Editorial

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Initial CABC: Advances that have led to increased survival in military casualties

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Introduction

The theatre of war has for centuries provided a platform from which to build upon medical technologies and surgical techniques and the most recent conflicts in Iraq and Afghanistan are no exception. The limiting nature of austere environments, both in terms of diagnostics and personnel, and the extent of the trauma seen, meant that methods that worked in civilian pre-hospital medicine were less transferrable requiring more novel methods to be adopted. Historically, the dominant mechanism of injury on the battlefield has overwhelmingly been penetrating in nature with nearly 75% of casualties involved in either explosive fragmentation injuries or gunshot wounds.[1] Despite the high force injuries sustained by the casualties, the survivability of those injured is now upwards of 90% compared with 84% in Vietnam and 80% in World War II.[2] Eastridge et al. examined the loss of life from 2001 to 2011 during the Iraq and Afghanistan campaigns, reviewing 4596 battlefield fatalities and demonstrated that 87.3% of all injury mortality occurred in the pre-MTF (Medical Treatment Facility) environment; of the pre-MTF deaths, only one quarter (976 casualties) were deemed potentially survivable.[1] In other words, most fatalities occur before ever encountering a surgeon and as such, the focus for improving survival should be on those 976 pre-MTF deaths with innovation targeted at combat medics and infantry soldiers and so must be easy to use and lightweight to allow it to be deployed far-forward. To analyse where these marginal gains can be achieved, the primary survey must first be broken down to explore the specific patterns of injury on the battlefield, how far forward technologies can be deployed and how this fits with the current evacuation chain.

Primary survey

Catastrophic haemorrhage

Catastrophic haemorrhage is undoubtedly the leading cause of preventable death on the battlefield and the introduction of the Combat Application Tourniquet has dramatically improved survival. However, a bleed that is non-compressible in nature, for example, in torso and junctional zone bleeding remains extremely challenging to manage.[3] In 2014, Morrison et al. evaluated 10 years of consecutive UK combat casualties to identify patients who might have benefitted from REBOA (Resuscitative Endovascular Balloon Occlusion of the Aorta)[3] and identified 174 deaths with indications for REBOA of whom 145 died in the pre-MTF environment with a mean time to death of 75 min. They concluded that the military should explore the use of REBOA during the en route phase of care for patients with evidence of non-compressible haemorrhage that are at risk of exsanguinating before definitive haemorrhage control.[3] Since then we have seen an uptake of REBOA in civilian trauma management with London's Air Ambulance being the first in the world to pioneer this procedure in the pre-hospital environment.[4] Smith et al. have since combined their experience of combat injuries with the known capabilities of REBOA to suggest a combat care implementation strategy.[4] They describe that although it can provide haemostasis for non-compressible torso haemorrhage, it must be in the context of an overall surgical plan and should be restricted to deployment in the distal aorta. They believe that in well-trained hands it does have promise as a resuscitative tool provided the moment the balloon is inflated the patient is moving towards an MTF; they even suggested prophylactic use of REBOA which could be inserted but not inflated until the patient shows signs of deterioration.[4] We believe that this may be of potential use on the battlefield given cases of success in the pre-hospital

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environment, however, continued research, specifically into partial REBOA (P-REBOA), intermittent REBOA (iREBOA) and selective aortic arch perfusion (SAAP) is required which are known to mitigate some of the adverse consequence associated with prolonged aortic occlusion.[5] Should these techniques be adopted on the battlefield, military-specific guidelines and appropriate training will be required.

A novel potential alternative to REBOA is the use of ResQFoam™ (Arsenal Medical, Watertown MA), a self-expanding polyurethane foam that can be injected through the umbilicus and expands within 1 min to conform to the anatomy of the internal organs resulting in a local tamponade effect.[6] The foam is non-adherent and is easily removed at the point of definitive care. Currently, only swine studies have been published but a multi-centre phase I trial REVIVE (Reducing Exsanguination Via In-Vivo Expandable foam) trial is underway.[7] However, in swine models, a major complication observed was focal ecchymotic bowel lesions from necrosis due to the pressure exerted by the foam, requiring surgical repair during foam removal.[6] It can be argued that this degree of morbidity is potentially acceptable, but the likelihood of this technology being available in the near future is low; however, it is clear that innovative thinking is pushing the boundaries of haemorrhage management on the battlefield.

