# Initial assessment and management of trauma encountered in the field

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## Abstract

This article covers the principles of trauma care relating to specific competencies within the military higher training module. The majority of these principles relate to the pre-hospital assessment and management of patients, introducing some of the nuances of military medicine in comparison to civilian practice.

**Keywords** Burns; cardiac arrest; forensic ballistics; head injury; military medicine; pelvis; thoracotomy; tourniquet; trauma severity indices; wounds and injuries

**Royal College of Anaesthetists CPD Matrix**: 3A10, 3A14, 2A02, 2F01, 1B04

## Learning objectives

After reading this article, you should be able to:

- outline the different trauma scoring systems available and their use
- describe the initial management of trauma patients specifically relating to pelvic fractures, ballistic trauma and traumatic cardiac arrest
- explain the initial management and resuscitation of patients relating to burns and head injuries
- demonstrate the placement of the Combat Application Tourniquet when clinically indicated

## Trauma scoring systems

Accurate and useful scoring in major trauma is a substantial challenge, and there are multiple scoring systems. Most concentrate on mortality outcomes rather than morbidity. Covered below are a few of the most widely recognized scoring systems.

### Anatomic scoring systems

**Abbreviated Injury Score (AIS)** developed in 1971, assesses the severity of anatomical injury using a single score for each injury sustained. Scores range from 1 to 6 (minor injury to incompatible with life). The AIS dictionary contains more than 2000 injuries.[1] The difficulty with AIS lies in the assumption that patients with the same AIS in different body regions would equate to similar odds of adjusted mortality. This further impacts on those scoring systems which include AIS, such as ISS, NISS and TRISS.

**Injury Severity Score (ISS)** created in 1974, is a non-linear score derived from the AIS. It is defined as the sum of the square of each of the three highest AIS scores in six predetermined body regions. The maximum score is 75. A patient with an AIS of 6 in one body region is given an ISS of 75. ISS was developed as a platform for trauma data registries and widely used for trauma research.[1]

Less frequently used anatomic systems include New Injury Severity Score (NISS), International Classification of Disease (ICD)-derived injury severity score (ICISS) and Anatomic Profile (AP).

### Physiological scoring systems

**Revised Trauma Score (RTS)** has been widely used to predict the prognosis of trauma patients and forms part of TRISS. It can be used as a pre-hospital triage tool but requires complex calculations. Triage RTS (T-RTS) is an adaptation that simplifies the triage method, using the parameters respiratory rate, systolic blood pressure and Glasgow Coma Scale (GCS).

**New Trauma Score** — Adaptations have been made to the RTS system, changing the respiratory rate for saturations, altering blood pressure intervals and using actual GCS instead of a GCS code. This has shown improved mortality prediction compared with the RTS.[2]

**The Glasgow Coma Scale** is familiar, internationally recognized and a valuable physiological predictor and prognostic tool. It looks at the best scores for eye opening, verbal and motor responses. Its use has also been validated in assessment of TBI patients.

### Combined scoring systems

**Trauma Score — Injury Severity Score (TRISS)** — Introduced in 1981 combines age, the Revised Trauma Score, Injury Severity Score and whether the injury was blunt or penetrating. Complex to use, but useful for predicting the probability of survival. The probability of survival of each patient is calculated using age, gender, GCS and ISS.

## Management of the traumatic pelvis

### Traumatic pelvic injuries

Pelvic fractures are high-energy fractures rarely found in isolation. The large pre-sacral venous plexus is the most common site of bleeding, followed by fracture surfaces and, more rarely, arterial injury. It is important not to underestimate the potential for retroperitoneal bleeding and large circulating blood volume

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loss. Mortality rates for all types of pelvic fracture have improved, but they still range from 5–15%.[3]

### Initial management and stabilization

A pelvic binder should be placed pre-hospitally if there is suspicion of a fracture. The binder can help reduce the fracture, temporarily stabilizing the pelvis and reducing pain. This also encourages clot formation and facilitates transport. It is important that it is placed correctly over the greater trochanters to provide support, also allowing access to the abdomen for laparotomy without removal. These patients should be managed in a major trauma centre with a consultant-led multidisciplinary trauma team.

