

## FOR DEBATE

The article that follows, on the use of tourniquets, by Lt Col Paul Parker and Lt Col Jon Clasper is intended to stimulate debate. It is NOT a statement of Defence Medical Services doctrine any more than it should be unreservedly accepted as a statement of best clinical practice, although its authors believe it to be so. Rather, it presents a point of view with which some will agree and some disagree. It is followed by a response from Col Tim Hodgetts and Lt Col Peter Mahoney justifying the current policy position. This article too should be read with a degree of intelligent scepticism. My intension as Journal editor is that these articles will stimulate a wide ranging and intelligent debate based on the evidence. I would urge you to read the articles critically and to join the debate by submitting your responses to me for possible publication.

It is my intention that this will be the first of an occasional series of debates and I would, therefore, be delighted to receive contentious but responsible and well informed articles which might be used to stimulate discussion. I also hope that we will be able to introduce a debate page on the RAMCJ website which will bring an even greater degree of immediacy to these discussions and provide another forum for intelligent debate.

## The Military Tourniquet

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### The Military Tourniquet

Advances in the management of military trauma have focussed on the critical need for early life-threatening haemorrhage control – the C-ABC of BATLS (1). These measures have included the recent liberal re-issuing of tourniquets: The use of tourniquets in conflict has always been controversial, with strong opinions both for and against their use (2,3). Whilst tourniquets may have saved lives, they have also caused un-necessary limb loss (3). It is therefore vital that all available evidence is critically analysed and any resulting treatment protocols constructed without excessive zeal, emotion or bias. Tourniquets are now applied for tactical or



Figure 1. Traumatic upper limb amputation from an RPG. A CAT and Plasticuff were applied in the pre-hospital phase. These were removed in the operating theatre - the stump did not bleed.

medical reasons, as this facilitates rapid evacuation of casualties from life-threatening situations – ‘care-under-fire’. Once safe ground is reached – we propose that a tactical tourniquet should be completely removed and a medical tourniquet adequately loosened off, the wound assessed, and direct pressure or pressure

bandaging, (or a novel haemostatic) applied to control any ensuing bleeding – ‘tactical field care’. This imperative will be a significant challenge in our ‘fog of war’.

There are only three significant datasets containing clinical information regarding the field use of military tourniquets. The first describes the Norwegian military experience in Iraq in 1991(4). 109 patients were treated in a Norwegian UN hospital in the demilitarized zone between Iraq and Kuwait. 68 of these patients had suffered major traumatic amputations during UN de-mining operations. There were two observation periods in the study: 31st July to 27th September and 28th September to 14th October. In the first period, tourniquets were liberally used and continuous bleeding distal to the wounds was frequently seen. Field protocols were then changed to a policy of ‘remove any tourniquets and dress the wound with a tight elastic bandage’. 3/18 (17%) died in the first period and 1/50 (2%) in the second ( $p<0.05$ ). Admission haemoglobin levels were 8.6g/100ml (10/18 – 56% requiring transfusion) in the first period and 10.5g/100ml (13/50 – 27% requiring transfusion) in the second ( $p<0.05$ ).

Criticisms can be made of this paper: The tourniquets were often home-made and there may also have been a learning curve in injury management. The current British Army tourniquet (CAT), whilst not home-made, is certainly not the equivalent of the medical tourniquets used in hospitals today (*vide infra*). This paper is still clear evidence however that tourniquets may not only be ineffective, but might actually be dangerous when used on traumatic amputations. This is also our opinion based on our own experience of traumatic amputations, which we consider as injuries that rarely bleed, and in which a tourniquet is rarely if ever indicated (Fig 1).

Indication for tourniquet application	(%)
Mass casualty event	38
Amputation	23
Under fire situation	23
Bleeding from multiple locations	6
Need for immediate airway management	3.5
Injury does not allow direct control of bleeding or failure to stop bleeding by direct pressure bandaging	3.5
Total darkness	2

Table 1: Israeli Defence Force – Tourniquet Application Indications

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The second dataset is from the Israeli Defence Force Medical Services(5). This describes the application of 110 tourniquets to 91 casualties between 1997 and 2001. However, of the 110 tourniquet applications that the authors reported, only 53% were deemed appropriate. A tourniquet was deemed indicated if the clinical situation fulfilled one of the criteria outlined in Table 1. A tourniquet was then only deemed effective if it stopped all distal bleeding. The authors reported that only 78% of the applied tourniquets were effective.

