Management of major trauma

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Trauma

INTRODUCTION

Patients suffering from multiple injuries present enormous demands at all levels within hospitals, particularly on those attending to the patient within the first few hours of hospital admission. This article outlines a system for the management of major trauma victims in the Emergency Department.

The Advanced Trauma and Life Support (ATLS) Program, devised by the American College of Surgeons (ACS), is widely accepted as the standard for the initial care of trauma victims, whether the patient is treated in an isolated rural area or a well-resourced trauma centre. This article follows many of its recommendations, with additions from other sources.

EPIDEMIOLOGY OF TRAUMA

Every five seconds someone in the world dies as a result of an injury. Injuries kill about 5.8 million people each year; more than malaria, tuberculosis and HIV/AIDS combined.[1] Among the causes of injury are acts of violence, road traffic collisions, burns, drowning, falls and poisoning. Road traffic injuries are the leading cause of injury-related deaths worldwide.

Within the last few decades our understanding of the nature of injuries has improved and today both intentional and unintentional injuries are viewed as largely preventable events, rather than as unavoidable accidents. Injury prevention strategies are having an impact in most developed countries, where trauma is still the leading cause of death in people between the ages of 1 and 44 years. More than 90% of the world's deaths from injuries occur in low and middle income countries.[2]

Despite injury prevention strategies, injury-related disease burden is expected to increase dramatically by 2020, particularly in the case of road traffic injuries, interpersonal violence, war and self-inflicted injuries. By 2020, it is estimated that more than 1 in 10 people will die from road traffic injuries.[3] Global trauma-related costs are estimated to exceed US$500 billion annually. The true cost of trauma, however, can only be measured when it is realised that trauma victims tend to be society's youngest, and potentially most productive, members.

TRIMODAL DEATH DISTRIBUTION

Mortality due to injury occurs during one of three time periods or peaks.

First peak

This occurs at the time of the injury. Very few of these patients can be saved, because of overwhelming primary injury to major organs or structures such as the brain, heart or great vessels. Only prevention can significantly reduce this peak of trauma-related deaths.

Second peak

The second peak occurs within minutes to several hours following the injury. Trauma care is directed at this period because many of the causes of morbidity and mortality during this time are preventable by avoidance of secondary injury due to hypoxia, haemorrhage or any process that leads to inadequate tissue perfusion. Deaths that occur during this period are usually due to intracranial haematomas, haemopneumothorax and major haemorrhage from viscera, bones and vessels.

Third peak

This occurs several days to weeks after the initial injury and is most often due to sepsis and multiple organ dysfunction. Although this stage usually occurs in a high dependency area, improvements on initial management upon admission will reduce morbidity and mortality during this period.

PREPARATION

Ideally a designated resuscitation area should be available to receive trauma patients. Basic equipment requirements include:

- Airway equipment should be tested and placed where it is immediately accessible,

- Warmed intravenous fluids should be ready to infuse when the patient arrives,

- Specific provision should be made for children, with appropriate sizes of equipment to deal with all ages and equipment for intra-osseous fluid administration,

- Appropriate monitoring capabilities should be immediately accessible.

Summary

Trauma is a major cause of death around the world. This article gives an overview of the basics of management of patients who have suffered major trauma. Several areas of practice have evolved in the last few years, following the experience of the armed services in conflict zones.

Some sections such as management of cervical spine injury, thoracic injury and patients with major burns are dealt with in detail in other articles in this edition of *Update*.

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It may be necessary to improvise, particularly in remote areas where resources are limited.

An effective method to call for additional medical assistance should be in place, as well as a means to ensure rapid responses by laboratory and radiology personnel. Transfer agreements with trauma centers should be established and operational. Patients with multiple injuries are best treated by a well-organised and trained team, made up of members who are competent in assessing and treating the range of life-threatening injuries commonly seen. Where possible, staff should have attended an ATLS course (or equivalent such as PTC, Primary Trauma Care), although in smaller hospitals a full trauma team will not be available.

A schematic diagram of a full trauma team in their various positions is shown in Figure 1. Where there are limited resources, individuals in the team will assume more than one role and specialist resources (e.g. the surgeon) may move serially from one patient to another, dependent on the need for specialist assessment and intervention skills.
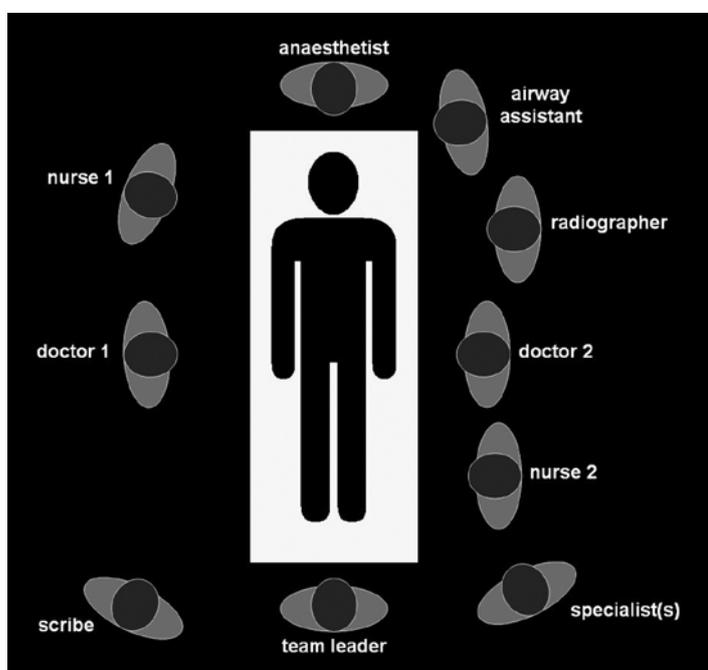

Figure 1. *Schematic diagram of a trauma team and their positions around the patient.*

The overall management of the patient is the responsibility of the team leader. If there are enough staff the team leader should adopt a 'hands off' approach, in order to maintain an overview of the resuscitation. The trauma team's responsibility is to complete the **primary survey** and necessary resuscitation and subsequently complete the **secondary survey**, if time allows, as well as recording all diagnoses and treatments given. The team leader must ensure that this is achieved effectively and rapidly. Specific tasks are allocated to different members of the team at an early stage; in a well-practiced team this is done before the patient arrives.

