the trauma kits of a fire agency, and all medical personnel were trained on the use of the dressing via a multimedia presentation. Personnel at the receiving hospital were also trained on product removal. Over the course of 15 months, EMS personnel were asked to complete case report sheets each time a HemCon Bandage was used in the field, focusing on time to bleeding cessation, wound characteristics, and suspected bleeding type. Emergency Medical Services personnel were instructed to use the bandage after traditional methods to control bleeding had failed. During the course of the study, there were 37 uses of the HemCon Bandage, and complete data sheets were available for 34 cases. The bandage controlled hemorrhage in 79% of the 34 cases, 74% within 3 minutes of application. In 74% of the 34 cases, direct pressure initially failed to control bleeding, and the HemCon Bandage was effective in stopping bleeding in 76% of the 25 cases.<sup>10</sup> The HemCon Bandage failed to stop bleeding within 10 minutes in 7 cases. Brown et al attributed 6 of the 7 failures to user error. From their research, Brown et al concluded that the HemCon Bandage was beneficial in stopping uncontrolled bleeding in the civilian EMS setting when traditional methods such as direct pressure failed. The researchers did caution that the use of the HemCon Bandage by civilian EMS providers might be more appropriate in populations with a higher

incidence of penetrating trauma, which is supported by military studies on the product.<sup>25</sup> Proper training on the use of the bandage was also stressed because user error was a contributing factor in most of the documented failures in the study. Emergency Medical Service providers in this study identified similar issues using the bandage related to cutting and fitting the bandage into the wound as were identified by Wedmore et al.<sup>25</sup> Brown et al<sup>10</sup> reported that, when cases with user error are removed from the analysis, the success rate increases to 97%, which aligned with the results of Wedmore et al.

TraumaDEX has also been investigated outside of military and animal models, and positive results have led to the support of this topical hemostatic agent in the civilian setting.<sup>26</sup> In this study, 29 healthy subjects had 2 incisions  $(5 \times 1 \text{-mm-deep each})$  placed on their forearms. One incision was treated with TraumaDEX, and the other incision was the control site. Both incisions were treated with 30 seconds of gentle pressure after the application of the TraumDEX to the test site, and bleeding times were recorded. TraumaDEX was found to have an 84-second average time to hemostasis compared with 381 seconds for a nontreated control site. Bleeding time was decreased by 5 minutes with the use of TraumaDEX compared to the control site.<sup>26</sup> Additionally, 79% of the subjects had immediate cessation of bleeding on the treated site. Seven days post treatment, there was no difference in the scar between the treatment and control groups. There were also no adverse reactions to the use of TraumaEX reported in this study. Ereth et al<sup>26</sup> concluded that, because of TraumaDEX's improved bleeding times, low cost, and low risk, the product had "significant advantages over other hemostatic agents".

## Considerations for Use in the Prehospital Setting

Pusateri et al caution us "that a 'one-size-fits-all' approach may not be appropriate when considering hemostatic treatments, and the potential for harmful effects must be taken into account when making judicious decisions as to hemostatic agent use".<sup>15(p675)</sup> Each emergency situation varies, as does the location of the wound and structures involved (arteries, veins, or both). Different topical hemostatic agents have different indications and contraindications for use. Prehospital emergency care providers need to review product information before purchasing any type of hemostatic agent and may want to consider purchasing more than one type of agent to meet the potential needs of the organization.<sup>27</sup> Purchasers should also be cautioned that hemostatic agents do not have generic names and are marketed under trade names, so each company's products may work differently than another.<sup>8</sup>

The method of removing the agents at the time of surgery is also a consideration for selection and use for topical hemostatic agents. Most agents, such as all the QuikClot products, require removal prior to surgery. Currently, only rapid deployment hemostat (RDH) and dry fibrin sealant dressing (DFSD) do not require removal. For the study on HemCon use in the civilian setting conducted by Brown et al,<sup>10</sup> the receiving hospital was trained on the removal of the product prior to the start of the study.

The cost of various hemostatic agents is another consideration when selecting products. The price of different agents varies

greatly between products and distributors (Table 2). Brown et al<sup>10</sup> concluded that the price of HemCon is the greatest limiting factor to its use the civilian EMS system, while Ereth et al<sup>26</sup> reported that raw material and production costs lead to TraumaDEX costing considerably less than other topical hemostatic agents.