58 tourniquets out of 110 were therefore applied for the 'indicated' reasons and 52 for non-indicated – these were applied mainly to wounded but not actively bleeding limbs or to actively bleeding sites without any prior attempts at direct bandaging. Neurologic complications occurred in seven limbs of five patients. This included one case of bilateral peroneal and radial nerve paralysis (6). Ischaemic times in these cases ranged from 109 to 187 minutes. 16 formal amputations were performed. Effective tourniquet application was more likely when the injury involved the upper limb (94%) than the lower limb (71%). The authors correctly noted that care provision in the military environment is not the same as in a safe well lit emergency department. Ongoing hostile fire – making high limb elevation impractical, darkness, a single care provider faced with a multiple casualty situation, may have made the rapid utility of a tourniquet more appropriate than a pressure dressing.

This is the most commonly quoted paper and is often used to justify the use of field tourniquets. However, when using strict clinical criteria as the endpoint, that is, successful application to a bleeding wound where pressure dressings have not worked, in only 5% (3 cases out of 110 in a 5 year period) was the tourniquet actually used to control potentially life-threatening haemorrhage. In this paper the majority of tourniquets were applied for tactical and not medical reasons. Even then 29% of those tourniquets applied to the lower limb did not work.

The third dataset comes from the extensive experience of the 31st Combat Support Hospital in Iraq(7). Between January and December 2004, 3444 patients were admitted, 2000 with extremity injuries. 166 matched patients with significant extremity trauma were identified as meeting the trial entry criteria. 67 patients arrived with pre-hospital tourniquets and 99 without. Mean Abbreviated Injury Score on arrival was 3.4 with a mean Injury Severity Score of 17.2. There were no statistically significant differences in arrival vital signs, pH, base deficit, and haematocrit or blood requirements – including Factor VIIa.

Care was also taken to ensure that the same spectrum of injuries was being measured. Wound distribution (apart from upper-arm injuries) was the same. Average tourniquet times were 70 (5-210) minutes. Overall (when the data was available) 2.3% were incorrectly applied – e.g. distal to the wound on the limb. 23.2% of tourniquets were deemed ineffective at controlling bleeding on arrival (4 thigh, 3 knee/leg, 2 forearm, 1 arm). 20.9 % of the patients in the tourniquet group had no vascular injury or major amputation. Formal vascular reconstruction was required in 52.5% of the non-tourniquet and 29.9% of the tourniquet group ( $p<0.004$ ). This would indicate that significant vascular injuries were not usually associated with any life-threatening haemorrhage.

Amputation was required in 26.3% of the non-tourniquet group and 41.8% of the tourniquet group( $p<0.04$ ): If the spectrum of injuries is as similar as the authors intended, then tourniquet use may have caused limbs to be lost. Limb salvage was performed in 66.7% of the non-tourniquet group and 53.7% of the tourniquet group(NS). Although not significant, there was a trend towards an increased amputation rate in the group in whom a tourniquet was applied. Death occurred in

4.1% of the non-tourniquet group and 4.4% of the tourniquet group(NS). Tourniquet use resulted in the un-necessary loss of 2% of limbs. Tourniquet use did not therefore save lives.

Why are so many military tourniquets deemed 'ineffective' (8-10)? It is vital to appreciate that military tourniquets will never be as effective or as safe as civilian versions. Under laboratory conditions, four out of seven commercially available 'military' tourniquets did not reliably occlude distal arterial blood flow and none were completely effective when applied to the thigh(9). Civilian tourniquets are selected to be the appropriate circumference for the limb in contrast to slim single-sized military devices: Civilian tourniquets are pneumatic with calibrated pressure controls; broad requiring less force and applied over a layer of padding. Every use is accurately documented and timed. They are applied to an anaesthetized patient.

