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REVIEW ARTICLE

Application of Current Hemorrhage Control Techniques for Backcountry Care: Part Two, Hemostatic Dressings and Other Adjuncts

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Decade-long advances in battlefield medicine have revolutionized the treatment of traumatic hemorrhage and have led to a significant reduction in mortality. Part one of this review covered the use of tourniquets on the extremities and the newer devices for use in junctional areas. Part two focuses on the use of hemostatic agents or dressings, pelvic binders, and tranexamic acid. Field applicable hemostatic dressings are safe and effective in controlling hemorrhage not amenable to extremity tourniquet application, and newer agents with increasing efficacy continue to be developed. Most of these agents are inexpensive and lightweight, making them ideal products for use in wilderness medicine. The use of pelvic binders to stabilize suspected pelvic fractures has gained new interest as these products are developed and refined, and the prehospital use of tranexamic acid, a potent antifibrinolytic, has been found to be life saving in patients at risk of death from severe hemorrhage. Recommendations are made for equipment and techniques for controlling hemorrhage in the wilderness setting.

Key words: hemorrhage, hemostasis, trauma, prehospital, hemostatic agents, topical, dressing, bandage

Introduction

This review is the second of a two-part article translating recent advances in military and prehospital medicine to wilderness medicine care. Part one focused primarily on tourniquets, both extremity and junctional. Part two now turns to hemostatic dressings for control of compressible hemorrhage. We round out the discussion of other hemorrhage control adjuncts by reviewing pelvic fracture stabilization as well as the prehospital use of tranexamic acid (TXA) to assist in treating casualties at risk of lethal hemorrhage.

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CASE PRESENTATION

A climber was descending from the summit by glissading when he noticed that he was uncontrollably veering into a set of rocks. A poorly executed attempt at self-arrest with an ice axe resulted in a severe laceration to the left side of his neck before he crashed into the rocks below. You arrive several minutes later and note a significant amount of blood loss with the climber desperately trying to control the active bleeding from his injury while complaining of severe pelvic pain. Because of the area of injury, a tourniquet could not be used so you take a hemostatic dressing from your kit and begin to pack the injury firmly and reinforce the wound with a pressure dressing. No resources were available for air evacuation and self-extrication is the only viable alternative.

Hemostatic Dressings

The last decade has witnessed a surge of products designed to manage severe bleeding in areas not amenable to tourniquet application or when a tourniquet might be deemed inappropriate. Collectively, these

products are termed hemostatic dressings, namely, gauze style dressings or powder or granular agents. However, despite a multitude of preclinical animal studies and numerous human case reports and series, no hemostatic dressing has emerged consistently as the best across all studies. In the prehospital phase, hemostatic dressings have the potential to reduce morbidity and mortality through the early control of hemorrhage. The ideal properties of a hemostatic agent for military use closely parallel those required for use in austere wilderness scenarios: lightweight, compact, simple to apply, durable under extreme conditions, long shelf life, inexpensive, safe, and effective.[1]

Two primary factors affect the efficacy of hemostatic products. The first is the mechanism of action. Some agents concentrate clotting factors at the site of injury, others form a mucoadhesive seal around the wound, and yet others are procoagulants that either activate the coagulation cascade or provide exogenous clotting factors to the injury site.[2] The second factor affecting efficacy is the form in which the agent is delivered: wafer, granule, or gauze. The ability to conform to the wound geometry is essential to efficacy. Some agents may not conform well to complex wound geometry if the injury has a significant soft tissue defect (cavitary) whereas others may not be placed easily into smaller penetrating wounds from gunshot wounds or impalements.

In 2003, the first hemostatic agents selected by the Committee on Tactical Combat Casualty Care (CoTCCC), an organization that forms the foundation of US military prehospital combat care, were the HemCon bandage and then QuikClot granules. Continued testing of newer products by both US Army and US Navy laboratories found that Combat Gauze, WoundStat, and Celox were consistently more effective than the previously selected hemostatic agents.[3–6] In 2008, Combat Gauze was selected as the first-line agent, with WoundStat recommended as the backup. However, subsequent animal safety studies showing extensive tissue inflammation, as well as embolization of the material in 1 subject, led to the removal of WoundStat from the CoTCCC guidelines.[7] More hemostatic dressings are in development and testing, with encouraging results.[8–14] Table 1 provides an overview of first, second, and third generation hemostatic products designed for prehospital application.

MECHANISMS OF ACTION

Agents that concentrate clotting factors work through the rapid absorption of the water content of blood. That leaves remaining coagulation proteins and platelets at the site of the wound. The archetype product is QuikClot, adopted by the US Navy as its initial hemostatic agent of choice. It is a granular zeolite mineral that absorbs water, but it generates an exothermic reaction that has caused some safety concerns.[15,16] A newer generation product with larger granules contained in small bags, Quikclot ACS+, does not lead to significant heat generation.[17] Both TraumaDEX and BleedArrest are granular products that contain mucopolysaccharide hemispheres that absorb plasma to concentrate clotting factors and form a gel around the wound site.[18]

Mucoadhesive agents (chitosans) react with blood and wounded tissue to form a gluelike substance that effectively seals, or tamponades, the wound. Chitosan refers to a series of polymers derived from crustacean chitin.[19] The hemostatic properties of chitosan appear to be formed by direct electrostatic interaction between negatively charged cell membranes of the erythrocytes and positively charged chitosan. These agents display strong adherence to tissues and physically seal bleeding wounds; hence, they act independently of the coagulation cascade.[20,21] The archetype product here is the HemCon bandage, adopted by the US Army as its first-line hemostatic agent. Another chitosan-based agent is granular Celox. Because the mucoadhesive barrier is a physical phenomenon, there is a theoretical danger of rebleeding if an originally hypotensive patient is resuscitated to normal blood pressure.[22]

Procoagulants either activate the coagulation cascade or supply clotting factors at the site of injury. Combat Gauze, the only agent in this class approved by the Food and Drug Administration (FDA), is impregnated with kaolin, which activates the intrinsic pathway of coagulation. Salmon thrombin-fibrinogen (STF) dressing is a proprietary mixture of lyophilized salmon thrombin and fibrinogen, which is layered onto a water-soluble dressing composed of dextran. The action of STF is similar to that of human thrombin and fibrinogen and is applied directly to the injured vessel. The dextran immediately goes into solution upon contact with water (ie, blood), allowing hydration of the thrombin and fibrinogen molecules, which leads to polymerization into a fibrin clot.[13,14,23] The FDA has not yet approved STF.

FORM FACTORS

The first hemostatic agents to be used by the US military had some undesirable properties that were not realized until utilized on the battlefield. The HemCon bandage was a rigid wafer difficult to adequately place in deep or smaller wounds. It could be cut with trauma shears, but even that made it difficult to apply.[24] Granular agents such as QuikClot and WoundStat also posed problems. For the surgeon cleaning the wound, they were difficult