Advance warning of the arrival of a severely injured patient in the emergency department enables emergency department staff to alert the trauma team, who should assemble in the resuscitation room. Each member of the team should wear gloves, a plastic apron and eye protection. Where possible both a general surgeon and an orthopaedic surgeon should be members of the trauma team.

Objectives of the trauma team[4]

- Identify and correct life threatening injuries.
- Resuscitate the patient and stabilize vital signs.
- Determine the extent of other injuries.
- Prepare the patient for definitive care, which may mean transport to another centre.

Box 1. *Trauma team roles and responsibilities. (ODP - operating department practitioner; RSI - rapid sequence induction; ED - emergency department)*

Team Leader (Emergency Physician)
- Controls and manages the resuscitation.
- Makes decisions; prioritises investigations and treatment.

Anaesthetist
- Responsible for **assessment and management of the airway** and ventilation.
- Counts the initial respiratory rate.
- Administers oxygen; performs suction; inserts airway adjuncts; endotracheal intubation (RSI).
- Maintains cervical spine immobilisation and controls the log roll.
- Takes an initial history (AMPLE – see below).

Airway Assistant (ODP or ED Nurse)
- Assists in preparing equipment for advanced airway intervention.
- Assists with advanced airway intervention, e.g. applies cricoid pressure.
- This role may be undertaken by Nurse 1.

Doctor 1 (Emergency Physician or Surgeon)
- Undertakes the primary survey: **<C> + B to E**.
- Clinical findings are clearly spoken to team leader and recorded by the scribe.
- Performs procedures depending on skill level and training.

Doctor 2
- Performs procedures depending on skill level and training.

Nurse 1 (ED Nurse, 'Airway')
- Applies monitoring equipment and assists with procedures.
- Assists advanced airway intervention (unless ODP present).

Nurse 2 (ED Nurse, 'Circulation')
- Undresses patient & assists with procedures.

INITIAL ASSESSMENT AND RESUSCITATION - <C>ABC

Every trauma patient should be assessed using the same systematic method, preferably using a team approach.

An 'ABC' approach has become established across the spectrum of advanced life support programmes. Experience and evidence with combat casualties has shown that external peripheral haemorrhage is the leading cause of combat casualty death. As a result, the UK and US militaries have replaced ABC with <C>ABC, where <C> stands for **catastrophic haemorrhage control**. This is being increasingly adopted by the civilian community.

A horizontal approach to trauma management, where systems are managed simultaneously, is preferable to a vertical approach, where systems are managed in order of priority, but this is dependent on the size and skill set of the trauma team.

Box 2. *An overview of trauma management*

Primary survey and resuscitation

- **C**atastrophic haemorrhage control
- **A**irway and cervical spine control
- **B**reathing
- **C**irculation and haemorrhage control
- **D**isability
- **E**xposure

Secondary survey

Definitive management

PRIMARY SURVEY AND RESUSCITATION

The purpose of the primary survey is to identify immediate life threatening conditions. These should be treated as soon as they are diagnosed, before continuing the survey. Whilst the primary survey is ongoing, any deterioration in the patient's clinical condition should be managed by reassessing from the start of the protocol, as previously undiagnosed injuries may be revealed.

Catastrophic haemorrhage control

Immediate control of obvious bleeding is of paramount importance. The use of **tourniquets** is now recommended for the management of life threatening bleeding from open extremity injuries, in the pre-surgical setting.

Pressure bandages, rather than tourniquets, should be applied in the case of minor bleeding from open wounds in extremity injuries. When uncontrolled arterial bleeding occurs from mangled extremity injuries, including penetrating or blast injuries or traumatic amputations, a tourniquet is a simple and efficient method to control haemorrhage.[6-10] Tourniquets should be left in place until surgical control of bleeding is achieved, however this time-span should be kept as short as possible.[6-9]

It may not be possible to staunch catastrophic haemorrhage, particularly if it is internal, for example within the abdomen or chest cavities. In these circumstances, surgery must not be delayed.

Airway and cervical spine control

The main objective, in the early management of the severely injured patient, is to provide sufficient oxygen to the tissues in order to prevent secondary organ failure and central nervous system damage.

The first priority is to ensure a clear and unobstructed airway. If the patient can answer questions appropriately, then it is unlikely that there is any immediate threat to the airway. Noisy or laboured breathing or paradoxical breathing movement (when movements of the chest and abdomen are out of phase) is evidence of obstruction, that must be corrected.

Head injury with impaired consciousness and reduced pharyngeal tone is the commonest trauma-related cause of airway obstruction. The airway may also be soiled with vomit, blood or foreign material. Blunt or penetrating injuries that obstruct the airway include maxillary, mandibular and laryngotracheal fractures and large anterior neck haematomas.

Patients who have been exposed to significant blunt trauma are at risk of unstable cervical injuries. During airway interventions, neck movement must be minimized to avoid spinal cord damage. 2-12% of major trauma victims have a cervical spine injury and 7-14% of these are unstable.[11]

Any patient with a possible cervical spine injury should have their neck immobilized in a neutral position to prevent further damage. Immobilization of the cervical spine must be continued, until a complete clinical and radiological evaluation has ruled out injury. This can either be done manually (manual in-line stabilisation of the neck - MILS) or with a correctly sized hard cervical collar, lateral blocks (or sandbags), and straps across the forehead and chin piece of the collar (see article on page 112).

