

Lessons learned from the casualties of war: battlefield medicine and its implication for global trauma care

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Summary

According to the Global Burden of Disease, trauma is now responsible for five million deaths each year. High-income countries have made great strides in reducing trauma-related mortality figures but low–middle-income countries have been left behind with high trauma-related fatality rates, primarily in the younger population. Much of the progress high-income countries have made in managing trauma rests on advances developed in their armed forces. This analysis looks at the recent advances in high-income military trauma systems and the potential transferability of those developments to the civilian health systems particularly in low–middle-income countries. It also evaluates some potential lifesaving trauma management techniques, proven effective in the military, and the barriers preventing these from being implemented in civilian settings.

Keywords

trauma, military, developing world, innovation

Introduction

The link between military and civilian medicine has deep historical roots.¹ In high-income countries each successive conflict that the military engages in affords the opportunity to contribute improvements in trauma care, many of which are translated into civilian healthcare systems.² The wars of the last decade in Iraq and Afghanistan have changed the nature of injuries seen on the battlefield leading to further trauma management innovation.³ Lessons learned in these hostile environments have guided many developments in trauma care in high-income countries resulting in improved casualty outcomes and a lower mortality rate; an objective shared by the civilian and military trauma doctrine.²

On the other hand, trauma management is a neglected epidemic in low- and middle-income countries, both in civilian and conflict settings.⁴ Trauma is

responsible for more global deaths annually than HIV, malaria and tuberculosis combined, but receives a fraction of the attention and funding.⁴ Death from accidental or non-accidental injury has fast become the leading cause of death in young people in low–middle-income countries.⁵ One of the greatest challenges to implementing any sort of trauma intervention in a resource-poor setting is the inadequacies in the health system in which it is set. Weak health systems and poor public funding test both the feasibility and the sustainability of trauma care development.⁴ With trauma constituting such a significant portion of mortality, and with many simple cost-effective solutions being pioneered in the military setting in high-income countries, this area should be one of the most active research areas for cost-effective health investment and knowledge transfer.⁵ In spite of the heterogeneity (fiscal, health systems development, etc.) of low–middle-income countries, there is a commonality of need for cost-effective interventions for dealing with trauma irrespective of the different barriers that each country presents.

The battlefield has been a key area for innovations in trauma care⁶ and throughout the great wars of the last two centuries, military and civilian trauma care have evolved synergistically.⁷ Physicians in the American Civil War first noted that prompt attention to casualties, debridement of wounds and amputation to prevent systemic infection all had the potential to preserve life. World War I witnessed the institution of casualty evacuation reducing the time from point of wounding to reaching a medical facility, and in World War II the first use of blood transfusion and fluid resuscitation in combat hospitals was instituted; alongside the introduction of antibiotics, these developments were hailed as the turning point for survival rates of those injured on the battlefield. An intense exposure to such high volumes of trauma victims is

Table 1. A summary of studies reviewed.

Study	Medical innovation reviewed
Allcock et al. ¹⁰	Massive transfusion protocol: The adaptation to include 1:1 ratio RBC to plasma
Beekley ¹¹	Proximity of medical facilities to frontline and therefore casualties, improved evacuation timelines
Brodie et al. ¹²	Tourniquet use for massive haemorrhage control in extremity wounds/amputation
Hodgetts et al. ¹³	Adaptation of trauma management framework from ABC to C-ABC
Malchow and Black ¹⁴	Evolution of pain management to include multimodal analgesia and increased use of peripheral nerve blockades
Ling et al. ¹⁵	New practices in traumatic brain injury facilitating rapid evacuation and sophisticated prostheses for amputations
Kehoe et al. ¹⁶	Progress in pre-hospital care and casualty evacuation
Walters and Mabry ¹⁷	Enhanced training in first aid for every enlisted soldier and upgraded 'field dressing' packs to include a tourniquet

cited as one of the main reasons for such huge leaps forwards in care. Coupled with this, the dynamic and reactive environment of conflict fosters an attitude among physicians to strive for better clinical outcomes.⁷ The burden of morbidity in conflict is, however, increasing.⁸ The reason for this is two-fold; first, due to medical and logistical developments the lives of many more seriously injured soldiers are being saved, even those who have experienced injuries previously deemed 'unsurvivable'.⁸ Second, there has been a shift in tactics used in most low-intensity modern conflicts, with greater emphasis on maiming soldiers rather than killing them, as this has a greater impact on enemy resources (Gawande, 2004).⁴⁰

