

THE MANAGEMENT OF MAJOR TRAUMA

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Introduction

Accidental injury is probably the most serious of all the major health problems facing developed countries. In the developing world the impact is just

as great but has not been as extensively studied. Head injury was the commonest reason for admission to the Intensive Care Unit at the University Teaching Hospital in Lusaka over a ten year period from 1978-1988 with between 90 and 123 cases per year (approximately 20% of all admissions). In the UK, there are approximately 15000 deaths annually attributable to accidents. One third of these are due to road traffic accidents i.e. almost 100 people per week die in road accidents. For every death, two people suffer permanent disability. In the USA, injuries are the

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leading cause of death up to the age of 44. Many accidents are preventable and this is a major health issue for planners in health economics.

Major Trauma

Patients suffering from multiple injuries are commonly known as **major trauma victims**. Such patients present tremendous demands at all levels within hospitals particularly on those doctors, nurses and clinical officers caring for the patient within the first hours of hospital admission. It is in this context that systems for major trauma care have been developed. In this review we will set out a system for the management of major trauma victims and discuss the principals of anaesthesia for such patients. We will emphasise the importance of recognising mechanisms of injury and thereby identifying those at risk of life-threatening injury. The article will be illustrated by actual case studies.

Trauma Teams

Victims of major trauma are best treated by a well organised and trained team made up of staff competent in assessing and treating the spectrum of life-threatening injuries commonly seen. An experienced physician anaesthetist, possessing airway and resuscitation skills and confidence in dealing with unconscious patients, is a vital member of the team and in many UK hospitals is the team leader. The role of the non-physician anaesthetist is similar using airway skills under the direction of a surgical colleague.

Whenever possible both a general surgeon and an orthopaedic surgeon should be members of the trauma team. Their presence can reduce delays in the accident department, improve the early diagnosis of life threatening injuries and lead to earlier surgery when required. Having both specialists present prevents one doctor becoming overwhelmed by complex problems in an unstable patient. The team should include a radiographer when available. Adequate protection including gowns, gloves and eye protection should be worn by staff. It is often possible for the team to be given prior warning of a casualty arriving, thereby allowing time for preparation. Accident & Emergency departments should have a **resuscitation area** set aside to receive major trauma victims with anaesthetic airway equipment and drugs, intravenous fluids with blood giving sets and blood warmers.

Surgical sets should include equipment for the following procedures: urinary catheterisation (including suprapubic), peritoneal lavage, pleural drainage (chest drains sets with underwater seal) and needle and surgical cricothyrotomy. Specific provision should be made for children with appropriate sizes of equipment to deal with all ages and equipment for intraosseous fluid administration (*see Update 5*).

Methods of Managing Trauma

A multidisciplinary approach is required in the management of major trauma and the same technique for assessment and treatment of each patient should be followed. Most modern trauma systems therefore have a fairly rigid protocol to follow, thus reducing the opportunity for misdiagnosis.

The most widely taught system is the Advanced Trauma Life Support (ATLS) Program for Physicians, devised and disseminated by the American College of Surgeons (ACS). This article follows many of their recommendations. The management of major trauma has also been reviewed in the ABC of Major Trauma published by the British Medical Journal, Tavistock Sq. London, WC1H 2JR (ISBN 0-7279-0291-1).

Timing of Death Resulting from Trauma

The mortality due to injury occurs during one of the following time periods:

- ♦ The **first peak** of death occurs at the time of the injury. It may be instantaneous or within the first few minutes and is due to overwhelming **primary injury** to major organs or structures such as brain, heart or great vessels. In most situations these injuries are irrecoverable, although rapid treatment and transfer may salvage some patients. Primary prevention has a major role in reducing the incidence of these injuries.
- ♦ The **second peak** lasts from the end of this first period to several hours after the injury has taken place. It is during this time that many causes of morbidity and mortality are preventable by avoidance of a **secondary injury** due to hypoxia, haemorrhage or any process that leads to inadequate tissue perfusion. Reversible conditions may include intracranial haematomas, major haemorrhage from

viscera, bones and vessels or pneumothoraces. Most trauma care is directed at this period as skilled assessment and treatment should reduce mortality and disability. Even with moderate facilities many lives can be saved by simple measures.

- ♦ The **third peak** of death occurs days or weeks after the injury and usually happens in a high dependency area where sepsis and multiple organ failure ensue. Advances in intensive care treatment may reduce these deaths but improvements in initial management on admission will also reduce morbidity and mortality during this period.

Immediate Assessment and Management

The patient suffering multiple trauma must be thoroughly assessed on admission so that life threatening injuries can be corrected. The condition of the patient must be stabilised and plans made for further treatment of their injuries. The team leader is responsible for assessing the patient and co-ordinating the work of the other members of the team, whose role is to treat the injuries as directed by the leader.

All trauma cases should receive:

- ♦ *Primary survey (assessment) and resuscitation*
- ♦ *Secondary survey*
- ♦ *Definitive treatment*

However, any life threatening condition identified during assessment must be treated immediately before proceeding to the next phase. The amount of time taken to proceed from one phase to the next varies.

Primary Survey and Resuscitation

The purpose of the primary survey is to diagnose immediate life threatening conditions. These should be treated as soon as they are discovered before continuing the survey. The survey is planned as follows:

- ♦ **A**irway control with cervical spine protection
- ♦ **B**reathing
- ♦ **C**irculation and control of haemorrhage

- ♦ **D**isorders of the central nervous system
- ♦ **E**xposure of the whole body

During the course of the primary survey, any deterioration in the patient's clinical condition should be managed by reassessing from the start of the protocol, as a previously undiagnosed injury may become apparent.

Airway control with cervical spine protection:

ensure that a clear and unobstructed airway is present. If the patient can answer questions appropriately then it is unlikely that there is any immediate threat to the airway. Noisy or laboured respiration or paradoxical respiratory movements (when movements of the chest and abdomen are out of phase) are evidence of obstruction which must be rectified. Vomit, blood or foreign material in the mouth should be removed manually or with a rigid sucker. Sometimes a simple chin lift will prevent the tongue of an unconscious patient obstructing the airway, but often there will be need for further measures. Performing a jaw thrust (taking care not to disrupt the cervical spine control) will often open the airway. An oropharyngeal airway may also help but must be inserted carefully. It must never be inserted into the pharynx of a patient with an intact gag reflex as it could induce retching or vomiting. In these circumstances a nasopharyngeal airway can be inserted provided there is no suspicion of a basal skull fracture.