Resuscitation with blood products, initially allowing for permissive hypotension, should be initiated if there are concerns about bleeding. This can be commenced pre-hospitally. If there are no contraindications, patients should receive tranexamic acid. Resuscitation can be assisted by arterial blood gas analysis and thromboelastography, if available. Dependent on stability for transfer to CT, adjunctive imaging in the emergency department includes chest and pelvic X-rays and eFAST. eFAST scanning is not sensitive enough to reliably detect retroperitoneal haematoma and cannot give information about solid organ integrity. However, eFAST's ability to show gross fluid collections within the chest, abdomen and pelvis is useful in patients unsuitable for CT, helping the surgeons identify which body cavity to open first.[4]

Both pre-hospitally and in the emergency department it is important to deliver adequate analgesia. This depends on associated injuries and conscious level, but intravenous opiates can be titrated, and ketamine provides a good adjunct with little associated haemodynamic change.

A trauma CT scan screens for injuries, with the addition of contrast allowing localization of bleeding to direct embolization if appropriate. Angiography and embolization has become the most effective non-operative intervention for arterial bleeding.[3] For example, in cases of pelvic trauma with associated haemorrhagic splenic injuries, embolization can obviate the need for laparotomy. In haemorrhagic splenic injuries associated with pelvic trauma, embolization should be considered, potentially avoiding laparotomy.[4] Fewer than 5% of patients suffer complications post embolization, although these can be serious, such as gluteal muscle necrosis.[4]

Patients with isolated pelvic fractures may be managed in a ward environment, ensuring a full secondary survey and referral to the pain team should analgesia be a concern.

### Surgical management

Exploratory damage control laparotomy is required for severe haemodynamic instability associated with indistinguishable haemoperitoneum. There is debate about the best means of pelvic stabilization.[4] Pelvic binders are often left in situ. Placement of a pelvic external fixation device may be beneficial prior to laparotomy.[3] Surgical packing may be required, with preperitoneal packing up to the bone.

Percutaneous pelvic fixation leads to definitive stabilization. This can be part of damage control surgery but may not be appropriate in the initial surgical management. Exploratory laparotomy may cause decompression and re-expansion of the retroperitoneal haematoma due to renewed venous bleeding.

### Operative anaesthetic considerations

These patients require robust multidisciplinary team work to ensure precise management. Good IV access, peripheral or central, is crucial. Arterial pressure monitoring may not have been placed in the emergency department but is invaluable in an emergency theatre setting, allowing accurate blood pressure measurement and intraoperative sampling.

Patients are likely to be managed in a critical care environment postoperatively. Postoperative analgesia should take a multimodal approach. Although regional techniques are not appropriate for unstable patients, local anaesthetic wound infiltration by the surgeons can be used.

## Military anaesthesia for severe burns

Burn injuries may occur in isolation, or in association with other trauma. Burns can be classified broadly according to their type and depth. The severity of burn may be further described by site, surface area and associated injuries/complications. The mainstay of burns management is supportive, with only a few specific therapies that are relevant to the pre-hospital environment. Military Clinical Guidelines for Operations include protocols for management of burns. Significant burns cause systemic injuries and can be a heavy burden, both in terms of the medical resources required and long-term morbidity.[5]

The pathophysiological sequelae of major burns are multisystem. A burn that is greater than 30% total body surface area (TBSA) is more likely to cause substantial cytokine release, the effects of which may result in multiple systems organ failure and increased risk of mortality, particularly in patients at extremes of age or with pre-existing comorbidities.

Knowledge of the history of the injury will help in the assessment of a patient with burns, as well as anticipation of their clinical course:

- When, with what, at what temperature (or concentration), and length of exposure?
- Did the burns occur in an enclosed or open space (the former being more likely to cause inhalational injuries), and was there an associated explosion (resulting in other injuries)?
- What other injuries, if any, has the patient sustained? Hypovolaemia in the initial hours following injury is rarely attributable to burns, so active bleeding secondary to other trauma needs to be considered.

