Although most extremity hemorrhage from trauma can be controlled with direct pressure and/or pressure dressings, the occasional uncontrolled hemorrhage can be life threatening. Tools that may be able to control such life-threatening extremity hemorrhage include hemostatic dressings, tourniquets, and several new devices that have recently become available. Hemostatic dressings, a relatively new concept, incorporate materials that increase coagulation into a dressing that is applied directly to the wound. Although the use of tourniquets has a long history, recent military conflicts have provided numerous studies that supported and refined their use. The novel extremity hemorrhage control devices effectively control bleeding in one of several ways: direct compression, arterial compression above the level of injury, and sealing the wounds’ edges, creating a hemoma. (Critical Care Nurse. 2016;36[1]:40-51)

Blood loss associated with traumatic extremity injuries (eg, open wounds, open fractures, amputations) quickly leads to hypovolemic shock and may be fatal if not rapidly controlled. The military’s experience in recent wars has demonstrated that early control of severe hemorrhage is critical and that extremity hemorrhage is a frequent cause of battlefield death.1,2 The consensus is growing about the use of some of these tools in civilian trauma.3,4 Some of the tools that the military has developed and used for traumatic extremity injuries are crossing over into civilian trauma care.

Basic Extremity Hemorrhage Control

Extremity hemorrhage may be controlled with direct pressure or a simple pressure dressing directly over the wound.5 However, the success of these methods is dictated by the amount of pressure and how long the pressure is exerted over the wound, which should be at least 5 to 10 minutes, the nature of the wound (large vs small, venous vs arterial, gaping vs puncture, simple vs amputation), and the hemodynamic stability of the patient. Various types of dressings made from differing materials have been used, from improvised dressings of whatever materials are at hand to sophisticated dressings used by emergency medical services (EMS) and military forces.6,9 Hemorrhage control using these methods is often successful when enough direct pressure is applied with the dressing, either manually, or in combination with pressure exerted by the bulk, composition, and tightness of the applied dressing. Hemorrhage from open fractures may also be treated with splinting (static or traction), in addition to direct pressure and/or pressure dressings. Partial or complete amputations often present unique challenges to hemorrhage control, but the same principles just described continue to apply.
If direct pressure and/or pressure dressings are not adequate to stop the hemorrhage, compression of an arterial pressure point proximal to the wound has been advocated, although no research has been done to support this technique of hemorrhage control. In addition, pressure point compression is ineffective in occluding distal flow. Continued digital pressure point pressure is difficult to maintain, for example, when a patient is being moved on a stretch or gurney. Other technologies have emerged to assist care providers in obtaining control of extremity wound hemorrhage, if direct pressure and pressure dressings are ineffective.

Hemostatic Dressings

Hemostatic dressings are dressings to which material has been added to enhance coagulation. All manufacturers recommend holding pressure on the wound for 2 to 5 minutes after the hemostatic dressings have been applied. Indications for use include bleeding that is uncontrolled with conventional methods and extremity wounds in areas that are not amenable to conventional dressings or tourniquets (e.g., groin or axillary wounds). Because of their ease of use and similarity to standard gauze dressings, these types of gauze hemostatic dressings have been compared with one another in research studies. The gauze bandages (QuikClot Gauze [also known as Combat Gauze; Z-Medica], Celox [Medtrade Products], Chitoflex [HemCon Medical Technology, Inc]) are impregnated with procoagulation materials but retain the characteristics of a standard gauze dressing. Currently, the US military uses Combat Gauze and the NATO nation forces use Celox gauze dressings. No one hemostatic dressing has been identified as consistently superior to the others in the laboratory or the clinical setting. Evaluation of QuikClot and Chitoflex precursors in actual hemorrhage indicated that they were effective in stopping bleeding or reducing the blood loss in 48 of 50 patients; they also were successful in controlling hemorrhage in 92% of 103 patients and were successful in stopping bleeding or improving hemostasis in 62 of 68 cases.