Case History

A 12 year old boy fell 30 feet from a tree onto his head. He was initially confused and then became quiet as his parents carried him to a mission hospital 5 miles away which was staffed by clinical officers and one doctor who was on leave. The clinical officer anaesthetist was called to see the boy. He started his assessment with the airway and immediately noted noisy respirations with very little airflow. Recognising that there was a possibility of neck injury he carefully lay the boy on his back, placed the head in the neutral position and performed a jaw thrust manoeuvre whilst holding the head immobilised. The airway obstruction was immediately relieved and he asked a colleague to place an oxygen mask over the face

and to find a semi rigid collar. This was carefully placed round the boy's neck, after which sandbags and tape were applied to ensure immobilisation. Shortly afterwards the patient recovered consciousness and began to breathe well without airway support. Only then did the anaesthetist let go of the child's head. He went on to assess the breathing and circulation. Having excluded other injuries and having stabilised the child's condition the anaesthetist accompanied the child to a district hospital 60 miles away in the back of an ambulance equipped with resuscitation apparatus. Simple airway manoeuvres often lead to an improvement in the head injured patient. It transpired that this child did not have a neck injury but the possibility could not be excluded and the precautions were essential. The boy had cerebral oedema and made a recovery over 10 days. He is now back at school.

Any patient with a possible cervical spine injury should have their neck immobilised in a neutral position to prevent further damage. Cervical spine damage is likely with deceleration injury, hyperflexion or extension injury or any blunt injury above the clavicles. A fracture of the first rib seen on chest X-ray indicates high energy transfer and should always raise suspicion of cervical injury as well as intrathoracic damage. When available a closely fitting firm cervical collar should be applied and sand bags placed either side of the head to ensure immobility. These are secured with adhesive tape as shown in figure 1.

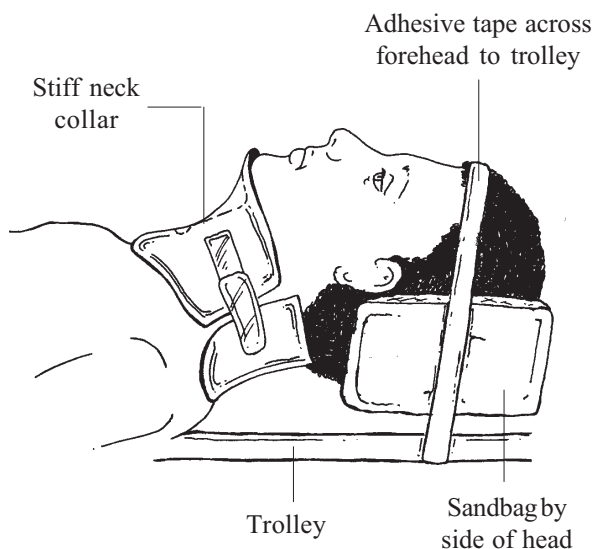


Fig.1.

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. Controversy exists as to the optimal route for intubation. Orotracheal intubation with in line immobilisation (not traction) of the cervical spine and use of a gum elastic bougie is unlikely to cause cervical spine movement (figure 2). Intravenous anaesthesia and muscle relaxation to facilitate intubation should only be used by experienced anaesthetists when successful intubation of the trachea with inline stabilisation of the cervical spine can be guaranteed. The combination of intravenous ketamine (or thiopentone in head injured patients) and suxamethonium is ideal. If continued anaesthesia and ventilation are required, a combination of intravenous agents can be used; an opiate, such as morphine in combination with a benzodiazepine such as diazepam and a non-depolarising muscle relaxant such as pancuronium are suitable. If severe facial disruption or anatomical disorders make intubation impossible, then a cricothyrotomy should be performed.

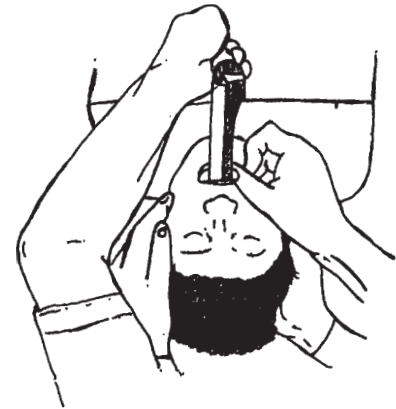


Fig.2. In-line immobilisation during laryngoscopy

Practical procedure- Cricothyrotomy (figure 3a & b). A 12 or 14 gauge cannula with a syringe attached is introduced through the cricothyroid membrane until air can be aspirated. The cannula is then advanced off the needle down the trachea. The hub of the cannula is connected to an oxygen supply. (It is important that all connections are tested beforehand). The patient can be oxygenated in this way, but ventilation to remove CO₂ cannot be achieved and respiratory acidosis will ensue. Spontaneous respiration is impossible through a needle cricothyrotomy.

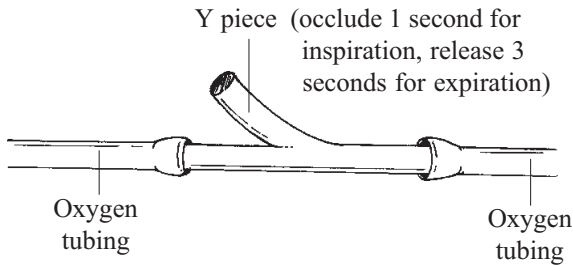


Fig.3a. Cricothyroid tubing set

A needle cricothyrotomy will ensure a supply of oxygen for a maximum of 10 minutes and it should be converted to a surgical cricothyrotomy to allow adequate ventilation. A horizontal incision is made through the membrane and a small (size 5.0-6.5) endotracheal or tracheostomy tube inserted.

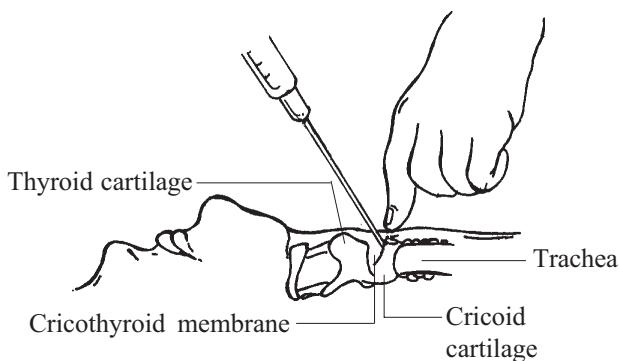


Fig.3b. Needle cricothyroidotomy

A tracheostomy carries a high complication rate in these circumstances, but may be considered if other methods have failed and a skilled surgeon is present.

Breathing: any obvious injuries must be noted, the trachea should be checked for deviation and both sides of the chest for expansion. The thorax must be percussed, and lung apices and the axillae auscultated. If the patient has been intubated but the position of the tube is in doubt, then listening over the stomach may reveal an inadvertent oesophageal intubation. The respiratory rate must be noted. If available, a pulse oximeter is useful as it gives an indication of the adequacy of perfusion as well as arterial oxygen saturation. High concentration oxygen (6-8 litres/minute) should be administered to every patient. The following life threatening conditions need immediate treatment:

- ◆ *Tension pneumothorax*
- ◆ *Massive haemothorax*
- ◆ *Flail chest*
- ◆ *Open chest wound*
- ◆ *Disruption of the tracheobronchial tree*

A **tension pneumothorax** is suggested by a rapid respiratory rate, mediastinal (and tracheal) shift away from the affected side, and hyper-resonance and reduced breath sounds on the affected side. It should be treated initially by needle decompression of the pleural cavity at the second intercostal space in the mid clavicular line, followed by formal pleural drainage with an underwater seal. It is important to remember that a simple pneumothorax may be converted to a tension pneumothorax when a patient is ventilated and in this situation a chest drain should be inserted prophylactically prior to commencing ventilation.