Physical examination should incorporate a full primary survey, before assessment of the burn is undertaken.

A burn is described according to the percentage TBSA that it covers, estimated using tools such as the "rule of nines" for adults or the Lund and Browder chart for paediatric patients under the age of 14 years old.[6] The severity of a burn is also gauged by its depth and location (if a "special site", such as the face).

### Anaesthesia for burns

Anaesthesia for a patient with burns may be required for a variety of reasons – to provide intubation and ventilation in the

 

situation of a compromised or at risk airway, where respiratory complications have occurred secondary to inhalational injury; for ongoing clinical care (such as wound debridement, skin grafting or escharotomies); or for treatment of concomitant traumatic injuries. Investigations include blood tests (full blood count, urea and electrolytes, creatine kinase and arterial blood gas with carboxyhaemoglobin), electrocardiogram, chest X-ray, bronchoscopy (for intubated patients) and urine analysis (output and presence of haemoglobinuria or myoglobinuria). These investigations will help to assess the degree of physiological derangement caused, and to target the resuscitation strategy. Monitoring may be challenging in cases where there are burns overlying monitoring sites. Early placement of an arterial line will provide both invasive blood pressure monitoring, for a patient who may be haemodynamically compromised and not able to tolerate a non-invasive cuff, and access for regular arterial blood gas analysis. Cross-matching the patient is judicious, as wound debridement can lead to rapid blood loss.

Ketamine is particularly useful for induction of patients with cardiovascular instability (e.g., secondary to vasodilatation caused by burn-induced systemic inflammatory response syndrome). It also causes bronchodilatation, which may be helpful if inhalational injury has occurred. For muscle relaxation, suxamethonium is contraindicated from 6 hours until 2 years after a major burn injury, owing to the risk of severe hyperkalaemia. Higher doses of non-depolarizing neuromuscular blocking drugs may be required due, in part, to the appearance of extra-junctional acetylcholine receptors. Postoperative pain may be significant and should be addressed with prompt multimodal analgesia.

Mechanical ventilation should employ a lung protective strategy (e.g. tidal volumes of 6–8 ml/kg). Patients with inhalational injury will require regular pulmonary toilet and bronchoscopic lavage. Carbon monoxide poisoning may necessitate ventilation with 100%, or even hyperbaric, oxygen.

Intravenous access, fluid resuscitation and electrolyte management can be challenging. The Parkland Formula (4 ml/kg × % TBSA burn in adults) provides a useful estimate of the crystalloid volume required for resuscitation during the first 24 hours after a burn injury has occurred, with half given over the first 8 hours and half over the following 16 hours. Fluid infusions are titrated against clinical response, measuring urine output (aiming for $>$ 0.5 ml/kg/hr in adults), intending to restore perfusion of the tissues and organs, whilst minimising oedema.[5] Any electrolyte disturbances should be treated.

Other anaesthetic considerations include measures to prevent hypothermia in patients whose inability to autoregulate while anaesthetized is exacerbated by evaporation of fluid from their wounds. This may be achieved by increasing the ambient temperature, using warming blankets and infusing pre-warmed fluids.

The anaesthetic management of a patient with severe burns requires multi-system assessment and support. Depending on the circumstances, suspicion of other concurrent trauma injuries must be explored and addressed.

## Blast and ballistic injuries

### Blast injury

Blast injury secondary to bombs and explosions can cause unique patterns of injury. Damage created depends on factors including the surrounding environment, type and amount of explosive. Explosion causes rapid conversion of a substance to a gas, substantially increasing the volume by more than a 1000-fold. Simultaneous increase in pressure causes the surrounding air to be compressed, forming a shock wave. This lasts only milliseconds, but is followed by a longer lower pressure blast wind.[7]

Explosions have the potential to inflict multi-system life-threatening injuries, directly and indirectly, on multiple patients. This is likely to create mass casualties, causing a major incident. The infrequency of these events creates challenges for local emergency services, including triage and initial management.

Blast injuries have several sub-categories, representing mechanisms of tissue injury. These all have implications for acute management and anaesthetic planning.