Table 1 Characteristics of the ideal hemostatic dressing for tactical applications

<table>
<thead>
<tr>
<th>Approved or cleared by the US Food and Drug Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stops severe arterial and/or venous bleeding in 2 minutes or less</td>
</tr>
<tr>
<td>No toxicity or side effect</td>
</tr>
<tr>
<td>Causes no pain or thermal injury</td>
</tr>
<tr>
<td>Poses no risk to medics</td>
</tr>
<tr>
<td>Ready to use and requires little or no training</td>
</tr>
<tr>
<td>Durable and lightweight</td>
</tr>
<tr>
<td>Flexible enough to fit complex wounds and is easily removed without leaving residues</td>
</tr>
<tr>
<td>Stable and functional at extreme temperatures (-10°C to +40°C) for at least 2 weeks</td>
</tr>
<tr>
<td>Practical and easy to use under austere conditions (low visibility, rain, wind, etc)</td>
</tr>
<tr>
<td>Effective on junctional wounds not amenable by tourniquet</td>
</tr>
<tr>
<td>Long shelf life (&gt; 2 years)</td>
</tr>
<tr>
<td>Inexpensive and cost-effective</td>
</tr>
<tr>
<td>Biodegradable and bioabsorbable</td>
</tr>
</tbody>
</table>

Owing to the continued interest and research in hemostatic dressings, the granule-based products have been supplanted by gauze-based dressings that incorporate some or all of the technology that was used to develop the granule-based products. In addition, the newer formulations of the dressings have eliminated the source of exothermic reactions that were a cause for concern with some of the granular products. Table 1 lists the ideal characteristics for hemostatic dressings.

QuikClot Gauze is a nonwoven gauze dressing that is coated with kaolin, an aluminum silicate that initiates coagulation by functioning as a surface activator when it comes in contact with blood. The dressing material (nonwoven rayon and polyester blend) combined with the kaolin promotes the formation of clots. In addition, kaolin activates the XII factor of the coagulation cascade and is dependent upon an adequately functioning coagulation cascade.

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resulting in profuse bleeding. In a review of the literature on QuikClot, Gegel et al concluded that published reports did not “conclusively demonstrate” that QuikClot was effective in stopping hemorrhage because the research reviewed focused on animal-based studies and lower level human studies. However, the most recent Tactical Combat Casualty Care guidelines recommend QuikClot for hemorrhage control when a tourniquet is not applicable.

Celox (Figure 1) is a gauze dressing that is impregnated with chitosan, a biodegradable compound derived from the shells of marine arthropods. When the positively charged chitosan comes into contact with the negatively charged red blood cells (RBCs) and platelets, a strong cross link is established that adheres strongly to the wound surface, sealing the wound with mucoadhesive activity. It is not dependent upon a functioning coagulation cascade to be effective. Chitoflex is another gauze dressing that is impregnated with chitosan and has a hemostatic cascade similar to that of Celox. Littlejohn et al noted that because of the mucoadherent properties of Chitoflex, the roll had a tendency to be adherent to itself when it came into contact with blood and recommended completely unrolling the roll before insertion. The animal and human studies done to evaluate hemostatic dressings are summarized in Tables 2 and 3, respectively.

Although kaolin is an inert material that is not absorbed into the body, Baldrick’s exhaustive review of the safety of chitosan noted that any chitosan absorbed is converted to naturally occurring glucosamine derivatives that are then used in the amino sugar pool or excreted. Given that chitosan is derived from the shells of marine arthropods, there is a reasonable concern about its interactions within the body. Waibel et al studied the possibility of allergic reactions to chitosan in patients with known allergies to shellfish and noted that no cases of allergic reactions in military personnel who were treated with this type of dressing and had a concurrent shellfish allergy have been reported.

Although a significant amount of research on the various hemostatic dressings has been done, Rall et al stated that “Despite their different compositions and sizes, the lack of clear superiority of any agent suggests that contemporary hemostatic dressing technology has potentially reached a plateau for efficacy.”

<table>
<thead>
<tr>
<th>Reference</th>
<th>Dressings evaluated</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causey et al</td>
<td>QuikClot vs standard gauze</td>
<td>Standard gauze failed 100% with first dressing and 83% with second dressing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QuikClot was 93% successful with first dressing and 100% successful with second dressing</td>
</tr>
<tr>
<td>Littlejohn et al</td>
<td>Celox vs QuikClot vs Chitoflex vs standard gauze</td>
<td>No significant differences between the dressings used in failure to achieve hemostasis, incidence of rebleeding, survival and mortality, and blood loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard gauze performed similarly to Celox, QuikClot, Chitoflex in all outcome measures</td>
</tr>
<tr>
<td>Sambasivan et al</td>
<td>Chitoflex vs standard gauze</td>
<td>No significant differences between Chitoflex and standard gauze in dressing failures, posttreatment blood loss, or fluid resuscitation requirements</td>
</tr>
<tr>
<td>Watters et al</td>
<td>QuikClot vs Celox vs standard gauze</td>
<td>No significant difference between QuikClot, Celox, and standard gauze in survival, dressing success, or total blood loss</td>
</tr>
<tr>
<td>Rall et al</td>
<td>QuikClot vs Celox vs Chitoflex</td>
<td>No significant difference between the 3 dressings in hemostasis or survival No significant differences in blood loss at 30 minutes and 150 minutes Blood loss at 10 minutes was significantly higher with QuikClot than with Celox ( P=.046 )</td>
</tr>
</tbody>
</table>
Dressings are used to control extremity hemorrhage, but another method of treating extremity wound hemorrhage has literally been around for centuries. Unfortunately, that time frame has allowed perpetuation of some myths that more current research has put to rest.