A **massive haemothorax** is suggested by reduced breath sounds, dullness to percussion and a shift of the mediastinum away from the affected side often accompanied by cardiovascular instability. It should be treated with formal pleural drainage and if the initial volume of blood exceeds 1500mls or bleeding persists at a rate exceeding 200ml/hr thoracotomy is indicated. Before diagnosing either of these conditions in a ventilated patient, it is important to check that the endotracheal tube is in the trachea and that it has not entered the right main bronchus as this may mimic some of the above signs.

Practical procedure - Pleural drainage (figure 4a,b,c): This is best performed in the fifth intercostal space at the anterior axillary line. A 32 French gauge or larger tube should be inserted without the use of a trochar, as this can cause significant damage. After skin incision, blunt dissection is performed and the pleura opened (4a). After an exploratory finger examination of the pleural cavity (4b) the tube is inserted in a postero-superior direction (4c), fixed to the skin and connected to a one way valve (for example an underwater drain). If no chest drains are available a nasogastric tube may be used with a drainage bag to drain blood (but not air). It is important that the system is closed to prevent air entering the chest via the drainage tube.

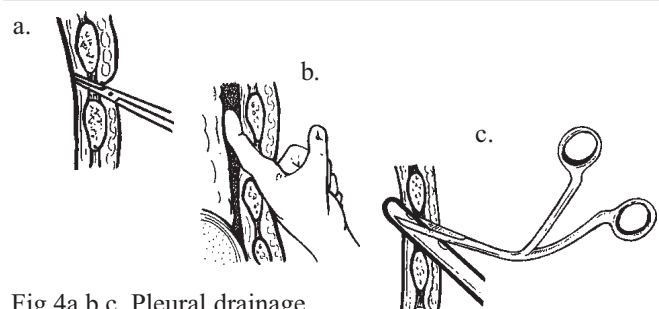


Fig.4a,b,c. Pleural drainage.

Flail chest means that part of the chest wall is able to move independently to the remainder and occurs when ribs are fractured in at least two places. It can be recognised when the flail segment falls during inspiration as the rest of the chest rises. It is always associated with significant pulmonary contusion resulting in hypoxia. If respiratory failure supervenes despite oxygen therapy and adequate analgesia (preferably epidural or intercostal blockade), then ventilation is required.

An **open chest wound** needs covering and sealing on three sides immediately (*figure 5*). A one way valve is formed by the flapping motion of the free edge of the dressing and this prevents air being sucked into the pleural cavity from the outside. This should be followed by formal pleural drainage and possible thoracotomy when the patient's condition has been stabilised. Once the pleural cavity is drained, the wound can be sutured or covered with an occlusive dressing.

Table 1.

Class of hypovolaemia	Class I	Class II	Class III	Class IV
Blood loss:				
% circulating volume (mls in adults)	<15	15-30	30 -40	>40
Pulse	Normal	100-120bpm	120 bpm Weak	>120bpm Very weak
Blood pressure:				
systolic	Normal	Normal	Low	Very low
diastolic	Normal	High	Low	Very low
Capillary refill	Normal	Slow	Slow	Absent
Mental state	Alert	Anxious	Confused	Lethargic
Respiratory rate	Normal	Normal	Tachypnoeic	Tachypnoeic
Urine output	>30mls/hr	20-30mls/hr	5-20mls/hr	<5mls/hr

Patients with **major disruption of the tracheo-bronchial tree** need immediate endotracheal or endobronchial intubation and thoracotomy (These injuries have a very poor prognosis). The condition is diagnosed most often by the presence of pneumomediastinum, pneumopericardium or air below the deep cervical fascia of the neck in a patient suffering a deceleration injury. Minor tears

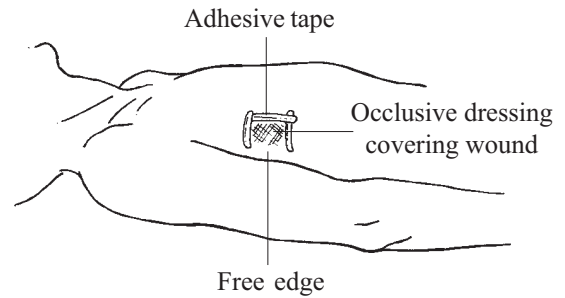


Fig. 5.

may sometimes be managed conservatively.

Circulation and haemorrhage control: any major haemorrhage that is visible should be controlled by direct pressure. Tourniquets should not be used to prevent bleeding from a limb as they occlude collateral circulation causing tissue destruction. Penetrating wounds should be identified and explored formally by a surgeon. Penetrating implements should be left in situ for formal surgical exploration. A rapid assessment of the cardiovascular system should be made including pulse rate, skin colour, capillary

refill (the time taken for colour to return to a finger pad after it has been briefly compressed >2 seconds is abnormal), level of consciousness and blood pressure.

An inadequate circulation is often called shock, and in multiply injured patients the most common cause is haemorrhage. It should be remembered that

blood loss from a fractured humerus can be up to 800mls, from a femur up to 2000mls and from a fractured pelvis up to 3000mls. In the early stages, hypovolaemia can often be tolerated without change in the systolic blood pressure due to autonomic nervous system reflexes. To assess the status of the patient the signs of inadequate circulation and the sympathetic response to it must therefore be elicited. Hypovolaemia is often categorised into the 4 classes shown in Table 1 with their appropriate signs. It must be stressed that there is variation from this guide, particularly in the elderly, in those with previous medical conditions or those who are taking cardiovascular medications who all tolerate hypovolaemia poorly, and in fit young patients who often tolerate it well. It should also be remembered that anaesthesia will obtund the signs of sympathetic nervous system activation. The weight of the patient will need to be estimated to calculate fluid requirements.

Management: Throughout the resuscitation period regular reassessment of the patient’s condition is required and the treatment should be monitored frequently, preferably by a pulse oximeter or a continuous reading electrocardiograph. Two large (14 gauge) cannulae should be inserted. The antecubital fossae is often the easiest site, but a venous cutdown may be required.

Alternatively, the external jugular vein or the femoral vein can often be cannulated. In patients with suspected thoracic or abdominal trauma, intravenous access both above and below the diaphragm is often recommended. Central venous access is rarely indicated for initial fluid replacement, but may be useful to guide fluid therapy by measuring the right atrial pressure. Blood should be taken at the time of

cannulation for crossmatch and in major trauma with shock eight units should be ordered as a priority. In Class III hypovolaemia blood is often needed before a full cross match is possible and in these circumstances blood banks should be able to provide uncrossmatched ABO compatible blood quickly. In patients not responding to volume replacement and those with Class IV hypovolaemia, uncrossmatched O Rhesus negative blood must be used and it is recommended that all Accident & Emergency Departments should have at least 2 units available at all times for immediate use.

