

# The use of tourniquets in the Australian Defence Force

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CURRENTLY, AROUND 3850 Australian Defence Force personnel are deployed overseas. When considering the various operational deployments in which the ADF is involved, the variation in time and distance in the evacuation of ADF personnel from the battlefield to level 2 and level 3 treatment centres is great. This raises questions regarding the application of tourniquet guidelines within the ADF as part of the evacuation procedure. Between Units, Corps or Forces, there has not been a unified approach to tourniquet model, training or implementation. We propose a model for the use of

## Abstract

- ◆ The value of the tourniquet in an exsanguinating patient on the battlefield is irrefutable. However, there remains controversy regarding the use of tourniquets in patients with poorly controlled haemorrhage and in those where evacuation may be prolonged.
- ◆ Issues regarding tourniquet use in large frontline operations have been raised in recent publications, and recommendations based on these experiences have been implemented by US Forces.
- ◆ Because most literature concerns the experience of US Forces, the application of this experience to Australian Defence Force deployments remains incomplete.
- ◆ A standardised tourniquet training protocol should be instituted by all ADF units, aimed at educating personnel on the benefits and risks of tourniquet use, and to ensure correct training in application procedure and tourniquet-monitoring procedure

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appropriate battlefield tourniquets and training for ADF deployments.

## Modern combat casualties

Historically, 20% of combat casualties are killed in action, defined as being killed before reaching a treatment facility.<sup>1</sup> Exsanguination (50%) and central nervous system injuries (36%) are the leading cause of death,<sup>2,3</sup> with the remainder being from devastating multiple injuries. The single major cause of death in salvageable battlefield casualties is haemorrhage,<sup>4</sup> and about 20% of these deaths are preventable if bleeding can be controlled promptly.<sup>5</sup> Haemorrhage before evacuation accounts for 49% of overall combat casualty deaths, whereas haemorrhage after evacuation accounts for just 1%.<sup>4</sup> Despite this relatively low figure, haemorrhage remains one of the leading causes of salvageable late death.

Improvements in body armour have been associated with decreased mortality secondary to thoracic, abdominal, and head trauma.<sup>6</sup> As a result of these advances, more combatants are surviving battle injuries than in previous conflicts, but they are incurring severe extremity injuries. In addition, the spectrum of injuries sustained in recent conflicts has tended to be predominantly multiple, as opposed to single battlefield injuries, and has tended to vary



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## 1 Chitosan bandage

Chitosan bandage (HemCon Inc, Tigard, OR, USA) was developed by the Oregon Medical Laser Center through a grant from the US Army Medical Research and Material Command. HemCon chitosan-based haemostatic dressing is approved by the US Food and Drug Administration for haemorrhage control. Animal data have shown the HemCon dressing to reduce haemorrhage and improve survival.<sup>25</sup>

Chitosan is a biodegradable carbohydrate found in prawns and lobster shells and many other animals. It bonds with blood cells to form a clot, and has some antimicrobial effect. Interestingly, chitosan is not hazardous to those allergic to prawns.



A recent review of its use in Operation Iraqi Freedom and Operation Enduring Freedom showed that, in 95% of the cases, the use of the HemCon dressing resulted in cessation of bleeding or improvement in haemostasis. In 66% of cases, dressings were used following gauze failure and were 100% successful, with no complications reported.<sup>26</sup>

## 2 QuikClot

QuikClot (Z-Medica, Newington, CT, USA) consists of a formula of zeolite volcanic mineral granules, and is marketed as being able to stop high-volume bleeding from open wounds. QuikClot is being used by ADF personnel on active duty in operations with US Forces. QuikClot has been tested in an experimental animal model and has US Food and Drug Administration approval.