Military tourniquets are applied over clothes containing creases or objects that may cause pressure or other skin problems. Effective military tourniquet application is usually intolerably painful (10). Finally, civilian tourniquets are rarely, if ever, applied for longer than two hours. In the Gulf Conflict of 2003, it was a mean of 6 hours until patients reached hospital (11) and 7 hours on Operation Herrick IV in 2006(12). Military tourniquets would currently be expected to be applied for at least this period of time. When this happens, amputation above the tourniquet is the only option.

Are tourniquets safe? We do not know, but they are probably not. Application for shorter than two hours may be considered 'safe', but much of the evidence is based on experimental animal work (13). Tourniquets induce a systemic inflammatory response (14) and applied at pressures in excess of 350mmHg cause a wound tissue hypoxia that can be measured up to a week later (15). No work exists on their safety in highly contaminated military limb wounds associated with significant bony and soft-tissue injuries. These already have a 50% infection rate and a secondary amputation rate of 10% (11). Any further ischaemia must be avoided if possible. No paper has long-term patient follow-up. One stated "fractures of the lower extremity as a result of GSW were associated with the longest hospital stays and highest complications" but did not associate this morbidity with a proposed liberal use of devices producing prolonged ischaemia (8).

Should tourniquets be intermittently released? This action was once thought to prevent prolonged ischaemia. This is no longer recommended as a brisk haemorrhage can occur and results in death from 'incremental exsanguination'(3). The 'Catch-22' here is that on-release bleeding is most likely to be due to reactive hyperaemia of the ischaemic limb because of the tourniquet – which is then re-applied! Following elective surgery, this reactive loss can amount to 500-1000mls. Prolonged tourniquet use is ultimately fatal. On Dublon Island in the South Pacific in July 1944, eight American Prisoners of War had upper and lower limb tourniquets applied as an 'experiment' by Japanese Naval doctors. When these were removed 7-8 hours later, two of the men immediately died (16). Our current casevac times do not guarantee that our 'modern' tourniquets will be applied for periods much shorter than this. Prophylactic above tourniquet amputation will again be the only option left to the surgical team.

In summary; to say that tourniquets are a safe and effective means of treating our combat injured soldiers is a failure to understand the nature of combat injuries to the limbs – tourniquets do harm and it is the ineffective ones that do the most harm. However, to say that tourniquets are unnecessary represents a failure to understand the nature of combat. In some circumstances, effective tourniquet application will do good. Whilst the forward use of a tourniquet, during a firefight can be

justified as it has a beneficial psychological effect, facilitates early evacuation and reduces exposure to enemy fire, it should be removed and replaced with a pressure, stump or cavity dressing, by a combat medical technician or medical officer, as soon as possible. Our current liberal tourniquet policy may be increasing the morbidity of what are already complicated limb wounds and further clinical study on effective haemorrhage control is clearly required. It would seem that we shall have look elsewhere to produce major shifts in the survival rates of our injured soldiers.

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# The Military Tourniquet: a response

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### Introduction

The commentary by Parker and Clasper (1) usefully debates potential disadvantages with tourniquet use. However, they imply that current policy has been reached through an inadequate appraisal of the available evidence. This response explains the complex academic processes behind clinical policy formulation and redresses both the authors' lack of knowledge of current training and the incomplete representation of UK audit data that underpin their criticisms.

To begin, we completely concur with their introductory and concluding statements that: *"Whilst the forward use of a tourniquet during a fire-fight can be justified as it has a beneficial psychological effect, facilitates early evacuation and reduces exposure to enemy fire, it should be removed and replaced with a pressure, stump or cavity dressing, by a combat medical technician or medical officer, as soon as possible." ...and... 'Once safe ground is reached - we propose that a tactical tourniquet should be completely removed and a medical tourniquet adequately loosened off, the wound assessed, and direct pressure or pressure dressing, (or a novel haemostatic) applied to control any ensuing bleeding - 'tactical field care.'*

This is the existing teaching within all levels of acute care training in UK Defence Services from first aid (2), through Army Team Medic to Battlefield Advanced Trauma Life Support

(3). The criticism of current policy will be answered by addressing a series of issues.