**Tourniquets**

Tourniquet use to stop extremity hemorrhage was described by the ancient Greeks. In the 18th century, Petit improved on an earlier screw design and is credited with coining the term “tourniquet,” from the French “to turn” (tourner). The use of tourniquets was decried by the physicians of both the Crimean (British) and American Civil wars. However, many of the complications that these physicians accredited to tourniquet application can actually be attributed to several other factors: (1) extended times from injury to initial physician evaluation (in many cases, up to days), (2) lack of a standardized tourniquet design (most were improvised), and (3) lack of knowledge regarding tourniquet application (inadequate pressure).

During World War I, physicians’ negative opinion of tourniquets continued, with both the British and French suggesting that a tourniquet be removed as soon as it is encountered, even though the patient may have been many hours from the time of injury. These admonitions had been gradually displaced by World War II; however, it was still thought that a tourniquet equaled amputation, despite the fact that tourniquets were recommended to be available for patients with known vascular injuries as they were being transferred. A seminal study of tourniquet application in more than 200 servicemen during World War II revealed no cases of gangrene attributable to the use of a tourniquet alone. In addition, they noted that not a single case of thromboembolic events, excessive edema, or skin or nerve damage was documented in these patients. World War II also heralded the shift from releasing the tourniquet every 30 minutes to allow collateral perfusion to leaving it in place until other means are available to stop the bleeding. The Korean War expanded on experiences from World War II and, in conjunction with improved vascular surgical techniques and rapid evacuation, provided more evidence that tourniquets were not inevitably linked to amputations. More current research regarding tourniquet use is summarized in Table 4.

Although many myths are associated with tourniquet use, research from the recent wars in both Iraq and Afghanistan show that tourniquets have few complications and are effective in both adults and children. The goal of care in using a tourniquet is simply to stop arterial bleeding distal to the application point where other methods are ineffective or not appropriate. The tourniquet should be wide enough (at least 2 inches [51 mm]) to compress the artery and stop the bleeding, without causing an inordinate amount of tissue damage from the compression. The wider the tourniquet, the less pressure is required to stop distal arterial blood flow. In addition, the tourniquet should be of an inelastic material, such as woven cloth, that will not stretch over time, thus decreasing the compression. A tightening mechanism that can be secured when the appropriate compression