A jaw thrust may be better at relieving airway obstruction with decreased consciousness than a chin lift. If tolerated, an oropharyngeal airway may maintain an open airway, whilst exerting less force on the

vertebrae. It should never be inserted into the pharynx of a patient with an intact gag reflex, as this can cause retching or vomiting. In these circumstances a nasopharyngeal airway should be inserted, if there is no basal skull fracture.

Endotracheal intubation is indicated if airway patency remains inadequate despite the above measures, or in the presence of apnoea or loss of protective upper airway reflexes. Other indications for intubation are listed in Table 1. Orotracheal intubation is a two-person technique with in-line cervical spine immobilization.

It is important to assess the patient's airway prior to attempting intubation, in order to predict the likely difficulty. Facial hair, trauma and burns prevent effective mask application. Mechanical trismus may hinder supraglottic airway and laryngoscope insertion. Laryngoscopy becomes more difficult in the presence of airway oedema, blood or burns. MILS and cricoid pressure increase the incidence of Cormack and Lehane grade 3 laryngeal views to 20%.[11] Backward, upward and right pressure ('BURP') on the larynx may help if it is anteriorly placed.

Failed intubation

Failed or difficult intubation is a common problem in this setting. It is important not to waste time with repeated attempts at intubation, while the patient is desaturating. Alternative methods of securing the airway should be started as soon as the problem is recognised. Management is guided by algorithms that are discussed in a previous edition of *Update in Anaesthesia*.[14,15]

If intubation is impossible, a laryngeal mask airway (LMA) will provide a temporary airway, but may not prevent aspiration. The intubating LMA (ILMA) may be easier to insert in the neutral position and provides the opportunity for blind intubation, although consistent success requires ongoing practice. If this fails, a cricothyroidotomy should be carried out; this is discussed in detail in a recent *Update* article.[15]

Box 3. *Tips for rapid sequence induction (RSI) and intubation*

- Check the ventilator, breathing system, laryngoscopes, tracheal tubes, suction and equipment for managing a difficult airway prior to commencing RSI.

- Routine monitoring should be applied.

- Have a plan for difficult or failed intubation.

- Where cervical spine injury is possible MILS is applied by an assistant, crouched beside the intubator, holding the patient's mastoid processes firmly down on the trolley.[12,13] MILS must simply oppose the force generated by direct laryngoscopy (which rotates the occipito-atlanto-axial complex) and must not cause traction, which could cause spinal cord injury.

- Remove the hard collar after MILS has been applied mouth opening is easier.

Breathing

Airway patency alone does not ensure adequate ventilation. Adequate gas exchange is required to maximize oxygenation and carbon dioxide elimination. Ventilation requires adequate function of the lungs, chest wall and diaphragm. Each component must be examined and evaluated rapidly. The patient's chest should be exposed and any obvious injuries noted. The respiratory rate should be measured; it is a sensitive indicator of physiological stress. Diaphragmatic (or 'paradoxical') breathing may be observed with cervical cord injury: the abdomen is seen to move in and out, rather than the chest.

The trachea should be checked for deviation and both sides of the chest assessed for expansion. The thorax must be percussed and the lung apices and axillae auscultated. The back of the chest and axillae

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Table 1. *Indications for intubation.*

Need for airway protection	Need for ventilation or oxygenation
Unconscious	Unconscious
Severe maxillofacial fractures	No respiratory effort
Risk of aspiration	Inadequate respiratory effort: (tachypnoea, hypoxia, hypercarbia, cyanosis):
• Blood	• Flail chest
• Stomach contents	• Pulmonary contusion
Risk of airway obstruction	• Blast injury
• Oedema	To regulate intracranial pressure by controlling CO_2 in severe, closed head injury
• Neck haematoma	To perform therapeutic and diagnostic procedures in uncooperative patients
• Laryngeal or tracheal injury	
• Stridor	
• Upper airway burns	

should not be forgotten, especially in the case of penetrating trauma, such as gunshot wounds, when an exit wound should be specifically sought. An odd number of gunshot wounds means that a wound has either been missed or that there is still a bullet in the body. The chest is examined when the patient is log-rolled off the ambulance trolley or hard board. Formal log roll and spinal examination is described in the secondary survey.

If available, a pulse oximeter is useful, as it gives an indication of the adequacy of perfusion as well as arterial oxygen saturation. High flow oxygen (6-8L.min⁻¹) should be administered to every patient. Oxygen is delivered to the spontaneously breathing patient via a Hudson mask with a non-rebreathing bag. Where ventilation is inadequate, this should be assisted by bag-valve-mask prior to RSI.

The chest Xray is part of the clinical examination in serious trauma and should be performed during the primary survey. A simple, easy, cheap and informative method of indicating the trajectories caused by penetrating injuries on chest Xrays is the application of bullet markers (for example, paper clips secured with micropore) to the wounds. Open clips can be applied to anterior wounds (forming a triangle) and closed clips to posterior wounds to help identify which is which.

Box 4. *Life threatening conditions that need immediate treatment*

- Tension pneumothorax

- Massive haemothorax

- Cardiac tamponade

- Flail chest with pulmonary contusion

- Open chest wound.

These conditions are described in more detail in the article on page 119.

Diagnosis of cardiac tamponade can be difficult. The classic diagnostic Beck's triad consists of venous pressure elevation, decline in arterial pressure, and muffled heart sounds. All of these signs can be easily misinterpreted in a noisy emergency department with a shocked patient. A FAST scan (Focused Assessment with Sonography for Trauma) is sensitive and specific for the evaluation of the pericardium for cardiac tamponade in penetrating trauma.[16] If haemopericardium is confirmed, needle pericardiocentesis may help in the short-term, however thoracotomy is the definitive treatment.

Circulation

The first step in managing shock in injured patients is to recognise its presence. The second step is to identify the probable cause of the shock state. Treatment should be initiated simultaneously with the identification of the probable cause. The time spent between injury and operation must be minimised for patients in need of urgent surgical bleeding control.[17]

Recognition of shock

Profound shock, with circulatory collapse and inadequate perfusion

of the skin, kidneys and brain, is easy to recognise. However, after the airway and breathing have been assessed, careful evaluation of the patient's circulatory status is important to identify early shock.

