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TACTICAL COMBAT CASUALTY CARE: TRANSITIONING BATTLEFIELD LESSONS LEARNED TO OTHER AUSTERE ENVIRONMENTS

Bleeding Control Using Hemostatic Dressings: Lessons Learned

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Based on lessons learned, many military battlefield trauma advances ultimately transition to enhance civilian trauma care. However, even with major strides to enhance battlefield hemorrhage control, it is unclear how effectively these techniques and products are being translated to civilian trauma. The purpose of this brief review is to present the evidence of current hemostatic product effectiveness, determine the evidence for transitioning of this technology to prehospital civilian application, and provide recommendations about potential use in the wilderness/austere setting. It is concluded that there is adequate evidence of hemorrhage control effectiveness in both military and civilian preclinical studies and clinical case series. The Committee on Tactical Combat Casualty Care recommends implementing approved hemostatic dressings as one part of a comprehensive hemorrhage control training and clinical management program. These recommendations for hemostatic dressings use by public safety and laypersons should be applied in acute transport urban settings or during prolonged care in austere environments.

Keywords: hemorrhage, hemostasis, hemostatic agents, topical, dressing, bandage

Introduction

Many historical advances in prehospital and operative care have occurred during wars and conflicts, with additional benefits when military lessons learned are transitioned to civilian medicine.[1,2] Since the beginning of the Afghanistan and Iraq military conflicts in 2001, many medical advances in military trauma care have been made to decrease morbidity and mortality based on more than 52,000 US combat casualties. Many of these clinical advances are being transitioned into the civilian sector—for example, external and internal hemorrhage control, coagulopathy, acidosis, and blood component therapy.[3–5]

Despite these recent advances, hemorrhage remains the leading cause of combat death and is the second leading cause of death after traumatic brain injury in the civilian sector.[3,6,7] Consequently, a vast amount of hemorrhage control research and development over the past 15 years has focused on controlling extremity hemorrhage because these wounds are potentially survivable.[3] Even civilian trauma epidemiology studies have concluded that early trauma deaths (from immediately on scene to 24 hours after) due to hemorrhage are regarded as potentially survivable, but only if adequate personnel and resources are immediately available.[6]

Research and development on topical hemostatic agents has rapidly expanded since 2000, and the majority of evidence supports their utility over plain gauze to control severe hemorrhage. In addition, great strides have been made in trauma-related awareness and education and training of all military personnel in the appropriate use of tourniquets and hemostatic dressings to control severe bleeding and prevent shock and death.[4,5] Hemostatic dressings are a valuable adjunct in external hemorrhage control when the source of bleeding is a location not amenable to tourniquet placement, such as in junctional regions (ie, neck, axilla, and groin).

Consequently, hemostatic agents and dressings have been implemented into Tactical Combat Casualty Care

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Table 1. First-, second-, and third-generation hemostatic products CoTCCC approved for battlefield use

Manufacturer	*Generation*	*Mechanism of action*	*Form*	*Application*
HemCon bandage, HemCon Medical Technologies, Portland, OR	1st	Cross links RBCs to form mucoadhesive barrier	4 × 4 inch wafer; 2 × 2 inch single-sided wafer	Placed firmly over wound, 3 min direct pressure
QuickClot granules, Z-Medica, Wallingford, CT	1st	Rapidly adsorbs water in an exothermic reaction to concentrate clotting factors	Granular zeolite (volcanic rock)	Pour deep into wound, pack standard gauze on top of granules, 3 min direct pressure
QuikClot combat gauze, Z-Medica, Wallingford, CT	2nd	Contact between kaolin and blood immediately initiates the clotting process by activating factor XII of the clotting cascade	Gauze impregnated with kaolin, an inorganic mineral	QuikClot comes in a variety of forms, including 4 × 4 dressings, trauma pads, rolled dressings, and Z-folded dressings
Celox gauze, MedTrade Products Ltd, Crew, United Kingdom	3rd	Cross-links RBCs to form mucoadhesive barrier	Chitosan rolled gauze Z-fold, 3 in × 10 ft	Packed into wound, 3 min direct pressure
ChitoGauze Pro, HemCon Medical Technologies, Portland, OR	3rd	Cross-links RBCs to form mucoadhesive barrier	Chitosan gauze Z-fold, 12 ft length	Packed into wound, 2–5 min direct pressure
XStat, RevMedx Inc, Wilsonville, OR	3rd	Cellulose sponges coated with chitosan to assist with a mucoadhesive barrier	92 flat, circular, compressed mini sponges packaged in a 60-mL syringe applicator	The applicator has a small diameter insertion device available for use in wounds with narrow wound tracts

RBCs, red blood cells.