### How were the DMS protocols developed?

Parker and Clasper state: *'It is therefore vital that all available evidence is critically analysed and any resulting treatment protocols constructed without excessive zeal, emotion or bias.'* The process by which UK DMS introduced the Combat Application Tourniquet (C-A-T™) and other 'novel haemostatic agents' was summarised in an Editorial in 2005 targeted at informing DMS clinicians (4).

The Surgeon General tasked RCDM in 2004 (5) to critically appraise emerging methods of external haemorrhage control in view of the number, severity and pattern of wounds being inflicted on UK and US forces. The objective was to inform clinical doctrine, equipment and training in relation to reducing battlefield death from external haemorrhage, which has been identified from Vietnam War data as the commonest avoidable cause of combat death (6).

A wide ranging review was undertaken drawing on UK and US operational experience, work from Defence Science and Technology Laboratories, appraisal of published and grey literature, and the Operational Surgical Services Review (7). Opinion and input was invited from all sectors of the DMS clinical trauma community: some engaged, some did not. The ultimate output has been the promulgation of a Surgeon General Policy Letter (8) endorsing the introduction of a modified Israeli elastic bandage, the C-A-T™ tourniquet, and a topical haemostatic agent (QuikClot™) following a period of operational evaluation.

Central to this change management process was the recognition that the strategy was 'emergent' as continuing industry innovation (incremental and dramatic) and ongoing

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operational experience demanded that the strategy would be reviewed annually. Following the first review in Sep 05 a case was made to introduce the newly licensed HemCon™ bandage into the Army Team Medic capability (1 in 4 combat soldiers), launched in Apr 06 and updated in Dec 06. A bridging training programme (9) was developed to accompany the operational evaluation and was delivered repeatedly on pre-deployment training by senior clinical staff. The effectiveness of this programme was assessed (10, 11). Within this teaching is a new clinical paradigm: rapidly treating catastrophic haemorrhage first (<C>ABC) before addressing traditional 'ABC' priorities. The reasoning behind this has been the subject of a separate editorial (12). The UK Special Forces Trauma Course (SFTC) had independently developed the acronym 'MARCH' (Massive compressible haemorrhage, Airway, Respiration, Circulation and Head injury) for the same reasons.

The haemostatics training has since been incorporated into BATLS (3), Army Team Medic course and MATT3 (2). The collective HOSPEX training at AMSTC includes management of haemorrhage casualties. The content of BATLS (3), Team Medic and MATT3 (2) are subordinate to the overarching doctrine of Clinical Guidelines for Operations (CGOs) (13). These guidelines were constructed following a wide consultation with the DMS community-again, some disciplines engaged, others did not. Our belief is that this represents a logical and robust process for the development, evaluation and continuing refinement of our clinical guidelines.

### What is currently being taught by the DMS?

Extracts from JSP 570, The 'BATLS 2005' manual (3) are reproduced here. The full content is already part serialised as a supplement to this journal (14) in order to give our clinicians wide access to the new concepts and practices.

*'When self-aid is necessary under fire it is suggested that the threshold for applying a tourniquet is low: once the fire-fight has been won the tourniquet can be loosened and the need for its continuing use re-evaluated. The same principle applies to buddy first-aid of a casualty while under fire, if the situation permits an opportunity to apply a tourniquet'.  
(Page 26 in the JRAMC supplement)*

**PRACTICE POINT:** Dressings combined with pressure and elevation are frequently effective for haemorrhage control. However, these procedures take time to complete and may be constrained by the need to remove clothing. In a situation where the physical threat persists be prepared to adopt an aggressive approach to haemorrhage control: this means having a low threshold for tourniquet use. **THE NEED FOR THE TOURNIQUET MUST BE REASSESSED WHEN THE THREAT HAS DECREASED** (Page 29 in the JRAMC supplement).