Signs of early shock include tachycardia, with reduced capillary refill time and skin temperature. Attention must also be paid to an increased respiratory rate and narrowed pulse pressure (the difference between systolic and diastolic pressure). Relying on systolic blood pressure as the only indicator of shock leads to delayed recognition of shock. This is because compensatory mechanisms prevent the systolic blood pressure from falling until up to 30 percent of the patient's blood volume is lost, particularly in young, fit patients.

The normal heart rate varies with age. Tachycardia is present when the heart rate is greater than 160 in an infant, 140 in a preschool age child, 120 from school age to purberty, and 100 in an adult. Elderly patients may not show tachycardia because of reduced cardiac response to catecholamine stimulation, or the concurrent use of medications such as beta-adrenergic blocking agents. The ability to increase the heart rate may also be limited by the presence of a pacemaker.

Identification of the cause of shock

Shock in a trauma patient can be classified as haemorrhagic or non-haemorrhagic. Haemorrhage is the most common cause of shock after injury and accounts for up to 50% of deaths in the first 24 hours after injury.

Nearly all patients with multiple injuries have hypovolaemia. Most non-haemorrhagic shock states respond partially, or briefly, to volume resuscitation. Therefore, if signs of shock are present, treat for hypovolaemia and then reassess the patient, as it is important to identify the few patients whose shock has a different cause, such as cardiogenic, neurogenic or even septic shock. Tension pneumothorax should also be considered.

Hypovolaemia can be divided into 4 classes as shown in Table 2, with their appropriate signs. This is a useful tool for estimating the percentage of acute blood loss. The extent of traumatic haemorrhage should be assessed using a combination of mechanism of injury, patient physiology, anatomical injury pattern and the patient's response to initial resuscitation.[17]

Patients presenting with haemorrhagic shock and an unidentified source of bleeding should undergo further assessment of further assessment of the major sources of acute blood loss in truama - the chest, abdominal cavity, pelvic ring and the long bones.[17] If pelvic instability is suspected, a tight pelvic binder or sheet should be wrapped around the pelvis at the level of the greater trochanters, as soon as possible.

Xrays of chest and pelvis, in conjunction with FAST or diagnostic peritoneal lavage (DPL), are recommended diagnostic modalities during the primary survey.[18]

FAST is now the imaging modality of choice when a trained operator is available. DPL is carried out less frequently, but is considered positive if 15ml of blood is obtained immediately, or if it is not possible to read print through the backwash from 1 litre of warmed saline infused into the abdominal cavity. The backwash fluid is sent for gram stain and analysis of the red blood cell count and white blood cell count. It also

Table 2. *American College of Surgeons, Advanced Trauma Life Support (ATLS) classification of blood loss, based on initial patient presentation for a 70kg male[18]*

	Class 1	Class 2	Class 3	Class 4
Blood loss (ml)	up to 750	750-1500	1500-2000	>2000
Blood loss (% blood volume)	up to 15%	15-30%	30-40%	>40%
Pulse rate (min⁻¹)	<100	100-120	120-140	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate (min⁻¹)	14-20	20-30	30-40	>35
Urine output (ml.h⁻¹)	>30	20-30	5-15	Negligible
Mental status	Slightly anxious	Mildly anxious	Anxious, confused	Confused, lethargic

should be examined for enteric, bilious, or vegetable matter content. A positive DPL in an adult classically requires one of the following results: 10ml gross blood on initial aspiration, >500 per mm³ white blood cells, >100,000 per mm³ red blood cells, or the presence of enteric or vegetable matter.[19]

Patients who are haemodynamically unstable and who have significant free intraabdominal fluid should undergo laparotomy, whereas those who are haemodynamically stable and who are either suspected of having torso bleeding (clinically or FAST positive) or have a high-risk mechanism of injury, should undergo further assessment using computed tomography (CT), if readily available.[17]

In selected centres, readily available CT scanners may replace usual radiographic imaging techniques during the primary survey.

Initial management of haemorrhagic shock

Definitive bleeding control and prevention of the lethal triad of hypothermia, coagulopathy and acidosis are key to the management of haemorrhagic shock.

Insert two large bore (minimum 16 gauge) peripheral intravenous (IV) cannulas. Other peripheral lines, cut downs and central venous lines should be used as necessary, in accordance with the skill level of the doctor who is attending the patient. The central route is only recommended for rapid fluid resuscitation when peripheral access is not possible, and a relatively short, large bore catheter (e.g. 8.5 Fr introducer sheath) should be used. For rapid access the external jugular vein may be used. Intraosseous access is well established in children and use is growing in adults.

At the time of IV insertion, take blood for type and crossmatch and baseline haematologic studies, including a pregnancy test for all females of childbearing age.

The CRASH-2 study has shown that tranexamic acid, a fibrinolysis inhibitor, given as early as possible to bleeding trauma patients, improves mortality from bleeding.[18] The dose is 1g IV over 10 minutes, followed by an infusion of 1g over 8 hours. If treatment is delayed three hours or later after injury, mortality is increased by haemorrhage.[20]

Arterial blood gas analysis should be performed where available. Insert an arterial cannula for blood gas sampling and invasive blood pressure monitoring if this technique is available.

Initial fluid therapy

Early treatment of injured patients has traditionally focused on aggressive resuscitation with high chloride-containing crystalloid solutions. Whilst recognizing that in many hospitals the choice of fluid is limited, we include a brief update on research on resuscitation fluids.

Resuscitation with crystalloid exacerbates each element of the lethal triad of hypothermia, coagulopathy and acidosis. Pre-hospital and early in-hospital resuscitation with crystalloids has been shown to increase morbidity and mortality in patients with penetrating torso trauma.[21]

The absence of clotting activity in both crystalloid solutions and packed red blood cells contributes to dilutional coagulopathy. High chloride content in crystalloid solutions exacerbates the acidosis of shock and prehospital fluid, maintained at room temperature, contributes to hypothermia.