(TCCC) Guidelines since 2003. Hemostatic dressings are only one item, along with pressure dressings, tourniquets, chest seals, and so forth, contained in the military individual first aid kit.[8] See Table 1 for an overview of first, second, and third generations of these approved hemostatic products. These products have contributed to the success in controlling extremity and compressible junctional hemorrhage in US and North Atlantic Treaty Organization military personnel.[9,10] Over the past decade, a number of reviews by authors from the United States and United Kingdom give greater detail on hemostatic agents and dressings used on the battlefield.[11–19]

As hemostatic product efficacy continues to evolve, there is limited information about how widespread combat casualty lessons learned for hemostatic dressings are disseminated in the civilian sector.[15] Thus, the purpose of this brief review is 1) to present the evidence of current hemostatic product effectiveness; 2) to determine the evidence for transitioning of this technology to prehospital civilian application; and 3) to provide recommendations about potential use in the wilderness/austere setting.

Mechanism of Injury (Combat/Civilian/Wilderness)

Traditional mechanisms of wounding historically have been different in combat and civilian settings. However, it should be appreciated that more than 53,000 civilians and military personnel were killed or injured by improvised explosive devices (IED) worldwide between 2011 and 2013. Trauma from penetrating fragmentation from explosive devices is becoming more common in developed countries, similar to what occurred in recent IED blasts in the civilian sectors (eg, at the Boston Marathon in 2014, in Paris in 2015, and elsewhere).[20] However, the best evidence from battlefield lessons learned regarding hemorrhage control should be applied similarly regardless of casualty incident location, barring any limitations on resources.

For the last 13 years of combat casualty care in Afghanistan and Iraq, the mechanism of injury has been penetrating in approximately 75% of casualties. The majority of these injuries are principally caused by fragmentation from IEDs (~74%), followed by gunshot wounds (~22%) and blunt trauma (~4%).[3]

Most combat deaths occur before the patient ever reaches a surgical team. The leading cause of mortality is hemorrhage (91%) from 3 key anatomic regions: truncal (67%), junctional (19%), and extremity (13%).[4,5]

In the civilian sector, the primary mechanism of injury resulting in morbidity and mortality is blunt trauma (78–89%), followed by penetrating trauma (11–22%). The proportion of the immediate to early deaths (50–60%) from either cause has remained unchanged, and death is primarily the result of traumatic brain injury or hemorrhage. Historically, these findings have been consistent over many decades.[6,7,21,22] However, in the wilderness setting, traumatic brain injury or multisystem trauma is the leading causes of morbidity and mortality for victims falling from height.[23–27]

The Evolution (2003–2016) and Effectiveness of Hemostatic Agents/Dressings

The history of the use by the Department of Defense of hemostatic agents and dressings for controlling major bleeding is presented by a several authors.[15,16,28,29] In brief, the initial 1996 TCCC Guidelines had no US Food and Drug Administration (FDA)-approved hemostatic agents applicable to battlefield (prehospital) care.[28] In subsequent hemostatic agent research, the objective was to develop an effective product to control major bleeding within minutes that was safe for the casualty and medic; easy to apply by medics or infantryman; lightweight, durable, and with a long shelf life; and inexpensive.[30] Eventually, by the 2003 TCCC guideline revision, a number of hemostatic products were reported to be efficacious to control massive bleeding in animal models.[31–35]

The 2 leading agents selected for use on battlefield casualties were the chitosan-based bandage HemCon (HemCon Medical Technologies, Portland, OR) and the zeolite powder QuikClot (Z-Medica, Wallingford, CT). Both products were deemed to be equally efficacious to control severe bleeding based on these initial preclinical studies, but no single agent was considered to be more advantageous at that time. However, based on reported observations by military surgical teams, first-, second-, and third-degree burns were observed in the surrounding tissues after use of QuikClot. A rapid exothermic reaction is produced when blood makes contact with QuikClot (zeolite) granules during application in soft tissue wounds and can result in burns.[36] Due to the adverse side effects of QuikClot granules, the Committee on Tactical Combat Casualty Care (CoTCCC) decided to designate the HemCon bandage as the initial hemostatic agent of choice.[8]