## Indications, Contraindications, and Precautions

**Indications.** Hemostatic agents are recommended for use during vascular injuries which cannot be controlled by direct manual pressure alone.<sup>8</sup> Their use is especially key when hemorrhaging occurs in areas not amenable to tourniquet placement, such as the inguinal and axilla regions, as well as the thorax and abdomen,<sup>8,12</sup> and over junctional hemorrhage.<sup>9</sup> While hemostatic agents are most often discussed in use in the military setting, Granville-Chapman et al<sup>8</sup> also suggest their use in mass casualty incidents and remote environments; both situations where transport to medical facilities may be delayed.

**Contraindications.** Contraindications vary based on the topical hemostatic agent and its main active ingredients; thus it is impossible to address all possible issues. In general, these products are not intended for internal (surgical) use, should not be used in the eyes, and are not indicated for use in the mouth according to the manufacturers of many of these products. For those agents containing chitosan (from shellfish), patients may need to be questioned about shellfish allergies.<sup>8,9</sup> For patients on coagulopathy, certain products, particularly those that rely solely on the blood-clotting activity of patients, may be less effective. Always refer to manufacturer directions for a list of contraindications and precautions.<sup>9</sup>

**Precautions.** Most topical hemostatic agents when applied still require 2–5 minutes of direct pressure to be effective, which was seen as a disadvantage in the military setting, but should be a nonissue working with the physically active population in the civilian setting. Other precautions vary based on the topical hemostatic agents and their main active ingredients. For example, with QuikClot, the old active ingredient was zeolite, which formed hydrogen bonds that generated heat. For large wounds, the amount of QuikClot required could generate so much heat that it can result in serious burns. In some cases, continuous blood loss may be preferable to burns caused by QuikClot.<sup>28</sup>

Thrombin is the main active ingredient in D-Stat Dry. In rare cases, patients may experience an allergic reaction to thrombin, which causes anemia. Some people experience swelling and rash at the site of application. Although there is no proven connection, some patients have complained of nausea and vomiting.

As stated by Pusateri et al,<sup>15</sup> topical hemostatic agents should be easy to use and require little training on the part of the prehospital emergency care responder. Prior to use in the field, all potential users of the products should familiarize themselves with all aspects of use. As stated above, some agents require 2–5 minutes of direct pressure to be effective.

The application of a tourniquet should also be considered prior to the use of any hemostatic agent. As discussed in Part 1 of this series, there is considerable evidence to support the use of tourniquets to control bleeding in the prehospital setting. Topical hemostatic agents can be applied in addition to the tourniquet if bleeding is still not controlled.

## EDUCATIONAL CONSIDERATIONS

## Equipment

Today, there are many different brands of topical hemostatic agent available in the marketplace (Table 2). Table 1 provides some of the ideal characteristics of topical hemostatic agents; however, all agents should be approved by the FDA prior to use in the sports medicine setting. Topical hemostatic agents should also have the ability to stop severe arterial and/or venous hemorrhaging (with additional direct pressure) within less than 2 minutes<sup>9</sup> while being used under a variety of conditions (low visibility, rain, wind, temperature) and should be effective on junctional wounds not amendable by tourniquet.<sup>9</sup>

Practicing the application of a topical hemostatic agent in the prehospital or educational setting requires very little equipment—normally just an agent/dressing and possibly an educational model. However, the cost of the agent/dressings can be very pricy (Table 2) for an activity that may be done once and then never used again. Thus, prior to any practice it may be advisable to determine if the use of such an agent is warranted and covered under state or service medical protocols.

## Preparing to Teach the Skill

Participant practice with topical hemostatic agents is recommended, as various types of agents may have unique features of operation. One challenge of teaching the concepts of hemostatic agents is that most institutional review boards will prohibit an ATE from inducing femoral lacerations in the classroom on live students. Even the use of porcine modules is going to require Institutional Animal Care and Use Committee permission and will likely be cost prohibitive; thus some form of simulation model is required. In Teaching Wound Care Management: A Model for the Budget Conscious Educator,<sup>29</sup> an innovative and cost-efficient means to educate athletic training students as to how to clean, close, and dress external wounds was addressed. Using this model approach, along with the concepts taught in Use of Advanced Bleeding Control Mechanisms in Athletic Training: A Shift in the Thought Process of Prehospital Care—Part 1: Tourniquets,<sup>2</sup> ATEs should be able to offer the students a meaningful experience in controlling severe, uncontrollable bleeding in the prehospital setting.