In a previously fit patient it may be necessary to accept a haemoglobin concentration of 8g/dl (as long as they are not hypovolaemic) due to the shortage of blood in many developing countries and the risks associated with transfusion (including transfusion reactions and HIV and other infections). Oxygen carrying capacity should be adequate at this level. Prompt surgery to prevent blood loss, autotransfusion and transfusion from compatible relatives must be considered. If facilities are available blood should also be taken for full blood count, electrolyte and glucose estimation, and an arterial sample should be taken for analysis of blood gas tensions and acid/base balance.

The type of intravenous fluid administered to a hypovolaemic patient prior to blood transfusion continues to be controversial, and will often depend on local policy and availability. Either crystalloid or colloid can be used as long as the following points are kept in mind:

1. Crystalloid solutions that expand primarily the extracellular fluid should be selected i.e. normal saline or Ringer’s lactate. Glucose (dextrose) only fluids should not be used unless there is no alternative.
2. As crystalloids rapidly leave the circulation, 3 times as much crystalloid compared with the volume of blood loss will be required.
3. Colloids remain within the blood vessels for longer and should be administered in volumes equal to the blood loss. However, they are excreted by the body and further infusions should be administered as required.

Table 2.

Type of blood	Time required for preparation
Full crossmatch	30 - 40 minutes
ABO compatible	10 minutes
Uncrossmatched O Rhesus negative	Available immediately

4. Blood is the best colloid in severe haemorrhagic shock. It should always be warmed if large volumes are administered rapidly.

The amount of fluid given will depend on the type and the extent of the injuries. If colloidal solutions are used, then 10-20mls/kg is an average initial requirement, and 20-30mls/kg if crystalloid solutions are used. Whenever possible the fluid should be warmed to prevent further cooling of the patient.

A sustained improvement in the signs of shock will hopefully be seen, and this suggests blood loss is less than 25% of the blood volume. If the improvement is short lived, this indicates continuing haemorrhage that requires control. Surgical intervention may be required and further blood transfusion necessary. If no improvement in the condition of the patient is seen, then the blood loss is greater than 40% and almost certainly from thoraco-abdominal or pelvic injury. It is in these patients that O negative blood should be considered.

Case History

A 36 year old fisherman was attacked by a hippopotamus whilst fishing on the isolated Lake Iteshi-teshi in Zambia. The hippo held him by the abdomen and in throwing him from the water lacerated the anterior abdominal wall exposing abdominal contents. The wound was 2 feet long and associated with some bleeding. The fisherman's friend placed a suture in the wound using a fishing hook and line and applied pressure to the wound to stop further blood loss. He was taken to University Teaching Hospital, Lusaka in the back of a pickup truck. The journey took 15 hours. On arrival the fisherman showed all the signs of Class IV hypovolaemia. He was promptly resuscitated with oxygen and 4 litres of warmed saline over ten minutes. Blood was taken for ABO compatible cross match and a urinary catheter inserted. There was no residual urine. Within 30 minutes of arrival in hospital he had already received 3 units of warm ABO compatible blood. His condition was much improved; he had regained consciousness and was able to talk about his ordeal, his pulse rate had fallen to 90 bpm, he had a blood pressure of 120/90 mmHg and he had passed 50ml of urine. Following

this prompt resuscitation, anaesthesia and surgery were uneventful, renal failure was avoided and the patient made a complete recovery. He is still fishing on Lake Iteshi-teshi.



Fig.6. Fisherman after attack by hippopotamus in Zambia.

Occasionally haemorrhage is not the cause of the hypotension. For example, septicaemia and spinal cord injury can cause hypotension, but in both there is a relative hypovolaemia and the treatment outlined above is unlikely to be harmful.

Hypotension may also result from cardiac failure which is, however, rare in trauma patients and is likely to be due to cardiac injury, either myocardial contusion (which should be suspected in blunt thoracic trauma), or cardiac tamponade (which should be suspected in penetrating chest injury when shocked patients do not respond to intravenous fluid and the hypotension is out of proportion to the apparent blood loss). Cardiac tamponade must be relieved immediately and is confirmed by Beck's triad; raised jugular venous pressure, muffled heart sounds and hypotension. Tachycardia and pulsus paradoxus (a 15% drop in systolic blood pressure during inspiration) will be present. Cardiac tamponade is treated by needle pericardiocentesis. If caused by a penetrating implement, this must be left in place while awaiting surgery.

Practical procedure- Needle pericardiocentesis (figure 7). With the patient attached to a cardiac monitor, a cannula is slowly inserted immediately to the left of the xiphisternum aiming for the tip of the left scapula and is constantly aspirated until blood appears. The tamponade can be aspirated (often with dramatic improvement in the patient's signs) and the cannula left in place for further aspiration. A thoracotomy may be required to stop

the bleeding. Widening of the QRS complex, ST segment changes or multiple ventricular dysrhythmias indicate myocardial damage and unlimited aspiration of blood unaccompanied by clinical improvement is indicative of ventricular aspiration.

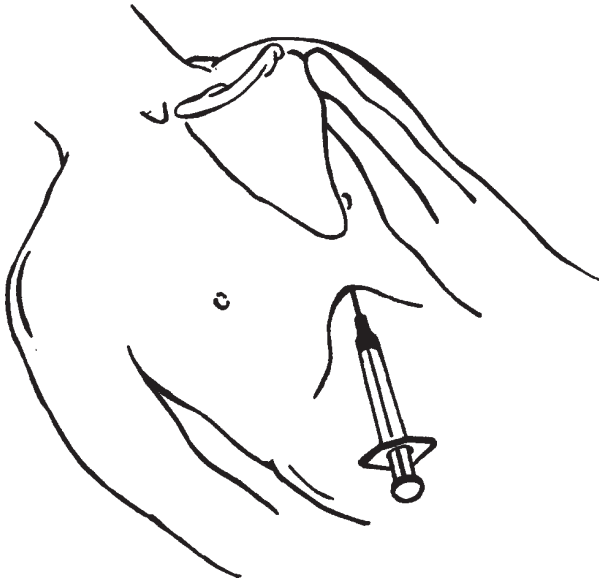


Fig.7. Direction of needle for perocardiocentesis.

All cases of traumatic cardiac tamponade require urgent surgical exploration.

Key points:

1. All trauma victims who are shocked have bled and are hypovolaemic until proven otherwise.
2. Commence rapid intravenous infusion immediately.
3. Warm intravenous infusions whenever possible.
4. Give warmed blood early in severe shock.

Disorders of the central nervous system: The central nervous system should be quickly assessed by ascertaining the level of consciousness, spinal

cord function and pupillary response to light. Conscious level is assessed by recording patient eye opening and motor response to various stimuli. These are graded as spontaneous, in response to direct questioning, uncomfortable stimuli or none at all. All four limbs should be tested for response to assess spinal cord function.

