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UK combat-related pelvic junctional vascular injuries 2008–2011: Implications for future intervention

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ABSTRACT

In a recent publication, 297 of 6450 (4.6%) military coalition deaths over ten years were reported to be due to junctional bleeding. The authors suggested that some of these deaths could have been avoided with a junctional haemorrhage control device.

Prospectively collected data on all injuries sustained in Afghanistan by UK military personnel from 1 August 2008 to 31 July 2011 period were reviewed, using the UK Joint Theatre Trauma Registry. All fatalities with significant pelvic injuries were identified and analysed, and the cause of death established to assess the potential role for a junctional haemorrhage control device.

Significant upper thigh, groin or pelvic injuries were recorded in 124 casualties, of which 93 died. Of these the pelvic injury was the cause of death in 37, but only 1 casualty with potentially survivable injuries was identified where death was due to a vascular injury below the inguinal ligament, not controlled by a CAT. This represents <1% of all deaths in this period, a lower figure than previously published. We further identified 32 casualties where the cause of death was due to a vascular injury between the aortic bifurcation and the inguinal ligament. Eight of these survived to a medical facility but subsequently died of their wounds. These represent a subset in which vascular control proximal to the inguinal ligament could have altered the outcome.

Some potentially survivable deaths due to exsanguination may be amenable to proximal vascular control. Our study does not substantiate previous conclusions that this can be achieved through use of a groin junctional tourniquet. We believe there may be a role for more proximal vascular control of pelvic bleeding, and this merits further research.

Introduction

Haemorrhage is the most common cause of potentially survivable (PS) death on the modern battlefield [1,2] accounting for almost 90% of the PS deaths seen on Operations Iraqi Freedom and Enduring Freedom [3]. Recognition of the importance of haemorrhage as a potentially remediable cause of death has led to the development of a paradigm shift in battlefield trauma management, with priority given to the control of catastrophic haemorrhage in Battlefield Advanced Trauma Life Support (BATLS) and Tactical Combat Casualty Care (TC3) guidelines [4–6]. Haemorrhage from the limbs can potentially be controlled using a tourniquet, and is referred to as compressible [5]. Due to its inaccessibility, haemorrhage from the torso, including that of the pelvis, has traditionally been held to be non-compressible, with definitive control believed amenable only to intervention through surgery or embolisation [7,8].

With the introduction of more effective body armour protecting the torso, the pelvis has assumed greater importance as an area where potential intervention could reduce battlefield deaths [9]. Further, the non-compressible nature of pelvic haemorrhage has been questioned; development of novel means of haemorrhage control has been driven by the belief that it may be possible to control bleeding in an area previously thought to be too proximal for compressive control [9]. Working on a similar principal to Lister's tourniquet, Groin junctional tourniquets have been suggested as a solution to haemorrhage too proximal for regular tourniquet control [10]. Currently the Combat Ready Clamp

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(Combat Medical systems, Fayetteville, NC, USA) (Fig. 1) is the only such device approved by the US Food and Drug Administration, although this may be the first of many. As this is such a new device, any evidence for its efficacy remains anecdotal only [11].

The benefits of a junctional tourniquet were evaluated in a paper by Kragh et al. [10]. To assess the possible benefits, they attempted to calculate the number of casualties that could have been saved through the introduction of such a device. They considered all the 6450 coalition deaths that occurred from October 1 2001 to April 30 2010. Using the classification system reported by Holcomb et al. [3], 1484 (23%) were deemed 'potentially survivable' (PS). Of these casualties with PS injuries, 297 (20%) had 'junctional injury and bleeding as a cause of death'. Kragh et al. felt that with a junctional haemorrhage control device, some of these deaths may have been avoided. As part of our clinical governance, there is an on-going requirement to review all UK combat fatalities, on a case by case basis, to identify potential survivors and opportunities for intervention. The purpose of our study was to formally review all pelvic junctional vascular injuries sustained by UK service personnel engaged in active service on Operation Herrick in Afghanistan over a 3 year period to determine potential benefits of new junctional haemorrhage control devices and whether they could have a role in the battlefield setting.

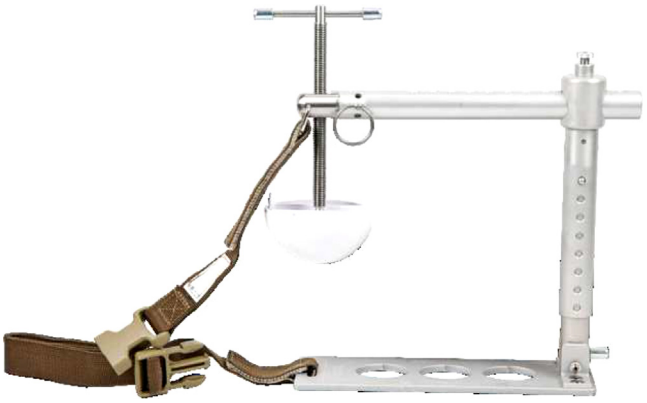

Fig. 1. Combat ready clamp.