The CoTCCC conducted a review of the literature on hemostatic dressings for potential tactical medicine guideline revision. The CoTCCC received input from combat-experienced first responders and trauma surgeons in an effort to capture their experiences with both QuikClot and HemCon. In addition, a review of any new studies using animal models of efficacy was conducted. It should be noted that the CoTCCC did not select an obvious winner in terms of efficacy in the laboratory or effectiveness based on case reports or series. In the 2006 TCCC guideline revision, both HemCon bandages and QuikClot granules were recommended to be carried by all combatants on the battlefield, but QuikClot was to be used as a secondary agent if HemCon was not effective or was not available.[30,37]

After the 2006 TCCC guideline revision as published in the Prehospital Trauma Life Support manual, a series of new hemostatic agents/dressings were evaluated for efficacy at both the United States Army Institute of Surgical Research and at the Naval Medical Research Center. The results from both studies reported that 2 new agents/dressings, QuikClot Combat Gauze (Z-Medica) and WoundStat (TraumaCure, Bethesda, MD), were consistently more effective than the previously recommended TCCC agents (HemCon and QuikClot).[38,39] Consequently, the CoTCCC voted to recommend QuikClot Combat Gauze as the first-line treatment for life-threatening hemorrhage that is not amenable to tourniquet placement. WoundStat was recommended as the backup agent.[15] The primary reason for this order of priority was that medics and corpsmen expressed their preference for a gauze-type hemostatic agent because powders or granule agents do not work well in wounds in which the bleeding vessel is at the bottom of a narrow wound tract or in windy battlefield environments.[28] WoundStat, a granular agent, was later removed from the TCCC Guidelines as a backup agent to QuikClot Combat Gauze because of embolic, thrombotic, and tissue complications reported in subsequent animal testing.[40]

After April 2008 and until 2014, no formal review of newer hemostatic agents/dressings was conducted. New and consistent data from animal models of severe hemorrhage indicated that chitosan-based hemostatic gauze dressings developed for battlefield application are at least as effective as QuikClot Combat Gauze. Nine studies reported good efficacy and equivalence of chitosan-based gauze dressings with QuikClot Combat Gauze dressing in preclinical extremity arterial hemorrhage models,[41–49] as concluded in a formal review.[15]

Additional peer-reviewed studies report successful outcomes using newer chitosan-based dressings (Celox Gauze, MedTrade Products Ltd, Crew, UK) in civilian

hospital-based case reports[50–52] and prehospital (battlefield) case reports and series.[53,54] Furthermore, no complications or safety concerns have been noted in these cases or across many years of chitosan-based hemostatic dressing use (HemCon bandage and Celox granules) in either the military[55,56] or civilian prehospital sectors.[57] Based on the evidence-based literature review, the CoTCCC voted to add both Celox Gauze and ChitoGauze Pro (HemCon Medical Technologies, Portland, OR) to the TCCC Guidelines along with QuikClot Combat Gauze.[15] Because of its effectiveness and usability, QuikClot Combat Gauze has remained the primary hemostatic gauze of choice in the TCCC Guidelines since 2008.

A new FDA-approved hemostatic product called XStat (RevMedx, Wilsonville, OR) was added to the CoTCCC Guidelines in 2015.[58] The evidence for its effectiveness is based on preclinical animal wound model studies and product ease of use.[45,59,60] This unique product was developed to fill a gap in hemorrhage control in deep-tract or narrow-entrance wounds. This syringe device places nonabsorbable, expandable, hemostatic sponges designed for temporary internal use into junctional, noncompressible wounds, which are not amenable to tourniquet use to control bleeding. The mini sponges expand upon contact with blood to fill the wound cavity and provide a physical barrier and pressure that facilitates formation of a clot. The device consists of sterile, nonabsorbable, radiopaque; compressed sponges; and may include an applicator to facilitate delivery into a wound. It is a temporary device for up to 4 hours of use until surgical care is acquired. XStat is not indicated for use in the thorax, the abdomen, the retroperitoneal space, the sacral space above the inguinal ligament, or tissues above the clavicle. XStat is intended for use in the battlefield or civilian tactical medical environment for low- and high-velocity gunshot wounds. This device can be considered for use in wilderness medicine for accidents causing deep penetrations (eg, from wild animal attacks, during hunting with either a long rifle or bow and arrows, and other sources such as an ice axe penetration during self-rescue) and other causes of penetration from individuals falling from height.