QuikClot sterile granules are poured into a wound, where they act as a molecular sieve and rapidly adsorb water in a non-chemical, physical reaction. This concentrates the clotting factors and blood cells, promoting rapid clot formation, which creates a stable clot that can be removed by irrigation and suction. The use of QuikClot leads to an exothermic reaction in which the temperature



rises more sharply when the QuikClot granules encounter water compared with blood. The temperature rises within 30–60 seconds and lasts several minutes, with a peak between 42° C and 44° C for about 30 seconds. The heat generated by this exothermic reaction has been reported to cause mild to severe pain and discomfort, and a variety of tissue-thickness burns. Although these complications have been reported, the ultimate complication rate and the intra-abdominal and intra-articular effects are not yet fully known.

depending on combatants' weaponry. Recently, fuel–air or thermobaric weapons have been used by the Russians in the Second Chechen War,<sup>7</sup> resulting in injuries that are internal, and may not be noticed initially by the medic or doctor. These weapons are designed to create an aerosol cloud that consumes oxygen, creating a fireball with a rapidly expanding wave front, which sears the surrounding area and flattens all objects within close proximity of the epicentre.<sup>8</sup> A thermobaric strike on a unit in an urban conflict is likely to be very bloody. The flame, overpressure or airborne debris potentially causes pressure-related injuries, including air emboli, concussions, multiple internal haemorrhages, lung collapse, eardrum rupture, as well as crush injuries, burns, and fractures.

In Iraq, explosively formed penetrator devices have been used by insurgents in attempts to penetrate Coalition armoured vehicles from a stand-off distance and cause casualties. Injuries secondary to improvised explosive devices, small arms and rocket-propelled grenades have been the most common reported, with motor-vehicle accidents also accounting for a high percentage of injuries.<sup>9</sup> Additionally, there has been an increase in the number of complex axillary–inguinal wounds reported, perhaps secondary to the use of Kevlar body armour in the Iraqi urban

combat zones. On modern battlefields, most injuries requiring surgical intervention involve injuries to the upper and lower limbs.<sup>10–12</sup>

In previous wars, such as Korea and Vietnam, evacuation strategies were fairly rigid and field hospitals were close to the front lines. The trend in modern warfare is toward rapidly non-linear battlefronts and urban conflicts,<sup>13,14</sup> with terrorist activities and guerilla warfare replacing more traditional combat. The difficulty of placing a level 3 surgical facility (for life- and limb-saving surgery) near the front line of battle in the dispersed asymmetrical guerrilla-style urban and remote war scenarios that exist in Iraq and Afghanistan presents complex challenges for military planners.<sup>15</sup> However, in Iraq, despite these challenges, prompt evacuation of the injured has led to improved survival.<sup>16</sup> All combat medics in the US are being trained in the use of tourniquets and all soldiers are issued with tourniquets; they are being used frequently. In Iraq, the number of combat casualties who died after having

been retrieved has been low,<sup>17</sup> with the average evacuation time being 45 minutes by helicopter,<sup>18</sup> and with seriously injured personnel being evacuated to Landstuhl Regional Medical Center in Germany.<sup>19</sup> The pattern of injuries in Iraq suggests peripheral wounds should be anticipated, and managed by compression and an effective dressing. If haemorrhage cannot be controlled, the addition of a combination of a haemostatic agent and the judicious use of a tourniquet has been proven to be lifesaving.<sup>20</sup> Holcomb (US Army) and other senior US military medical authorities have reported that preliminary analysis shows that the early use of tourniquets is associated with a lower mortality than later use, and that pre-hospital use is better than hospital use. Palsy and amputation rates from tourniquet use are about 1% each.<sup>21</sup>

### Modern tourniquet use

The value of the tourniquet in the exsanguinating patient on the battlefield is irrefutable. However, not all combat casualties who have a haemorrhagic wound are exsanguinating, and consequently many are not in need of a tourniquet. There is controversy relating to the appropriate use of tourniquets in combat casualties with poorly controlled haemorrhage, and in those whose evacuation may be prolonged. Theoretically, early and effective haemorrhage control is even more important in these situations and can save more lives than any other measure. As a result, the Israeli Defence Forces advocate the liberal use of tourniquets,<sup>22</sup> as do members of the US Special Forces.<sup>23</sup> In contrast, in civilian emergency medicine, the fear of tourniquet-related complications secondary to prolonged application has all but eliminated their use.