Exposure: all multiple injured patients should be completely undressed. Clothes are cut off if necessary to minimise undesirable movement. This allows a thorough survey of injuries. The patient should, however, not be allowed to become hypothermic- and should be kept covered when possible and the resuscitation room should be warm. Injured children lose heat rapidly when exposed (even in hot environments), particularly if they are wet.

During the course of the primary survey, the four most important rules to remember are:

1. *The patient should be repeatedly reassessed, particularly if clinical signs change.*
2. *Any immediately life threatening condition diagnosed should be rectified without delay.*
3. *Penetrating wounds and implements must be left for formal surgical exploration.*
4. *Any external bleeding should be stopped by using direct pressure.*

Secondary Survey: Following the initial survey and resuscitation, the patient should undergo a thorough secondary survey with the aim of documenting any other injuries. During this survey, however, the basics of the primary survey (airway, breathing and circulation) should be regularly reassessed to detect any unexpected deterioration. The patient is best examined from head to foot by the team leader. Tetanus immunisation and prophylactic antibiotics can be administered if necessary. A history should be obtained and finally, the standard radiographs of the lateral cervical spine, chest and pelvis are taken. (Remember however, that lateral cervical spine radiographs may fail to reveal up to 20% of injuries). The temperature of the patient should be recorded. This may require the use of a low reading

thermometer. Remember to keep the patient covered unless an examination or procedure is being carried out.

History: during the course of the secondary survey the following points must be clarified:

- ♦ Allergies
- ♦ Medications and tetanus immunity
- ♦ Previous medical history
- ♦ Last meal
- ♦ Events leading to the injury

Vital information can be gained from the history or the events leading to injury and particular attention should be paid to the mechanism of injury. The extent and severity of injury is related to the amount of energy transferred to the patient. In blunt trauma, commonly associated with road traffic accidents and falls, there are a number of situations which are associated with life-threatening injuries:

1. Road Traffic Accidents:

- ♦ where speeds were in excess of 40 mph
- ♦ where the victim was ejected from the vehicle
- ♦ where other victims were killed
- ♦ where there was severe disruption of the vehicle passenger compartment

2. A fall of greater than 10 feet (remember a patient who is six feet tall and sustains a head injury falling off a six foot wall has sustained an energy transfer to the head compatible with a total fall of twelve feet).

3. In penetrating trauma from gunshot the amount of tissue damage increases with the velocity of the bullet particularly if the bullet does not exit the body (when all of the projectile's energy is transferred to the tissues).

Head: a Glasgow Coma Scale score should be documented at this point (*Table. 3*). The scalp should be palpated for fractures, lacerations and other deformities. Adults rarely lose a significant amount of blood from scalp wounds but brisk bleeding should be stopped. Any injury to or around the eye should be noted. Periorbital and/or subconjunctival haemorrhage may indicate a base

of skull fracture and penetrating injuries or foreign bodies are not uncommon.

Blood or cerebrospinal fluid coming from the ears or nose also indicates basal skull fracture. When blood is mixed with CSF the presence of CSF can be demonstrated by dropping the blood onto blotting paper when a double ring is formed.

Facial fractures must be sought by careful palpation, but only treated at this stage if likely to compromise airway patency. Swelling or haemorrhage associated with such fractures may cause delayed respiratory obstruction and must be anticipated. Movement of the maxilla indicates a middle third facial fracture.

Table 3. Glasgow Coma Scale

<i>Eyes open:</i>	<i>Score</i>
Spontaneously	4
To speech	3
To pain	2
Never	1
<i>Best motor response:</i>	
Obeys commands	6
Localises pain	5
Withdrawal from pain	4
Abnormal flexion	3
Extends to pain	2
No response	1
<i>Best verbal response:</i>	
Orientated	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
Silent	1

Neck: the patient should be asked if they have any neck pain. With an assistant performing in-line immobilisation, the tapes, sand bags and neck collar should be gently removed and the neck examined for lacerations, swellings, tenderness or deformity of the cervical spine. Penetrating neck wounds must be explored under general anaesthesia.

A lateral X-ray of the cervical spine must show all the vertebrae including the body of the 1st thoracic vertebra. Traction downwards on the arms should help to obtain a good film. X-rays alone cannot detect all injuries to the cervical spine, and much depends on the history and examination as well as

an experienced review of lateral, antero-posterior and odontoid peg radiographs.

Thorax: The entire chest must be examined for signs of injury. This includes palpating for fractures of the clavicles and ribs and the presence of subcutaneous emphysema. Percutaneous drainage of haemo-pneumothoraces must be performed when they are diagnosed or strongly suspected. Pleural drainage must also be considered in those with multiple rib fractures, particularly if undergoing positive pressure ventilation, due to the risk of developing a tension pneumothorax. Deceleration injuries may cause tracheobronchial injury, transection of the thoracic aorta, cardiac injury or diaphragmatic rupture.

Complete **aortic transection** is immediately fatal. Incomplete aortic transection is suggested by the history, chest X-ray signs of widening of the mediastinum, pleural capping (fluid shadow at apex of lung), and a shift of the trachea to the right and/or inferior displacement of the left main bronchus. Treatment of these injuries needs specialist facilities. Aortogram X-rays are used to diagnose aortic injuries and careful control of the blood pressure is necessary perioperatively to prevent exsanguination.

Cardiac contusion may be suggested by the history, inadequate response to intravenous fluids, high central venous pressure and ECG changes. Investigations include echocardiography which may show abnormal heart wall movements and/or pericardial effusions. Inotropic agents such as an adrenaline infusion may be required. Echocardiography is also useful for diagnosing heart valve rupture.

Diaphragmatic rupture is commoner on the left and is diagnosed if abdominal contents are visible in the hemithorax on a chest X-ray. However, positive pressure ventilation may have been required if respiratory failure was present, and this may reduce the hernia. If a diaphragmatic injury is suspected a naso or oro-gastric tube should be inserted and the X-ray repeated. Surgical repair is required if the injury is diagnosed. Right sided ruptures are difficult to diagnose, but a raised or irregular hemidiaphragm may suggest a defect.

Abdomen: the abdomen must be inspected for signs of injury and the presence of free intra-peritoneal fluid. Penetrating wounds should be examined at laparotomy if they breach muscle. Eviscerated bowel must be covered with packs soaked in warm saline and replaced under general anaesthesia. Pelvic injury may be diagnosed by clinical examination, but an X-ray should always be performed. Blood at the urethral meatus, scrotal haematoma or on a high prostate on rectal examination indicate urethral injury in the male. In these situations a supra-pubic catheter should be inserted. Otherwise a urethral catheter should be inserted, and the presence of any obvious or microscopic haematuria sought. The rectal examination may also reveal blood or pelvic fractures, and an assessment of anal tone can be made. A lax anal sphincter may indicate that spinal cord injury has occurred. The stomach may dilate acutely in trauma patients, and may need decompression using a nasogastric tube (or an oro-gastric tube if a basal skull or mid face fracture is suspected). Vaginal examination may show a pelvic fracture or breach of the vaginal vault.