In low–middle-income countries the rapidly evolving infrastructure and construction sector, as well as more roads, has meant trauma has become a leading cause of death in young people (0–24 years old).⁹ Given the financial constraints in low–middle-income countries and the inherent costs in improving the health system, trauma care has been neglected in research. In this analysis, we examine the current state of military trauma care in high-income countries and how these developments could have wider cost-effective impact for helping deliver affordable trauma care in low–middle-income setting(s).

Methods

A literature search was conducted through the PubMed journal database. The key search MESH terms were: 'military medicine', 'civilian', 'trauma systems', 'innovation/advances/evolving/developments',

'collaboration', 'lessons learnt', 'Iraq and Afghanistan', 'low and middle income countries' and 'global application'.

The inclusion criteria for studies were ones examining military medical advancements. Exclusion criteria were studies on medical advances that had been made in civilian practice or those that focused on the transfer of information from civilian to military systems. Eight studies were found relevant to the area of analysis and reviewed in depth^{10–17} (Table 1). A large number of publications described the potential for military developments to be transferred to civilian practice, but none were specifically relating military advances in trauma care to developing healthcare systems.

Key advances in trauma pre-hospital care

Pre-hospital care has dramatically improved survival odds for those injured in combat,¹⁸ particularly use of Medical Emergency Response Teams (helicopter-borne, physician-led teams), to cut down time from battlefield trauma to hospital.¹⁶ One of the primary advantages of having a doctor on board is the possibility of conducting pre-hospital anaesthesia which can improve outcomes in patients with devastating injuries.¹⁶ Despite the uniquely challenging working environment of a tactical helicopter, Medical Emergency Response Teams deliver some of the most effective pre-hospital care.¹⁶ The lessons from military pre-hospital care have been clear. With (para)medically led teams, fast access and evacuation times all combine to save lives. However, most

advances in pre-hospital care have not been examined for feasibility in low–middle-income settings,¹⁴ e.g. delivery of first aid at the point of trauma. Early use of tourniquets and topical haemostatics has been a major lifesaver on the battlefield, yet consideration of how this could be deployed outside hospital settings in low–middle-income countries has yet to be given.¹⁹ Likewise, where air evacuation is now common in high-income countries, low–middle-income countries, particularly those with emerging economies, have yet to assess the cost effectiveness of air ambulance service for trauma. In spite of often poor road infrastructure, many low–middle-income countries still have trauma patients being transferred by private cars/vans to hospitals. The distances, poor infrastructure and high cost–gain ratio of implementing any form of air evacuation remain major barriers to executing any form of fast casualty evacuation programme suggesting that the focus needs to be at the point of trauma to stabilise patients for what are often long journeys to receive definitive trauma care.

Key technologies: intraosseous needles, tourniquet and blood transfusion

Intraosseous needles were originally developed for battlefield administration of fluids and analgesics for catastrophic trauma.¹⁹ Their robust placement is also valuable when working in a moving environment such as by air or poor roads, the latter being particularly attractive for low–middle-income countries where rough terrain causes normal cannulation, including central lines to come out.²⁰ Intraosseous needles are now standard practice for trauma care in high-income countries for use in severe trauma, normally road traffic accidents, as a direct response to its proven military success.²¹ The relative ease of training and placement make them an attractive proposition for use by paramedical staff and community health workers who are often the first to provide care in low–middle-income settings.

Tourniquets have been adopted for widespread use in the military as a battlefield necessity.²² Every soldier is issued with a tourniquet as part of a field dressing pack, and this has led to dramatic reductions in deaths from exsanguinating extremity wounds.¹² Innovation in tourniquet equipment and techniques continue; a new wide-gauge tourniquet is being trialled with the rationale that a wider surface area and adjustable pressure will enable haemorrhage control while protecting from nerve and vascular damage.²² Tourniquets have not been taken up extensively by high-income countries due to faster access to definitive surgical control in hospitals;¹⁹ however, for

low–middle-income countries this cheap, effective device could have a major impact on outcomes. Their training and application can be quickly and easily taught as part of basic first aid training. Cheap material design also means mass production and distribution is possible.