Despite the known risks, tourniquets have been used effectively on the battlefield in Iraq because of their judicious use and the rapid evacuation of casualties. However, the scenario of fast-moving military units with no clearly defined warfront, with the possibility of blocked support lines and the threat of random attacks at any time, is likely to cause unpredictable delays in casualties reaching surgical support.<sup>15</sup> As a result, issues regarding tourniquet use in large frontline operations have been raised, and recommendations based on these experiences have been implemented by US Forces. In response to the changing combat casualty care, tourniquet substitutes (ie, haemostatic substances) for the control of exsanguinating haemorrhage have recently been reviewed and approved for use in Iraq and Afghanistan.<sup>24</sup>

### Haemostatic agents

A variety of haemostatic substances have been developed, to be applied in the form of a dressing or powder. All these

### 3 Celox

Celox (Medtrade Biopolymers Inc, Bainbridge Island, WA, USA) is a granular haemostatic agent comprised of chitosan and “other agents”, and has been approved by the US Food and Drug Administration for haemorrhage control.

Chitosan is made from shrimp shells, the same substance that is in the “chitosan bandage” HemCon dressing. Celox is one of the new generation of haemostatic agents that has been reviewed for use by the ADF. It is reportedly effective on all blood temperatures and blood, including heparinised blood, and works independently of normal blood clotting factors to form a clot. Celox was tested in a wound model very similar to that used by Alam et al.<sup>28</sup>



Medtrade Biopolymers Inc advertise Celox as having no known adverse effects. They report it does not produce an exothermic reaction or cause burning, and report it is a natural antimicrobial agent. However, to date there are very few data on the effectiveness of Celox or the incidence of potential adverse effects. There is no literature on its effectiveness on the battlefield. The cost is similar to QuikClot, at \$20 a sachet.

substances induce coagulation, with different intervention points within the coagulation system. Many substances are available, with no ideal agent yet being identified.<sup>20</sup> Ideally, a haemostatic agent should be effective, easy to use, safe, logistically preferable, and durable. Some ADF members recently deployed with US Forces in Iraq have been issued either HemCon dressings (mainly US Army) or QuikClot sachets (being trialled by US Marine Corp). HemCon (Box 1) is 95% effective,<sup>26</sup> but is expensive, at \$90–\$100 per dressing; QuikClot (Box 2) is equally effective at \$20 per application (efficacy 92%, but the field experience by various providers was 100%<sup>27</sup>).

Celox (Box 3) is a newer haemostatic product that is reported not to have the same exothermic reaction effects that QuikClot casualties report. However, data are lacking to support this claim, or the superiority of Celox. These tourniquet adjuncts or substitutes have been reported to be most useful on areas where tourniquets cannot be applied to control bleeding. Furthermore, they have been reported to be most difficult to use in extremity injuries, where they cannot be placed easily onto or into the wounds.

#### 4 Suggested protocol for use of QuikClot

1. Apply direct, firm pressure to the wound using sterile gauze dressing or the best available substitute.
2. If bleeding is stopped or nearly stopped after 1 minute of pressure, wrap and tie bandage to maintain pressure on the wound and seek medical care.
3. If moderate to severe bleeding continues after 90 seconds, hold QuikClot haemostat package away from face and tear open at tabs.
4. Remove the bandages, and wipe away from the wound area as much excess blood and liquid as possible.
5. Immediately begin a gradual pour of QuikClot haemostatic agent in a back-and-forth motion onto the source of bleeding. QuikClot haemostat changes from its dry light beige color to a dark color as it adsorbs moisture and performs clotting.
6. Stop pouring promptly when you see a dry layer (original lighter color) of QuikClot haemostatic agent on the wound, indicating that there is no more blood to adsorb.
7. Immediately reapply direct pressure for 1–2 minutes, then wrap and protect the area with compression bandage, or the best available bandage to maintain pressure. Note: As some heat may be released from the wound while QuikClot performs its coagulation, protect hands with gauze or similar insulating material while applying pressure.
8. If moderate to severe bleeding continues, apply a tourniquet.
9. Transport the patient to a medical facility as soon as possible. Ensure the QuikClot package accompanies the patient so medical staff can follow the directions for removing QuikClot properly.