The current fluid of choice is a colloid such as 6% hetastarch suspended in a balanced salt solution that contains lactate (such as Hartmann's).[22] This has been shown not to exacerbate coagulopathy, even with substantial volumes, and has been shown to reduce blood loss in patients undergoing major surgery, compared with 6 per cent hetastarch suspended in 0.9% saline.[23]

The goal of resuscitation is to restore organ perfusion. This is achieved by the use of resuscitation fluids to replace lost intravascular volume and is assessed on clinical grounds. If blood pressure is raised rapidly, before haemorrhage has been definitively controlled, increased bleeding may occur, due to increased hydrostatic pressure on the wound and dislodgement of blood clots.

Those involved in military trauma are trained to withhold fluid resuscitation, unless a casualty has either an impaired mental state or absent pulse, and to give only enough fluid to reverse these abnormalities. Until surgical control of haemorrhage has been achieved, target fluid resuscitation to a blood pressure that is lower than normal, but maintains a level of tissue perfusion that is adequate for short periods. This target will depend on age and coexisting morbidities.[24]

This approach must be modified in traumatic brain injury and spinal injuries, because an adequate perfusion pressure is vital to ensure tissue oxygenation of the injured central nervous system. A mean arterial pressure of at least 90mmHg is required in patients with even slightly raised intracranial pressure.

Evaluation of fluid resuscitation and organ perfusion

The volume status of the patient is determined by observing the change in vital signs after the initial fluid bolus. Failure to improve the vital signs implies ongoing haemorrhage, and necessitates immediate surgical intervention and blood transfusion. Sensitive measurements that give valuable information regarding organ perfusion include urine output, lactate and base excess. If available, thromboelastography® (TEG®) and thromboelastometry (ROTEM®) are direct measures of coagulopathy and indicate which blood components are required. These should be monitored to estimate the extent of bleeding and shock, and the response to fluid resuscitation.

The potential patterns of response to initial fluid administration can be divided into three groups: rapid response, transient response, and minimal or no response. Vital signs and management guidelines for patient in each of these categories are outlined in Table 3.

If the patient remains unresponsive to bolus IV therapy, blood transfusion may be required. In this situation, consider the possibility of tension pneumothorax, cardiac tamponade or 'spinal shock'. Aggressive and continued volume resuscitation is not a substitute for definitive control of haemorrhage. Definitive control includes operation, angioembolization and pelvic stabilization.

Damage control surgery

Damage Control Surgery (DCS) is aimed at stopping bleeding and preventing further contamination. It is limited to the control of uncompressible haemorrhage and the insertion of vascular shunts. These are temporising procedures that are used to gain control of a rapidly deteriorating clinical situation. If damage control surgery is required, the primary survey should be interrupted and continued postoperatively.

Damage control surgery techniques can apply to the abdomen, chest, pelvis and long bones.

Patients with major trauma are at risk of developing impaired coagulation, metabolic acidosis and hypothermia, which significantly contributes to illness and death. To prevent this lethal triad, damage control surgery is a staged process, involving five critical decision-making stages.

The first stage is patient selection and the decision to perform damage control surgery. This should take place in the Emergency Department, if not before. The second stage is the operation and the 'damage control'. The third stage takes place in the intensive care unit, where the patient is resuscitated towards normal physiology. This is followed by 'relook' surgery or a definitive surgical procedure. The final stage is definitive closure of the body cavity.

The advantage of the DCS approach is that surgeons only do the more thorough and therefore longer surgery once the patient is stable.

Hypothermia

Hypothermia may be present when the patient arrives, or it may develop quickly in the Emergency Department, if the patient is uncovered and undergoes rapid administration of room temperature fluids or refrigerated blood.

Hypothermia, defined as a core body temperature below 35°C, is associated with acidosis, hypotension and coagulopathy in severely injured patients. It is a serious complication and is an independent predictor of mortality.[25] Steps to prevent hypothermia, and the risk of hypothermia-induced coagulopathy, include removing wet clothing, covering the patient to avoid additional heat loss, increasing the ambient temperature, forced air warming, warm fluid therapy and, in extreme cases, extracorporeal re-warming devices. The use of a high

Table 3. *American College of Surgeons, Advanced Trauma Life Support (ATLS) responses to initial fluid resuscitation[18]*

	Rapid response	**Transient response**	**Minimal or no response**
Vital Signs	Return to normal	Transient improvement, recurrence of decreased blood pressure and increased heart rate	Remain abnormal
Estimated blood loss	Minimal (10%-20%)	Moderate and ongoing (20%-40%)	Severe (>40%)
Need for more crystalloid	Low	High	High
Need for blood	Low	Moderate to high	Immediate
Blood preparation	Type and crossmatch	Type-specific	Emergency blood release
Need for operative intervention	Possibly	Likely	Highly likely
Early presence of surgeon	Yes	Yes	Yes

flow fluid warmer or microwave oven to heat crystalloid fluids to 39°C is recommended. One litre of crystalloid in a 600 Watt microwave oven for 60 seconds is usually enough. Blood products, however, cannot be warmed in a microwave oven, but they can be heated by passage through IV fluid warmers.

Blood replacement

The main purpose of blood transfusion is to restore the oxygen-carrying capacity of the intravascular volume. A target haemoglobin (Hb) of 7-9g.dl^{-1} is recommended.[17] Fully crossmatched blood is preferable, although the complete crossmatching process requires about 45 minutes in most blood banks. For patients who stabilise rapidly, crossmatched blood should be obtained and made available for transfusion when indicated.

Group-confirmed blood can be issued within 10 minutes. Such blood is compatible with ABO and Rh blood types, but incompatibilities of other antibodies may exist. Group-confirmed blood is preferred for patients who are transient responders. If group-confirmed blood is unavailable, type O packed cells are indicated for patients with exsanguinating haemorrhage. To avoid sensitization and future complications, Rh-negative cells are preferred for females of childbearing age.