Combat casualties often receive blood transfusions to prevent haemorrhagic shock.² One of the greatest successes in combat casualty care has been the adapted blood transfusion protocol. Exsanguination from major vascular trauma prevails as the leading cause of death of soldiers in combat; massive haemorrhage usually occurs from traumatic amputation or gunshot wound.²³ Massive transfusion is defined as the transfusion of 10 or more units of packed red blood cells over a 24-h period.²⁴ In addition to this, the military has begun trialling new medicines such as the ‘off-label’ use of recombinant activated factor VII and the cheap tranexamic acid which is effective at controlling life-threatening bleeding.^{25,26}

Aggressive treatment of the ‘lethal triad’ of hypothermia, acidosis and coagulopathy using haemostatic techniques, early damage control surgical intervention and massive transfusion has led to survival rates in military settings of over 86% compared to 40–60% in comparable trauma in civilian settings.¹⁰

Adoption of these transfusion practices in civilian high-income trauma care²³ has been relatively slow. Applying military transfusion protocols to the civilian context has been complex as practices need to be adapted to the severity of the trauma and cannot rely on a uniform response to haemostatic resuscitation.²³ With obvious challenges for high-income countries, the view is that *de novo* introduction of transfusion systems into low–middle-income countries is mostly not a cost-effective option,²⁷ but for those middle-income countries with transfusion protocols already in place, adapting the guidelines to include equal measures of clotting factors to red blood cells could save lives, but further research is needed in these settings, particularly urban middle-income with good secondary care and a high incidence of violent and non-violent related trauma.

Adapting the trauma management framework

As more research has been done in this area, it is now widely acknowledged that the most common cause of death from combat injury is exsanguination.¹⁰ Consequently, the military trauma paradigm has been redefined to put catastrophic haemorrhage as the main priority from the point of wounding. The standard, airway-breathing-circulation, is now assessed after haemorrhage has been brought under

control; <C>ABC with C standing for catastrophic haemorrhage.¹³ This adaptation reflects the differing nature of injuries seen in military and civilian settings, with a much higher injury severity score on average. Given that this 'intervention' is simply adapting a protocol, it may be relatively easy to implement in middle-income settings and this merits further exploration in terms of curriculum for trauma training of all point of first contact health workers and paramedical staff.

Pain management

A paradigm shift in pain management has accompanied the evolving nature of traumatic injuries seen on the battlefield,²⁸ where inadequate analgesia has been shown to be associated with poorer outcomes.¹⁴ Opioids have long been the cornerstone of strong analgesic therapy, but this treatment comes with its own complications. There is growing interest in so-called multimodal therapy for analgesia in the military trauma setting, encompassing a range of medications; the rationale being to exploit the synergistic action of pharmacological agents. This has allowed military care to provide safe and effective analgesia from point of wounding to evacuation. Alongside opioids, ketamine, antidepressants and anxiolytics, there is increasing use of regional analgesics (peripheral nerve block infusions or epidurals).²⁸ These allow pain to be well managed, without compromising respiratory function or risking other systemic side effects.²⁸ Many high-income civilian physicians are adopting this method for vulnerable patients such as the elderly with orthopaedic injuries and multiple comorbidities.¹⁴ For low–middle-income countries the issue is often one of drug availability and costs. Many countries have significant legal and cost barriers to obtaining opioid-based analgesics. However, with increasing generics and national manufacturing capabilities, e.g. Cipla in India, the ability to make cheap multimodal medicines and even combine these in novel formulations and quick delivery sets could actually provide far better trauma analgesia in resource-constrained environments. These improvements in manufacturing capability are also important in light of the strict legislation surrounding opioid importation in low–middle-income countries as they provide a structured national-based system for the provision of medicines for effective pain relief.²⁹