- **Primary blast injuries** – direct effect from the blast wave and over-pressurization impulse. This is likely to cause injuries within hollow organs and gas-filled spaces including middle ear, lung, and large bowel. It has also been implicated as a cause of traumatic brain injury (TBI) and can affect the extremities.[8]
- **Secondary blast injuries** – related to foreign objects and debris propelled by the blast wave becoming projectiles.
- **Tertiary blast injuries** – caused by blunt impact when the casualty is displaced by the forces of the explosion.
- **Quaternary blast injuries** – indirect injuries occurring as a consequence of the explosion, such as burns and smoke inhalation.

The majority of blast injuries are found in a military environment, where there is a disproportionate representation of extremity injuries due to detonation on or under the ground. Triage is extremely important for ensuring resources are directed appropriately to those with the most severe injuries, but also those with the greatest chance of survival.[8] Initial scene assessment and triaging prioritizes immediate management of life-threatening injuries, such as tourniquet application for major extremity haemorrhage. An advanced trauma life support approach should be applied to those patients prioritized for treatment. In the military setting, improved armouring and medical innovations, including haemostatic dressings and tourniquets, have reduced mortality.

On arrival at a medical facility a rapid primary survey often leads to re-triaging. The focus is on damage control, allowing time-limited surgical procedures to be carried out, such as rapid initial wound debridement to reduce infection rates. This is followed by patient optimization in a critical care environment before definitive management.

### Ballistics

Ballistics is the science of projectiles and firearms. Terminal ballistics is the study of how a projectile behaves when it hits a target and transfers its kinetic energy. If the target is biological, the term wound ballistics is applied.

Severity of any penetrating injury is related to the vicinity of the wound track to vital organs and large vessels. Dynamics of the projectile and local tissue reaction influence the nature of the gunshot wound. Energy transfer to the tissue is determined by the kinetic energy of the bullet ($KE = ½\ mv^2$), but also the specific tissue resistance to bullet penetration.

Where there is only an entry wound, all the bullet's energy has been distributed to the tissues. Where exit wounds exist, they are commonly larger and more irregular due to bullet tumbling.[9]

With high-velocity projectiles, cavitation is a process where tissue displacement lags behind the bullet. A temporary larger cavity is formed, which then closes down to leave a permanent wound track. The vacuum created during this process can also entrain foreign material. This temporary track can vary in size, depending on energy deposition and bullet motion, but can have a devastating effect on susceptible organs.[9]

## Military anaesthesia for head injuries

Primary traumatic brain injury (TBI) is the initial physical injury caused to brain parenchyma by mechanical forces. This results in activation of an inflammatory cascade, with further tissue damage, oedema, and decreased cerebral perfusion pressure (CPP). Patients with apparent or suspected TBI are vulnerable to secondary brain injury. Rapid management of TBI patients, including institution of neuroprotective strategies, is essential for moderating the impact of this cause of morbidity and mortality.

Any reduction in conscious level will render the patient at risk of airway obstruction and aspiration. Intubation and mechanical ventilation may be indicated, both for airway protection and to facilitate control of a patient's physiological parameters. Optimizing oxygenation ($SaO_2 \geq 90\%$) and ventilation ($PaCO_2$ 35 −40 mmHg) helps reduce intracerebral vasodilatation associated with hypoxemia and hypercarbia, counteracting any further rise in intracranial pressure and consequent reduction in CPP (= mean arterial pressure-intracranial pressure, MAP-ICP).[10] Although hyperventilation to lower $PaCO_2$ may be used as a temporizing measure for raised ICP, hypocarbia can cause a vasoconstriction-associated decrease in cerebral oxygenation and subsequent intracerebral ischaemia. Sedation will help to reduce cerebral metabolic requirements and seizure activity.

Neuroprotective management also includes maintenance of an adequate blood pressure (systolic ≥100 mmHg) to maintain CPP.[10] Brain Trauma Foundation (BTF) guidelines state that a single pre-hospital episode of hypotension (defined as systolic <90 mmHg) in a TBI patient is a statistically independent risk factor for a poor outcome. This becomes more challenging in the context of multi-system trauma, when a balance must be struck with permissive hypotension, as part of damage control resuscitation for catastrophic haemorrhage.

