

CASUALTY EVACUATION TIMELINES: AN EVIDENCE-BASED REVIEW

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Abstract

There is no tri-modal death distribution demonstrable in modern military conflict. Recent UK, Palestinian and Israeli data suggests that nine out of every ten injured soldiers that die do so within minutes of wounding from unsurvivable, unsalvageable trauma. Having the surgeon on the battlefield with the soldier has been shown to make no difference to these survival rates. Early definitive airway control using rapid sequence induction and intubation is of benefit to the head and airway injured. Once this airway is secured, these early survivors may be transported for up to 2 hours receiving intensive care level treatment: Hypotensive resuscitation with blood transfusion, administration of adjunctive clotting factors, hypothermia mitigation, administration of antibiotics, analgesics, novel haemostatics, splintage, FAST scanning can all be performed in flight. The second peak of death comes from truncal bleeding and CNS injury. Those with truncal (or junctional) bleeding require significant surgical, logistic and haemostatic support. Those with CNS injury require CT scanning and specialized neurosurgical care. These subgroups do best in large well-resourced hospital units which have the infrastructure, blood, climate control, knowledge and staffing levels to deal with them. Stopping elsewhere en-route to these larger centres is of uncertain benefit. Our resources must be optimised to save the many that could be saved, rather than dispersed for the few who will not. Wounded soldiers need to be undergoing surgery in the operating theatres of these large centres within three hours of wounding.

Casualty Evacuation Timelines

Introduction

In the wars of the last century, much was made of rapid transport to the nearest surgical resuscitation facility. In these intense high-casualty conflicts - highly-echelonized medical care and the 1:2:4 doctrinal approach was the norm. Buddy-Buddy aid at point of wounding, Regimental Aid Post care, Casualty Clearing Station care, Field Surgical Team care, Rôle 3 care and thence return to Base areas or the UK by train or ship. In our current relatively low-intensity conflicts in Iraq and Afghanistan – is it time for a rethink?

Who can we save?

All UK operational deaths are now subject to regular ADMST/ADMEM/DSTL consensus panel review. Excluding drowning, aircraft crashes and unpreventable deaths for operational or tactical reasons, the vast majority of our operational trauma deaths occur almost instantaneously due to unsurvivable injury [1]. In a separate study of MERT retrieval data over a similar period, there were at least 5 unexpected trauma survivors [2]. Four had significant blast/ballistic head/neck injury and one had burns inhalational injury, blast lung and 70% burns. Early definitive airway control in flight using rapid sequence intubation (RSI) was considered to be the significant factor in these patients' survival.

We now have much better data about the causation and timing of mortality in war. The commonest causes of death in Israeli soldiers during recent conflicts were: CNS injury (31%), exsanguination (30%), incineration (21%), CNS and exsanguination (10.9%). 93.7% died in the 1st hour after

injury, 2% died in hours 1-4 (6/7 exsanguination). After 4 hours, 4.3% died, mainly from head injuries and late infection (9/15 CNS - out to 75 days) [3]. A similar Israeli study noted a 95% penetrating trauma rate with 106 deaths. The average ISS was 42.5. Injury distribution was thorax 38%, head 24%, abdomen/pelvis 13% and neurological 12%. 88% of these wounded soldiers died within 30 minutes of injury [4]. This led to the recognition that unlike civilian trauma 'There is no tri-modal death distribution in military trauma, and that most soldiers are mildly injured or killed: Those that die, die early'. In modern conflict, there is no real military 'golden hour' [5]. Bellamy, in his major post-Vietnam review concluded 'whether the casualty receives care within the first hour after the injury is incurred is not a predictor of survival' [6].

If there is no 'golden hour' to administer treatment, is there then a 'platinum five or ten minutes'? If we pushed the surgeon completely forward – could we save more soldiers? Pauline Cutting worked for eighteen months as a surgeon in the Bourj al Borajneh refugee camp in Beirut, Lebanon in the late 1980s. She cared for 1200 war injured patients in two concentrated phases, one of six weeks and one of six months [7]. The hospital was situated within the refugee camp itself. The camp measured 400 by 500 metres and contained 9000 people. No injured person ever had to travel more than 250m from point of wounding to the hospital. The camp was attacked by machine-gun fire, mortars, grenades and tanks. One patient arrived alive, yet in respiratory arrest with a shell fragment transecting his spinal cord at C2.

There was only a delay of minutes therefore from point of wounding to arrival in hospital. 1276 patients presented to the hospital. Limb injuries accounted for 51% of all wounds and 63% of all ultimate survivors. CNS 14% and 9%, Face/Neck 9.5% and 10%, Chest 12.5% and 9%, Abdomen 10% and 9%. There were 160 deaths. 52% were dead on arrival (<5 minutes), 12% were dead before any significant resuscitation could be administered (5-15 minutes), 11% had an unsalvageable CNS

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injury, and 9% had uncontrollable haemorrhage from multi-system injuries. Therefore, despite the surgeon being on the battlefield with the victim, in 84% of cases, survival was not possible.