The initial XStat study[45] reported testing this hemostatic device in a swine model of subclavian artery and vein bleeding created through a 4.5-cm wound. This model was selected because bleeding subclavian vessels are difficult to compress compared with the inguinal (junctional) area, which allows for more effective pressure when applying hemostatic gauze. There were 8 animals in the XStat study group and 8 in a control QuikClot Combat Gauze group. The mini sponges were applied within the 4-minute application time window. One QuikClot Combat Gauze and one Kerlix gauze were used to pack the wound in the control group. These dressings were applied with 3 minutes of direct pressure, as per the manufacturer's directions. At 60 minutes, survival was 100% (8 of 8) in the XStat group and 37.5% (3 of 8) in the QuikClot Combat Gauze group.[45]

A more recent study conducted by researchers at the Naval Medical Research Unit, San Antonio, compared XStat with QuikClot Combat Gauze in a large animal model of subclavian bleeding. They reported that XStat was applied in less time than QuikClot Combat Gauze (31 seconds vs 65 seconds) and resulted in less blood loss during the application time. With XStat, they reported 100% survival in subclavian vascular injuries, a wounding pattern that has been observed to be highly lethal in trauma patients.[59]

Hemostatic Agent/Dressing Best Practices

Among many commercially available hemostatic agents/dressings, only 3 are currently recommended for use. (See full TCCC Guidelines at http://www.naemt.org/education/TCCC/guidelines_curriculum.) The recommendation of these 3 hemostatic products is based on an extensive evidence-based review of the literature on hemostatic dressings that show equal effectiveness.[15,16] However, based on the past battlefield duration of use since 2008 and reported good success, the CoTCCC recommends QuikClot Combat Gauze as the hemostatic dressing of choice and Celox Gauze and ChitoGauze Pro as alternative dressings when QuikClot Combat Gauze is not available. See Table 2 for the TCCC recommendations for management of severe bleeding.[61]

Clinical Evidence for Civilian Application

To date, many gaps remain in high-level evidence (ie, randomized prospective clinical studies) on the effectiveness of hemostatic agents/dressings in both military and civilian studies. The clinical evidence from past and present generations of TCCC-approved hemostatic agents/dressings comes from only 9 peer-reviewed military and civilian case reports and case series (Table 3).[55,57,62–69]

The initial studies reporting clinical use of Gen 1 hemostatic agents published a case series using the HemCon bandage.[55,57] They reported a 97% and 74% success rate in controlling hemorrhage, respectively. Rhee et al reported the largest case series on the original QuikClot granule Gen 1 product.[62] Of the 103 cases reported, 83 were external (vice intracorporeal), and all first responder uses were successful. They reported 92% efficacy with QuikClot granules with frequent

Table 2. TCCC Guidelines for the management of bleeding*

Assess for unrecognized hemorrhage and control all sources of bleeding. If not already done, use a CoTCCC-recommended limb tourniquet to control life-threatening external hemorrhage that is anatomically amenable to tourniquet use or for any traumatic amputation. Apply directly to the skin 2–3 inches above the wound. If bleeding is not controlled with the first tourniquet, apply a second tourniquet side by side with the first.
For compressible hemorrhage not amenable to limb tourniquet use or as an adjunct to tourniquet removal, use QuikClot Combat Gauze as the CoTCCC hemostatic dressing of choice.
Alternative hemostatic adjuncts:

- Celox Gauze or
- ChitoGauze or
- XStat (Best for deep, narrow-tract junctional wounds)

- Hemostatic dressings should be applied with at least 3 minutes of direct pressure (optional for XStat). Each dressing works differently, so if one fails to control bleeding, it may be removed and a fresh dressing of the same type or a different type applied.
- If the bleeding site is amenable to use of a junctional tourniquet, immediately apply a CoTCCC-recommended junctional tourniquet. Do not delay application of the junctional tourniquet once it is ready for use. Apply hemostatic dressings with direct pressure if a junctional tourniquet is not available or while the junctional tourniquet is being readied for use.
- Reassess prior tourniquet application. Expose the wound and determine if a tourniquet is needed. If it is needed, replace any limb tourniquet placed over the uniform with one applied directly to the skin 2–3 inches above wound. Ensure that bleeding is stopped.
- When possible, a distal pulse should be checked. If bleeding persists or a distal pulse is still present, consider additional tightening of the tourniquet or the use of a second tourniquet side by side with the first to eliminate both bleeding and the distal pulse.
- Limb tourniquets and junctional tourniquets should be converted to hemostatic or pressure dressings as soon as possible if 3 criteria are met: the casualty is not in shock; it is possible to monitor the wound closely for bleeding; and the tourniquet is not being used to control bleeding from an amputated extremity. Every effort should be made to convert tourniquets in less than 2 hours if bleeding can be controlled with other means. Do not remove a tourniquet that has been in place more than 6 hours unless close monitoring and lab capability are available.
- Expose and clearly mark all tourniquet sites with the time of tourniquet application. Use an indelible marker.