*'Realistically, Care Under Fire will extend only to the use of the C-A-T (Combat Application Tourniquet) while the fire-fight needs to be won: when the enemy is suppressed it will be possible to re-evaluate and proceed down the protocol and use dressings and haemostatic agents. (Page 29 in the JRAMC supplement).*

From Chapter 3, 'Care under Fire':

The following are notes from the 'Team Medic' teaching materials which endorses a 'ladder' of interventions to control external haemorrhage:

*Attempts to control haemorrhage should include:*  
**Direct pressure** through a dressing onto the bleeding point, most bleeding can be controlled with effective direct pressure.  
**Indirect pressure** is useful if there is extra man power available, otherwise it ties the medic to the pressure point.  
**Splintage** should not be reserved purely for broken bones, movement in a limb below the injury will disrupt blood clot and cause further bleeding.  
**Elevation** is effective and complements the other methods of haemorrhage control. Fractures to the limb should be looked for before elevating the limb.  
**Use of a tourniquet and/or HemCon® for external bleeding that cannot be controlled by pressure and elevation.** The forehead/cheek must be marked with a 'T' and the time if a tourniquet is applied. HemCon is suited for junction areas and high pressure bleeding'.

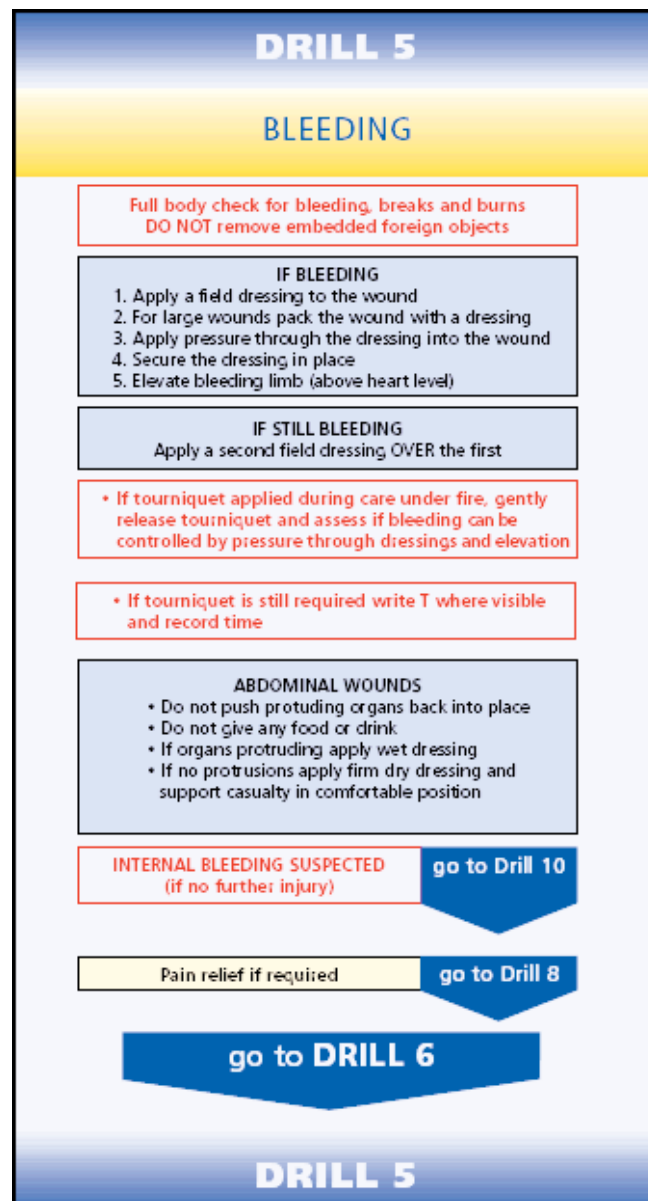


Figure 1. MATT 3 Drill 5 - Control of bleeding

A protocol from the revised MATT 3 (2) is produced here as Figure 1. Drill 5, 'Bleeding' instructs that tourniquets placed during Care Under Fire should be reviewed and attempts made to control haemorrhage by conventional means. Also included (Figure 2) is the Team Medic drill 5a 'haemorrhage control slide' that links with the above notes. These materials are presented to clarify to all clinical stakeholders what is currently

