From Bastion to Birmingham.

What have we learnt from acute military trauma care and how has it impacted on emergency treatment of civilian trauma?

Rajpal Nandra¹, Paul Parker ², Keith Porter³.

¹ Orthopaedic Specialist Trainee, West Midlands Deanery, U.K.
² Consultant Orthopaedic, University Hospital Birmingham.
³ Professor of Clinical Traumatology, University of Birmingham.

Correspondence: Mr Rajpal Nandra  
Email: rajpalnandra@nhs.net

©The Author(s). This article is an open access publication.

Abstract

Military medical innovation has significantly improved battlefield casualty survival. In recent warfare, we observed higher rates of survival than expected. In fact, a quarter of those severely injured were not expected to survive at all. In Afghanistan and Iraq medical teams had to adapt to changing mechanisms of injury, notably the improvised explosive device, which often resulted in major haemorrhage. The lessons learnt during recent deployments has altered how we manage civilian major trauma here in England, which comprises a trauma network of 24 level 3 centres. These networks are supported by robust pre-hospital care, diagnostics, senior doctor input and service evaluation. We discuss the key logistical and medical innovations that have transitioned into civilian trauma systems with a focus on haemorrhage control and damage control resuscitation and surgery.

Keywords:
Major trauma; Damage Control; Massive Transfusion; Haemorrhage; Military

Introduction:

Since the start of the century there has been a significant deployment of UK military resources to Afghanistan (2001 – 2014) and Iraq (2003-2009). Battlefield injuries during these wars were often due to blast from improvised explosive devices (IED) posing challenges to field medics, which they became accustomed to dealing with during thirteen years in Afghanistan. Casualty survival rates were higher than anticipated; in fact, a quarter of those severely injured were not expected to survive at all (1-3). The survival models used may not have been tailored to the casualty load and mechanisms of injury and may need to be updated for future conflicts.

Separate to these conflicts was the North Atlantic Treaty Organisation (NATO) extraction time frame, where casualties should reach a level 3 medical facility within seven hours of injury. Embedded field medics, the centrality of Camp Bastion and the helicopter-borne medical emergency response team (MERT) was key to timeline implementation. They will not be available (initially) in future conflicts (4).

This combination of injury mechanism and prompt medical care has driven a shift in major trauma innovation that is now implemented into many civilian systems. These comprise six broad areas: Consultant led care; the ethos of damage control; standardised training programs and treatment guidelines; real-time system evaluation and enhancement; rehabilitation to achieve occupation reintegration; effective clinical and scientific research (5).
In 2016, NICE acknowledged new evidence and issued guidance on major trauma care (NG39, NG40), encompassing those hard-won battlefield principles (6,7). Delivering acute medical care, initially in austere environments, such as Afghanistan, posed unique challenges, not least the hostile environment and limited resources injured combatants found themselves in. Later on, in the conflict we saw care delivered by a purpose built, well-resourced and structured hospital. The hospital was resourced with two CT scanners, an MRI scanner, 24-hour radiology and ITU. There were many transferable skills and systems that could directly enhance UK civilian trauma. This article will discuss the changes to civilian trauma systems that have been successfully implemented, with a focus on haemorrhage control.

Pre-hospital care

The allied joint doctrine for medical support states that injured battlefield combatants be transferred from the point of injury to a level 2 medial facility capable of delivering damage control surgery within 2 hours (8,9). Recent modification endorsed by the UK Defence Medical Service introduced the platinum ten minutes to save lives and limbs (8). (Figure 1)