Other strategies to maintain CPP include taping, rather than tying, the endotracheal tube and positioning the patient 30° head up, to assist cerebral drainage and lower ICP. If there are clinical signs of a raised ICP (e.g. a dilated pupil), administration of intravenous hypertonic saline (3−5 ml/kg of 3%) can help to reduce cerebral oedema by creating an osmotic gradient that mobilizes intracerebral fluid in to the systemic circulation (thereby also augmenting blood pressure, without the subsequent potent diuresis and possible hypotension associated with mannitol). Plasma sodium levels should be monitored.

It is important to assess a TBI patient's baseline neurological function, using the Alert, Voice, Pain, Unresponsive (AVPU) scale or Glasgow Coma Scale (GCS), as well as their pupil size and reactivity, particularly pre- and post-administration of anaesthetic drugs.

The anaesthetic management of a TBI patient may impact critically on their outcome. A rapid sequence induction is not without risk of complications, particularly in a group of patients whose already unstable physiology may be further compromised by anaesthetic drugs.[11] Agents that are commonly used to induce anaesthesia rapidly in the pre-hospital environment are fentanyl, ketamine and rocuronium. A modified technique using intravenous fentanyl, ketamine and rocuronium in a 3:2:1 (unit drug per kilogram patient weight) ratio, or 1:1:1 ratio in more haemodynamically compromised patients, achieves suitable intubating conditions. Concerns regarding the use of ketamine for TBI patients, in whom a high MAP could exacerbate a raised ICP, have largely been disproved.[12] Careful laryngoscopy technique will help to prevent excessive sympathetic stimulation. Rocuronium is a useful muscle relaxant in trauma, because it has a rapid onset, long duration of action and can be reversed pharmacologically if required.

Cervical spine problems should be suspected in trauma patients where their injury involves a large transfer of energy or obvious injury to the neck. Stabilization of the cervical spine (with manual in-line techniques during intubation) should be undertaken. Anaesthesia can be maintained safely using either inhalational or intravenous agents. Inhalational anaesthetics produce a dose-dependent increase in cerebral blood flow (CBF) that may lead to a rise in ICP, although this is less likely with a minimum alveolar concentration of <1, but most inhalational agents also lower the cerebral metabolic rate ($CMRO_2$). Nitrous oxide should be avoided, because it increases CBF and $CMRO_2$. All intravenous anaesthetics, apart from ketamine, decrease CBF and $CMRO_2$, although evidence shows that ketamine does not cause a rise in ICP.[12]

Placement of an arterial line, for beat-to-beat monitoring of blood pressure and measurement of blood gas components, is recommended. Unless a TBI patient requires either blood product resuscitation, or a dose of hyperosmolar therapy, isotonic solutions should be administered in favour of hypotonic ones, because the latter more readily cross the blood brain barrier and worsen cerebral oedema and raised ICP. Finally, avoidance of hyperthermia, which increases cerebral metabolic rate, has been shown to be of benefit in TBI.

Anaesthetic management of TBI patients is challenging, particularly in military austere and resource-limited environments. However, careful monitoring and manipulation of physiological parameters are crucial for preserving and protecting the brain.

## Current concepts in the management of traumatic cardiac arrest

Trauma may be a primary or secondary event in the situation of cardiac arrest of a trauma patient. Differentiation is often possible, based on the history of the patient and the circumstances of their arrest. It is crucial that a patient who has suffered trauma as a result of a medical cardiac arrest is treated according to the universal Advanced Life Support (ALS) algorithm. Initial management of traumatic cardiac arrest (TCA) focuses on addressing potentially reversible causes simultaneously rather

 