If assessment is difficult or equivocal, then diagnostic peritoneal lavage is indicated. It should not be performed if there is a need for urgent laparotomy i.e. penetrating trauma, unexplained hypovolaemia, extruded bowel or radiological evidence of intra-abdominal trauma.

Practical procedure- diagnostic peritoneal lavage (DPL). A naso/oro-gastric tube and urinary catheter must be in position. Under sterile conditions, after infiltration with lignocaine and 1 in 200,000 adrenaline, a vertical skin incision is made one third of the distance from the umbilicus to the symphysis pubis. The linea alba is divided and the peritoneum entered after it has been picked up to prevent bowel perforation. A peritoneal dialysis catheter is inserted towards the pelvis and aspiration of material attempted. 1 litre of warm 0.9% saline is then infused, and after a 5 minute dwell time is allowed to flow back by gravity to a bag placed on the floor.

Indications for laparotomy are: the presence of bile, enteric contents or >5mls of blood aspirated before fluid is infused, or the inability to read standard newsprint through the returned fluid in the bag.

Limbs: Fractures, wounds and discoloration must be noted. Check pulses in all limbs even if no fracture is suspected. Fractures compromising circulation must be reduced to prevent distal ischaemia. If possible, sensation in the limbs is assessed. Fractures should be splinted to reduce pain and the risk of fat emboli. Swabs should be taken from open wounds, which can then be covered with a sterile dressing.

Contaminants and devitalised tissue should be removed. Large blood losses may be associated with long bone and particularly pelvic fractures, but in a shocked patient they must not be assumed to be the only cause. Early fixation of these fractures may reduce blood loss, accelerate mobilisation of the patient and reduce the severity of fat embolism. Signs such as increased limb swelling, pain and disordered sensation suggest compartment syndrome and urgent decompression by surgical fasciotomy is required.

Spine: hypotension with bradycardia is unusual in hypovolaemia but, if present, does not exclude haemorrhage, especially in elderly patients. It is, however, more likely to be due to spinal cord damage in a patient with a history suggestive of spinal injury. Fluid replacement should be guided by careful cardiovascular monitoring to prevent circulatory overload. Other indicators of cord damage are acute urinary retention, diaphragmatic respiration, priapism (persistent abnormal penile erection), lax anal sphincter and flaccid paralysis of the limbs. The cervical and thoracolumbar regions are most commonly affected by trauma, and appropriate radiographs should be taken. The patient must be log

rolled (*figure 8*) and the entire spine examined for deformities or injuries. The rest of the back should also be examined at this point to exclude other injuries.

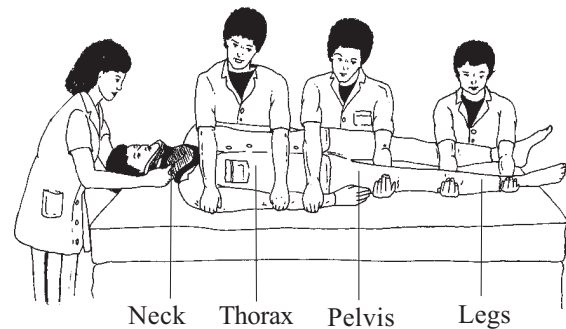


Fig. 8a. Preparation of log roll manoeuvre

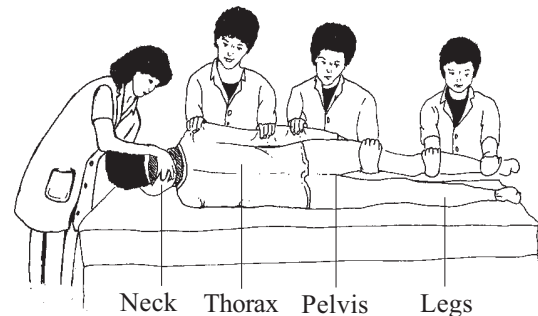


Fig. 8b. Log roll

Definitive treatment

The further treatment of the patient will depend on the injuries detected during the preceding examination. The highest priority is given to those that are life threatening. Thoracic and abdominal conditions may warrant surgery at this stage.

Case History

Following initial assessment and resuscitation, a 21 year old road traffic accident victim still had the signs of class 3 hypovolaemia after 6 litres of saline and 2 units of O negative blood had been given. Her abdomen was distended and the hospital had run out of blood that morning. The anaesthetist asked for the autotransfusion bottles to be made ready in theatre, and moved the patient into the operating theatre. A number of sterilised 500ml bottles containing 2g of sodium citrate and 3g of dextrose made up to 120ml with sterile water were ready. Anaesthesia was induced once the surgeon was scrubbed and the patient draped for laparotomy. This revealed a free intraperitoneal rupture of the spleen with over 2 litres of intraperitoneal blood. There was no obvious bowel injury and the blood

Key point

During the secondary survey, a reassessment of the primary survey (airway, breathing and circulation) is often indicated. This takes priority over any other procedure being carried out. Once the secondary survey has been completed, the primary survey should be repeated to prevent any new complications from occurring during the course of the definitive treatment.

appeared to be uncontaminated. The blood was collected 500ml at a time into a kidney dish and the splenic vessels clamped. The scrub nurse poured the anticoagulant from the first of the prepared bottles into the kidney dish with the blood and mixed well. The nurse then filtered the mixture of blood and anticoagulant through 4 layers of sterile gauze back into the bottle, replacing the stopper, discarding any clots, and handing it to the anaesthetist before repeating the process with the next bottle. The anaesthetist then transfused the blood via a blood giving set (all of which have a 120micron filter). Four bottles of blood were returned to the patient who survived and made a good recovery. Autotransfusion is effective but needs preparation. If you cannot prepare your own anticoagulant as described, use the anticoagulant from purpose designed venisection bags available in your local blood bank.

Transfer of the patient with multiple trauma can be hazardous. In all but the most desperate situations, the condition of the patient should be stabilised prior to transfer. The level of monitoring must be maintained during transport, adequate resuscitation equipment and drugs should be available, hypothermia avoided and the receiving area must be warned of the condition of the patient. The staff who accompany the patient should be experienced in transport of the critically ill.

Head injured patients

The definitive management of these patients is beyond the scope of this article, but some basic points can be reviewed. Many hospitals in the world do not have access to neurological services such as Computerised Tomography (CT) scanning. None the less, much can be achieved. In a review of severely head injured patients in hospitals in the developing world without access to CT scan or a neurosurgeon, 25% of a series of 214 severely head injured patients (Glasgow Coma Scale 8 or less) made a good recovery.

As with all trauma patients, the treatment of those with head injuries is dependant on the principle that no further damage should occur to the injured brain after the initial trauma. Any process resulting in inadequate brain perfusion may cause a secondary

brain injury, and hypoxia, hypercarbia and hypotension must be prevented. The primary survey and secondary survey will help to detect these problems. The Airway, Breathing and Circulation should be assessed and treated appropriately, the nervous system surveyed and the entire patient examined.