Methods

We reviewed the UK Joint Theatre Trauma Registry (JTTR) for details of all UK military casualties in Afghanistan between 1 August 2008 and 31 July 2011. The JTTR is a UK military trauma database of all injured casualties treated by UK Defence Medical Services, collected contemporaneously by dedicated trauma nurse specialists in theatre, established to comply with clinical governance regulations to ensure that high standards of medical care are provided to service personnel injured on operations [12]. We identified all fatalities who had sustained upper thigh, groin and pelvic injury in an attempt to identify mitigation role for novel treatments that may have altered the outcome. All injuries sustained were documented with injury severity calculated using both the Injury Severity Score (ISS) [13], and the New Injury Severity Score (NISS) [14], each based upon the Abbreviated Injury Scale [15]. The Abbreviated Injury Scale (AIS) is an anatomically based scoring system used in trauma to assess injury severity: injuries are classified according to the region of the body affected, according to severity, on a 6 point scale. ISS comprised the sum of the squares of the worst AIS in three separate body regions; NISS uses the sum of the square of the three worst AIS scores, regardless of body region. There is no explicit pelvic category in the AIS classification; injuries to this region can be accommodated in either the abdominal or extremity sections, depending on the nature of the injury. All injuries involving bony and vascular trauma to the proximal femur and pelvis, and pelvic visceral injuries were included, and form the basis for the denominator of our calculations.

Killed in action (KIA) has been defined as a combat death that occurs before reaching a medical treatment facility, and Died of Wounds (DOW) as that which occurs after reaching a medical treatment facility [16]. The determination of DOW or KIA status was made at presentation to the first medical facility. The determination of DOW or KIA status was made at presentation to the first medical facility.

The cause of death was established for all fatalities; we specifically evaluated whether the cause of death was attributable to the pelvic/thigh injuries. From this group we identified fatal injuries below (or at) the level of the inguinal ligament, as these could be mitigated by a groin junctional tourniquet, or above the level of the inguinal ligament, which could not. All pelvic vascular deaths were divided into unsurvivable and potentially survivable, according to the injuries sustained, through consensus decisions by a group comprising senior orthopaedic trainees and a senior orthopaedic surgeon, using primary source material from HM Coroner and trauma nurse specialists. Due to the presence of multiple injuries, it was possible to attribute more than one injury as a cause of death.

Data were analysed using SPSS v 20.0 statistical software (IBM, NY, USA). For correlation, Spearman's rho test was applied. A p-value less than 0.05 was considered statistically significant.

Results

Over the 3 year period, 293 casualties sustained a significant injury to the pelvis, or to the upper thigh. Of these, 125 casualties had sustained a significant pelvic injury (pelvic AIS 3 or greater). Data are shown in Table 1, according to the AIS score of the worst injury sustained, and illustrated in a flowchart (Fig. 2). Increasing fatality rates are directly correlated with increasing injury severity scores, illustrated in Table 1 ($p = 0.0145$). Vessels amenable to compression with a groin junctional tourniquet, i.e. the proximal femoral vessels, were damaged in only one instance in potentially survivable deaths following significant pelvic injury (Fig. 2). This equates to 0.8% of all significant pelvic injuries. However, in addition to a vascular injury of the proximal thigh not controlled by conventional windlass thigh tourniquets, this casualty also had

Table 1
Significant pelvic injuries in Afghanistan (August 2008–July 2011).

Worst AIS	Number (%)	Survived (%)	KIA (%)	DOW (%)	Died (%)	Median ISS	Median NISS
3	7 (5.6)	7 (100)	0	0	0	22	27
4	14 (11.2)	10 (71.4)	2 (14.3)	2 (14.3)	4 (28.6)	41	44.5
5	66 (53.6)	14 (20.9)	40 (59.7)	13 (19.4)	53 (79.1)	50	66
6	37 (29.6)	1 (2.7)	35 (94.6)	1 (2.7)	36 (97.3)	75	75
Total	125	32 (25.6)	77 (61.6)	16 (12.8)	93 (74.4)		