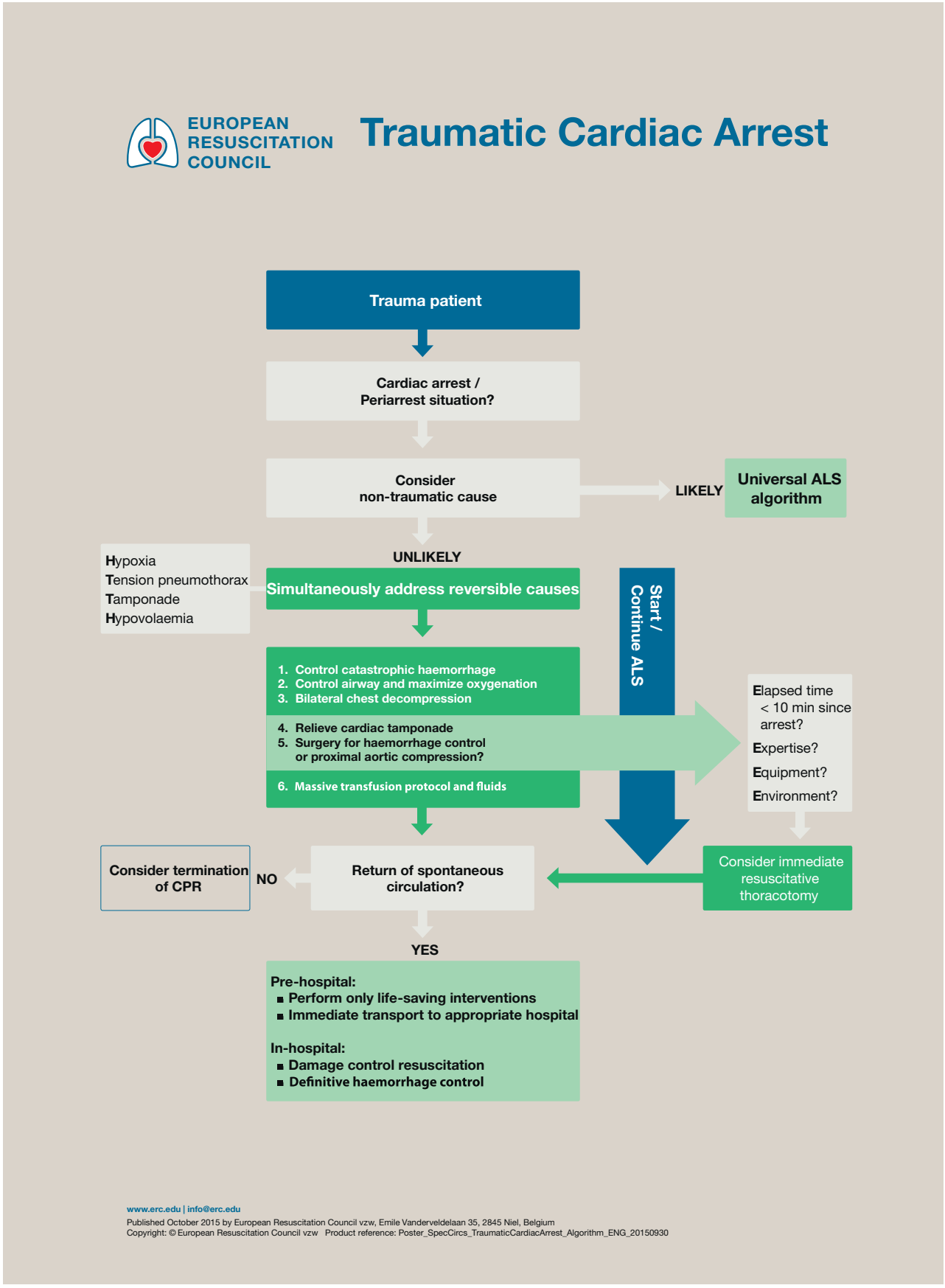


**Figure 1** European Resuscitation Council algorithm for the management of traumatic cardiac arrest 2015. (Reproduced with kind permission from: Truhlar A, Deakin CD, Soar J et al. European Resuscitation Council Guidelines for Resuscitation 2015; 95:148–201.)

than on delivery of chest compressions, which are less likely to be successful under these circumstances (Figure 1).

TCA is broadly categorized as blunt or penetrating but can be managed according to the 'HOT' principles: Hypovolaemia, Oxygenation, Tension pneumothorax/cardiac Tamponade.