This pathway prioritises assessment, resuscitation and prompt transfer to a facility that can effectively manage injuries sustained. The casualty will rapidly pass through a hierarchy of medical expertise along this timeline, with the clear objective of early assessment and rapid interventions by senior medical officers. The success of multi-disciplinary consultant led care in Afghanistan and Iraq has prompted early triaging (at the point of injury) and tiered hospital alerts. On a national scale the UK has established a major trauma network where severely injured patients are diverted to a major trauma centre (MTC), bypassing trauma hospitals or Trauma Units (TU) (Level 2) unless immediate resuscitation with rapid sequence intubation is required within 45 minutes of the emergency call (7). These implementations were based upon a report by Anderson., 1999 and the NCEPOD, Trauma who care report (2007) which looked at civilian trauma. In Afghanistan, three treatment scenarios were established with adapted treatment priorities and protocols (10). Broadly resulting in a staged approach to trauma care based upon the tactical threat; Care Under Fire (a fire fight is ongoing), Tactical Field Care (the fight is over, but resources are limited) and Combat Casualty Evacuation Care (when the casualty is being extracted from the incident). Combat pre-hospital trauma life support implements this change and may induce future changes in civilian trauma pathways based upon the mode and setting of injury.

Major trauma centres have recently introduced a tiered alert system, for example a “Code Red” call for major traumatic haemorrhage. The “Code Red” alert mobilises a consultant led multidisciplinary team and resources including transfusion protocols, interventional radiologists and operating theatre staff that are waiting for the patient’s arrival – not vice versa. Consultants receiving such patients leading to early treatment plans will improve survival, although this is yet to be proven (5). To aid pre-hospital care providers, NICE advocates the use of decision-making triage tools to estimate injury severity and patient’s needs. We lack a uniformly accepted and validated triage tool suited to this task. The military utilise Injury severity score but the popularity of the Trauma Induced Coagulopathy Clinical Score (TICCS) is increasing (11). The TICCS score is reliable in ruling out the need for damage control resuscitation (DCR), (NPV 100%, AUC 0.98). The concern with all of the predictive tools is under or over estimation with devastating consequence (12).

With increasing data and research, emergency care providers hope to establish an effective pre-hospital triaging tool to direct individual care towards appropriate resources. This will reflect civilian patient demographics and mechanisms of injury, which differ to combat induced injuries. Using TARN data, decision curve analysis, with intention to treat may add value to this debate.

Damage control Resuscitation

The manifestations of uncontrolled haemorrhage are hypothermia, acidosis and coagulopathy, the ‘terrible triad of trauma’ (13). This is a potentially reversible state and during recent military campaigns, damage control resuscitation (DCR) prioritised haemorrhage control and ‘haemostatic’ resuscitation to reduce avoidable fatalities (14). Damage control resuscitation advocates emergent tourniquet use, proactive massive transfusion protocol activation and very early use of anti-fibrinolytic agents (15). The synergistic effect of these interventions yielded improvements in military survival and we are increasingly seeing them used in UK trauma networks.

The first systematic change to military care was the modification of the resuscitation algorithm to <C>ABC, thus prioritising catastrophic haemorrhage
<C> before proceeding to airway (16). It is perhaps the most significant contribution to trauma care by the military. Observations that external haemorrhage has become the leading cause of death in combat casualties and the availability of haemostatic agents, tourniquets and field dressings supported this change. Battlefield advanced trauma life support has adopted this change, it has not yet been adopted by the 10th edition ATLS manual, which may be due to difference in mechanism of injury and lower incidence of catastrophic haemorrhage. One concern is that potentially avoidable deaths do not receive the targeted treatment they require. Dorlac et al. raised concerns with the level of haemorrhage control administered to exsanguinating patients who had signs of life on arrival to the emergency department but subsequently died (17).

**Tourniquet devices**

Tourniquet devices have been re-instated to both military and civilian trauma systems with data endorsing use to gain early haemorrhage control and minimise blood loss (18). Tourniquet application is not a benign procedure. Application leads to extremity acidosis (lactate), reduced limb temperature and low tissue oxygen tension compounded by carbon dioxide accumulation (19). There are also concerns over pressure related nerve injury and tissue necrosis (20). Although a simple cost-effective device, inappropriate use or improvised devices may result in avoidable complications. The re-instatement in 2005 used a standardised device coupled with an education program and protocol. Following implementation battlefield tourniquet use increased 10 to 20-fold with low complication rates and improved survival rates (21-23).