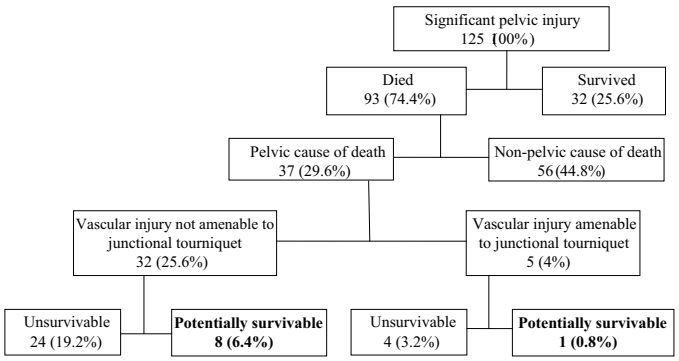

Fig. 2. Flowchart of all UK casualties with significant pelvic trauma from Afghanistan over a 2-year period.

significant intra-abdominal injuries, including a 50% renal artery laceration, as well as major incompressible bleeding from the perineum; survival may not have been possible even with more proximal groin vascular control. We also identified 32 casualties who died as a result of pelvic injuries distal to the aortic bifurcation, but proximal to the inguinal ligament; 21 of these were directly due to bleeding from a major vessel in the pelvis. Of the 32, eight survived to a medical facility but subsequently died of their wounds, including four of those with a major vessel transection.

Discussion

Junctional trauma has been defined as that spanning the root of an extremity and adjacent torso, in which the proximal and distal extents of the wound are in anatomically distinct regions [17]. Attempts to control haemorrhage from junctional areas such as the groin have frequently been unsuccessful, as direct manual compression is often ineffective. In a non-benign tactical situation, it is also impractical [17]. As a result, haemostatic agents capable of temporising the effect of the injury in order to allow transfer to an appropriate surgical facility have recently been adopted by the UK Defence Medical Services. The agents used by UK forces include topical haemostatic agents QuikClot (Z Medica Corporation, Wallingford, Connecticut, USA) and HemCon haemorrhage control bandage (HemCon Inc, Portland, Oregon, USA) [18]. Although extremity injuries were reported as responsible for the majority of combat wounds in the war phases of Iraq and Afghanistan [19,20], junctional trauma provided only a small subset of these. Clouse and colleagues [21] audited 6801 casualties presenting to Balad Air Base, the US level 3 surgical facility in Iraq, over a 24 month period up to August 2006. 324 (4.8%) were diagnosed with vascular injuries: of these, extremity injuries accounted for 74.9%. However, the external iliac, common femoral artery (CFA) and profunda femoris arteries were injured in only 1, 3 and 4%, respectively. It is important to appreciate that, although junctional trauma is potentially catastrophic, it is rarely seen, even in a military context.

Notwithstanding the low number of potential applications for a groin junctional tourniquet, there are practical reasons why they may not be as effective as hoped. The effect of direct compression over the external iliac artery was assessed in a study by Blaivas and colleagues [22]. While direct pressure over the abdominal aorta and common iliac arteries could be shown sonographically to cause cessation of common femoral artery flow, pressure over the external iliac artery resulted in an increased common femoral artery (CFA) flow. Pressures greater than 80 lbs were applied which, despite being insufficient to obstruct flow, proved to be intolerable by all patients. The inability to control flow with EIA compression may have been due to pain – not an issue in the moribund, but more significantly, with EIA compression flow increased. If a groin junctional tourniquet was inaccurately placed it may exacerbate the bleeding.

The efficacy of pressure application over the common femoral artery in the groin was also examined by Swan et al. [23]. Despite maintenance of pressure sufficient to obliterate the distal pulse, Doppler signal was detected over the posterior tibial artery after an average of 20 s, presumably due to a collateral circulation bypassing the pressure point. These experiments led Swan et al. to describe pressure point control as a 'euphemistic misnomer'. Although the Blaivas study reported no complications, this was following pressure application measured in seconds, not the hours that may be required in extremis. With the use of tourniquets over common femoral vessels, there may be significant complications, including ischaemic injury, infection, secondary compartment syndrome and proximal amputation [24]. Reperfusion may also result in the requirement of fasciotomy after periods of prolonged ischaemia [25]. If the potential benefit outweighs the potential harm, then use of groin tourniquets could be supported; thus far the evidence remains unproven. Junctional tourniquets have been compared favourably to regular windlass tourniquets [10], such as the Combat Action Tourniquet (CAT) (Composite Resources, Rock Hill, SC, USA) (Fig. 3). Like windlass tourniquets, truncal tourniquets have been designed to be small, lightweight, low-cost, quickly applied and easy to use.