### Hypovolaemia

**Haemorrhage control** — The majority of external or extremity bleeding can be controlled by compression, elevation and splinting. Open wounds can be packed with haemostatic agents, such as CELOX-impregnated gauze. Suspected internal and non-compressible haemorrhage can be controlled definitively by surgical intervention. The CRASH-2 trial shows that intravenous administration of the antifibrinolytic tranexamic acid is beneficial when given within three hours of injury occurring.[13]

**Damage control resuscitation (DCR)** — This largely becomes relevant if there is return of spontaneous circulation post-TCA, and comprises only necessary interventions to establish a survivable physiological status, before definitive injury repair is undertaken. Damage control surgery (DCS), for control of haemorrhage and treatment of contamination is undertaken concurrently with DCR. DCR is synonymous with the concept of balanced resuscitation and consists of permissive hypotension and haemostatic resuscitation.

- Permissive hypotension (which does not apply during TCA) involves maintaining a blood pressure that is low enough to reduce haemorrhage but high enough to preserve end-organ perfusion. The overall purpose is to limit significant increases in blood pressure (aiming for a systolic of 90 mmHg) until surgical control of bleeding has been achieved. Higher blood pressure thresholds are advised for patients with traumatic brain injury, to maintain cerebral perfusion pressure. A novel hybrid resuscitation strategy proposes limiting hypotensive resuscitation to sixty minutes duration, to mitigate risks including poor oxygen delivery and significant metabolic acidosis.[14]
- Haemostatic resuscitation (which applies throughout management of TCA) involves a balanced strategy advocating early use of blood products in ratios similar to whole blood - red blood cells, plasma and platelets administered 1:1:1. This aims to avoid complications associated with crystalloids, including dilution of red cell and coagulation factor concentrations, worsening acidosis, exacerbation of hypothermia, oedema and immune system activation/cellular injury. In a time-critical TCA situation, where hypovolaemia secondary to haemorrhage is a potentially reversible cause of the arrest, early and aggressive fluid resuscitation is required, even if only crystalloid is available.

### Oxygenation

To address hypoxia in TCA, airway management aims to establish a definitive airway by means of intubation and mechanical ventilation, thereby maximizing oxygenation.

### Tension pneumothorax

Chest trauma can lead to disruption of the visceral pleura, parietal pleura or tracheobronchial tree. If a one-way valve is formed, air that flows in during inspiration can become trapped in the pleural space and cause a tension pneumothorax. This can lead both to hypoxia and an increase in intrathoracic pressure that impedes venous return to the heart, which may result in cardiac arrest. In a patient in TCA, bilateral chest decompression is achieved more reliably and effectively by open thoracostomies than needle thoracocentesis. Siting thoracostomies is the first step in performing a resuscitative thoracotomy (RT).[15]

### Tamponade

Cardiac tamponade occurs when the pericardial sac is filled with fluid under pressure, resulting in cardiac arrest secondary to compromised cardiac function. Tamponade is more common with penetrating trauma. TCA in penetrating trauma to the chest or epigastrium is one indication for immediate RT. Estimated survival rates for RT are 15% for patients with penetrating chest wounds and 35% for those with penetrating cardiac wounds, contrasting starkly with only 0—2% for patients with blunt chest trauma. It is unclear whether blunt trauma patients should undergo RT in the pre-hospital environment. Ultrasonography may assist with diagnosis of the underlying cause of the TCA. It is difficult to determine the elapsed time threshold in a situation of penetrating trauma, although the European Resuscitation Council Guidelines for Resuscitation 2015 advise that the time from loss of vital signs to commencing a RT should not exceed ten minutes.