---

**Table 3** Human studies that used hemostatic dressings

<table>
<thead>
<tr>
<th>Reference</th>
<th>Dressings evaluated</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trabottoni, et al</td>
<td>Standard dressings vs QuikClot</td>
<td>Mean (SD) time to hemostasis was significantly shorter with manual compression with QuikClot compared with manual compression with a standard dressing: 5.4 (1.5) vs 25 (15) min (P &lt; .001)</td>
</tr>
<tr>
<td>Ran et al</td>
<td>QuikClot</td>
<td>Eleven of 14 cases (79%) had hemorrhage successfully controlled with QuikClot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three failures were related to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aortic injury</td>
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<tr>
<td></td>
<td></td>
<td>Gluteal injury with femur and iliac wing fracture and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>penetrating rectal trauma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extensive degloving thigh injury</td>
</tr>
<tr>
<td>Tan and Bleeker</td>
<td>Celox</td>
<td>Six of 7 cases (86%) had hemorrhage successfully controlled with Celox</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One failure was related to hemorrhage from a skull fracture</td>
</tr>
<tr>
<td>Reference</td>
<td>Study scenario</td>
<td>Results</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dorlac et al&lt;sup&gt;33&lt;/sup&gt;</td>
<td>5½ years of data from 2 level I trauma centers in Houston Evaluated 14 patients who had positive vital signs in the field and arrived with cardiopulmonary resuscitation in progress</td>
<td>Eight of the 14 patients could have survived if they had been treated with tourniquets</td>
</tr>
<tr>
<td>Lakstein et al&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Evaluated 550 patients treated by Israeli Defense Force (IDF) for use of tourniquets from 1997 to 2001 Ninety-one patients had a total of 110 tourniquets applied</td>
<td>Fifty-eight tourniquets applied for appropriate situations (failure to control bleeding with bandaging, wound characteristics, tactical considerations) Tourniquets were effective in 78% Fifty-two tourniquets were placed when they were not indicated</td>
</tr>
<tr>
<td>Beekley et al&lt;sup&gt;34&lt;/sup&gt;</td>
<td>Evaluated 165 patients treated at the 31st Combat Support Hospital, Iraq, from January 1 to December 31, 2004 Admitted with traumatic amputation, major extremity vascular injury, or documented prehospital tourniquet placement</td>
<td>Of the 7 deaths without tourniquet application, 4 were potentially preventable with the effective use of tourniquets A total of 80 tourniquets were placed on 67 of the study’s patients No bleeding on arrival in 83.3% of the patients with tourniquets and 60.7% in patients without tourniquets (Fisher exact test, ( P = .03 )) With patients with an Injury Severity Score (ISS) greater than 15, no bleeding was noted on arrival in 85% of the patients with tourniquets and 17% of patients without tourniquets (( P &lt; .001 ))</td>
</tr>
<tr>
<td>Kragh et al&lt;sup&gt;35&lt;/sup&gt;</td>
<td>Evaluated tourniquet use in 1462 casualties treated from March 19 to October 4, 2006, at a combat support hospital in Baghdad, Iraq Two hundred thirty-two patients had 428 tourniquets applied to 309 injured limbs</td>
<td>415 (97%) applications of tourniquets were indicated by either medical or tactical situation One tourniquet was effective in 167 of 203 (82%) applications and 2 side by side tourniquets were effective in 97 of 106 (92%) applications</td>
</tr>
<tr>
<td>Kragh et al&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Evaluated tourniquet use in 1462 casualties treated from March 19 to October 4, 2006, at a combat support hospital in Baghdad, Iraq Two hundred thirty-two patients had 428 tourniquets applied to 309 injured limbs</td>
<td>Nine of 10 patients who were in shock when the tourniquet was applied died (90%) compared with 22 of 222 patients who were not in shock when the tourniquet was applied who died (10%); ( P &lt; .001 ) 22 of 194 patients with prehospital-applied tourniquets died (11% mortality) compared with 9 of 38 patients who died after tourniquet was applied in the emergency department (24% mortality) (( P = .05 )) In 5 patients in whom tourniquets were indicated but not used, the survival rate was 0% compared with 87% survival in patients who had tourniquets applied (( P &lt; .001 ))</td>
</tr>
<tr>
<td>Kragh et al&lt;sup&gt;37&lt;/sup&gt;</td>
<td>Further evaluated tourniquet use in 238 patients in the study above&lt;sup&gt;35&lt;/sup&gt; Evaluated an additional 267 patients in a combat support hospital in Baghdad, Iraq</td>
<td>Data regarding mechanism of injury, use site, survival rates, and morbidity rates were similar in both studies Survival was 99% when tourniquet was applied before shock compared with an 18% survival rate if the tourniquet was applied after the onset of shock Tourniquet use in absence of shock was associated with survival (( P &lt; .001 )) Tourniquet use in prehospital setting was associated with survival (( P = .02 ))</td>
</tr>
</tbody>
</table>

<sup>Continued</sup>
is reached is also important. A number of commercial tourniquets are available\(^4\) (see Figures 2 and 3). Although pneumatic tourniquets are available, one concern is that they are more likely to fail in austere environments, so the remainder of this section will apply to the more commonly used tourniquets shown in Figures 2 and 3.

