

Haemostatic dressings in prehospital care

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ABSTRACT

Massive haemorrhage still accounts for up to 40% of mortality after traumatic injury. The importance of limiting blood loss after injury in order to prevent its associated complications has led to rapid advances in the development of dressings for haemostatic control. Driven by recent military conflicts, there is increasing evidence to support their role in the civilian prehospital care environment. This review aims to summarise the key characteristics of the haemostatic dressings currently available on the market and provide an educational review of the published literature that supports their use. Medline and Embase were searched from start to January 2012. Other sources included both manufacturer and military publications. Agents not designed for use in prehospital care or that have been removed from the market due to significant safety concerns were excluded. The dressings reviewed have differing mechanisms of action. Mineral based dressings are potent activators of the intrinsic clotting cascade resulting in clot formation. Chitosan based dressings achieve haemostasis by adhering to damaged tissues and creating a physical barrier to further bleeding. Acetylated glucosamine dressings work via a combination of platelet and clotting cascade activation, agglutination of red blood cells and local vasoconstriction. Anecdotal reports strongly support the use of haemostatic dressings when bleeding cannot be controlled using pressure dressings alone; however, current research focuses on studies conducted using animal models. There is a paucity of published clinical literature that provides an evidence base for the use of one type of haemostatic dressing over another in humans.

INTRODUCTION

After traumatic injury, haemorrhage adversely affects patient outcomes and is the commonest cause of preventable death in this setting. Responsible for 30%–40% of trauma mortality, almost a half of these deaths will occur in the pre-hospital period.¹ In addition to contributing directly to early mortality, hypotension caused by blood loss is a major factor in the development of secondary brain injury² and bleeding exacerbates the acute coagulopathy that can occur as a primary response to trauma.³ Massive haemorrhage leads to inadequate tissue perfusion causing cell hypoxia and anaerobic respiration. The resultant metabolic acidosis impairs clotting and roughly a third of all trauma patients with bleeding will be coagulopathic on admission to hospital.⁴ Hypothermia also rapidly develops in haemorrhaging patients, especially those who are exposed for examination or who have decreased motor activity due to unconsciousness or sedation. Core body temperatures below 34°C lead to slowing of clotting enzyme activity and decreased

platelet function⁵ and survival of patients with core temperatures below 32°C is very rare without surgical intervention. These three factors, acidosis, coagulopathy and hypothermia, together form a lethal triad that is well known for its major role in trauma morbidity and mortality.³ Although there is little published literature describing the incidence of life threatening haemorrhage in the UK civilian population, it is recognised by The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) that effective and timely haemorrhage control may be the single most important step in the emergency management of the severely injured patient.⁶ In the military, acute haemorrhage is responsible for up to 80% of the mortality in patients with potentially survivable injuries.⁷ Recent advances have been made in the fields of resuscitation, massive transfusion and coagulation management; however, preventing blood loss before arrival at hospital could save more lives than any other intervention.⁸

Compressible haemorrhage can normally be stopped using constant, direct manual pressure; however, this prevents the care provider from continuing their management and can slow the delivery of the patient to definitive care. The pre-hospital application of tourniquets is associated with increased survival⁹ but many wounds are unsuitable for their use. Junctional zones, such as the neck, axilla and groin, contain large vascular structures and present a particular problem for haemorrhage control.¹⁰ Using gauze bandages to compress a bleeding wound has been the mainstay of haemorrhage control for many centuries. In the 21st century, there has been growing interest in field dressings that employ additional haemostatic mechanisms and are therefore more effective than gauze at preventing blood loss. Military campaigns in Iraq and Afghanistan have focused research efforts to develop products that act as an adjuvant to the body's normal blood clotting capacity. These novel dressings decrease prehospital blood loss, help to prevent the development of the lethal triad and decrease associated mortality. The purpose of this educational review is to summarise the literature on the main haemostatic agents that are currently available on the market for use in the prehospital environment.

METHODS

Electronic literature searches were undertaken using Medline and Embase (Ovid). To capture articles available online prior to publication, searches were repeated using PubMed, excluding Medline articles. The initial search for English language articles relating to haemostatic dressings included alternative spellings (such as haem or hem) and both combat and battlefield dressings. Article

abstracts were filtered for dressings that are used in prehospital care and that are currently available on the market. Agents found to be ineffective in preclinical traumatic haemorrhage models were excluded.^{11–14} Products that have already been withdrawn from the market after safety concerns, for example WoundStat,^{8, 15} and the first generation QuikClot (QC) granules^{16–18} have also been excluded from this article.