Whilst evidence for their efficacy is awaited, truncal tourniquets are anticipated to control pre-hospital bleeding, thereby increasing the duration of survival of a casualty to enable evacuation to a forward surgical facility. The intended users are anticipated to differ from those using windlass tourniquets: whereas CAT tourniquets are routinely issued to deployed UK soldiers, Kragh et al. [10] envisaged that the use of truncal tourniquets would be by senior medic or physician's assistants, under supervision by a physician, at a location such as a battalion aid station. Pre-hospital medical care for casualties in Afghanistan is initiated by the soldier himself or by colleagues, all of whom have received some limited basic medical training. Truncal or junctional tourniquets may have an application in military medicine, but it seems unlikely that they would be best deployed at the section level; they may have a role at a Regimental Aid Post (RAP) or the during specialist medical evacuation due to the detailed anatomical knowledge and training that would be required. We believe that more widespread availability of these devices would inevitably lead to inappropriate use which could have serious ramifications in terms of additional morbidity.

In our study, the 8 casualties with intra-pelvic vascular PS injuries who survived to a medical facility represent a subset in which vascular control proximal to the inguinal ligament may have improved the outcome. Future research into strategies to reduce mortality from groin vascular injury should focus on the control of bleeding that arises above the inguinal ligament, rather than from

Fig. 3. Combat action tourniquet.

the groin-abdomen junction. One such technique, intra-arterial balloon tamponade has been used as an emergency measure in the management of life threatening haemorrhage from pelvic fractures [26]. Recent research has confirmed its efficacy in the management of pelvic haemorrhage in a porcine model. This is particularly so when the haemorrhage is associated with a coagulopathy, commonly seen in the multiply injured military trauma casualty [27,28]. Access is usually achieved via an accessible femoral artery, and a balloon catheter inserted proximal to the site of bleeding, and inflated. In the case of pelvic fractures, this was to the infra-renal aorta. Although in the hospital setting, this is usually performed by an interventional radiologist, it is a technique that could be used in the pre-hospital setting with appropriate training. Further work into the applicability, safety and efficacy in humans is needed for novel methods of proximal vascular control.

Our aim was to identify vascular injuries of the pelvis and proximal thigh that could not be managed with a conventional thigh tourniquet but which could potentially be amenable to more proximal control. We therefore limited our analysis to those with potentially life-threatening injuries, and excluded all those with AIS < 3. This is appropriate as all significant injuries to the iliac and femoral vessels gain an AIS score of 3 or greater. Despite limiting our analysis to those who sustained a significant pelvic injury, the majority of deaths in our study (63%) were not directly attributable to the pelvic injuries sustained. Examination of the ISS and NISS scores illustrates the increasing severity of the injury patterns involved as, for many, the pelvic injury was only one component of a constellation of injuries.

Our study is a retrospective study, using data derived from the UK JTTR trauma registry. There are weaknesses inherent in the use of such data, including the possibility of intra- and inter-observer error in the severity and diagnosis of injuries, misclassification of these, and errors made both when data were originally collected and when transferred to the computerised record. No data were available on mounted or dismounted status, vehicular type, or position in vehicle if mounted. These data have been restricted due to their sensitive nature.

Further, we have made assumptions on the cause of death, using the AIS scores of the injuries sustained, with cause of death attributed to the more severe injury or injuries. With multiply injured casualties, the exact cause of death can often not be inferred, and is in all probability often due to a combination of the injuries sustained; inferring that the injury (or injuries) with the higher AIS score is (are) the cause of death is flawed, but it does provide strong evidence to the most likely cause. It is apparent that lower scoring injuries sustained contemporaneously could be responsible. There is, however, no way of categorically establishing cause of death, and we believe that our approach is the only sensible way to try to estimate the mechanism responsible. We have arrived at our conclusions based on robust JTTR records, made in the field hospital on casualty admission, allied to the findings at post-mortem of HM coroner.

Conclusion

Based on our review of casualties who sustain significant pelvic or proximal thigh injuries, attempts to save life through control of the arteries in the groin via a groin junctional tourniquet would be largely ineffective, in part due to the scarcity of suitable injuries. For bleeding proximal to the inguinal ligament, identified in 32 casualties, 8 of whom were potentially survivable, it is necessary to gain control proximal to the site of bleeding, which would require control of the aorta or common iliac vessels. In the event of a common iliac vessel injury, identified in one of our cohort, only control proximal to the aortic bifurcation would suffice. Based on this evidence there may be a role for more proximal control of haemorrhage in the trauma setting, but the benefits of routine deployment of junctional groin tourniquets would be limited.

Although the figures were not available to us, incorporation of the much larger US JTTR data may have demonstrated a benefit for a greater number of patients from pelvis and proximal extremity injuries and provided an indication for the use of groin junctional tourniquets. Given the importance of controlling junctional haemorrhage, this merits further research.

Conflict of interest statement

NMW, WE and JCC are all employed by the Ministry of Defence. There are no other potential conflicts of interest.

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Fig. 3 was provided by North American Rescue, Greer, SC, USA.

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