#### 5 Combat Application Tourniquet



tive Group). As a result of discussions, the Consultative Groups agreed to introduce and train ADF personnel being deployed on operations in the application and indications for the use of QuikClot. However, there remains no standardised protocol as to when to use bandaging alone for haemorrhage control, when to apply a tourniquet and for how long, and when to apply a haemostatic agent.

The role of the modern tourniquet and the effectiveness of new haemostatic products were reviewed at a recent symposium, *Extremity War Injuries II: development of clinical treatment principles*.<sup>29</sup> Most literature concerns the experience of US Forces, and the resources and infrastructure that are available to those forces on deployment. These differ from those used by the ADF, and the applicability of this experience to ADF deployments remains debatable, and requires resolution. This raises the question whether such potentially detrimental lifesaving protocols need to be addressed by the military medicine specialists.

I am a fan of tourniquets after my time in Iraq. I believe the anti tourniquet policy of the [International Committee of the Red Cross] is justified in their circumstances of huge delays, no reliable [aeromedical evacuation] etc, but I feel the [International Committee of the Red Cross] can limit their opinions to their own unique situation (Maj David Read, General Surgeon, SSO, RAAMC).

Brigadier Robert Atkinson (Former Assistant Surgeon-General – Army) represented the ADF at this symposium and has called for a review of the ADF policy on tourniquet use. He has highlighted the uncertainty that time and distance in transport to a combat medical facility may pose, and suggested that Medical Officers be involved in the decision-making process as part of a definite protocol. Following this, the Orthopaedic and General Surgical Consultative Groups discussed the issue of “tourniquets and their use in the emergency setting” in an e-forum, with remarks from members of the Trauma and Anaesthetic Consultative Groups being noted. Rosenfeld posed the questions of

#### Combat casualty control of peripheral haemorrhage

Brigadier Jeffrey Rosenfeld (Chair, General Surgery Consultative Group) recently attended the Battlefield Surgery Conference at the Uniformed Services University of Health Sciences in Washington, where damage control resuscitation (including haemostatic agents) was one of the three themes. Although the effectiveness of these alternative products appears promising, Rosenfeld recently commented that

any introduction of [Celox] or any other similar product such as QuikClot would have to be done in a very controlled way. We do not need another trial of QuikClot. The product does work, but it does not replace standard haemostatic techniques . . . If there is little or no human data then I would not be in favour of its introduction.

These views are “shared by the Orthopaedic Consultative Group” (Lt Col Andrew Ellis, Chair, Orthopaedic Consulta-

tourniquet use, including indications, time limits for how long they should be applied, who should carry the tourniquets, and who should have the authority to use the tourniquets. It was also suggested that “the use of tourniquets needs to be adapted for the circumstances of a particular operation” (Rosenfeld).

Although most ADF specialists agree that combat tourniquets are potentially lifesaving devices, there remain divided opinions on their implementation.

The judicious use of tourniquets with early conversion to pressure dressings saves lives and limbs. Military medics in the field should have a thorough knowledge of the pros and cons of the arguments for and against their use, and should be taught how to effectively apply and use tourniquets and pressure dressings (Maj Michael Damp, General Surgeon SSO, RAAMC).

Commander Hamish Foster agrees, but states: “The indications are probably few and limited; the potential for harm with indiscriminate use is great: direct pressure on bleeding points should still be the mainstay of emergency/first aid control of haemorrhage”.