* For full TCCC Guidelines, see http://www.naemt.org/education/TCCC/guidelines_curriculum.

complications of excessive heat and pain. The majority of the peer-reviewed case series are primarily with QuikClot Combat Gauze because this is the hemostatic gauze of choice since 2008. Two retrospective case series (n=14 cases) and (n = 122 cases) using QuikClot Combat Gauze in the Israel Defense Force personnel were based on multiple penetrating injuries caused by improvised explosive device or gunshot wounds in many anatomical regions per casualty.[63,66] They reported a range of 79% to 89% success rate to control hemorrhage, respectively.

In addition, good effectiveness was recently reported using QuikClot Combat Gauze in the civilian sector in both the United States and the United Kingdom when applied to injuries caused by blunt and penetration mechanisms. In 3 civilian peer-reviewed case series with 30, 95, and 125 patients, authors reported success rates of 73%, 95%, and 89%, respectively, in controlling severe bleeding in their patients.[64,65,68]

The only peer-reviewed case series using HemCon ChitoGauze Pro is based on a 2.5-year prospective study using ambulance calls in 2 Netherland-based emergency medical services.[67] They reported applying ChitoGauze dressing in 66 patients only after conventional treatment (gauze dressing with manual pressure) failed to control external traumatic bleeding or if conventional treatment was unlikely to achieve hemostasis based on injuries occurring in many different anatomical regions. ChitoGauze only failed to stop or minimize bleeding in 7 of 66 (10%) patients. They concluded that this is the largest prospective study of use of hemostatic dressings in civilian health care and the second largest case series in a prehospital setting; ChitoGauze was determined to be an effective and safe hemorrhage control adjunct in the prehospital.[67] To date, other than studies on military casualties, there are no civilian peer-reveiwed studies reporting the use of Celox Gauze.

Recommendation for Wilderness Medical Providers

Based on military lessons learned from over a decade of success in controlling severe bleeding, there is good

Table 3. Hemostatic agent and dressing peer-reviewed clinical case series, 2006–2016