Coagulopathy

Severe injury and haemorrhage result in the consumption of coagulation factors and early coagulopathy. Massive transfusion, with the resultant dilution of platelets and clotting factors, along with the adverse effect of hypothermia on platelet aggregation and the clotting cascade, all contribute to coagulopathy in injured patients.

Routine practice to detect post-traumatic coagulopathy should include the measurement of international normalized ratio (INR), activated partial thromboplastin time (APTT), fibrinogen and platelets. INR and APTT alone should not be used to guide haemostatic therapy however.[17] If available thromboelastography® (TEG®) or thromboelastometry (ROTEM®) should be performed to assist in characterising the coagulopathy and in guiding haemostatic therapy.

Consideration of early blood component therapy, including thawed fresh frozen plasma (FFP), platelets and cryoprecipitate, should be given to patients with class 4 haemorrhage.

A fibrinogen of less than 1g.L^{-1} or a prothrombin time (PT) and APTT of >1.5 times normal, represents established haemostatic failure and is predictive of microvascular bleeding. Early infusion of FFP (15ml.kg^{-1}) should be used to prevent this occurring, if a senior clinician anticipates massive haemorrhage. Established coagulopathy will require more than 15ml.kg^{-1} of FFP to correct.[21] The most effective way to achieve fibrinogen replacement rapidly, is by giving fibrinogen concentrate, or cryoprecipitate if fibrinogen is unavailable.[19]

1:1:1 red cell:FFP:platelet regimens are reserved for the most severely traumatised patients.[21] A minimum target platelet count of $75 \times 10^9.L^{-1}$ is appropriate in this clinical situation.[17]

Calcium

Ionised calcium levels should be monitored during massive transfusion, as hypocalcaemia develops during massive transfusion, as a result of the citrate used as an anticoagulant in blood products. It has been suggested that calcium chloride be administered during massive transfusion if ionised calcium levels are low or electrocardiographic changes suggest hypocalcaemia.[17]

Further management of massive haemorrhage

Once bleeding is controlled, blood pressure, acid-base status and temperature should be normalised; vasopressors should be avoided. The patient should be actively warmed. Coagulopathy should be anticipated and prevented if possible; if present, it should be treated aggressively. Following treatment for massive haemorrhage, the patient should be admitted to a critical care area for monitoring and observation, including monitoring of coagulation, haemoglobin and blood gases, together with wound drain assessment, to identify overt or covert bleeding.

Venous thromboprophylaxis

Standard venous thromboprophylaxis should be commenced as soon as possible after bleeding has been controlled, as patients rapidly develop a prothrombotic state.

Disability - rapid neurological assessment

Check the pupils for size and reaction to light and assess the Glasgow Coma Score (GCS) score rapidly. If the patient requires urgent induction of anaesthesia and intubation, remember to perform a quick neurological assessment first.

A:	Alert
V:	Responding to Voice
P:	Responding to Pain
U:	Unresponsive

A simple pneumonic for a crude but simple GCS assessment is AVPU:

Patients who score 'P' or 'U' on the AVPU scale are likely to need intubating. 'P' roughly corresponds with a GCS of 8/15.

Checking glucose levels is an important part of the primary survey, as it may reveal a potential cause for the trauma. For example, hypoglycaemia in a diabetic patient leading to a road traffic crash.

Exposure

Undress the patient completely and protect from hypothermia with warm blankets or a hot air blower.

CONSIDER NEED FOR PATIENT TRANSFER

During the primary survey and resuscitation phase the evaluating doctor often gathers enough information to decode whether to transfer the patient to another facility. This transfer process may be initiated by administrative personnel, at the direction of the examining doctor, while additional evaluation and resuscitative measures are underway. Once the decision to transfer the patient has been made, communication between the referring and receiving doctors is essential.

SECONDARY SURVEY

Secondary survey takes places following the primary survey and resuscitation, when the patient has been initially stabilised; it is a top to toe examination and should involve, as per the traditional ATLS teaching, 'fingers and tubes in every orifice'. As any clinical picture can evolve, the team should ensure their assessment is continuous and any change in the condition of the patient should result in reassessment, starting again with <C>ABC.

At this stage, if not already given during handover on the arrival of the patient, an 'AMPLE' history should be obtained as a minimum.[27] Emergency services, relatives, friends or other witnesses can be used for this, if the patient is unable communicate effectively.

An AMPLE history incorporates:

> **A**llergies,
>
> **M**edication,
>
> **P**ast medical history,
>
> **L**ast meal and,
>
> **E**vents leading up to the point of injury.

The mechanism of injury is a vital clue to possible injuries sustained and pictures taken by Emergency Services on scene can be invaluable. In the case of a road traffic collision, factors such as position of the patient in the vehicle, restraints worn, speed of collision, vehicle rollover, passenger ejection and other casualties or fatalities are key indicators of the nature and severity of injury. Risk factors for significant injury in falls include falling from heights over 1m or 5 steps. With burns it is important to know what substance has caused the burn and the duration of exposure to that substance. It is also crucial to exclude exposure to hazardous substances, which may pose a threat to the medical team, as well as to the patient.

Head and neck

Assessment should begin with a mini neurological exam and formal GCS estimation. GCS trends are especially important in the trauma patient. If there is any suspicion of head injury, this must be assumed to be the cause of a decreased GCS, until proven otherwise. Along with respiratory rate and systolic blood pressure, the GCS helps make up the Revised Trauma Score. This is a physiological scoring system that is based on the first set of data obtained from the patient and which has shown high inter-rater reliability and accuracy in predicting mortality. Lower scores correlate with higher mortality rates and it is recommended that patients with a score of 4 or less should be managed at a designated trauma center where possible.[28]

The head and neck should be thoroughly examined for wounds and signs of skull fractures. Beware of depressed skull fractures that may be masked by overlying haematomas, but which merit CT and neurosurgical consultation. Signs of base of skull fracture include:

- Epistaxis

- Cerebrospinal fluid (CSF) otorrhoea or rhinorrhea (check for halo sign on gauze)

- Raccoon eyes

- Subconjunctival haemorrhage with no visible posterior limit

- Haemotympanum

- Battle's sign may be a late sign (bruising over mastoid process).