It seems then that there is a definite group who survive the early trauma but succumb to inexorable exsanguination or the sequelae of secondary brain injury at the 4-6 hour point. Extremity bleeding is usually amenable to control by dressing, pressure, QuikClot®, Hemcon® and tourniquet use. The brain injured can be cared for initially by resuscitation, airway protection and maintenance of an oxygenated cerebral circulation. After this they need CT scanning, rapid access to neurosurgical surgery (not necessarily performed by certified neurosurgeons) and maintenance in a neurosurgical focussed ICU. Prevention of secondary brain injury is crucial. Thus decompressive craniectomy, evacuation of intra-cerebral haematoma, debridement of compound brain wounds, monitoring of accurate intracranial pressure (CPP and CPO₂) are the keys to treatment. The complexity of this approach requires significant infrastructure and logistical support [8].

Truncal bleeding, which may be ameliorated by in-flight transfusion, but which is not amenable to pre-hospital control requires surgical intervention. A damage control surgery (DCS) approach is often required. Abdominal surgery is required in 9% of all military trauma survivors and very early surgery will only save an extra 10% of this 9% [6,9]: a less than 1% benefit. This surgery cannot and should not be performed without an adequate back-door casevac backup. However, if we have adequate casevac – we then do not need to perform this surgery forward. In current operations we deploy one true abdominal trauma surgeon per theatre, so to do the most good for the most people, the patients must come to him and his fully-resourced team(6). Recent US military surgical experience from Iraq showed an average transfusion requirement of 8.6 units of PRBCs and 0.64 units of whole blood, in the first 24 hours. The average estimated intra-operative blood loss was 2.4 litres per case – half the circulating blood volume of the average soldier [10,11]. 92 patients underwent formal DCS in the US 31st CSH in Iraq in 2004. The average transfusion requirement was 12 units of PRBCs, 7 units of FFP and 2.5 units of whole blood per patient. DCS is just not possible without this blood, oxygen, ITU and robust logistic chain support [12].

Missed injuries are another cause of preventable death. A study of 108 Patients in a Canadian trauma centre showed clinically significant missed injuries in 51 (44%) of deaths. Injuries were missed in 29% of in-hospital deaths and in 100% of A+E deaths.

Abdominal injuries (43%) and head (34%) injuries were the most commonly missed [13]. The military rate is reportedly lower at 4.8% [14]. Missed injuries are deemed to be mostly avoidable and are commonest when patients with blunt trauma are transferred in from other facilities - a rate of around 60%(15)Secondary survey does not constitute definitive assessment and needs to be supplemented by tertiary trauma survey; CT is the best modality for this [16]. CT scanning is also a useful adjunct for transmediastinal penetrating trauma [17], flank wounds [18], transmidline abdominal trauma [19] and neck wounds [20]. CT scanning is not available forward.

Historical review

UK military planning is predicated on the 1:2:4 hour rule (previously 1:2:6). That is, advanced first aid within one hour, resuscitation surgery within two hours and definitive surgery within four hours. The basis of this 'rule' is unclear. It may have come from Field Army planners. The 4 hour limit may have been derived from the NATO guidelines for surgery on closed head injury. Certainly, there is no mention of 1-2-4 in the AMS

Core Doctrine [21]. Colonel John Watts (UK Professor of Military Surgery in the 1950s) in his book, 'Surgeon at War' [22] had a final chapter: - A Note on War Surgery, in which he refers to 'Friedrich's safe period' of 8 hours, by which time war wounds should have been excised. Friedrich was a German surgeon who worked on Guinea pig wounds in the 1890s. This may be the basis of that 6 hour rule. Watts also theorized that early antibiotic chemotherapy could prolong this interval and possibly double it. This is now known to be correct. The 1:2:4 hour rule should be perhaps now be best thought of only as a 'planning yardstick' [23].

Napoleon had Larrey and his 'flying ambulances'. Casualty Clearing Stations (CCS) were introduced by the British in WW I to shorten time to surgery. These put 'hospitals' nearer the trenches. Casualty evacuation times were long - 20 hours on average. The first Field Surgery Pocket Book (FSPB) published in 1918, stated in its first paragraph - The rule at the front is: 'Get the wounded man to the casualty clearing station as soon as possible' [24]. It does not mention any 6-hour rule. The FSPBs of WWII (1944) and afterwards (1962) talked about surgery taking place within 6 hours. The British average for WWII and Korea was 10hrs

The campaign in the Oman (Dhofar, Sallalah) in 1972 remains the only time that this clock was beaten [25]. In 1973 Melson and Volkers noted that strategic ambulance pre-positioning saved valuable time. Helicopters greatly increased the distance that could be covered by a single surgical centre (Fig 1). They noted the positive effect of two prime factors - good first aid and rapid evacuation. Virtually all patients arrived by helicopter within one to two hours of injury. This approach brought a greater percentage of all casualties to the surgical centre alive, but with severe and often multiple injuries – to the trunk, neck and head. They stated in 1975 that "Their management requires the best of modern facilities and skills". They also empirically and proactively treated trauma coagulopathy with fresh blood and fibrinogen (in a 1:1 ratio) adding fresh frozen plasma when available.