Adequate training is essential to the successful placement of a tourniquet. Ideally, the tourniquet should be placed before enough blood has been lost for shock to occur, so recognition of when to place a tourniquet is important, as noted in the shift from A, B, C to <C> A, B, C to immediately stop uncontrolled hemorrhage.\(^4\)

The initial and primary use of a tourniquet may bypass the use of direct pressure and pressure dressings by providing the most effective hemorrhage control.\(^4\) The limb should have no clothing between the tourniquet and the skin because such clothing might allow the tourniquet to slip during movement of the patient.\(^3\)

Once the tourniquet is appropriately positioned, it is tightened until the arterial blood flow distal to the wound ceases and the distal pulse is no longer palpable. If the tourniquet is not tightened to the point of stopping the distal arterial flow, it will create a venous tourniquet effect, which allows arterial blood to perfuse the limb while preventing venous outflow and thus engorges the limb. This engorgement then leads to increased distal compartment pressure or expanding hematoma formation and the possible development of compartment syndrome and potential exsanguination.\(^4\)

In the rare situation where a correctly applied tourniquet does not stop the arterial blood flow from the wound, applying more compression to the tourniquet will more likely cause significant tissue damage without stopping the arterial blood flow distal to the wound. In this situation, a second tourniquet may be applied proximal to the first tourniquet.\(^6\)

Successful tourniquet use in a patient who is conscious will most likely cause marked pain. This pain does not indicate that the tourniquet is incorrectly applied or too tight. The pain must be treated appropriately and should not induce the health care provider to release the tourniquet. Once applied, the tourniquet is left in place and not loosened until a physician is available to assess its utility and effectiveness and definitively treat the source of the bleeding. Every time the patient is moved, the tourniquet should be reexamined to make

### Table 4

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study scenario</th>
<th>Results</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kragh et al(^3)</td>
<td>Evaluated tourniquet use in pediatric patients (4-17 years old) in both Iraq and Afghanistan from May 17, 2003, to December 29, 2009</td>
<td>Survival rate of 93%</td>
<td>None identified</td>
</tr>
<tr>
<td>Brodie et al(^3)</td>
<td>Evaluated tourniquet use in United Kingdom field hospitals in Iraq and Afghanistan from February 4, 2003, to September 30, 2007</td>
<td>Survival rate was 87% (61 of 70 patients)</td>
<td>One case of nerve palsy</td>
</tr>
</tbody>
</table>

**Note:** The table continues on the next page.
sure that it has not become loose. When a tourniquet is applied and when it is removed should be documented to help the physician understand how much time the tissue distal to the tourniquet was ischemic.41 One technique used in the prehospital setting is to use an indelible marker to place a “T” on the patient’s forehead with the time the tourniquet was applied.6 In addition, the tourniquet must be readily identifiable and should never be covered up by blankets or dressings.44 Although dressings and tourniquets are effective, there are some situations where a different approach may be appropriate, such as when the wound is over a compressible or junctional space.

**Novel Hemorrhage Control Devices**

Junctional (axilla, groin, neck) hemorrhages are especially difficult to control because of their unique anatomic locations that are too proximal to apply tourniquets, even though they are considered compressible spaces.40 Eastridge et al45 evaluated “potentially survivable” deaths, using data from the 2 recent conflicts (Iraq, Afghanistan), and reported that 19% of deaths evaluated were caused by this type of wound. In another study published in 2013, Kragh et al46 reported the rate to be 17%. Those authors further noted that no means of controlling such hemorrhage was available (at the time of their publication). However, several devices have recently become available to treat these potentially fatal wounds. All of these devices are used with a gauze or hemostatic dressing between the wound and the device. Kragh et al47 evaluated a number of these devices and reported that they all have similar effectiveness in stopping junctional bleeding and preventing blood loss in a mannequin model.

**Junctional Clamp**

The Combat Ready Clamp (Combat Medical Systems; Figure 4) provides direct pressure over a junctional wound. The effectiveness of the Combat Ready Clamp was demonstrated in a swine model of a femoral artery wound, where the authors reported that the device was effective in controlling hemorrhage.50 Both Doppler and computerized tomography revealed that once the device was applied, no arterial flow was visible distal to the device. As the device was approved by the Food and Drug Administration only in 2010, no data on the long-term effects of use of the device are available. Other devices also have been developed for treating junctional wounds.
Junctional Tourniquets

Unlike the Combat Ready Clamp, the various junctional tourniquets involve a belt that tightens around the area of the wound. Each device has a unique method of providing direct compression of the wound.

One such device is the Junctional Emergency Treatment Tool (North American Rescue; Figure 5). Using a perfused cadaver model, Gates et al\(^5\) reported that the Junctional Emergency Treatment Tool could be applied in 10 seconds and provided immediate occlusion of the common femoral artery. In addition, thanks to the compressive design of the device, it also acted as a pelvic binder, which could be helpful with concurrent pelvic fractures.