If any of the above is present, a CT head should be performed.[29] In the absence of CT facilities, a plain skull Xray will show skull fractures. Any open skull fracture requires antibiotics and theatre. If neurosurgery is not available, any lateralising signs that develop should be treated by performing a craniectomy following 3 burr holes.

Head injury is classified as mild (GCS 14-15), moderate (GCS 9-13) or severe (GCS 3-8). In civilian trauma, 80% of head injuries fall into the mild category, 10% into moderate and 10% are severe. A patient with GCS less than 8 requires intubation.

Prevention of secondary brain injury is described in the article on page 107.

The neck should be inspected and palpated for wounds, surgical emphysema, tracheal deviation and ruptured larynx. Distended neck veins may be hard to elicit if the trauma patient is hypovolaemic but, if present, should raise suspicion of cardiac tamponade or tension pneumothorax. A neck wound should not be explored unless in an an operating theatre.

Whilst the head is held, the hard collar can be temporarily removed and the C-spine palpated for bony tenderness or deformity. If the patient's GCS is less than 15, if they are under the influence of drugs or alcohol, or if they have another distracting injury, then the C-spine cannot be cleared without imaging and the patient will have to remain immobilized.

Further clearance of cervical spine injury is described in the article on page 112.

Chest

Immediately life-threatening chest injuries should have been dealt with by this stage. This is the time to carry out a more detailed inspection, palpation, percussion and auscultation and to review the chest Xray taken during the primary survey. Potentially life threatening injuries should be considered and excluded. These are described in the article on page 119.

In paediatric trauma, it is important to remember that significant intrathoracic trauma may have been sustained, despite the absence of rib fractures or other bony injuries.

It is crucial in the recovery of patients with chest injuries to ensure they have effective analgesia, so that they can achieve adequate ventilation.

Patients with rib fractures may require intercostal nerve blocks and those with a flail chest might benefit from a thoracic epidural for the first few days. These patients are at risk of developing atelectasis and subsequent pneumonia.
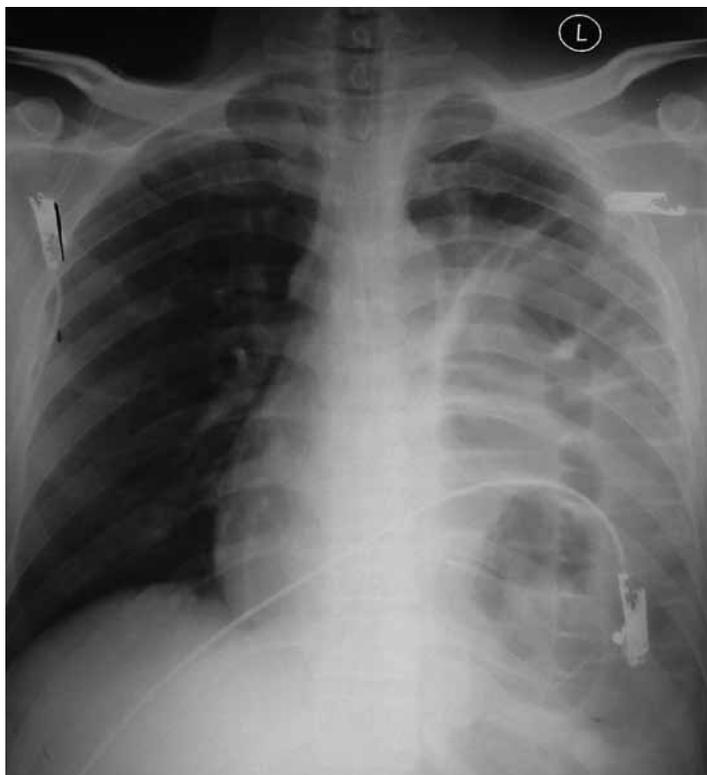
Figure 2. *Chest Xray of a 32-year-old male, unrestrained driver in an RTC who suffered left sided diaphragmatic rupture with respiratory compromise. He required urgent laparotomy and was intubated by RSI with a double lumen tube.*

Abdomen

As mentioned previously, a haemodynamically compromised patient, who is FAST positive, requires immediate surgery. Secondary survey should then take place, once damage control surgery has been carried out. If the patient is stable after the primary survey, however, he should have a full abdominal examination carried out. If FAST or CT is not available, then continuous reassessment may be required; changing clinical signs may indicate the need for laparotomy.

A suspected pelvic fracture should already have been splinted during the primary survey, using a firmly tied sheet if nothing else is available. There is no requirement to 'spring' the pelvis. Look for obvious deformity and palpate once. The pelvis should be immobilized on any suspicion of a fracture, until it can be formally imaged; preferably using CT. Traction may be required if the leg length is unequal, especially in shear fractures. Bruises over the iliac crests, pubis, labia or scrotum indicate possible pelvic fracture.

All creases and crevices should be examined, particularly in victims of penetrating trauma. Do not forget to look at the perineum and to perform a vaginal examination if indicated.

All trauma patients should have a urinary catheter inserted, unless there is concern about urethral injury (blood at meatus, high riding prostate on rectal examination), in which case a supra pubic catheter should be used. Urine output should be maintained at >0.5ml.kg^{-1}.hr^{-1} in adults and >1ml.kg^{-1}.hr^{-1} in children, unless the patient has suffered a crush injury, when at least double this output should be achieved. Output should be measured accurately using an urometer, remembering that the initial residual urine volume obtained on catheterization is not included in the measured response to resuscitation. It should be tested for blood and glucose and then discarded. Macroscopic haematuria should be investigated; this can be done initially using contrast enhanced Xrays or CT. All females of childbearing age should have a urine pregnancy test performed.