# **Model Preparation**

Begin by creating your wound care model following the directions from *Teaching Wound Care Management: A Model for the Budget Conscious Educator.*<sup>29</sup> Before securing the resistance band, consider placing an eye wash cup under the band to act as a reservoir for fluid. If you are not worried about making a mess, attach a length of the clear silicon tubing  $(1.5-1.8 \text{ m} \times 4.76 \text{ mm})$  to the limb with approximately .3–.6 m of extra tubing hanging distally. This extra length helps create some space between the instructor

and student. Using zip ties, secure the silicon tubing to the anatomical model. In either case, it may be necessary to wrap the anatomical model with plastic wrap used to secure an ice pack to a patient's body to keep the model from getting wet.

Provide some tension to the resistance band, but be sure the band is taut horizontally and vertically, but again not so taut that the elastic band pulls away from the anchor points or leaves gaping holes when an incision is made. Using 1-inch white athletic tape, secure the resistance band at the radiocarpal joint and proximal humerus and/or acromioclavicular joint and along the borders of the elastic band. Using a scalpel, carefully make an incision either over the eyecup or at the end of the silicon tubing. If using an eyecup, fill the cup with fluid. Be careful not to cut too deeply to avoid damaging the muscle model. If you find you have puckering of the band, it is probably too taut and needs to be loosened. The model is now ready to be used to teach how to use a hemostatic agent.

## **Teaching the Skills**

Using a 35-mL (or larger) syringe, water (colored red, if so desired), and towels to collect water, educators can now demonstrate severe bleeding. Attach the syringe to the distal end of the tubing or apply fluid to the eyecup. If using the tubing (our recommendation), depress the plunger to move the water through the tube. Do not depress the syringe plunger too quickly; this will cause the syringe and tubing to separate. From here, follow the skills steps for the application of a topical hemostatic agent found in Table 3.

In lieu of the use of an actual topical hemostatic agent, consider the use of commercial granular absorbent material or even saw dust (though this might be very messy). Many types of commercial absorbent materials can be found in the marketplace, most that are designed for the sanitary disposal of blood, vomit, urine, and other liquids. In this teaching example, a small prepackaged quantity of the absorbent material can be used to simulate the topical hemostatic agent. Be sure though to review the products material safety data sheet (MSDS) prior to using it in class.

# CONCLUSIONS

The use of topical hemostatic agents by athletic trainers is not always within our foundational education for a variety of reasons. Having the requisite training on a fundamental lifesaving skill is paramount given the likelihood of an athletic trainer being "first" on the scene of an emergency situation. In the presence of severe uncontrollable external hemorrhaging, where direct pressure and tourniquets fail and for areas where tourniquets are not amendable, consideration for the use of topical hemostatic agents is warranted. While the vast majority of the current research on topical hemostatic agents is limited to animal studies and the military, its use in the prehospital has value. Products such as HemCon and various generations of QuikClot products have been widely available and used in the military setting since 2003. As the next generation of topical hemostatic agents becomes more available, additional research needs to be conducted in the prehospital setting. As topical hemostatic agents come and go on the market, athletic trainers need to be cognizant of

Table 3. Using a Topical Hemostatic Agent in the Prehospital Setting

Step	Procedure
1.	Initiate body substance isolation procedures during patient care encounter, and activate the emergency action plan.
2.	Identify severe (massive) extremity bleeding.
3.	Attempt the application of direct pressure to control bleeding. Proceed to tourniquet application when the inability to quickly control bleeding is identified. Proceed to hemostatic agents when a tourniquet is contraindicated or the tourniquet is unable to control bleeding.
4.	Tear open the topical hemostatic device. <sup>a</sup>
5a.	If using roll gauze impregnated with the hemostatic agent, tightly pack the unraveled gauze directly into the bleeding site.
	Pack the remaining wound cavity with impregnated gauze or standard gauze.
5b.	If using a granular hemostatic agent, pour the contents of the package directly into the bleeding site. Pack the remaining wound cavity with standard gauze.
6.	Apply firm pressure directly to the wound for 3–5 minutes.
7.	Frequently reevaluate the injury site for active bleeding, increasing direct pressure as needed.
8.	Contact medical resources and advise of the application of a hemostatic agent; save the packaging to present to medical resources.

9 Expedite transport to an appropriate medical receiving facility.

<sup>a</sup> Always defer to the manufacture's recommendations for proper usage.

product changes. Finally, due to potential complications, education to include simulated application of these devices is necessary.

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