Airway

Unlike civilian trauma, combat airway management shows significant differences, especially in the mechanism of injury. In combat trauma, the need for airway management is overwhelmingly due to penetrating injury,[8] which is associated with increased risk of difficulty or even failed airway.[9] As such, combat airway management due to the mechanism alone, regardless of the external situation, is likely to make the task more challenging and more likely to require a surgical cricothyroidotomy (SC). Mabry estimated that whilst the military rate of US surgical airway insertion was approximately double the civilian rate, it still occurred in less than 1% of all US military trauma admissions, suggesting that only the most critically ill patients received a surgical airway.[8] Kyle et al. performed a study into the success of airway insertion over an eight-year period in Afghanistan and found that despite the relative inexperience of the operators an overall success rate of 92% was achieved.[10] SC is considered a last resort procedure in a difficult airway algorithm; however, it has been suggested that in certain situations it may be counterproductive to delay a surgical airway intervention; in such circumstances, SC may be the best 'first resort' in definitive airway management.[11] Mabry et al. describe a novel approach in which awake SC is performed first and discuss three cases of 'inevitable surgical airway', which they define as, an airway which due to being altered by severe trauma or other anatomical disruption requires advanced management. They believe that in certain situations, for example, with large numbers of casualties, RSI (Rapid Sequence Induction) and intubation is not practical for one individual to acutely manage. They believe that combat medics should be trained to recognise an airway that is likely to require SC due to, for example, disrupted anatomy and instead of persisting in treating SC as a 'final solution' start with an awake SC technique. This will allow medics to begin oxygenation and ventilation sooner than if RSI was tried and failed and also allows the medic to care for other casualties much sooner, ultimately leading to improved survival rates across the board. Currently, this is a lifesaving manoeuvre taught to all Combat Medics and has seen usage on the front line.[12]

Breathing

Tension pneumothorax (tPTX) remains a significant cause of mortality in both civilian and military trauma, with a reported incidence of 1%–5%[1,13–15] with survival dependent on early recognition and prompt decompression. The current gold standard for treatment is needle thoracocentesis with a 14- to 16-gauge angiocatheter (14–16G AC) in the second intercostal space at the mid-clavicular line.[16] However, the reported incidence of decompression failure using a traditional 5-cm-long 14G AC is 17%–60%.[17] Inadequate catheter length, kinking of the angiocatheter, luminal obstruction or inadequate diameter to quickly relieve tension physiology are some recognised reasons for failure. As such, there exists a need for a device with a much higher success rate with fewer failures. Some alternative devices include a modified Veress-type needle (mVN), laparoscopic trocar (LT) and 10-gauge AC.

Leatherman et al. performed a randomised comparison of these three decompression devices and found that although mVN performs in an equivalent fashion to the current standard 14G AC, the failure rates of both were unacceptably high; they did report, however, that the 10G AC and 3-mm LT provide rapid effective rescue from both t-H/PTX and PEA arrest greater than 90% of the time recommending that there is now sufficient evidence for replacement of the 14G AC with a larger bore device (10G AC) on the battlefield.[16] This has also been reflected in the latest Advanced Trauma Life Support (ATLS) guidelines which advocate thoracocentesis in the fifth intercostal space, just anterior to the mid axillary line.[18]

Circulation

Haemostatic resuscitation in austere environments where the possibility of prolonged field care exists requires not only early control of bleeding but also management of Trauma Induced Coagulopathy (TIC).[19] TIC is a global failure of coagulation which can develop within minutes of major traumatic haemorrhage,[20] arising from the interplay between coagulation, inflammation and cellular dysfunction of platelets and endothelium via both exogenous and endogenous mechanisms. Tissue hypoperfusion and tissue factor release are thought to be responsible for the early hypocoagulation and hyperfibrinolysis through the activation of the protein C pathway.[20] Furthermore, hypothermia induces platelet dysfunction and reduces the coagulation enzyme activity (especially fibrinogen), particularly in acidosis.[20]

All these mechanisms cause a slower formation of a more fragile blood clot, which can increase the chance of further blood loss. Tranexamic acid (TXA) given within 3 h improves outcomes following trauma.[21] The CRASH-2 trial demonstrated that TXA reduced all case mortality in trauma patients without increasing risk of thromboembolic complications and noted a 32% reduction in death due to bleeding when TXA was given within 1 h of injury, but conversely an increase in bleeding-related deaths if the drug was administered more than 3 h after injury.[22] This has resulted in TXA becoming a mainstay in trauma and other settings and is routinely administered by the clinician-led Medical Emergency Response Team (MERT).[22,23]