The following agents are included: QuikClot Advanced Clotting Sponge + (ACS+), QuikClot Combat Gauze (QCG), QuikClot Combat Gauze XL (QCX), HemCon ChitoFlex (HCF), HemCon ChitoGauze (HCG), Celox Gauze (CEL) and modified Rapid Deployment Haemostat (mRDH). Table 1 provides a comparison of their main characteristics and table 2 summarises the most recent published literature for each dressing.

ZEOLITE BASED DRESSINGS

QC agents have been used by military and civilian emergency medical services in the treatment of haemorrhage after trauma for over 10 years. The first and second generation products were based on a naturally occurring material called zeolite. These dry mineral granules rapidly absorbed the water in blood in an exothermic reaction, concentrating cells and clotting factors and leading to haemostasis. Repeated concerns were raised regarding the exothermic nature of this haemostatic process. Tissue surface temperatures after application of the agent exceeded 95°C and led to full and partial thickness cutaneous burns¹⁶ and there were several examples of patients receiving secondary injuries.^{17, 18} Despite being an effective haemostatic agent with a reported efficacy of 92% in 103 human cases,¹⁹ a second generation dressing was developed to address these safety concerns.

QuikClot ACS+

Although still zeolite material, the ACS+ was modified to yield a reduced exothermic reaction in contact with liquid²⁰ and packaged in a loose mesh bag to facilitate easy application and removal. ACS+ has been tested in five published studies since 2009.^{12, 13, 21–23} The first, using a swine 6 mm arteriotomy model, was stopped after six consecutive failures to achieve haemostasis.²¹ In two comparison studies of 10 different haemostatic dressings, in both arterial puncture and transection swine models, ACS+ performed better than standard gauze in controlling bleeding and improving survival.^{12, 13} In a further model with standardised injury to both femoral artery and vein, although overall survival and blood loss for ACS+ was significantly improved in comparison with an Army Field Dressing, three other haemostatic agents outperformed ACS+.²² The most recent published study using a model of complete transection of both femoral artery and vein demonstrated equal survival rates and similar blood loss when comparing standard gauze

dressing and ACS+.²³ The only published case of ACS+ being used in a patient describes a high velocity firearm injury leading to an acetabular and femoral neck fracture. The dressing failed to stop the haemorrhage, as it was unable to be applied directly to the source of the bleeding.¹⁹

KAOLIN BASED DRESSINGS

A third generation of dressings manufactured by QC use a different aluminium silicate mineral called kaolin. Kaolin is a potent activator of the intrinsic clotting pathway accelerating clot formation within a wound.

QuikClot Combat Gauze

Early testing by both the US Army's Institute of Surgical Research²⁴ and the US Navy Medical Research Centre^{12, 13} produced promising results (with either a prototype dressing called X-Sponge or QCG itself). Shortly after this, the US Committee on Tactical Combat Casualty Care voted to recommend QCG as the first line treatment for life-threatening haemorrhage not amenable to tourniquet placement. This replaced the QC zeolite granules and HemCon dressing that had previously been used. As a pro-coagulant rather than adhesive dressing, haemostasis is achieved when a clot is formed within and around the QCG. This takes time to achieve and can result in greater blood loss than other agents.^{25, 26} As a coagulopathy will eventually develop in patients who are exsanguinating³ and QCG is dependent on a functioning clotting cascade to achieve haemostasis, this scenario may limit its effectiveness although there have been no published case reports describing this. In a review of 14 uses of QCG by the Israel Defence Force in 2009 in the Gaza Strip, a success rate of 79% was reported with failures attributed only to severe soft tissue and vascular injuries.²⁷ The US Naval Medical Research Unit (NMRU) has however recently conducted a direct comparison of the most promising haemostatic gauzes with QCG, their current gold standard. When measuring time to initial haemostasis, total haemostasis time, blood loss, fluid requirements during resuscitation and overall survival, QCG was outperformed by three other dressings (QCX, CEL and HCG).²⁸