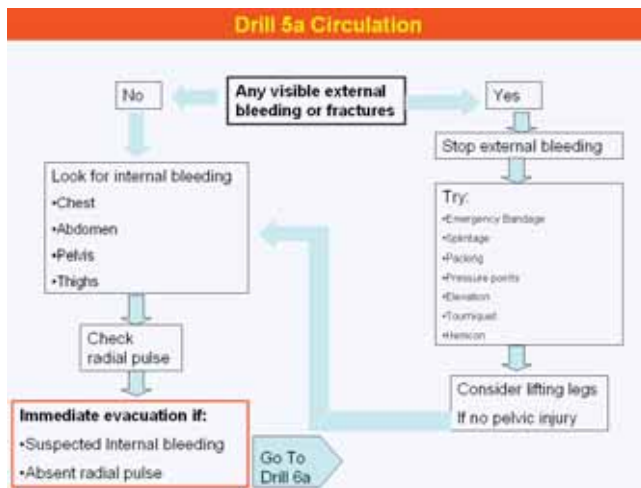


Figure 2. Team Medic teaching algorithm for control of haemorrhage

being taught. If clinicians have concerns that this is not being delivered correctly or the message is unclear then ADMEM RCDM is to be informed so corrective action can be taken.

### The UK Experience.

Introduction of new equipment is not without risk and a major concern was (and is) the inappropriate use of tourniquets or other haemostatic agents causing injury to casualties. The majority of our information about UK use of haemostatics comes from the continuing audit of all major trauma casualties (deaths and survivors) utilising the UK Joint Theatre Trauma Registry (JTTR) maintained by ADMEM RCDM (15, 16).

UK casualties who have suffered serious injury are evacuated back to RCDM in Birmingham. Casualties are tracked and interviewed by ADMEM Trauma Nurse Co-ordinators and all clinical notes from Role 1 through to Role 4 are audited. UK casualties who have been killed on operations are repatriated to UK via RAF Brize Norton. Post mortem examination is carried out in Oxford and Inquests are (mainly) conducted under the jurisdiction of the Oxford Coroner. Information about cause of death and injury patterns is shared with MOD and analysed by ADMEM RCDM.

The current UK experience of tourniquet use in major trauma is: '33 uses from 6/6/04 to 09/02/07 recorded on UK JTTR with no direct complications from tourniquet use noted at post mortem or on review of patients at Role 4 (RCDM).' JTTR captures all patients for which a Trauma Team was activated (and/or who met the criteria for a Trauma Team): there may be tourniquet uses that are "inappropriate" and are not captured on this database. **ADMEM RCDM need to know about any inappropriate uses so that training protocols can be audited and adjusted as necessary: this will be possible through the weekly telephone conferences to be introduced between Role 4 and deployed R2E from March 2007.**

Of note is that when the novel haemostatic techniques were introduced in 2005 the aim was for every use to be audited using a simple A4 Audit form: this has proved too burdensome for some members of the DMS. Parker and Clasper raise a concern about UK evacuation times referring to an analysis of eighteen MERT (Medical Emergency Response Team) missions during Op Herrick IV (their reference 12). They quote a mean figure of 7 hours until patients reached hospital and deduce that 'military tourniquets would currently be expected to be applied for at least this period of time. When this happens amputation above the tourniquet is the only option'.

The UK teaching on tourniquet removal has been dealt with. While there is no question that some operational casualty evacuations have involved considerable delay for a variety of

reasons (such as troops being in contact with the enemy), the ongoing ADMEM analysis of *two hundred and seven* MERT missions has revealed an average call to hospital time of 2 hours and fifty four minutes. We recommend that firm conclusions about UK casevac and related treatment protocols are not drawn from incomplete audit data.