Traumatic brain injury

Traumatic brain injury has become the signature injury of recent wars, predominantly due to blast injuries from improvised explosive devices.³⁰ Of all

individuals medically evacuated due to injuries sustained from hostile assault, 28% had a traumatic brain injury.³⁰ In response to the surge in these injuries, management guidelines have been introduced for the diagnosis and treatment of traumatic brain injury. Traumatic brain injury can be difficult to identify at time of injury so guidelines state that in those with head injuries and an impaired Glasgow Coma Score (of 13 or below) immediate evacuation to a facility with a neurosurgeon is indicated.¹⁵ Hypertonic saline treatment is a relatively new proposal developed from military medicine. Sodium chloride solution is used to manage acute elevations of intracranial pressure.¹⁵ The appeal of this method is that it will not compromise intravascular volume while still increasing osmolarity; particularly relevant in wounded soldiers as they frequently suffer substantial haemorrhage in addition to their head injury.¹⁵ This method may be less applicable in civilian settings though, as the vast majority of patients with head injury have not also experienced haemorrhagic shock.¹⁵

Another promising treatment for traumatic brain injury is the use of modest hypothermia, which has been shown to decrease possibility of vasospasm after severe combat blast injury.¹⁵ Decompressive craniotomies, rarely used in civilian practice, have also gained popularity among military neurosurgeons.³¹ In addition to permitting brain swelling and allowing for localised brain cooling, it also enables control of intracranial pressure.¹⁵ Intracranial pressure has previously been notoriously difficult to control during evacuation and more conventional methods such as pharmacological coma are fraught with difficulties.¹⁵ Although aggressive, decompressive craniotomies are the most practical approach. This approach to managing traumatic brain injury depends on access in low–middle-income countries to suitably trained surgeons, which will be absent in many settings and countries. However, even without a dedicated neurosurgical unit training could introduce task shifting for general trauma surgeons to allow them to perform limited decompression craniotomies even at level 1 (district settings). In light of the upcoming report by the Lancet Commission on Global Surgery into the training needs for surgery at level 1, there is an opportunity for reviewing this in most middle-income settings with a view to instituting this type of training.

Non-medical lifesaving advancements

Mobility of combat hospitals and proximity to casualties

Many improvements in the clinical outcomes of injured soldiers have come, not from changing

medical practices, but from analysing the way in which trauma care is executed on the frontline and if there is scope for improving efficiency.¹¹ When Combat Support Hospitals were introduced they were frequently criticised for being too large and cumbersome to meet the needs of the agile troops, and were often far behind the advancing ground forces.¹¹ They were adapted after the First Gulf War (UK designation – Operation Granby) in order to improve mobility and flexibility. This change in reduced the time from point of wounding to the casualty arriving at a medical facility and consequently dramatically reduced death rates on the battlefield.¹¹ This idea eventually evolved to form the Forward Surgical Teams we see today in current conflict, just a few miles from the frontline. This concept, the importance of medical facility proximity, has relevance to civilian trauma systems in low–middle-income countries. The presence of community health centres and improved transport systems to larger facilities has brought down the death toll from trauma; however, many countries even in high trauma urban settings still lack any planning or general oversight of the management of trauma.³² In resource-constrained settings potential changes could be made by analysing the existing transport patterns of those who are injured³³ and redesigning cost-effective outreach of trauma care using relatively straightforward planning and organisation (command centres) even where care is distributed over an array of public and private providers.

First aid training for trauma

Another logistical adaptation that has saved lives is the enhanced battlefield first aid training given to soldiers before and during deployment.³⁴ At the point of wounding, basic medical care such as haemorrhage control with tourniquets and topical haemostatics such as the HemCon field-dressing¹³ can be delivered.³⁴ All soldiers are taught haemorrhage control techniques.¹⁷ If a non-medical comrade can deliver care from the point of wounding until medical help arrives, this dramatically increases the chance of survival.¹⁷

Also imbedded in the units on the frontline are combat medical technicians who have enhanced training in trauma care.³⁴ They are qualified to provide advanced first aid, administer strong analgesics for pain relief and call for helicopter evacuation when necessary.³⁴ Care is embedded at the point of wounding, and improvements in evacuation capabilities mean timeframe for moving casualties to the next echelon of care is much reduced.³⁴ The notion of training individuals in first aid if they work in a

situation where casualties are regularly taken is widely applicable in high-income countries.³³ Soldiers are trained in first aid for rapid delivery of care after the point of wounding.³⁴ Following a similar principle, those working in the public sector and where frequent accidents occur, such as bus drivers, taxi drivers and the police force, could be trained in basic first aid, given equipment to use and given two-way radios in order to alert hospitals of incoming patients in many developing countries.³³