Author	*Military or civilian*	*Study type/ Hemostatic dressing*	*Summary*
Leonard et al[68]	Civilian	Restrospective case series; 2nd Gen QuikClot Combat Gauze	Ninety-five patients were managed by prehospital personnel with a hemostatic dressing and/or tourniquet. Forty received QuikClot Combat Gauze, 61 tourniquet, and 6 both products. The median age was 40 years; 29% were female. QuikClot Combat Gauze was 89% effective. Minimal morbidity was associated with QuikClot use. CAT was 98% effective. Median tourniquet time was 21 minutes (6–142), the median ISS was 9 (1–50), and mortality was 9.8%. QuikClot Combat Gauze is a safe and effective adjunct for hemorrhage control in rural civilian trauma across a wide range of injury patterns.
Te Grotenhuis et al[67]	Civilian	Prospective case series; 3rd Gen ChitoGauze	Largest prospective study in civilian healthcare. Sixty-six patients were treated with ChitoGauze. Twenty-one patients were taking anticoagulants or had a clotting disorder. The injuries were located in the extremities (n = 29), the head and face (n = 29), or the neck, thorax, and groin (n = 8). ChitoGauze resulted in cessation of hemorrhage in 46/66 (70%) patients, ChitoGauze reduced hemorrhage in 13/66 (20%) patients and failed to control hemorrhage in 7/66 (10%) patients. No side effects have been observed during treatment. Authors demonstrated that ChitoGauze is an effective and safe adjunct in the prehospital treatment of massive hemorrhage.
Zietlow et al[65]	Civilian	Retrospective case series study; 2nd Gen QuikClot Combat Gauze	A total of 125 patients were treated with tourniquets and/or hemostatic gauze in the prehospital setting: 77 tourniquets were used for 73 patients and 62 hemostatic dressings were applied to 52 patients; 7 patients required both interventions. MOIs for hemostatic bandage use were blunt (50%) and penetrating (35%) trauma, and other MOIs (15%). Hemostatic bandage was applied to head and neck (50%), extremities (36%), and torso (14%); 95% success rate. Authors reported that civilian prehospital use of hemostatic gauze is feasible and effective at achieving hemostasis.
Shina et al[66]	Military	Retrospective case series study; 2nd Gen QuikClot Combat Gauze	In the study, 122 patients had 133 hemostatic dressings applied. Injury mechanism was penetrating in 104 (85.2%), blunt in 4 (3.3%), and combined in 14 (11.5%) patients. Thirty-three dressings (27.8%) were used for junctional hemorrhage control (pelvis, shoulder, axilla, buttocks, groin, neck), and 92 dressings (72.1%) were placed in nonjunctional areas. Nonjunctional dressings included 63 (47.4%) applied to the extremities, 14 (10.5%) to the back and 4 (3%) to the head. Hemostatic dressing application was reported as successful in 88.6% (31/35) of junctional hemorrhage applications and in 91.9% (57/62) of extremity hemorrhage applications. Authors concluded that hemostatic dressings seem to be an effective tool for junctional hemorrhage control and should be considered as a second-line treatment for extremity hemorrhage control at the point of injury.
Travers et al[64]	Civilian	Prospective case series; 2nd Gen QuikClot Combat Gauze	Physicians were asked to complete a specific questionnaire after each use of QuikClot Combat Gauze. Thirty hemostatic dressing uses were prospectively reported. The wounds were mostly caused by cold steel (n = 15) and were primarily cervicocephalic (n = 16), with 19/30 active arterial bleedings. For 26/30 uses, hemostatic dressing was justified by the lack of control from other hemostasis techniques; 30 applications were associated with 22 complete cessations of bleeding; 6 decreases of bleeding;

Table 3 (*continued*)

Author	*Military or civilian*	*Study type/ Hemostatic dressing*	*Summary*
			and ineffectiveness in 2 cases. The application of QuikClot Combat Gauze permitted the removal of an effective tourniquet that was applied initially for 3 patients. No side effects were reported for QuikClot Combat Gauze. Authors conclude that the provision of hemostatic dressings in civilian resuscitation ambulances was useful in providing an additional tool to limit bleeding.
Ran et al[63]	Military	Retrospective case series; 2nd Gen QuikClot Combat Gauze	Fourteen uses were reported and reviewed (out of a total of 56 hemostatic interventions in 35 cases). Hemostatic dressings were applied to injuries to the head, neck, axilla, buttocks, abdomen, back, and pelvis in 10 cases, and to extremities in 4 cases. In 13 cases (93%) the injuries were caused by blast or gunshot mechanisms. The success rate was 79% (11/14). Failure to control hemorrhage was reported in 3 cases in 3 different locations: neck, buttock, and thigh. All failures were attributed to severe soft tissue and vascular injuries. No complications or adverse events were reported.
Rhee et al[62]	Both	Self-reporting survey; 1st Gen QuikClot granules	A total of 103 cases of QuikClot granule (1st Gen) use: 69 by the US military in Iraq, 20 by civilian trauma surgeons, and 14 by civilian first responders. There were 83 cases involving application to external wounds and 20 cases of intracorporeal use by military and civilian surgeons. All field applications by first responders were successful in controlling hemorrhage. The overall efficacy rate was 92%.
Brown et al[57]	Civilian	Retrospective; 1st Gen HemCon bandage	Of 37 uses, complete data were available for 34 cases. Wound location involved the head, neck, or face in 13 subjects and extremities in 18 subjects. One case each involved the chest, abdomen, and axilla. The bandage was effective in 27/34 (79%) cases, 25/34 (74%) within 3 min of application. In 25/34 cases, direct pressure had initially failed to control bleeding, and the HemCon Bandage was effective in 19/25 (76%). The HemCon Bandage failed to stop bleeding within 10 min in 7 cases. The HemCon Bandage is an effective adjunct for uncontrolled external hemorrhage when traditional measures, such as pressure and gauze dressings, fail.
Wedmore et al[55]	Military	Retrospective Survey of use; 1st Gen HemCon bandage	Sixty-four case uses of the HemCon dressing were reported and reviewed by 2 US Army physicians for a total of 64 combat uses. Dressings were used externally on the chest, groin, buttock, and abdomen in 25 cases; on extremities in 35 cases; and on neck or facial wounds in 4 cases. In 66% of cases, dressings were used after gauze failure and were 100% successful. In 62 (97%) of the cases, the use of the HemCon dressing resulted in cessation of bleeding or improvement in hemostasis.