QuikClot Combat Gauze XL

QCX has been produced after some wounds were found to require two packs of the original QCG. It is 4" wide and folded in two to produce a two-ply gauze (in comparison with QCG that is 3" wide and single-ply only). In the same NMRU study, QCX excelled in two specific areas, immediate haemostasis and reduced total blood loss. Of particular note, however, was that the mass of QCX was nearly twice that of QCG. The observed performance differences may therefore have been due to the total mass of gauze applied rather than the greater quantities of active ingredients.²⁸

Table 1 Haemostatic agents

	Manufacturer	Active ingredient	Dressing type	Dressing size	Cost
QuikClot Advanced Clotting Sponge+	Z-Medica	Modified zeolite	Granules in mesh bag	3.5 oz sponge	£40
QuikClot Combat Gauze	Z-Medica	Kaolin	Z-fold gauze	7.5 cm×3.7 m	£35
QuikClot Combat Gauze XL	Z-Medica	Kaolin	Z-fold gauze	10 cm×3.7 m	£65*
HemCon ChitoFlex	HemCon Medical Technologies Inc	Chitosan	Gauze roll	7.5×71 cm	£193
HemCon ChitoGauze	HemCon Medical Technologies Inc	Chitosan	Z-fold gauze	7.5 cm×3.7 m	£35
Celox Gauze	MedTrade Products	Chitosan	Gauze roll	7.6 cm×3.0 m	£44
Modified rapid deployment haemostat	Marine Polymer Technologies, Inc	Poly-N-acetyl glucosamine	10 cm × 10 cm dressing	10 cm×10 cm	£658*

*Price converted from USA dollars into GB pounds

Table 2 Summary of recent studies

Agent	Study	Experimental or clinical	Additional agents compared	Key findings	Side effects/Safety concerns
QuikClot Advanced Clotting Sponge+ (ACS+)	Devlin <i>et al</i> ²³	Experimental	SD, HCF, CEL	▶ No significant difference between dressings or standard gauze for blood loss, rebleeding or survival	ACS+ was difficult to place in small incision
	Clay <i>et al</i> ²²	Experimental	SD, HC, WS, CX	▶ All haemostatic dressings significantly superior to standard field dressing	Nil
	Kheirabadi <i>et al</i> ²¹	Experimental	HC, WS, CX	▶ ACS+ removed more quickly and easily due to packaging in bag	Nil
	Arnaud <i>et al</i> ^{12, 13}	Experimental	SD, WS, CX, QCG, HCF, HC	▶ Treatment with ACS+ failed to produce haemostasis in six consecutive experiments therefore removed from testing ▶ ACS+ in top four best performing dressings (in addition to CX and HCG) as determined by survival, lower blood loss and rebleeding ▶ This finding was replicated in both transection and puncture study models	Nil
QuikClot Combat Gauze (QCG)	Rall ²⁸	Experimental	QCX, CEL, HCG	▶ QCG outperformed by three other dressings. Significant difference in time to initial haemostasis (compared with QCX) and blood loss (compared with QCX and CEL)	Nil
	Schwartz <i>et al</i> ²⁵	Experimental	HCG	▶ Greater total blood loss and longer time to initial haemostasis in QCG group compared with HCG (not significant)	Nil
	Littlejohn <i>et al</i> ²⁶	Experimental	SD, WS, HCF, CX	▶ QCG did not outperform other agents in this study ▶ Proper wound packing and pressure reported to be as important as use of haemostatic agent	Nil
	Ran <i>et al</i> ²⁷	Clinical		▶ Success rate of 79% in use during 14 cases (13 were gunshot or blast). Failures attributed to severe soft tissue and vascular injury	Nil
	Kheirabadi <i>et al</i> ³⁹	Experimental	SD, WS	▶ Safety evaluation of new haemostatic agents QCG and WS ▶ QCG comparative with normal gauze with no safety concerns ▶ Significant safety concerns for WS	Nil
	Arnaud <i>et al</i> ^{12, 13}	Experimental	SD, WS, CX, ACS+, HCF, HC	▶ QCG in top four best performing dressings (in addition to CX and ACS+) as determined by survival, lower blood loss and rebleeding ▶ This finding was replicated in both transection and puncture study models	Nil
QuikClot Combat Gauze XL (QCX)	Rall ²⁸	Experimental	QCX, CEL, HCG	▶ QCX had significantly better rate of immediate haemostasis and reduced total blood loss compared with QCG. This may however have been secondary to the larger dressing size	Large dressing took on average 15 s longer to pack wound
HemCon ChitoFlex (HCF)	Devlin <i>et al</i> ²³	Experimental	SD, ACS+, CEL	▶ HCF performed equally well in mitigating blood loss and promoting survival in comparison with other dressings ▶ No agents were superior to SD in this model of limited access	Nil
	Littlejohn <i>et al</i> ²⁶	Experimental	SD, WS, QCG, CX	▶ Rebleeding in HCF group occurred at twice rate of others but no statistically significant difference in any end points between groups ▶ If HCF not unrolled completely prior to insertion, it became 'glued' together on contact with blood	HCF had to be folded multiple times to be made small enough to treat limited access wound
HemCon ChitoGauze(HCG)	Rall <i>et al</i> ²⁸	Experimental	QCG, QCX, CEL	▶ Outperformed QCG throughout ▶ No significant difference in end points of initial haemostasis, blood loss and survival compared with QCX and CEL	Nil
	Schwartz <i>et al</i> ²⁵	Experimental	QCG	▶ Less total blood loss and quicker time to haemostasis than QCG although not statistically significant	Nil
	Xie <i>et al</i> ³¹	Experimental	QCG	▶ Less total blood loss and quicker time to haemostasis than QCG although not statistically significant	Nil
Celox Gauze (CEL)*	Rall ²⁸	Experimental	QCG, QCX, HCG	▶ Significantly less blood shed at 10 min compared with QCG ▶ Outperformed other dressings with 90% survival ▶ Second longest wound packing time	Nil
	Watters <i>et al</i> ³⁵	Experimental	SD, QCG	▶ No statistical difference in performance between CEL and SD although manufacturer's recommendations not followed in this model and no compression used after dressing applied to wound	Nil
	Milner <i>et al</i> ³⁴	Experimental	Omni-Stat	▶ Achieved haemostasis in a model of moderate systemic heparinisation	Nil
Modified rapid deployment haemostat (mRDH)	King ³⁷	Clinical	mRDH	▶ Effective haemostat for controlling bleeding within a hospital setting	Rebleeding may occur on dressing removal
	King <i>et al</i> ³⁸	Clinical	mRDH	▶ Successful haemostasis in 82% of cases in a variety of injury types including both trauma and surgical causes	