An intubated patient should have a nasogastric or orogastric tube inserted to help reduce gastric dilatation and minimise diaphragmatic splinting, thereby improving ventilation.

Indications for laparotomy in the trauma patient are largely dictated by the patient's physiology.

Limbs

Catastrophic limb haemorrhage should have been dealt with at the very start of primary survey. During the secondary survey all four limbs should be thoroughly re-examined for deformity, wounds and neurovascular status. An alert patient will be able to indicate which areas are painful on passive movements. It is important to seek signs such as swelling and crepitus in unconscious patients. Palpate the muscles and have a high index of suspicion for compartment syndrome in trauma, especially in the unconscious patient.

Compartment syndrome occurs when the pressure within an osteofascial compartment of muscle causes ischaemia and then necrosis. Common areas where compartment syndrome occurs are the lower leg, forearm, foot, hand, the gluteal region, and the thigh. The ischaemia may either be caused by an increase in compartment size, for example swelling secondary to revascularisation or by decreasing the compartment size, for example a constricting dressing.

The signs and symptoms of compartment syndrome include pain greater than expected (and this typically increases by passive stretching of involved muscles), paraesthesia in the distribution of the involved peripheral nerve, decreased sensation or functional loss of the nerves that traverse the involved compartment and tense swelling of the involved region. A palpable distal pulse is usually present in a compartment syndrome.

Intracompartmental pressure measurements may be helpful in diagnosing a suspected compartment syndrome, particularly if the patient is unconscious. Tissue pressures that are greater than 35 to 45mmHg suggest decreased capillary blood flow that results in increased muscle and nerve anoxic damage. Systemic blood pressure is important because the lower the systemic blood pressure, the lower the compartment pressure required to cause a compartment syndrome. Pressure measurement is indicated in all patients who have an altered response to pain.

Any deformities should be realigned and splinted. Ensure adequate analgesia and appropriate imaging prior to these manoeuvres. Examine pulses and document findings both before and after manipulation. If there is vascular compromise, reduction should take place before imaging. In every case, imaging should be performed after reduction.

All wounds should be cleaned and then covered loosely with iodine soaked gauze. Photographs may be taken of the wounds to prevent multiple examinations by different specialties.

It should be noted that the presence of pulses does not exclude vascular injury. It is important to suspect vascular damage based on mechanism of injury. If there is more than a 10% difference in blood pressure between the right and left limbs (comparing arm with arm and leg with leg, not arm with leg), then angiography is mandated.

Analgesic options are broad but will depend on available medications and expertise. Possibilities include IV paracetamol, non-steroidal anti-inflammatory agents, morphine, nerve blocks such as fascia-iliaca or femoral nerve blocks, sedation and Entonox® (50% oxygen and 50% nitrous oxide).

Open fractures require broad spectrum IV antibiotics and any wound should prompt consideration of tetanus prophylaxis. If there is uncertainty about whether a patient has received 3 tetanus toxoid immunizations, then a booster should be given. In addition to this, a tetanus prone wound (such as a dirty wound covered with foreign material) should be covered with tetanus immune globulin.[18]

Log roll

If not already performed during the primary survey, a log roll should be carried out for all trauma patients, ensuring full in-line spinal stabilisation is maintained throughout. A team of five is required for this. The anaesthetist at the head end will co-ordinate and give commands to move the patient. Three personnel will stand along one side of the patient and take charge of the shoulders and chest, pelvis and legs respectively. The patient is rolled away from the injured side where possible, taking care of lines and tubes, and the fifth team member inspects and palpates the spine and back. A rectal examination should also be performed to check anal tone, to exclude a high riding prostate, and to look for blood on the glove, that may indicate a rectal injury.

TRANSFER TO DEFINITIVE CARE

The requirement for transfer is individual to each trauma patient. Patient outcome is directly related to time elapsed between injury and definitive care.[17] It is essential to be aware of the capabilities of the primary receiving hospital and of any potential secondary referral units, in order to make the initial decision to transfer. As mentioned earlier, a Revised Trauma Score of less than four is used to indicate that a patient should be managed in a major trauma centre.[28]

Timing of transfer is largely based on the stability of the patient; damage control surgery may be required prior to transport. Other key decisions include how to transport the patient and which medical staff should accompany them. The answer to these questions will also be individual to each case and will depend partly on what transport options exist and on the skill set of available staff. Ideally an intubated patient should be accompanied by an anaesthetist, but in smaller hospitals, such a move could leave that hospital without anesthetic cover.

Once the decision is made to transfer, good communication between referring and receiving facilities is crucial. It is the responsibility of the referring doctor to initiate this and to ensure that the patient arrives

with accurate and comprehensive documentation. It is also vital to ensure that <C>ABCDE have been addressed and stabilised as far as possible, that tubes and lines have been fully secured and that the patient has adequate analgesia or sedation for the journey. An example transfer form is included in ATLS 8th edition.[13,18]

SUMMARY

Evaluation and resuscitation of the major trauma patient requires a coordinated approach from a well-trained and rehearsed team. The process is logical; starting with <C>ABCDE (to ensure that nothing is missed) and it should involve concurrent activity from team members, with a horizontal approach to resuscitation to ensure that this happens in an expeditious and efficient fashion.

During the primary survey, life threatening injuries are treated as they are found. Once the patient is stabilised, a thorough secondary survey is carried out, which is a head to toe examination of the patient, with further investigations and injury management taking place as required. The patient is then packaged and dispatched to the most appropriate area or facility for definitive care.

It is strongly recommended that any member of staff who could be involved in the resuscitation of a trauma patient should complete an ATLS or PTC course. Details can be found at http://www.rcseng.ac.uk/education/courses/atls.html and www.primarytraumacare.org/

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