Schroll et al., investigated tourniquet use in civilian trauma, reporting safe application in 89% and a low mortality rate of 3% (24). Closer inspection of the study group injury showed injury severity scores that were lower than most military series and 37% underwent an amputation. What these observations tell us is that early tourniquet application, in patients with uncontrollable bleeding resistant to direct pressure and haemostatic dressings is beneficial to survival. The 2016 NICE guidance for trauma assessment and initial management recognised this, endorsing the use of tourniquet devices (6). For safe implementation health care professionals must be educated on application and avoid prolonged use beyond two hours (20). Implementation of safety checks and education must parallel the use of tourniquets in civilian patients to prevent prolonged tourniquet use that unnecessarily risks pressure ulcer formation, nerve compression syndromes and reperfusion injury.

**Therapeutic agents and transfusion products**

Tranexamic acid has been shown to reduce traumatic haemorrhage and mortality (25). This therapeutic agent binds to plasminogen and inhibits fibrinolytic activity. Tranexamic acid is now used in civilian and military trauma (26,27). Clot protection is important in trauma care and the motive for the use of permissive hypotension. Numerous resuscitation protocols have been used to restore intravascular volume. Component blood products have gained popularity over all crystalloids or single therapy freeze dried plasma (28,29). Massive transfusion protocols, administering packed red cells, plasma and platelets (1:1:1) to recreate (using components) whole blood administration, are used in military and civilian emergencies (30). Saline administration in trauma is now seen as directly increasing morbidity and mortality.

In mass casualty or austere environments, the US, UK and the Norwegian military have developed additional strategies, including rapid blood collection, walking donors and buddy to buddy transfusion, it is unlikely resources in the UK will be exhausted to require this. However, there is clearly survival benefit from major transfusion protocol implementation and also the use of fresh whole blood products (30,31). Alcock et al., report an 86% survival rate in 59 combat personnel receiving more than 10 units of blood. Five of seven soldiers have survived after receiving more than 100 units of red blood cells (32). Researchers have found significantly improved survival rates when blood components are given 1:1:1 (33).

This improved survival has been attributed to the proportional transfusion of fibrinogen or the 1:1:1 transfusion principal (28). The PROPPR trial in America found a small difference in early civilian mortality, favouring massive transfusion protocols, the study was hindered by control group cross-over. The authors reported no difference in secondary outcomes (acute respiratory distress syndrome, multi-organ failure and thromboembolism) (34). Dente et al., halved mortality rates at 24 hours following MTP implementation but their mean transfusion ratio was only 1:1.5 (35). Thus, combined transfusion of
fractioned blood products is showing promising survival rates and safety in civilian trauma. The PAMPER trial is currently investigating trauma survival rates following air ambulance administration of blood products to the patient at the scene, it may not show a benefit to that seen in military settings (36).

**Damage control Surgery**

We now recognise that early but lengthy definitive surgery raises risk of cardiorespiratory complications and favour damage control surgery (DCS), which augments resuscitation to restore physiological parameters (37-39). Operative time in DCS is short, prioritising wound decontamination, haemorrhage control and skeletal stabilisation using minimally invasive orthopaedic techniques for extremities. Damage control laparotomy, via a wide exposure allows rigorous evaluation of bleeding and haemorrhage control. Definitive surgery is postponed until resuscitation successfully restores physiological parameters, thus tempering inflammatory responses and its sequelae (ARDS and MODS) (40,41).