CAT, combat application tourniquet; ISS, injury severity score; MOIs, mechanisms of injury.

evidence, albeit limited data, from civilian studies to make recommendations for hemostatic dressing use in civilian emergency medical systems and austere environments. A recent noteworthy evidence-based review of hemorrhage control was put forth by the American College of Surgeons (ACS) Committee on Trauma, which advocates the use of tourniquets and hemostatic agents in the prehospital setting. See Table 4 for the 3 recommendations on hemostatic dressing use in the civilian sector.[69]

Table 4. Evidence-based prehospital guideline recommendations for hemostatic dressings[69]

Topical hemostatic agents
Recommendation 1
We suggest the use of topical hemostatic agents, in combination with direct pressure, for the control of significant hemorrhage in the prehospital setting in anatomic areas where tourniquets cannot be applied and where sustained direct pressure alone is ineffective or impractical.
Strength of Recommendation: Weak
Quality of Evidence: Low
Remarks: Although the evidence was low, data from animal models are consistent, suggesting reduced hemorrhage with these agents compared with standard gauze, and the committee believed that junctional hemorrhage and torso wounds may benefit from the combination of direct pressure and hemostatic dressings.
Recommendation 2
We suggest that topical hemostatic agents be delivered in a gauze format that supports wound packing.
Strength of Recommendation: Weak
Quality of Evidence: Low
Remarks: This recommendation was based on military experience and animal studies suggesting that products that allow packing of the wound have superior hemorrhage control.
Recommendation 3
Only products determined effective and safe in a standardized laboratory injury model should be used.
Strength of Recommendation: Weak
Quality of Evidence: Low
Remarks: The US Army Institute for Surgical Research has developed a standardized large animal model for comparison of hemostatic dressings. The committee believed that all new products should be subject to this testing.

Hemostatic dressings are now recommended for civilian first aid,[70] emergency medical services personnel, civilian tactical medicine,[71] and in wilderness medicine,[72] as well as the new course called Stop the Bleed, as hosted by the National Association of Emergency Medical Technicians (see http://www.naemt.org/about_ems/stop-the-bleed-campaign). This new course was recently developed based on TCCC Guidelines following an active shooter incident at a Connecticut elementary school. This is a nationwide federal government–based effort to educate and train laypersons to manage severe bleeding caused by either home or industrial accidents, blunt trauma, active shooter incidences, and other mass casualties.[73,74]

A hemorrhage control algorithm for backcountry use was previously published.[74,75] The following items are recommended for an individual hemorrhage control kit for use in austere environments: 2 rolls of gauze, 2 pressure dressings, 2 hemostatic dressings, and 2 tourniquets.[75] Both hemostatic dressings and tourniquets should be the same commercial products approved for use by the CoTCCC.[75,76]

Summary

Hemostatic agents and dressings for managing hemorrhage on the battlefield have evolved since 2003. The focus has been on developing more effective and safe hemostatic products and, through enhanced training, how best to use them. The majority of hemostatic studies are preclinical animal models; clinical studies have been very limited until recently. Consequently, the quality of evidence has been rated low, and any recommendation of use has been considered weak. However, larger case series are now being reported worldwide in the civilian prehospital setting with fairly high levels of success in controlling severe bleeding. Consequently, an expert panel convened by the ACS Committee on Trauma now recommends using the currently approved CoTCCC hemostatic products in civilian settings. This includes not only urban but also austere environments, as one part of a comprehensive program for managing severe bleeding.

Any program should begin with effective training, based on proven methods; in application of manual direct pressure; wound packing with plain gauze or hemostatic gauze; pressure dressing; and application of one or more tourniquets as needed. Future hemorrhage control research is needed in gap areas, including randomized control studies and ongoing evaluation of new products and devices for unique and challenging anatomical regions that are not amenable to tourniquet application (eg, groin, neck, face, scalp) and which can be equally used in military and civilian populations. Future technology will continue to yield innovations for controlling severe bleeding in austere or wilderness environments and will, in turn, prevent shock and death.

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