*Many more studies exist that test Celox Granules, and only those testing Celox Gauze have been included here.

CX, Celox granules, HC, HemCon Dressing, QCG, QuikClot Combat Gauze; SD, standard gauze/dressing; WS, WoundStat.

CHITOSAN BASED DRESSINGS

Chitosan is a naturally occurring biodegradable polysaccharide derived from shellfish such as shrimp. When incorporated into a dressing, it is able to achieve haemostasis by attracting red blood cells into the bandage creating an adherent seal over the

wound. In 2002, a chitosan bandage called HemCon was introduced into the military for use in the treatment of external haemorrhage after being found effective in reducing blood loss and improving survival in a model of severe venous haemorrhage and hepatic injury in swine.²⁹ To work effectively, the

dressings has to be placed directly onto the bleeding wound in order to allow adhesion. A relatively stiff plastic backing restricted its use in many wound types and led to the development of more flexible alternatives.

ChitoFlex

Improved products are now available that are thinner and conform more easily to wounds. Developed in 2006, HCF is a dual sided chitosan roll that was shown to outperform both the original HemCon bandage and chitosan granules in achieving haemostasis in a lethal groin injury model.³⁰ Despite the new dressing being more flexible, additional studies have shown no significant superiority in the efficacy of HCF compared with alternative dressings.^{12 13 23 26}

ChitoGauze

The HCG dressing is a non-woven medical gauze coated with a uniform layer of chitosan. Relatively new, it is manufactured by HemCon Medical Technologies Inc. and stops bleeding by controlling the rate of blood flow through the dressing. The chitosan coating also helps to adhere the gauze to the wound site creating a physical barrier to continued bleeding. Two studies using an arterial haemorrhage swine model have compared HCG with QCG. The sample sizes were too small to demonstrate statistically significant differences between the two; however in the first, the mean time to haemostasis was 12 min in the HCG group compared with 38 min in the QCG group.³¹ This was replicated in a second study with 13 and 32 min to achieve haemostasis, respectively.²⁵ In both studies, total blood loss in the HCG group was lower than the QCG group.^{25 31} The NMRU study used HCG as one of its test agents. HCG required the smallest volume of fluids for resuscitation, outperformed QCG on almost all criteria and showed no significant difference in haemostasis or blood loss to GCX or CEL.²⁸