In an ideal scenario, injured soldiers would be rapidly evacuated to receive Damage Control Surgery and be given TXA within 1 h; however, evacuation times can vary and with the unpredictable nature of future warfare we cannot say with certainty that evacuation times will be within this window. Culligan and Tien believe that TXA should be used in the more forward setting before the response team arrives believing that it should be administered to casualties on the battlefield intramuscularly (IM) due to the experience the military already has with delivering drugs through the IM route. As such, packaging TXA into an auto-injector is the next logical step.[24] However, according to Wright, TXA administration is currently restricted to physicians only, impairing the ability to administer this drug early.[23] TXA has been proven to be safe, effective and given that the British military is already familiar with morphine auto-injectors, would require little extra training. As such we should be considering how this life-saving medication can be used further forward and potentially translating to the civilian environment.

Past conflict has demonstrated that the use of fresh frozen plasma (FFP) in a 1:1 ratio with red blood cells increases the survival rate of massively transfused patients. However, this product requires time to be thawed and then transported to the casualty which is impractical in the austere environment.[20] A substitute to FFP has been developed by the French Military Health Service known as French Lypophilised (freeze-dried) Plasma (FLYP) which is as effective as FFP for improving thrombin generation and clot formation[25] with its effectiveness demonstrated in combat-injured patients at the French Role 3 MTF in Kabul.[26] It can be stored for two years at room temperature and reconstitution time is less than 6 min.[27]

In real-life conditions during Operation Barkhane in the Sahel region of Africa where it was stored for three months at temperatures ranging from 28°C to 53°C, 55% of the fibrinogen activity persisted.[28] The Israeli military use FLYP early as the primary resuscitation fluid (the 'plasma first' concept), at the point of injury when massive haemorrhage is suspected and systolic BP is below 80 mmHg (or an absent radial pulse) without reported adverse events.[19] Overall, there is significant evidence to support early use of FLYP as a resuscitation fluid for patients with haemorrhagic shock.

Fibrinogen plays an important role in the development of TIC and low fibrinogen levels on admission to hospital are predictors of early mortality in trauma patients and are associated with larger blood loss and the need for transfusion.[29] It has also been shown that fibrinogen levels do not normalise during damage control resuscitation, despite high ratio of plasma and platelets.[29] Early high-dose fibrinogen supplementation has been shown to be of benefit and correct this coagulopathy. A retrospective study, conducted in a Role 3 MTF, showed that an increased fibrinogen-to-red blood cell ratio transfusion was independently associated with improved survival.[30] Cryoprecipitate and fibrinogen concentrate (FgC) are the two concentrated sources of fibrinogen for replacement.[29]

Cryoprecipitate also contains factor VIII, von Willebrand factor, factor XIII and fibrinonectin but require frozen storage and thawing, making it difficult to transport in the austere environment.[29] FgC on the other hand, much like FLYP, is easy to use in the field, readily available and easy to store at room temperature. The Centre for Trauma Science (C4TS) at Barts and The London School of Medicine and Dentistry are currently conducting a large multi-centre Randomised Controlled Trial to evaluate early cryoprecipitate in major traumatic haemorrhage (CRYOSTAT-2); however, results from this trial may take several years to surface.

Conclusion

Evidence shows that most casualties who die on the battlefield do so before ever reaching an MTF and as

such research should be focussed on the crucial first hours of care. The ever-changing nature of the battlefield setting requires the UK Defence Medical Service to be ready for all eventualities and so regular updates of guidelines must be performed, especially as time to evacuation may result in an increased need for prolonged field care. Novel solutions to the problems of managing life-threatening trauma in the austere environment need to be developed and aimed at field medics and front-line soldiers who will be best placed to deliver immediate interventions but they must be easy to use, lightweight and functional despite harsh extremes of temperatures.

Some new innovations appear promising but require more data and evidence of safety. We are yet to see greater uptake of REBOA and a change in the recommended gauge of needle for decompression of tension pneumothorax; however, this may change in the coming years. There is promising work being done on fibrinogen and the 'plasma first' concept using FLYP, but it is often more of a case of logistics than science. For example, TXA demonstrates an excellent safety profile and improves outcomes, but this is not enough to allow it to be used far forward. Hopefully this will be reassessed soon and TXA auto-injectors will be seen to be used at the point of injury. The future of trauma medicine in the austere environment is on the cusp of introducing some exciting new interventions that will no doubt enhance survival on the battlefield too.

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