As with the Junctional Emergency Treatment Tool, the SAM Junctional Tourniquet (SAM Medical Products) includes a belt that is placed around the pelvis, but instead of using a T-handled screw, this tourniquet uses a target compression device that is inflated with the use of an attached hand pump (Figure 6). Davidson and colleagues\(^5\) used Doppler and perfusion imaging to study the effect of a SAM Junctional Tourniquet on 10 healthy volunteers. In 9 of the 10, the Doppler signal indicated that the posterior tibial artery was occluded. Pain was the limiting factor in the 1 patient where the Doppler signal was not occluded. During occlusion with the SAM Junctional Tourniquet, blood flow to the affected thigh and calf muscles was decreased by 65% to 75%, but moreso in the calf muscles. Even with the occlusion of the posterior tibial artery, perfusion imaging showed some residual muscle perfusion. A recently published report\(^5\) provided a case study with the first known use of a SAM Junctional Tourniquet for an inguinal junctional hemorrhage.

The abdominal aortic junctional tourniquet (Compression Works) is a belt-like device that is applied over the wound or arterial compression point (Figure 7). Lyon et al\(^5\) reported that blood flow through the common femoral artery was eliminated in 7 of 9 healthy volunteers and significantly reduced in the other 2. Taylor et al\(^5\) reported that blood flow through the common femoral artery was eliminated in 15 of 16 healthy volunteers. The one failure was in a volunteer who was above average weight, height, abdominal girth, and body mass index. A recent journal article\(^5\) described the first use of the abdominal aortic junctional tourniquet to treat junctional hemorrhage in the axilla.

As all of these devices are relatively new, not enough research has been done for one device to be

---

*Figure 5* The Junctional Emergency Treatment Tool comprises a belt that slips around the buttocks and is then cinched tight with the 2 base plates positioned over the wound or just caudal of the inguinal artery (a line between the anterior iliac crest and the symphysis pubis). The base plate is then stabilized and the threaded T-handle is rotated clockwise, tightening until the bleeding stops or the distal pulses are occluded. Each of the T-handles can then be secured with an attached toggle device.\(^5\)

Image courtesy of North American Rescue, Greer, South Carolina (used with permission).

*Figure 6* The SAM Junctional Tourniquet comprises a belt that is placed around the pelvis, but instead of using a T-handled screw, this tourniquet uses a target compression device that is inflated with the use of an attached hand pump. The belt is placed under the patient, with the target compression device positioned over the wound. The two ends of the belt are then connected by using a buckle. The brown strap handles are then pulled in opposite directions until an audible click is heard and the strap handles are secured with Velcro (hook and loop connectors). The target compression device is then inflated, using the attached hand pump, until the bleeding stops or the distal pulse is no longer palpable. A second device may be placed on the opposite side if necessary. This tourniquet is approved for use in the inguinal and axillary area and is the only device approved for use as a pelvic binder.\(^5\)

Image courtesy of SAM Medical Products, Wilsonville, Oregon (used with permission).
recommended over another. However, ongoing research may eventually winnow the field down to 1 or 2 devices.

**iTClamp**

A new device, the iTClamp (Innovative Trauma Care), provides an alternative to hemostatic dressings and other novel hemorrhage control devices in the extremities but also in junctional or compressible spaces such as the groin, axilla, and scalp (Figure 8). The initial study of the iTClamp’s effectiveness was completed on 2 cadavers that were perfused with pulsatile sterile water to simulate blood flow. Wounds were then made in multiple arteries of the thigh, groin, neck, arm, and scalp. One cadaver was used as a control, with no intervention, while the second cadaver’s wounds were closed with the iTClamp. When the fluid loss from the similar wounds was compared, the iTClamp significantly reduced the fluid loss from all wounds. In addition, movement of the cadaver did not cause any movement of the iTClamp.

One study has been published that compared the iTClamp with standard gauze and a control in a swine model of groin injury. Those researchers reported a statistically significant increase in survival when the iTClamp was used and a statistically significant decrease in external blood loss when an iTClamp was applied early compared with when gauze was used.

