Treating Traumatic Bleeding in a Combat Setting

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Hemorrhage, which produces such terror in the bystanders . . . should never unnerve the surgeon, who requires all of his self possession . . . to cope successfully with this ebbing away of life.

J.J. Chisolm, Surgeon General, Confederate States of America[1]

Despite numerous technologic advances that have substantially changed the management of combat casualties in hospitals, the prehospital management of combat casualties remains remarkably similar to that during World War II. A number of recently recommended changes to prehospital combat casualty care are simply modifications of World War II era recommendations that were not followed. Even dry fibrin sealant dressing (DFSD), a new product still under investigation, had its origin in studies conducted during World War II.[2]

The first step in managing seriously wounded casualties is to control hemorrhage as much as possible. If ongoing hemorrhage is external, rapid, and potentially controllable, then hemorrhage control efforts take precedence even over airway management.[3,4] For seriously bleeding casualties, each drop of oxygen-carrying blood kept within the blood vessels may literally mean the difference between life and death.

In forward combat areas, the first approach for hemorrhage control continues to be direct pressure on the bleeding site. When possible, direct pressure is combined with elevation of the bleeding site above the level of the heart, and digital pressure is applied over a proximal arterial pressure point. Both of these methods lower the pressure at the point of bleeding. When performed correctly, these simple hemorrhage-control measures can stem significant hemorrhage, including arterial hemorrhage. Unfortunately, the circumstances of combat often make these basic control measures impossible to perform properly. Prolonged pressure is physically demanding and prevents the person providing it from engaging in other tasks.[5]

A useful field technique for maintaining sustained direct pressure on a bleeding wound is to place a sandbag inside a clean cover and place it directly over the pressure dressing on the wound. With this basic concept, BioHemostat (Hemodyne, Inc., Richmond, Virginia), a recently developed product, may help control serious hemorrhage while preserving some distal flow. This product combines a traditional pressure dressing with an attached bag containing a water-absorbing polymer that can rapidly absorb up to 140 times its weight in blood (or water). As the bag expands, it can apply significant direct pressure and produce a tourniquet-like force on the site of bleeding, while allowing collateral vessels to continue to perfuse distal parts.[6] The addition of a hemostatic agent such as fibrin or chitosan to this dressing could enhance its hemostatic properties.

Tourniquets have long been considered the last resort for catastrophic extremity hemorrhage.[7] Although properly applied tourniquets are clearly effective in controlling distal extremity hemorrhage, the liberal use of tourniquets traditionally has been discouraged because of their associated risks.[1,8] The use of tourniquets evolved during World War II as field experience with them was gained. Early in the war, it was noted that tourniquets were used too frequently and removed too often. In some cases, the official policy, which recommended periodic loosening of tourniquets, resulted in death through incremental exsanguination. This policy was reversed later in the war, such that, once a tourniquet had been applied, it was not to be loosened or removed until immediate control of hemorrhage and replacement of blood loss were possible.[9]

Since World War II, numerous studies have been performed to determine the maximal tourniquet time before irreversible tissue damage occurs.[10–21] The general conclusion is that, in most cases, a tourniquet can be left in place for 2 hours without causing permanent nerve or muscle damage. Most studies, however, noted that there is no completely safe tourniquet time. Almost all of those studies were performed with normovolemic patients undergoing elective orthopedic surgery. The extent to which the results of those studies can be applied to tourniquet use among hypotensive combat casualties is therefore unclear. Other factors that play a role in tourniquet-induced tissue injury are cuff inflation pressure and the tourniquet tissue pressure, i.e., the higher the tissue pressure, the shorter the time before permanent muscle and nerve injury occur.[21]

It was observed during World War II that the standard Army-issued tourniquet, a 1.5-inch-wide, cotton-strap tourniquet that is still issued today, was ineffective. The same observation was made after every war since World War II, including Operation Enduring Freedom in 2002 and Operation Iraqi Freedom in 2003.[22] During World War II, it was decided that 6 feet of 0.5-inch surgical rubber tubing was a better tourniquet. This was also the conclusion of a recent panel discussion regarding tourniquets that was sponsored by the U.S. Army Medical Research and Material Command, although concerns were raised about the high tissue pressures that can occur with application of this type of tourniquet.[23–26] The current recommendations regarding the use of tourniquets in forward areas, which include liberal tourniquet use in active combat and later reassessment and replacement as time and circumstances permit, are surprisingly similar to those made after the Korean War.[24,25,27]

In some desperate circumstances, such as a very proximal penetrating femoral artery or vein injury for which a tourniquet cannot be applied to control bleeding, it is tempting to try blind clamping of the bleeding vessels with a hemostat. Regardless of the circumstances, this technique cannot be recommended unless the end of the severed vessel can be clearly observed, which is rarely the case with proximal injuries.[28]

Fortunately, some new products that are available or in development may help control catastrophic hemorrhage among combat casualties when standard measures are ineffective. One new product that is in the final stages of U.S. Food and Drug Administration testing is the DFSD. The DFSD and other fibrin-containing products have been very effective in controlling hemorrhage among simulated combat casualties, but a complete field trial with the DFSD has not been performed.[29–38] Unfortu-

TABLE I

HEMOSTATIC DEVICES AND AGENTS USED TO CONTROL BLEEDING IN COMBAT SETTINGS

Device/Agent	Method of Action
Tourniquets	Direct pressure
BioHemostat	Water-absorbing polymer expands and produces direct pressure
DFSD	Fibrin slows blood loss
QuikClot	Granular zeolite concentrates clotting agents at site of injury
HemCon	Mucoadhesive action closes bleeding sites
rFVIIa	Initiates and amplifies clotting at wound sites

nately, this dressing is very expensive; therefore, it is unlikely to be used by basic combat medics, in whose hands it would have the greatest benefit.

A much less expensive hemostatic agent is QuikClot (Z-Medica, LLC, Newington, Connecticut). QuikClot is a granular zeolite that adsorbs water, creating significant heat of adsorption. When poured onto a bleeding site, QuikClot promotes clot formation by concentrating clotting agents. This product has been effective in controlling hemorrhage among simulated combat casualties, albeit at the risk of some iatrogenic burn injury, but it has not been scientifically tested in field use.[39] Initial reports regarding the efficacy of QuikClot during recent combat operations in Iraq were mostly negative when the product was used by combat medics/corpsmen.[40] However, military physicians with experience using the product reported successful hemorrhage control with QuikClot when other measures failed. This suggests that the apparent ineffectiveness of the product with prehospital personnel in Iraq was probably attributable to improper or insufficient training.

Although many other products have been marketed for combat hemorrhage control, one of the few shown to be effective in military laboratory testing is the HemCon hemostatic dressing (HemCom, Inc., Tigard, Oregon). HemCon is a moderately expensive, chitosan-based dressing that has a mucoadhesive activity that makes it ideal for consideration as a hemostatic agent.[40] Pusateri et al[41] demonstrated the effectiveness of this dressing in a swine severe injury model. Preliminary reports regarding the effectiveness of this dressing during recent combat operations in Afghanistan and Iraq were mixed but were mostly favorable.[42]

A product that holds promise for the control of catastrophic hemorrhage in combat operating rooms but that is unlikely to be used in prehospital settings, for several reasons, is recombinant activated Factor VII.[43-49] This factor is discussed in more detail by Maureane Hoffman in this supplement. Although the management of traumatic bleeding in combat settings presents unique challenges, the addition of new hemostatic products to standard techniques may improve control of catastrophic hemorrhage among combat casualties (Table I).

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