In middle-income settings where emergency medical services do exist, relatively low-cost interventions could have a substantial impact on improving pre-hospital trauma care such as a wider geographical distribution of ambulance dispatch and further training for ambulance staff which have been shown to be highly effective in Latin America.³⁵

Contextual application of innovations

Emergency medical services form an indispensable component of healthcare systems in all resource settings.³⁶ There is a common assumption that emergency care is inherently expensive, and as such it has been neglected in health systems development programmes.³⁷ However, in resource-constrained settings there are many approaches that could be introduced at minimal cost and potentially have significant impact on lives saved. Moreover, this is an area where invested money and resources could have a far wider impact than many other areas of medicine. It is important that while the trauma and emergency systems are being developed any changes introduced are evidence-based and appropriate for a country's needs.³⁸ The financial constraints in developing countries mean interventions must be simple, cost-effective changes in the trauma system.³² In the process of developing the trauma systems in these settings, difficult decisions must be made to allocate scarce resources to injury prevention, pre-hospital care, emergency department and the operating theatre.³² In order to assess where the greatest difference can be made, it is important to analyse where in this system the most preventable mortalities lie.³³

Transferability of advances to civilian setting in developing countries

War drives medical advances through necessity.³⁶ In spite of the evidence that civilian trauma care can benefit from the experiences on the battlefield, there remain several barriers and limitations to the utilisation of these techniques.

Defence medical systems have been the backbone of support in facilitating necessary changes arising

from frontline experience.²⁰ The defence health system has evolved to become reactive and dynamic in response to this demand. Most civilian healthcare settings, particularly those in low–middle income countries do not operate on a similar system of responding rapidly to potential advances. This may be due in part to the significantly lower number of serious casualties, but also the civilian setting is far more constrained by bureaucracy, poor systems development, budgetary constraints and more formal legal boundaries.³⁹ Particularly in low–middle-income countries with major military forces, there is still a disconnection between the defence medical services of that country and civilian trauma care. This is a missed opportunity.

The majority of articles published in the area of military medical innovations are descriptive and retrospective in nature and not subject to rigorous clinical scrutiny which is the backbone of normal civilian health systems.³⁹ In the past, data collected on combat casualty care have been analysed years after the war in question and then conclusions drawn from the military experience about potentially beneficial practices. The recent wars in Iraq and Afghanistan have demanded real-time data collection and analysis, and immediate application of this knowledge to improve clinical outcomes on the battlefield. Justifiably, the existing federal laws limit experimentation in the combat zone. However, recognising the need for progress in this area a number of physicians working with 31st Combat Support Hospital in Baghdad, Iraq formed a research group in 2004.³⁹ Primarily as a result of their efforts, care of combat casualties has been documented, analysed and continued to evolve.³⁹ This sort of research is essential for understanding possible cost-effective innovations for trauma care in low–middle-income countries.

Conclusion

Despite the obvious benefits of a collaborative system in which military and civilian breakthroughs both contribute to a growing pool of knowledge in this field, there are challenges to the seamless evolution of trauma care.¹ Systemic, individual and contextual barriers exist in the implementation of successful military techniques within both high-income and low–middle-income settings. In addition to these barriers, low–middle-income countries must also contend with prohibitive financial constraints, weak healthcare systems and poor governance.

However, the evidence in this review illustrates the potential for military medical advances to benefit civilians in most low–middle-income countries.

As with many interventions aimed at improving healthcare in low–middle-income countries, uniform approaches to instituting change are often inappropriate and interventions should be adapted to the setting. The inconsistent nature of trauma itself and the diverse contexts in which it occurs call for individually tailored management practices and context-specific developments being adopted.

High-income civilian populations have already benefitted from battlefield innovations, but the relevance of these advancements to the global community and those in the low–middle-income countries is neglected in the literature. However, some straightforward techniques discussed here, introduced to military use because of their innate simplicity and low cost, hold great potential for use in low-resource settings and their transferability needs to be further explored with properly designed and conducted research programmes with direct links to policy and implementation if found successful.

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