Celox Gauze

Celox has been available for the treatment of emergency bleeding since 2006. Available in both a granular and bandage form, its active ingredient is the natural polymer chitosan. It works independently of the body's clotting mechanism, bonding to the surface of red blood cells to produce a gel like plug or clot. In the comparison by Arnaud *et al* of 10 different haemostatic dressings using both a groin transection and groin puncture model, Celox granules were rated among the four highest performing dressings.^{12 13} It has also been used successfully in the clinical setting. A series of cases describes the use of Celox granules in 21 military patients with gunshot wounds. In 18, clotting occurred in less than a minute. Three required further applications of Celox granules to control severe arterial bleeding but no failures were described.³² In its granular form, Celox is a light powder and is said to be more difficult to apply in the field, especially in windy or low-visibility conditions.⁸ It is also available, however, in a syringe-like applicator that is designed to deliver the agent directly to the deepest part of a small penetrating wound.

Celox granules have also been bonded to the surface of a gauze roll. This alternative CEL dressing is used by the UK military as its haemostatic agent of choice. Four published studies have compared CEL with alternative agents. The first tested CEL against HemCon and QC granules in a mixed venous and arterial haemorrhage model. CEL reduced rebleeding to 0% and improved survival to 100% outperforming the other agents.³³ The second used a major hepatic injury model in

heparinised swine. In the CEL group, haemostasis was achieved in five of six applications after 5 min pressure and in the sixth after a further 2 min of pressure. This was despite the addition of a significant amount of heparin to the model to make it more challenging.³⁴ The third used a model designed to simulate a care under fire scenario. Once the dressings had been applied, no additional compression was applied. There was no significant difference in survival, dressing success or total blood loss between the three agents used.³⁵ All of the dressing manufacturers recommend a period of compression immediately after dressing application and pressure is one of the first steps in the first aid control of any haemorrhage. It is therefore difficult to use this study in direct comparison with other studies that have demonstrated superior haemostasis with advanced haemostatic agents when applied according to the manufacturers' recommendations.³⁵ In the recent NMRU study, CEL was compared with the current US gold standard QCG. CEL prevented visible bleeding from the wound for the longest period of time and had the highest observed survival rate.²⁸ Like QCG, however, the dressing is almost twice the weight of QCG and HCG and takes longer to pack into a wound. The study was not designed to differentiate between performance differences that were secondary to a higher dressing mass rather than difference in dressing type or weight of active ingredient.

MODIFIED RAPID DEPLOYMENT HAEMOSTAT

The mRDH dressing is manufactured using fully acetylated poly-N-acetyl-glucosamine as its active ingredient. Its mechanism of action is thought to be via activation of platelets and the coagulation cascade, local vasoconstriction and agglutination of red blood cells. The original rapid deployment haemostat was shown to be ineffective at controlling severe bleeding;⁸ however, the modified version, with a greater proportion of active ingredient, has been demonstrated to be effective in both venous and arterial haemorrhage and in coagulopathic patients.³⁶ A case series describes the use of mRDH during combat operations in Iraq. Complete haemostasis was achieved in 14 of 19 wounds although rebleeding occurred in three cases on dressing removal.³⁷ The mRDH bandage was also used to control bleeding in a prospective observational study of 106 trauma victims. Wounds varied widely and the bandage was used at the discretion of the physician; however, haemorrhage was successfully controlled in 82% of patients.³⁸ Both of these reports focus on the use of mRDH in a hospital setting and in several instances multiple dressings were required to control the bleeding. As the most expensive dressing included in this review, unless reduced, cost may preclude its widespread use in a civilian prehospital setting. Recent comparative studies of alternative haemostatic agents have also not included the mRDH bandage making it difficult to directly compare their relative efficacies.