Assessment: obviously, injuries to the head such as lacerations, bruising or evidence of fractures raises the possibility of an intra-cranial injury, but the presence of a head wound is not necessary for a serious injury to exist. If present wounds should be gently explored and documented. Dysfunction of the nervous system during the primary and secondary survey is assessed. A trend of clinical signs is useful and can be recorded on an appropriate chart (*figure 9*). This may be photocopied if required and used in your hospital.

A difficult problem in many trauma cases is differentiation between those patients who have a depressed conscious level due to cardiorespiratory problems and those who have a brain injury. It is also important to decide which patients require neurosurgical intervention. Although detailed examination, repeated observations and skull radiographs may help, the majority of seriously head injured patients undergo CT scanning in the developed world to assess the need for surgery. CT's reveal intracranial haemorrhages, cerebral oedema, midline shift and mass effect. They do not, however, show many changes in those patients with diffuse axonal injury. CT scans may give a false sense of security if performed soon after the traumatic event (up to 6 hours). The vast majority of patients going for CT scanning will require intubation and ventilation and this should be performed in a suitable area before transferring the patient.

Treatment: significant extradural and subdural haematomas require urgent evacuation. In units far from a neurosurgical centre, the general or orthopaedic surgeons must perform the necessary procedure. Where no CT facilities exist clinical indications of an intracranial haematoma in a patient with a head injury include a decreasing level of consciousness and a dilated pupil on the same side as the haematoma and less limb movement on the opposite side.

Management of patients with serious head injury is somewhat controversial. In most units in the UK, a period of sedation and controlled ventilation is undertaken. This allows a period of stability to be attained and cerebral oxygen delivery to be optimised, but it prevents serial measurements of the patient's level of consciousness. Each case must therefore be considered on its own merits. Controlled ventilation should be performed to treat hypoxia, repeated vomiting, agitation, fitting or evidence of raised intracranial pressure (ICP).

Raised ICP is suggested by a Glasgow Coma Scale of less than 8, slow pupillary responses to light, respiratory rate abnormalities, hypertension and bradycardia. The most reliable method of evaluating the ICP is to measure it directly, although there is no clear evidence that outcome is improved and many hospitals in UK do not routinely measure ICP in head injuries. Several methods are available including the intraventricular, subdural, extradural and intra-parenchymal monitors but none are commonly available in developing countries. They also have a significant complication rate due to bleeding, infection and brain injury.

When treating head injuries ensure that conditions predisposing to rises in intracranial pressure are managed properly. Therefore pain, fever, bladder distension, hyponatraemia, hypoxia, hypercapnia, hyperglycaemia and hypertension must all be treated. The patient should be nursed with a slight head-up tilt and endotracheal tubes must be taped (not tied) to encourage cerebral venous drainage. Raised intrathoracic pressure and rigid cervical collars also may impede venous return and ventilation patterns should be tailored individually. Sandbags, headtapes or external fixation e.g. calipers should be considered in the presence of a cervical spine injury. Coughing should be avoided, and therefore neuromuscular blockade may be required provided the patient is adequately sedated.

Once these general causes have been treated, any deterioration warrants consideration for repeat CT scan if this is available. The presence of a significant haematoma needs evacuation. Cerebral oedema is often treated with mannitol in order to increase the osmolarity of the blood. In the trauma setting, however, the blood-brain barrier may be disrupted

allowing leakage of the mannitol thereby exacerbating the problem. It should therefore be used with care. Drainage of CSF may help to reduce ICP but requires an intraventricular catheter. Intracranial pressure can also be reduced temporarily by hyperventilation which results in cerebral vasoconstriction and thereby a reduction in intracranial blood volume. However, this effect only lasts for about 12 hours by which time homeostatic mechanisms reset themselves. Theoretically hyperventilation can also induce cerebral hypoxia, and most centres now ventilate patients to obtain a pCO₂ in the low-normal range. Cerebral blood volume can also be reduced indirectly by reducing the cerebral oxygen consumption. This is the rationale for the treatment of a raised temperature (and in some centres, the induction of mild hypothermia) and therapy with barbiturates. Although the latter decrease ICP, there is little evidence to confirm their effectiveness. If required, controlled ventilation is usually instituted for a period of 24 - 48 hours. If the patient is stable after this time, sedation may be stopped and the patient assessed. Re-sedation and ventilation may be required if neurological function is poor.

During the patient's hospital stay the head injury must not lead to inadequate holistic care. Attention must therefore be made to analgesia, prevention and treatment of infection, nutrition and physiotherapy. Poor recovery from head injury often overwhelms the family caring structure, and rehabilitation should be organised at the earliest opportunity. Apparent recovery may mask more subtle psychological defects, and therefore all patients recovering from severe head injuries must be assessed appropriately.

Anaesthesia for trauma patients

As with anaesthesia for all patients, the key to successful trauma anaesthesia is the adequate assessment and pre-operative resuscitation of the patient. In all but the most urgent surgery, there is sufficient time for this to be undertaken.

Preoperative assessment: all injuries should be noted. If the patient has been admitted using the trauma method outlined above, then it is unlikely that serious injuries will have been missed. When faced by patients who have not been subjected to a rigorous

trauma team admission the anaesthetist should thoroughly examine the patient for head, spine, thoracic and abdominal injuries. The treatment of injuries that are life threatening or have the potential to become so must be given priority.

Continuous neurological observations will be disrupted by the administration of a general anaesthetic so that only emergency surgery should be undertaken during the period of observation. The feasibility of local or regional anaesthesia should be explored if surgery is required.

Those with thoracic injury should be investigated for the presence of fractured ribs as well as haemo- or pneumothoraces or other damage. If positive pressure ventilation is to be used then consideration must be given to prior insertion of an intra-pleural drain to prevent the development of a tension pneumothorax during anaesthesia. Possible cardiac contusion must not be overlooked. A 12 lead ECG recording may assist in detecting this in patients with chest trauma. It may present as hypotension despite adequate fluid replacement in a patient at risk. A CVP line is useful in such patients.

Starvation time prior to trauma anaesthesia is a contentious issue. In the patient undergoing immediate or early (<12 hours) operation the most important time interval is that between their last meal and injury, as after this time gastric emptying may cease. In those undergoing later surgery after a period of stabilisation and observation on the ward, the patient is often assumed to have an empty stomach if they are not in severe pain or have no other preoperative reasons to delay gastric emptying.

In addition a specific anaesthetic assessment should be performed. The appropriate investigations depend on the injuries sustained and the procedure to be undertaken. A blood crossmatch must be performed and an adequate volume of blood ordered. Premedication is usually not necessary if the patient is being kept pain free and the procedure is well explained. Preoperative antibiotics and tetanus vaccination are usually required.