### Resuscitative thoracotomy[15]

- Position the patient in the supine position while other procedures (intubation, IV access) are undertaken.
- Apply skin antiseptic.
- Perform bilateral thoracostomies in the fourth or fifth intercostal space anterior to the mid-axillary line (using scalpel and Spencer Wells forceps).
- Join the thoracostomies with a deep scalpel skin incision.
- Cut through the intercostal muscles and parietal pleura using medical shears, from the thoracostomies to either side of the sternum.
- Perform a finger sweep under the sternum.
- Cut through the sternum, with medical shears or Gigli saw.
- Open the 'clamshell', manually or using rib spreaders.
- Identify the heart and 'tent' the pericardium with forceps before cutting a small hole with scissors, extending it vertically upwards and downwards.
- Evacuate any blood clots.
- If the heart makes no spontaneous movement, flicking it may cause contractions to return. If not, perform internal cardiac massage. Simultaneous compression of the aorta against the spinal column by an assistant may help to maximize coronary and cerebral perfusion.
- Bleeding from myocardial wounds should be controlled initially with a finger. Sutures may be required, placed to avoid occlusion of coronary arteries.
- IV volume should be given.
- If return of spontaneous circulation (ROSC) is achieved there may be significant internal mammary/intercostal vessel bleeding, which may need to be controlled with artery forceps.
- In the situation of ROSC the patient will require sedation.


**Figure 2** Combat Application Tourniquet. (Reproduced with permission.)

**Figure 3** Military emergency compression bandage. (Reproduced with permission.)

Management of TCA is complex and time sensitive. There are potentially life-saving interventions that can be made pre-hospitally – which should be undertaken by highly trained clinicians using the right equipment, and should not delay definitive care.

## Combat application tourniquet (CAT) and haemorrhage control compression dressing bandage

Ballistic trauma and battlefield deaths related to extremity injury and major haemorrhage have been identified as the cause of more than half of potentially preventable deaths. This has led to the adaptation of the military trauma algorithm for blast and ballistic injuries from ABC to <C> ABC. <C> represents catastrophic haemorrhage – life-threatening bleeding amenable to control by use of direct pressure, a tourniquet or bleeding control interventions. This is taught throughout the military, on courses such as the Team Medic and Battlefield Advanced Trauma Life Support (BATLS) courses.

The CAT (Figure 2) and first field dressing (Figure 3) have become standard issue for military personnel. Within the civilian environment, where blunt trauma is more common, there is still some controversy surrounding tourniquet use in pre-hospital trauma. This relates to concerns about inappropriate application and length of time left in place, where direct pressure may have been sufficient to stem bleeding. NICE has recognized that effective tourniquet application can prevent mortality, outweighing the potential adverse outcomes.

Military Clinical Guidelines for Operations (CGOs) advise initial management of catastrophic haemorrhage. Where appropriate, a tourniquet should be placed early, 2–3 inches proximal to the wound or limb amputation, on bare skin and tightly enough to stop the bleeding. It is designed for self and 'buddy' application. Initially the main Velcro strap should be placed around the limb tight enough that no more than two fingers can fit under the strap. The tourniquet has a windlass rod system for effective tightening. Once tight enough, the time band should be fastened over the clip and time of application noted. If lower limb bleeding is not controlled, a second tourniquet can be applied proximal to the first. It is important to check the tourniquet is secure prior to patient transfer, and the wound should be continuously reassessed for bleeding. Addition of other haemostatic dressings may be required including Celox, which is useful for junctional areas and has been shown to result in a statistically significant improvement in survival.[16] Celox contains chitosan, which acts by ionic bonding, working independently of the body's clotting cascade. It should be packed tightly into a wound, covered and compressed for approximately 5 minutes. It should not be applied to open chest, abdominal or head wounds.

These are interim measures to stop bleeding, but it is important to consider evacuation to an appropriate medical facility for surgical management as early as possible.

## Summary

This article provides a summary of the key management of a number of military trauma scenarios, the principles of which can be applied in the civilian setting. These include avoiding the triad of hypothermia, acidosis and coagulopathy, which requires careful resuscitation. In hospital, local major haemorrhage protocols are activated to provide early hybrid resuscitation and targeted blood product administration, directed by thromboelastography where available. Cell salvage can be used, and rapid infusion devices allow heated delivery of controlled volume resuscitation. Along with temperature regulation, electrolytes should be monitored and replaced appropriately. Multidisciplinary critical care management of major trauma patients is paramount to optimizing their outcome. ◆

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