SAFETY

All of the haemostatic agents described above are classed as medical devices and have received regulatory approval for marketing. This means they are not required to undergo testing to the same extent as pharmaceutical products prior to clinical use. Several safety concerns have been raised over previous haemostatic products. These have included the risk of secondary burns from the original zeolite QC granules,¹⁶ and the potential for endothelial injury and distal thrombosis with WoundStat granules.³⁹ WoundStat is an aluminium phyllosilicate clay material that activates the intrinsic clotting cascade in the same way as kaolin, the active ingredient in QCG. Despite

having a similar mechanism of action to WoundStat, the safety of QCG is comparable with standard gauze.⁸ Chitosan based products have had a long history of use in humans, both during surgery and in the prehospital environment, without any reported safety concerns. No side effects or adverse events have been described in three case series reports of experience with chitosan products.^{32 40 41} As chitosan is derived from shellfish, patients with known shellfish allergies underwent challenges with both chitosan powder and bandages. No patients reacted adversely demonstrating that the product is safe in these subjects.⁴²

THE IDEAL HAEMOSTATIC AGENT

No single dressing matches all of the characteristics that Kheirabadi describes an ideal haemostatic agent having (see box).⁸ Although aimed at tactical use, the properties apply in equal measure to a civilian prehospital environment. Material form impacts on a dressing's ease of use, ease of removal and flexibility when fitting complex wounds. Granular products that are poured into a wound may not be as effective as those applied through an applicator as they are more difficult to place on the point of bleeding.²⁶ They tend to stick to wounds making removal harder and have the added risk of thrombo-emboli forming from loose granules that penetrate into the vascular lumen.²⁷ Lengthier gauze dressings take longer to pack into a wound and will therefore delay the onset of firm pressure and potentially the onset of haemostasis. The thicker chitosan dressings such as HCF have been found to stick together when in contact with blood outside the wound.²⁶

Dressings must be relatively inexpensive and cost effective. Off the shelf prices of dressings currently available on the market vary between £35 and £658 for each individual dressing pack (see table 1). Catastrophic haemorrhage is thankfully a relatively rare event in civilian emergency medical services in the UK making a long shelf life crucial. Both the chitosan and mineral based dressings described have a shelf life of 3 years and remain stable and functional over a range of temperatures.

An ideal dressing would require little or no training. Granular products are more difficult to apply deep into a wound close to the point of bleeding. Experience using Celox granules for the control of massive traumatic bleeding in an enhanced care

medical facility in Afghanistan found haemostasis more effective when an improvised applicator allowed the granules to be applied deeper into the wound.³² Gauze dressings and compression have been used to treat wounds for decades. The gauze haemostatic dressings follow the same application principles and have a minimal training burden; however, any agent can fail if applied incorrectly and appropriate training is the key to minimise this risk.

CONCLUSIONS

In order to prevent blood loss and reduce the mortality associated with exsanguination and the development of the lethal triad, novel haemostatic therapies are required in the prehospital environment. Recent military campaigns have driven rapid improvements in technology and civilian emergency medical services can learn from their experience. However, existing evidence to differentiate with real statistical significance between the key dressings currently available on the market is limited. There are very few published case series describing the use of haemostatic dressings in a clinical setting. This reflects the inherent difficulties of conducting research in the prehospital environment, especially a randomised controlled trial. Patients are often unable to provide consent and in a setting of catastrophic haemorrhage, the little time available must be used to perform life saving interventions and assessments of patient eligibility prior to treatment would be inappropriate. Although there are many anecdotal reports of haemostatic dressing use in the media, in reality, a more robust system of data collection is required to allow better evaluation and more realistic comparison between the dressings currently available.

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Box Kheirabadi's characteristics of the ideal haemostatic dressing for tactical applications⁸

- ▶ Approved for use in humans by appropriate regulatory body
- ▶ Stops severe arterial and/or venous bleeding in 2 min or less
- ▶ No toxicity or side effect
- ▶ Causes no pain or thermal injury
- ▶ Poses no risk to medics
- ▶ Ready to use and requires little or no training
- ▶ Durable and lightweight
- ▶ Flexible enough to fit complex wounds and easily removed without leaving residues
- ▶ Stable and functional at extreme temperatures
- ▶ Practical and easy to use in austere conditions (low visibility, wind, rain, etc)
- ▶ Effective on junctional wounds not amendable by tourniquet
- ▶ Long shelf life (>2 years)
- ▶ Inexpensive and cost effective
- ▶ Biodegradable and bioabsorbable

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