Despite most ADF medical specialists advocating judicious use of tourniquets, there are scant formal guidelines to control their use. Indeed, although there is a standard Australian Army protocol for the use of tourniquets, the implementation and methods of training are not uniform between Units. Lt Col Paul Myers (General/Vascular Surgeon SSO, RAAMC) has pointed out additional factors that need to be contemplated when considering the use of a tourniquet:

[In my practice] I have been the definitive treating doctor taking complete clinical and legal responsibility for the outcome, and with (I hope) a clear idea of what I am doing, why, what the next steps will be, and the time course in which those steps can and will be achieved. I don't think a general duties medico, being the first medically trained person to see and treat a casualty, can usually make that decision. He/she simply doesn't know what the time course to some sort of definitive treatment will be. Very few injuries are that clear cut that a tourniquet is required, *and* is better than direct pressure, *and* that the casualty will die without it. No doubt there will be some. But few will fulfill these criteria.

Indeed, continuation of care is rarely applicable in the military environment, further supporting the necessity for guidelines to control implementation of tourniquet use and institute accountability.

As a result of the stimulated debate on the subject, several amendments to the Australian Army protocol have been suggested. Some of these are summarised here.

### **Sect 4-3. Management of external bleeding**

First aid training should include the application of a haemostatic substance by any ADF member rendering assistance, preferably a trained medic under a medical officer's supervision, if a standard dressing fails to stop an external haemorrhage. This should be incorporated into standard soldier training, and medical assistant and medical officer training courses, as an adjunct for management of injuries where other methods have failed to achieve haemostasis.

All deploying personnel should be equipped with QuikClot (or an equivalent) and trained in its use (Box 4).

An amendment to the “Management of Bleeding” flow chart<sup>30</sup> should be made, to include an algorithm for the indications for, and application of, QuikClot (or an equivalent).

### **Sect 4-4. Management of uncontrolled haemorrhage**

Ideally, only ADF medics (or similarly trained personnel) or more qualified personnel may apply a tourniquet. Application should only be as a last resort to control exsanguinating haemorrhage; when a standard bandage and application of a haemostatic substance has failed to stop the haemorrhage and when the wound is on a peripheral limb. The tourniquet of choice is the Combat Application Tourniquet (Box 5), and all medics and approved personnel should be trained in its application.

The guidance of a medical officer should be sought at the earliest practicable time, for approval to continue the use of the tourniquet, as this is where serious complications can arise.

The medic is responsible to note the time of tourniquet application by writing “TK” (referring to tourniquet) and the time of application on the casualty's forehead with a permanent marker (which probably should be issued with the tourniquet). After 30 minutes while awaiting transport to a medical facility, the tourniquet should be removed slowly and the wound examined for bleeding. The tourniquet may be left off if there is no sign of bleeding; or if bleeding continues, an attempt should be made to control bleeding with a dressing, with reapplication of the tourniquet if bleeding cannot be controlled (noting the time of re-application). This procedure may be repeated twice while awaiting transport to a medical facility. Where evacuation may be prolonged (ie, longer than 90 minutes), the treating medic must seek authorisation from a medical officer to continue the use of the tourniquet (preferably a medical officer from the facility to which the casualty is to be evacuated). Ideally, tourniquets are not to be applied longer than 90 minutes.

## Summary

These recommendations aim to simplify the decision-making process and maintain a high standard of medical treatment in the ADF. In summary, only when a standard bandage and application of a haemostatic substance has failed to stop a haemorrhage, should an ADF medic or more highly qualified person attempt to apply a combat application tourniquet. Additionally, a standardised tourniquet training protocol should be instituted by all ADF Units, aimed at educating personnel on the benefits and risks of tourniquet use, and to ensure correct training in application procedure and tourniquet-monitoring procedure. The guidance of a medical officer should always be sought at the earliest practicable time.

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30. Australian Army. Land warfare procedures — general 1-2-5. Chapter 4. Figure 4-1: Management of bleeding.

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