Damage control laparotomy (DCL) is associated with significant complication rates and hospital readmissions, but the long-term survival benefit is indisputable (42). Despite differing mechanisms of injury and patient demographics fascial closure rates following DCL are comparable in military and civilian cases (43). In emergent situations, dealing with physiologically deranged bleeding trauma patients, poor decision making impairs patient selection. Poorly selected patients who have poorly undertaken DCL are likely to experience complications (44). These critical, time dependent decisions are made by experienced military consultants, similarly, major trauma centres are transitioning to consultant led care, to improve early patient selection. In penetrating trauma DCL has a positive effect on survival (45). Bograd et al., found higher rates of complications and similar mortality rates comparing penetrative wounds in military patients having DCL compared to single stage laparotomy. The DCL patients had higher transfusion volumes and lengthier ITU admissions, perhaps indicative of a positive influence on survival considering the extremis of this cohort (45). Damage control laparotomy clearly has an important role in bleeding, haemodynamically unstable patients. There is also evidence to support the important role of damage control resuscitation, which performed synchronously with surgery leads to enhanced outcomes (46).

Traumatic extremity injuries are thought to be best managed with DCS or DCO (Damage Control Orthopaedics) using external fixators to stabilise skeletal fractures and treating open wounds with early antibiotics and debridement before definitive surgery (47-49). There is again a body of opinion that the idea of DCO versus Definitive Care is binary and outmoded and that ‘Early Appropriate Care” (EAC) with its deeper understanding of trauma physiology is a better and more fluid approach (50).

**Research, audit and patient education**

Appropriate data collection remains key. The Trauma and Audit Research Network (TARN) was established more than a quarter of a century ago to scrutinise the efficacy of traumatic injury care in the UK. Military and civilian data registries are increasingly common with a propensity to identify inadequate processes and provide epidemiological data. When reviewing the most influential articles generated from the database authors, highlighted...
several studies describing the efficacy of trauma systems, the heightened risk to patients on warfarin, the increased mortality following cerebral contusion and comparisons to EuroTARN (51). Data collection and analysis remain vital for ongoing audit and adaptation during conflict and essential to standardise trauma care across networks in the UK (52). A recent TARN report confirmed the changing demographic of trauma patients with mean injury age increases paralleling an ageing UK demographic (53,54). Studies of this nature, reporting changing trauma trends, help to strategize trauma care and resource services accordingly.

There are presently 24 major trauma centres in England which provide rapid access to computer tomography and clinical expertise 24 hours a day (55). Early findings suggest improvements in time to CT and other performance indicators but a probable lag time to overall mortality improvement (56). In America trauma remained at the same level of survival despite increasing severity of injury and other demographic changes (2). This was attributed to DCR, DCO, DCS and improved imaging.

A UK program to train lay civilians in basic trauma care provision as first responders is ongoing. Immediate buddy-buddy help on the battlefield and standardised basic medical training contributed to mortality reduction (3). The Hartford Consensus on Marauding Terrorist Firearms Assaults (MTFAs) recognised this, prompting the addition of ‘treat’ to the recommended bystander response of “run, hide and tell” (57). Citizen AID is designed to offer basic training and multiplatform guidance to keep bystanders calm, effective in mass casualty scenarios with a view to them offering basic medical care, such as the application of a tourniquet (57).

Conclusions

In modern medicine few would agree with Hippocrates (Hippocrates, c. 460 – 370 BC) who stated, ‘war was the only proper school for a surgeon’. Military combat care reacted well to evolving threats and changes in mechanism of injury. Thus, we saw the implementation of major transfusion protocols and the application of tourniquets. Civilian trauma has learnt from these medical and logistical innovations to improve the standard of care. Trauma networks and damage control surgery originated from civilian trauma systems, similar work capturing data and encouraging research innovation to adapt to changes in trauma will continue to improve outcomes and continue the synergistic relationship with combat trauma.

Conflict of Interest Statement:

None of the authors have any conflicts of interest.

Funding:

No funding or sponsorship was received.

References


35. Dente CJ, Shaz BH, Nicholas JM, Harris RS, Wyrzykowski AD, Patel S, et al. Improvements in