Fig 1. Sallalah Casevac by the FSTs dedicated UH-1 'Huey' Helicopter

Good first aid was provided by medical orderlies on the ground and by trained helicopter crewmen during evacuation. A medical officer was placed on the helicopter when evacuation time was longer than 1 hour. Emphasis was placed on early airway control with intubation, occlusion of chest wounds with intercostal drainage and control of external blood loss with blood and plasma infusion. Rapid evacuation was provided by a simple radio communication net stipulating a direct link with the incident point and the surgical centre. This was combined with a helicopter crew on 24hr standby with a Bell UH-1 'Huey' that could be airborne in 2-3 minutes. In Sallalah 91.25% (73/80) of the wounded arrived alive. 56 had sustained major injuries. 2 died in hospital giving an overall survival rate of 88.75%. Previous figures from Korea were 76.6%, contemporaneous figures from Vietnam were 83.4% [25].



Fig 2: The Huey set up to take six casualties. Three could be carried transversely with more space.

Recent UK Experience:

Entry operations have always had long timelines. On an early study from Operation Telic 3, mean time from initial watch-keeper casualty report to arrival at Rôle 3 was 4 hours 31 minutes (Range 21 minutes to 23.2 hours). All patients were transported by helicopter. Mean time from arrival at R3 to surgery was 5 hours 18 minutes. The mean total time from casualty report to initial surgery was 9 hours and 50 minutes for all wounds and for GSW or fragment wounds, 5 hours 10 minutes [26].

Average pre-hospital times on Operation Telic 4 were 1 hour and 49 minutes. Time from first medical care (no data on time from injury to first medical care) to initial surgery was 2 hours 45 minutes. A time to surgery of less than 4 hours for head injuries was found to be unachievable (pre-hospital delay time, 3 hour and 3 aircraft ventilated patient transfer to Baghdad, CT on arrival, then surgery) [27]. In Iraq and Afghanistan in 2007, pre-hospital times are now around 2 hours 54 minutes [28]. Is this too long or is it too short? It is a commendable claim that during the Falklands War in the 'Red and Green Life Machine' (The Hospital in Ajax Bay), no-one died there and that all who were evacuated to this facility survived. This is true and is indeed a testament to the surgical teams who worked there. However it may also have been a function of the up-to-24 hour casualty evacuation timelines. Simply, the longer the timeline, the greater the likelihood that all patients admitted to any surgical facility will survive.



Fig 3: Surgery on a modern table, in a well lit, fully resourced, air-conditioned operating theatre (Camp Bastion).

When timelines are too short, limited resources may be used on those who cannot be saved. Our own relatively limited experience in an forward FST in Iraq in 2003 had 0% deaths [29]. No DCS procedures were performed. The US Army Rangers in Somalia had a 3% in-hospital death rate - two out

of three damage control abdominal surgery patients [30]. The 555 US Army FST in Iraq had a 1.9% death rate - three Iraqi pts, all penetrating torso injuries undergoing damage control abdominal surgery [31]. One DCS patient may exhaust a small FST.

In there then an optimal timeline for our modern asymmetric battlefield? One that combines timeliness with pragmatism? One that will not exhaust valuable human and rotary resources trying to save the dead, and yet will save those that remain? One that accepts that the nearest facility may not necessarily be the best? There is no randomized controlled trial on this subject, but there is merit in a common sense approach. From our ADMST, Palestinian and Israeli data, a goal of less than 30 minutes is clearly simplistic, futile, and simply unachievable. Over 4 hours, the data now suggests that this is when the head injured start to succumb to secondary brain injury and the slow torso and junctional bleeders start to die. It is also when bacteria on superficial wound surfaces begin to divide and penetrate tissue.

It is now clear from ADMEM MERT data that we can not only transport safely in this interim 1-4 hour period, but also provide life-saving intervention-based medical care. Rapid sequence induction, anticipatory treatment of trauma coagulopathy (ATTaC - with PRBCs, Cryoprecipitate, Platelets and RHFVIIa) from golden hour boxes, DDAVP/pressor circulatory tuning, novel haemostatic measures, hypothermia mitigation, FAST and splintage - can all be performed just as well in flight as in a static emergency department. Such appropriately triaged and treated patients can be admitted directly to the operating theatre on arrival (fig 3), having passed through an MD-CT scanner on the way there. The modern Israeli approach of a zero-echelon medical plan for low intensity warfare with air superiority is likely to be correct. This implies; training junior commanders in emergent tactical evacuation from the hot zone, immediate cross-load onto a medical transport platform, and transfer to definitive care. They simply state - 'don't stop, ever!' [32].

In summary, our resources must be optimised to save the many who could be saved, rather than dispersed for the few who will not. We should aim to have the wounded soldier, in the well-resourced operating theatre at the two to three hour point. Our helicopters must have the range to match this ambition. This will save the most people, because at four hours, our junctionally wounded, torso penetrated and head-injured soldiers will begin to die.

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