### The US Experience

Col John Holcomb, Commander of the US Army Institute of Surgical Research, has shared information on two US military studies. The first of these is the paper by Beekley *et al* (17) (cited by Parker and Clasper as reference 7) presented at the Western Trauma Association Meeting, Big Sky, Montana, in March 2006 and currently under consideration for publication. Parker and Clasper conclude from this data that 'tourniquet use resulted in the unnecessary loss of 2% of limbs'. The authors of the paper draw different conclusions from their material: 'Pre-hospital tourniquet use was associated with improved hemorrhage control, particularly in the worse injured subset of patients. Although this data set does not show an improvement in survival, it is biased towards those patients surviving to reach the combat support hospital. No adverse outcomes (secondary amputations or neurologic deficits) related to tourniquet use were noted' (Beekley *et al* 2006). Beekley *et al* also state that 'analysis of the injuries in the 7 patients who died revealed that 4 of these deaths were potentially preventable with adequate tourniquet placement'.

The second study is a prospective survey performed by Col John Kragh of casualties who required tourniquets at the 10th Combat Support Hospital in Baghdad from Mar 06 to Oct 06 (18). This is currently under consideration as an abstract for AAST 2007 and so it would be inappropriate to publish the details here, other than to say the abstract concludes: 'Prehospital tourniquet use vs. those applied late in the ED saved lives. No limbs were lost solely from tourniquet use. Education directed at early, prehospital tourniquet use should continue'. We look forward to seeing both these studies published in full and drawing appropriate lessons from them.

### The Israeli Experience

The paper by Lakstein *et al* (19) is a valuable 'warts and all' review of the use of tourniquets by Israeli Defence Forces over a four year period. The authors themselves grade tourniquet use as 'indicated' (see table 1 in Parker and Clasper's commentary) for either 'clinical' or 'situational' reasons (e.g. Care under fire) or 'non-indicated'. We agree with the observation that 3 tourniquets were applied because of failure to control bleeding by direct bandaging but also believe that the 'situational' applications were justified. Current UK teaching would be for these applications to be reviewed once the situation was under control, a policy advocated by the Lakstein *et al* (19) as 'early conversion [to pressure bandaging] as soon as possible'. Lakstein *et al* (19) attribute the use of 'non-indicated' tourniquets to a combination of stress and lack of experience on the part of most of the medical care providers. This observation has been very valuable in driving realistic training scenarios for UK personnel.

### Conclusions

Debates on tourniquets are not new (20). UK DMS does not have a casual attitude to tourniquets. The current training programmes and protocols are a considered balance of risk and benefit. Evidence based questioning of UK DMS Clinical protocols is welcome, for only by constant review of what we are teaching and delivering will casualty care improve. Questions regarding the current haemostatic protocols (and other clinical protocols) must include:

■ Are the protocols correct?

- Is the training correct?
- Is it being delivered correctly?
- Is it being understood?

Feedback on and critique of current protocols is most constructive if people have undergone the required training (or have at least familiarised themselves with the material) and know what is being taught.

It is inaccurate to dismiss current protocols as 'zealous, emotional or biased' (1) and such a statement fails to credit the many DMS personnel (doctors, nurses, medics, MSOs, strategists and logisticians) who have worked hard to bring BATLS, Haemostatics, Team Medic, MATT 3, CGOs and HOSPEX to fruition and continue to do so by their commitment to training delivery.

ADMEM has received inappropriate complaints from deployed clinicians who stated they had not been exposed to the haemostatics training materials (or other equipment recently introduced) before deployment. A review of their pre-deployment preparation showed they had elected not to attend BATLS or HOSPEX because they regarded themselves as clinically experienced. The conclusions to draw are clear. The best way for Clinicians to influence course content and delivery is to become involved and take a degree of ownership. Ongoing audit of clinical performance on operations and casualty outcome is essential. To be effective this demands widespread and active engagement by DMS personnel.

As well as haemostatics other critical clinical issues have been recently reviewed by ADMEM RCDM including:

- Strategies for improved battlefield analgesia (21)
- Fluid resuscitation.
- The structure and competencies of SH-borne medical team (22).

We look forward to the Journal of the Royal Army Medical Corps becoming a forum where these and other issues can be intelligently debated.

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