The first use of the iTClamp in the United States was recently documented. A 64-year-old man had a 7-inch-long (18 cm), 1-inch-deep (2.5 cm) chainsaw wound to the left upper arm. A medical flight crew responded to a referring hospital, where personnel were unable to control the bleeding from the patient’s wound. The medical flight crew applied 2 iTClamps and the bleeding was under control within 2 minutes (for photos of the wound and its treatment, see Clark).
Nursing Implications

The key message regarding extremity hemorrhage control is to stop the bleeding, using the simplest methods as soon as possible to prevent shock and the worsening of shock. Direct pressure and pressure dressings are the most common and effective tools in preventing extremity hemorrhage. However, in situations where these methods are not successful, having access to, and knowledge of, additional tools can potentially save lives. Although tertiary trauma centers may not use these devices, they are being used by EMS and may be encountered by nurses working in such centers. Nurses working in the prehospital environment may be required to use these devices and they may be beneficial in small rural health care facilities, which usually do not have extensive surgical capabilities. Therefore, nurses need to be aware of these devices and how they control hemorrhage. However, each of the technologies discussed in this article has its own particular issues.

Hemostatic Dressings

The current generation of hemostatic dressings are simply gauze with an added agent to increase coagulation at the wound. The most important concern regarding the use of these dressings is to ensure that the wound is not disturbed until the surgical capability to repair the damage is immediately available. Which type of dressing to use is unclear: multiple studies have shown the superiority of one type over another and other studies have shown no superiority of one over another. As Rall et al27 noted, it is possible that we have reached the theoretical limit of technology in these dressings. However, given their low cost and probable marked effectiveness, it makes intuitive sense to use them when necessary.

Tourniquets

A tourniquet should be applied in any situation where the health care provider determines that the patient is actively losing blood from an extremity wound, sometimes as the initial hemorrhage control method. The US military has adopted this strategy and provides both entry level and ongoing training regarding the use of tourniquets.41

Given the potential for complications related to tourniquet use, nurses must be provided with the training necessary to apply the tourniquet correctly and to monitor it while it is on the patient. It is imperative that the device not be released until the surgical capability to control the bleeding is immediately available. If the patient is awake, pain control related to the tourniquet will be a major concern, but pain control must be considered in the context of the patient’s entire injury pattern.

Novel Hemorrhage Control Devices

Although little research on these devices has been done, the design and potential effectiveness of these devices are intriguing. When the devices are used by either EMS or a health care facility, it is important for the nursing staff to be aware of the device’s potential use and that it may appear on a patient for whom they are providing care. It is especially incumbent upon the EMS agencies to notify their trauma centers when these devices are introduced into the prehospital setting. As with hemostatic dressings and tourniquets, it is imperative that the wound and devices are not disturbed until the surgical capability to repair the damage is immediately available.

Implications for Research

Given that the majority of research in this article is from combat simulations and situations, it is prudent to ask what relevance it has for civilian trauma care. When one looks back over the years, multiple instances of changes in trauma practice have come from prior military experience, starting with the advent of use of ambulances in the Napoleonic wars, progressing through the identification of DaNang lung (adult respiratory distress syndrome [ARDS]) from the Vietnam war, to the extremity wound care from the recent experiences in Iraq and Afghanistan.

War unfortunately provides an opportunity to evaluate trauma practice specifically because a large number of relatively healthy persons are traumatically injured and treated in a consistent, tiered trauma system. Fortunately, civilian trauma systems do not have to deal with the large numbers of trauma patients that our military colleagues are trained and equipped to handle. In addition, the number of civilian patients that would be needed to fulfill the statistical power to generate reliable data is, in the author’s view, insurmountable.

The key message regarding extremity hemorrhage control is to stop the bleeding, using the simplest methods as soon as possible.
Given those facts, we must be grateful to our military colleagues for providing us with data and research that can potentially be used to guide civilian trauma care. Although we may not have the health care organizational structure or access to the number of patients needed to do valid statistical comparisons, we can publish animal research and case studies that could provide further information about the wound care techniques described in this article.

Of the devices described in this article, the novel hemorrhage control devices have little animal or patient research to support their use. However, Filips et al recognized this deficit and suggested further research in jagged wounds, compared with hemostatic dressings, and in coagulopathic patients.

**Conclusion**

Wound extremity hemorrhage is often easily treated with direct pressure and pressure dressings. However, most seasoned trauma nurses have had the experience of dealing with a patient whose extremity hemorrhage was uncontrolled by these methods. Understanding how the myths regarding “old” technology, such as tourniquets, have been proven to be just that; how a standard dressing may be improved by the addition of a hemostatic agent; and how a new device may be used quickly and effectively may save a life.


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Control of Traumatic Extremity Hemorrhage
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