Following assessment pain relief should be administered to the injured patient if surgery is going to be delayed. A variety of methods are available

including nerve blocks, opioids (not in head injuries as they may mask deterioration in the patient's conscious level) or non-steroidal anti-inflammatory drugs such as aspirin or diclofenac (avoid in patients with peptic ulceration and asthmatics). Opioids are best administered slowly intravenously and titrated against effect. If they are given intramuscularly the drug may not be absorbed. Nitrous oxide (often in a 50% mixture with oxygen as "Entonox") is a useful analgesic which lasts as long as the patient breathes it. It should only be given to conscious patients who can hold the mask for themselves and must be avoided in chest injuries (risk of tension pneumothorax) and in diving accidents (risk of decompression sickness "bends"). It is a particularly useful agent to give the patient when they are about to be lifted or moved in a painful fashion.

Induction of anaesthesia: local or regional anaesthesia may be appropriate but multiple procedures in different body areas precludes it. The hypotension seen with epidural or subarachnoid blockade will be greater if the patient is hypovolaemic and this must therefore be corrected before the block is performed. Spinal or epidural anaesthesia must not be undertaken in head injured patients due to the risk of spinal CSF leakage giving rise to coning of the medulla.

General anaesthesia can be performed in the normal manner assuming the patient is adequately resuscitated and precautions are taken to prevent aspiration of stomach contents. Monitoring must be instituted prior to induction and a central venous catheter may assist in cases in whom a large blood loss is expected. Care should be taken not to move a suspected cervical spine injury during positioning of monitoring and airway manoeuvres. Depolarising neuromuscular blocking agents (suxamethonium) must be avoided in those with spinal cord damage or multiple injuries if the anaesthetic takes place more than 24 hours from the time of trauma. This is to prevent catastrophic potassium level rises which may occur in these patients for up to 6 months following the injury. Ketamine raises ICP and must be avoided in those at risk.

Thiopentone must be very carefully titrated and much smaller doses are usually needed in injured patients. Ketamine is a suitable induction agent for

patients who have been, or who are hypovolaemic.

Maintenance of anaesthesia: Ventilation is controlled following the administration of a non-depolarising muscle relaxant to prevent hypercarbia as this will cause a rise in intracranial pressure. A combination of nitrous oxide (unless contraindicated - see below) and oxygen with a low concentration of an inhalational agent and opiates are suitable. Deep levels of anaesthesia with respiratory depression in the spontaneously breathing patient and coughing on the endotracheal tube cause a rise in intracranial pressure and must be avoided. Adequate attention must be paid to the prevention of hypothermia. Warmed intravenous fluids, blankets to cover the patient and a woolly hat are useful to limit heat loss. In prolonged procedures the temperature should be recorded (this can be done with an axillary thermometer) and appropriate action taken if it falls. Remember that halothane is more depressant to the cardiovascular system than ether or intermittent ketamine.

The positioning and movement of the patient must be carefully planned and supervised to prevent exacerbation of any injury. If actual or potential air filled spaces (pneumothoraces or suspected intracranial air with compound skull fracture) are present then nitrous oxide must be avoided. This is to prevent enlargement of the space due to rapid

diffusion of nitrous oxide.

Blood loss can be large and in long procedures vigilance is required. The urine production must be monitored and an output of at least 1 ml/kg/hr should be maintained. The most likely cause of oliguria is hypovolaemia and intravenous fluid therapy should be titrated against urine output. Where there is difficulty about deciding how much fluid replacement is required and particularly in the presence of thoracic injuries, central venous pressure should be monitored.

In addition the patient must be observed carefully for any changes in vital signs which are unexpected and which might be the result of undiagnosed injury (for example hypotension caused by intra-abdominal bleeding may persist during an operation to stabilise a fractured femur). Good communication between surgeon and anaesthetist is vital.

Unexplained hypoxia in the perioperative period where there is a longbone or pelvic fracture may be due to **fat embolism** associated with the release of intramedullary fat into the venous circulation from the fracture site. This can occur at any time following fracture, but is more common if surgical fixation is delayed for longer than 8 hours. The lung injury is characterised by pulmonary capillary leak leading to pulmonary oedema (this occurs in the absence of heart failure and is known as low pressure pulmonary

oedema). The X-ray findings are characteristic (*figure 10*). Hypoxaemia is always present and respiratory failure common. The lung injury can be associated with systemic capillary injury (the fat embolus syndrome) commonly affecting the cerebral circulation, leading to confusion and drowsiness. A petechial rash is usually present over the trunk and conjunctiva due to systemic capillary damage. Renal impairment can occur. Treatment of fat embolism involves respiratory support with oxygen therapy and

ventilation, and circulatory and renal support if



Fig. 10. Chest X-ray

required. When suspected, fat embolism should also be treated with 500 mg intravenous methylprednisolone given over 30 minutes. Remember, however, there are other causes of hypoxia in the peri-operative period.

Reversal of anaesthesia and postoperative care:

No patient should have their neuromuscular blockade reversed until they have been adequately resuscitated and have a normal blood pressure and pulse rate and adequate urine flow. Following prolonged surgery, and in patients with injury to a number of body systems, particularly head and chest, a period in the recovery room of 24 hours with continuous close observation and availability of an anaesthetist should be considered. Alternatively such patients should be admitted to an intensive care unit where adequate analgesia with intravenous opiates, ventilation, and treatment in response to a change in condition (for example blood loss due to a coagulation defect) can be provided.

Case History

A nine year old girl was admitted to a University Teaching Hospital following a serious car accident in which two people were killed. On primary survey she was dyspnoeic, though her airway was clear. She had absent air entry on the left side of her chest and dullness to percussion. Her trachea was not deviated. She was in hypovolaemic shock with a pulse of 150/minute and unrecordable BP. A distended abdomen was noted as was her depressed conscious level. There was some response to voice but she was making incomprehensible groaning sounds. Both pupils were reacting normally and there was a haematoma on her forehead. Her weight was estimated to be 30kg

Oxygen was immediately given at 8 litres / minute

via a face mask and blood taken for crossmatch whilst two intravenous cannulae were inserted. Initially she was given a fluid loading of 10mls/kg body weight (300mls) of saline and then this was repeated using Haemaccel. This improved her blood pressure for only a short time and therefore another 300mls of Haemaccel was administered and then 2 units of uncrossmatched group O negative blood, which were warmed in a basin of water at hand temperature. During this time a surgeon had performed a secondary survey and decided to do an immediated laparotomy where a ruptured spleen was resected. He had also inserted a chest drain on the left side preoperatively and drained a haemo-pneumothorax.

Anaesthesia was induced with ketamine 1.5mg/kg and suxamethonium 1.5mg/kg and maintained with intermittent ketamine and a muscle relaxant. Two further fluid boluses of Haemaccel were given after which the child stabilised. Postoperatively the child made a good recovery and was discharged home.

Summary

The key to successful trauma management involves prior preparation of the resuscitation room and creation of a trauma team in which the anaesthetist plays a vital role. Once mobilised, the team should be co-ordinated by a leader who should follow a regime based upon a primary survey and resuscitation, a secondary survey once the patient has been stabilised and prompt initiation of definitive treatment. A full history should identify mechanisms of injury. Anaesthesia for the trauma patient must involve a full assessment of the actual and potential injuries with the appreciation that resuscitation is often ongoing and the patient's condition can change dramatically.